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Digital Preservation of Cultural Heritage: An Analysis of 3D Technologies and Their Impact on Value Creation

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1. Introduction

In the era of Digitalization, our world is gradually welcoming a transformational change. The fusion of art, innovation, and technology has produced a new approach toward the preservation and conservation of Cultural Heritage while modifying how individuals capture value from it. Beyond the traditional methods, through which we have always approached History, Arts, and Cultural Heritage, 3D Technologies help us to take part in the past, immersing ourselves in historical sites, exploring old cities, and being able to hold artifacts in our hands. What's more, the use of such technologies brings businesses and organizations to take part in a new process within the implementation of their business models, applying new methods and initiatives that can grant access to digital tools. If, as consumers, we change the way Culture is perceived, there must necessarily be a change in the process through which Culture is "produced" and diffused among individuals. Therefore, this thesis aims to deeply analyze the gradual development that 3D Technologies recently had, capture the significant change in how innovation technologies can create new ways of participating in Culture, and identify both economic and cultural values produced by this sector.

Firstly, Chapter I will offer a general overview of the 3D Technology Market, underscoring the remarkable recent growth that it has globally obtained. What's more, we'll discuss the benefits and costs deriving from 3D Technologies and their impact on businesses. Secondly, Chapter II will go deeper into the analysis of 3D Technologies in the field of Cultural Heritage, with a detailed explanation of digital tools, including 3D Printing, 3D Scanning, 3D Modeling, Virtual Reality (VR), and Augmented Reality (AR), and their applications to major historical sites. Moreover, implications of such technologies at a business level will be examined through the framework of the Business Model Canvas, clarifying how digitalization may adjust the ways the value of culture is captured by an organization and perceived by its customers. Lastly, Chapter III will be focused on the case study of the Digital Restoration of the UNESCO World Heritage Site of Palmyra, in Syria, made possible thanks to the support of 3D Technologies, including 3D Scanning, 3D Modeling, 3D Printing, and Virtual Reality (VR). The specific project on Palmyra will open the discussion about the importance of digital reconstruction, after the deterioration of culture due to political conflicts, as the Syrian war, and about what technological innovations in the Cultural Heritage field signify to cultural organizations and institutions, and to the overall audience.

2. Chapter I – The 3D Technology Market

The 3D Technology market offers a wide range of opportunities across various industries and sectors. Since its inception, 3D Technology has played a significant role in the market and has driven the digital transformation of several industries – Automotive, Industrial, Healthcare, Media & Entertainment are only the tip of the iceberg of the set of industries profiting from such technology.

The following chapter will provide a comprehensive overview of the 3D Technology Market, define its core concepts, and explore the benefits and costs associated with its application. Understanding the market for 3D Technology is crucial to grasp its significant impact on how Cultural Heritage preservation gains fundamental tools and methodologies required to examine, restore, and present historical sites, artifacts, and works of art in immersive and interactive ways.

2.1 Market Overview: Size, Growth, and Regional Distribution

3D Technology stands for "three-dimensional technology, providing some illusion of depth perception through which viewers enjoy different types of experiences" [1].
This type of technology has revolutionized the digital world, enabling the creation of photorealistic digital prototypes of real-life objects in 3D environments, providing new tools to share information engagingly and appealingly, and optimizing efficiency and costs through the simplification of production processes.

Collecting data from the 3D Technology Market can provide worthwhile insights into the importance and impact of these technologies, especially during the most recent years, within a wide range of industries. Indeed, predictions on the global market for 3D Technology show that

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[1] Snehil Masih, "What Is 3D Technology: The Future And Applications," To the Verge, May 5, 2022, https://www.totheverge.com/what-is-3d-technology/.

its value will expand from \$171.4 billion in 2020 to \$703.4 billion in 2030, at a CAGR of 16.3% from 2021 to 2030 [2].

Through the analysis of the 3D Technology Market by its regional distribution, it's possible to look at the percentage of 3D Technologies used by each continent in the world.

Figure 1 shows the 3D Technology Market Analysis by Region in 2019. The market is analyzed across the following continents: Asia Pacific, North America, South America, MEA (Middle East and Africa), and Europe.

Given the Regional share in 2019, it's possible to make the following predictions on performing markets:

   i. Asia Pacific is presumed to be the largest market in 2024 due to its 39.34% distribution in 2019. Its main 3D Technologies come from high investments, especially in the Health, Education, and Consumer Electronics sectors.

  ii. North America may be considered at the forefront due to investments in several industries, such as Civil, Architecture, Media & Entertainment, Medical, and Industrial Manufacturing with 24.12%.

 iii. South America, with its 20.15% of the global share in 2019, is the best-performing market between 2019 and 2024.

  iv. MEA's regional share in 2019 was 9.30%, with the highest allocation towards the medical sector.

   v. Europe has the slowest growing market between 2019 and 2024, with only 7.09% of the global 3D Technology share, even though startups and large corporations invest more and recognize the potential of such technologies.

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[2] "3D Technology Market Size, Share & Trends | Analysis - 2030," Allied Market Research, n.d., https://www.alliedmarketresearch.com/3d-technology-market#:~:text=3d%20Technology%20Market%20Outlook%20%E2%80%93%202030.
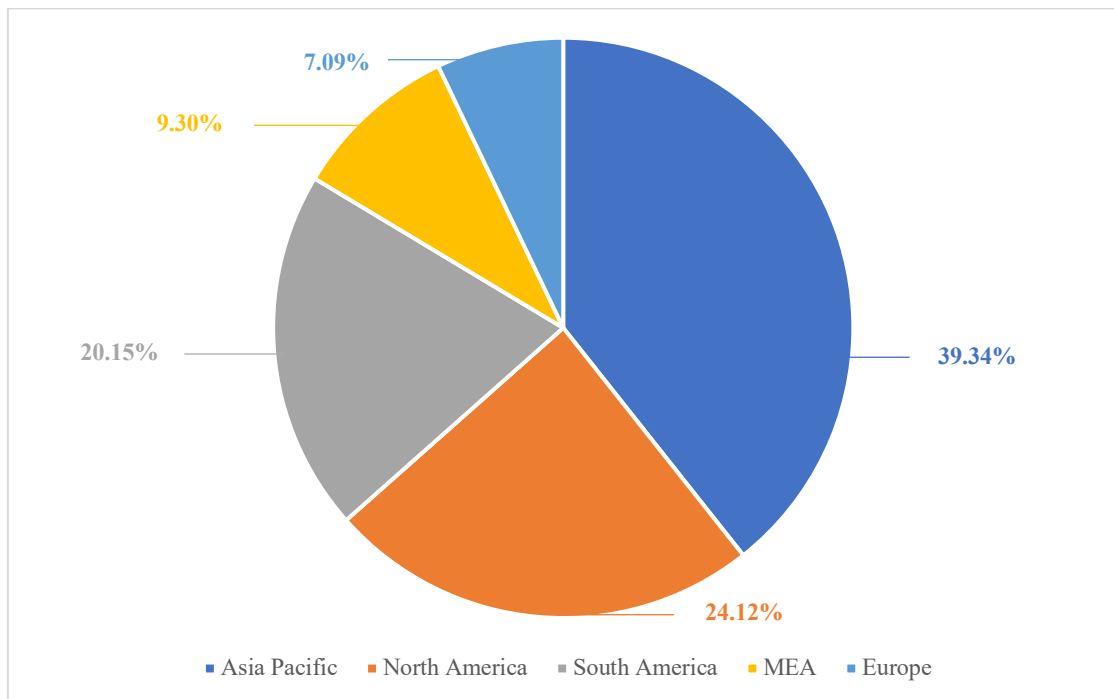
These data provide compelling evidence of the remarkable growth of the 3D Technology Market, particularly in recent years. Undoubtedly, this upward trajectory is also expected to persist in the future.

Several key factors are driving the expansion of the 3D Technology market, including technological advancements, the increasing adoption of such technologies to different industries, and the rise in investment in Research & Development by governments.

To start with, the emerging technological advancements in the 3D Technology Market play a crucial role for businesses and industries, where the application and effectiveness of such technologies are continuously being enhanced.

This observation can be well explained by examining the use of 3D Printing Technology. Indeed, taking the Automotive industry as an illustrative example, it's possible to observe how manufacturers manage to well exploit 3D Printing Technology. The application of such technology to the production process of vehicles enables saving the time that is needed for a

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[3] *3D Technology Market by Application and Geography - Forecast and Analysis 2022 - 2026.* Technavio.com, p.16. Accessed June, 2023.

product to get to the market and, nevertheless, minimizes its costs of production [4]. Furthermore, in the Healthcare Industry, 3D Printing improves the product quality and reduces the costs and time to market, but also supports surgeons during certain procedures with the creation of printed 3D human organs.

What's more, the increasing adoption of 3D Technology has created a significant impact on market expansion. At the outset of the development of these technologies – around the 80s, when the first ever 3D printer was patented by Chuck Hull [5] – the first industries to welcome 3D Technologies were those strictly related to Manufacturing Production, Design, Media & Entertainment, and Healthcare, with the advent of the first 3D movies and 3D dental implants. At a later stage, the Fashion, Food, and Furniture industries joined the list of those that were already applying 3D Technologies, with the introduction of new methods of production – virtual modeling of garments, 3D printed food, and automated cooking.

Ultimately, the governments are playing an important role by investing in Research and Development. The results from the 2022 EU Industrial R&D Investment Scoreboard show that the EU 2022 investment in R&D had a rebound of 8.9% after a drop of 2.2% in 2021 due to the Covid-19 Pandemic, revealing the importance of such investments for the improvement of technology capabilities under the ongoing global digital transformation, together with investments in skills and infrastructures [6]. The investment in R&D represents an initiative set by the government to financially support companies and institutions, fostering innovation, and reducing the R&D gaps with main global competitors.

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[4] Ian Campbell, David Bourell, and Ian Gibson, "Additive manufacturing: rapid prototyping comes of age", *Rapid Prototyping Journal 18*, No. 4, (June 8 2012): 255-258, https://doi.org/10.1108/13552541211231563.

[5] Eileen Kennedy, *"Designing the Digital World,"* Pressbooks, April 12, 2021, https://openpress.universityofgalway.ie/designingthedigitalworld/.

[6] Publications Office of the European Union, "The 2022 EU Industrial R&D Investment Scoreboard: Extended Summary of Key Findings and Policy Implications.," Publications Office of the EU, 2022, https://op.europa.eu/en/publication-detail/-/publication/20201203-7f4f-11ed-9887-01aa75ed71a1.

2.2 Definition and Application of 3D Technologies

Next to the 3D Technology Market Overview, the subsequent section is dedicated to elucidating each 3D Technology that this thesis aims to focus on. Definitions and features of the technologies will be followed by an exploration of their respective allocations. The latter portion will illustrate how 3D Technologies are employed within various industries and businesses, defining their pivotal role in the production of products and services.

3D Printing

3D Printing Technology or Additive Manufacturing can be defined as "the method of creating a three-dimensional object layer-by-layer using a computer-created design" [7].

The first approach to 3D Printing was dated May 1981, when Dr. Hideo Kodama of the Nagoya Municipal Industrial Research Institute developed the first method for 3D printing technology, by publishing the specifics of a "rapid prototyping" method. At that time, Charles W. Hull, co-founder, and chief technology officer of 3D Systems, filed his patent for Stereolithography (a printing technique implementing Ultraviolet light to create a 3D object by adding layers upon layers) with other new features – the STL file format. In 1987 he released the first 3D printer and created 3D Systems [8].

Over the past twenty years, 3D Printing Technology has been applied to a wide span of industries and businesses, from Aerospace to Biomedical, resulting in increasingly diverse industrial applications, and has even been employed within Reconstruction and Digital Art fields.

In the Aerospace industry, 3D Printing plays an important role, given the complexity, high–cost, and time-consuming manufacture of aerospace components. AM techniques may also be applied for the repair of aircraft engine parts, such as compressors, turbine, and combustor castings. In the Healthcare industry, 3D Printing has become a game-changer, given its relevance in producing surgical simulations and creating patient-specific implants, significantly improving medical outcomes in the operating rooms.

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[7] "What Is 3D Printing? - Technology Definition and Types." Twi-Global.com, accessed June 3, 2023. https://www.twi-global.com/technical-knowledge/faqs/what-is-3d-printing.

[8] Hwaiyu Geng, *Manufacturing Engineering Handbook, Second Edition* (McGraw-Hill Education, 2015).

The application of 3D Printing to the Automotive industry has opened the possibility of reducing costs and time of production of high-end, specialized automobiles and their most complex parts.

When discussing the application of such technologies, it's crucial to acknowledge the recent incorporation of 3D Printing Technology in industries such as Fashion and Education. The application of 3D Printing across various industries not only leads to significant reductions in production costs and time, but also plays a pivotal role in minimizing material waste and fostering an environmentally conscious economy.

3D Scanning

A 3D scanner is a technology that examines a physical object or environment to gather data about its shape and perhaps appearance. Digital three-dimensional models can then be created using the collected data. The last half of the 20th Century saw the development of 3D Scanning as a response to the need to precisely recreate the surface of objects and their environment. In the 1960s, the first 3D Scanning technology was created. 3D Scanning has found its application in numerous industries. In the Entertainment industry, this type of technology helps to create 3D models for movies and video games, scanning real-world objects and creating a model using 3D modeling software. Moreover, it can play an important role in Reverse Engineering – the process of creating a digital representation of an existing physical object or system – where 3D scanning captures the geometric data of the object and digitally creates its replica. Furthermore, in Civil Applications, scanning roadways makes it possible to gather data about the period rate of deterioration, guaranteeing accessibility and safety [9].

3D Modeling

3D modeling is the process of creating a three-dimensional representation of an object or scene using specialized software or computer-aided design (CAD) tools [10].

[9] Milan Edl, Marek Mizerák, and Jozef Trojan. 2018, "3D LASER SCANNERS: HISTORY AND APPLICATIONS", *Acta Simulatio* 4, no. 4: 1–5. https://doi.org/10.22306/asim.v4i4.54.

[10] Pance, "Creating Stunning 3D Models for the Metaverse," *Renovi Studios*, June 16, 2023, https://renovistudios.xyz/creating-stunning-3d-models-for-the-metaverse/.

The digital modeling relies on parameters that will be used as reference across each feature of the object. Also, these parameters will be the support to add dimensions to the work, including dimension, volume, and mass. The entire process is accomplished by a drafter, whose main task is to create digital 3D models of parts and make a blending. The significant contribution that 3D Modeling can bring is the possibility to generate a 360° visualization of the object [11].

After the 70s, when the first 3D Modeling software was created by Ivan Sutherland – an American electrical engineer and computer scientist – 3D Modeling has found extensive applications across various industries, revolutionizing the ways objects are designed, visualized, and manufactured.

In Product Design and Manufacturing industries, 3D Modeling is used to create virtual prototypes before products are physically fabricated; in Healthcare and Medical, three-dimensional models are essential for the development of 3D Printing, helping to produce customized implants; in Architecture and Construction, it helps to visualize building designs and communicating ideas to clients.

Virtual Reality (VR)

Virtual reality (VR) is best described as "a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation (a virtual world)"[12].

Jaron Lanier came up with the phrase "virtual reality" in the middle of the 1980s as he funded VPL Research, Inc. to create the first visual programming language. However, the creation of virtual worlds came before this, in 1956, when Morton Heiling developed Sensorama, a multisensory experience display system that included sound, sensation, and smells. But it was during the 70s and the 80s, thanks to NASA's VIEW (Virtual Interface Environment Workstation) project combining a head-mounted display with gloves for tactile interaction, that Virtual Reality found its foundation. The benefit of such technology extends to diverse

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[11] Cameron Coward, *A Beginner's Guide to 3D Modeling: A Guide to Autodesk Fusion 360* (No Starch Press, 2019).

[12] William R. Sherman, and Alan B Craig, *Understanding Virtual Reality: Interface, Application, and Design.* (Morgan Kaufmann, 2018).

domains, encompassing Education and Science. Specifically, in the realm of Education, Virtual Reality opens the opportunity for students and researchers to immerse themselves in historical sites or locations, deleting the necessity for physical presence. In the latter scenario, the technology facilitates the analysis and acquisition of scientific data, enabling scientists to employ a multitude of scientific visualization tools for the examination of complex weather phenomena in real-time [13].

Augmented Reality (AR)

Augmented reality represents "a type of virtual reality in which synthetic stimuli are registered with and superimposed on real-world objects; it is often used to make information otherwise imperceptible to human senses perceptible" [14].

The 1950s saw the beginning of augmented reality development. In 1957, Sensorama, the first application of augmented reality, was created by Morton L. Heilig. Then, in 1992, Thomas Caudell and David Mizell coined the phrase "augmented reality". After that, the application of augmented reality significantly grew as a result of technological and mobile advancements. Nowadays, Augmented Reality has witnessed substantial development and has permeated diverse industries to a significant extent. In the Health field, such technology can help minimize the risks from surgical operations through an augmented reality navigation system, with the use of a three–dimensional sensory system. Augmented Reality may also be applied to the Advertisement area for marketing purposes. AR enables users to engage with products and brands in a dynamic and captivating manner, allowing clients to visualize products in their real environment before making a purchase or creating games through which customers can take participation [15].

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[13] Sherman and Craig, *Understanding Virtual Reality: Interface, Application, and Design*.

[14] Sherman and Craig, *Understanding Virtual Reality: Interface, Application, and Design*.

[15] İbrahim Sünger and Serkan Çankaya, "Augmented Reality: Historical Development and Area of Usage," *Journal of Educational Technology and Online Learning* 2, no. 3 (September 30, 2019): 118–33, https://doi.org/10.31681/jetol.615499.

2.3 Benefits and Costs of Applying 3D Technologies

The next section aims to offer an outline of the advantages and drawbacks deriving from the use of 3D Technologies. Indeed, on the one side, such technologies are innovative and manage to satisfy business clients' and customers' needs, while contributing to improving social welfare. On the other side, however, they imply significant costs. Therefore, it's critical to deeply comprehend what is the value that such technologies can bring to industries and businesses, compared to the traditional methods.

Primarily, the application of 3D Technologies offers flexibility in manufacturing components of products and objects, as opposed to conventional approaches. In 3D Printing, for instance, complex features may be easily made by single pieces, with no need to sacrifice part functionality for the ease of manufacture [16].

Furthermore, thanks to the use of 3D Scanning and 3D Modeling, real-life objects can be easily turned into virtual replicas, characterized by an accurate reproduction of physical details and features that sometimes could be impossible to obtain with traditional methods. 3D Modeling is also a key resource for communicating and collaborating with stakeholders and clients. Indeed, in the Design Industry, customers are more likely to make purchases before any construction work is done when they can see in 3D how the ended product will look. Regarding the creation of virtual and digital realities, the benefit lies in providing users with exceptionally immersive experiences that prompt interaction and simulate lifelike scenarios. This ability is particularly beneficial in the fields of Medicine, Aerospace, and Healthcare, where Virtual and Augmented realities can give support for training purposes.

Figure 2 shows the graphical representation of 3D Printing Enterprise Usage Benefits.

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[16] Samuel H. Huang et al., "Additive Manufacturing and Its Societal Impact: A Literature Review," *The International Journal of Advanced Manufacturing Technology* 67, no. 5–8 (October 16, 2012): 1191–1203, https://doi.org/10.1007/s00170-012-4558-5.

Figure 2: 3D Business Benefits [17]
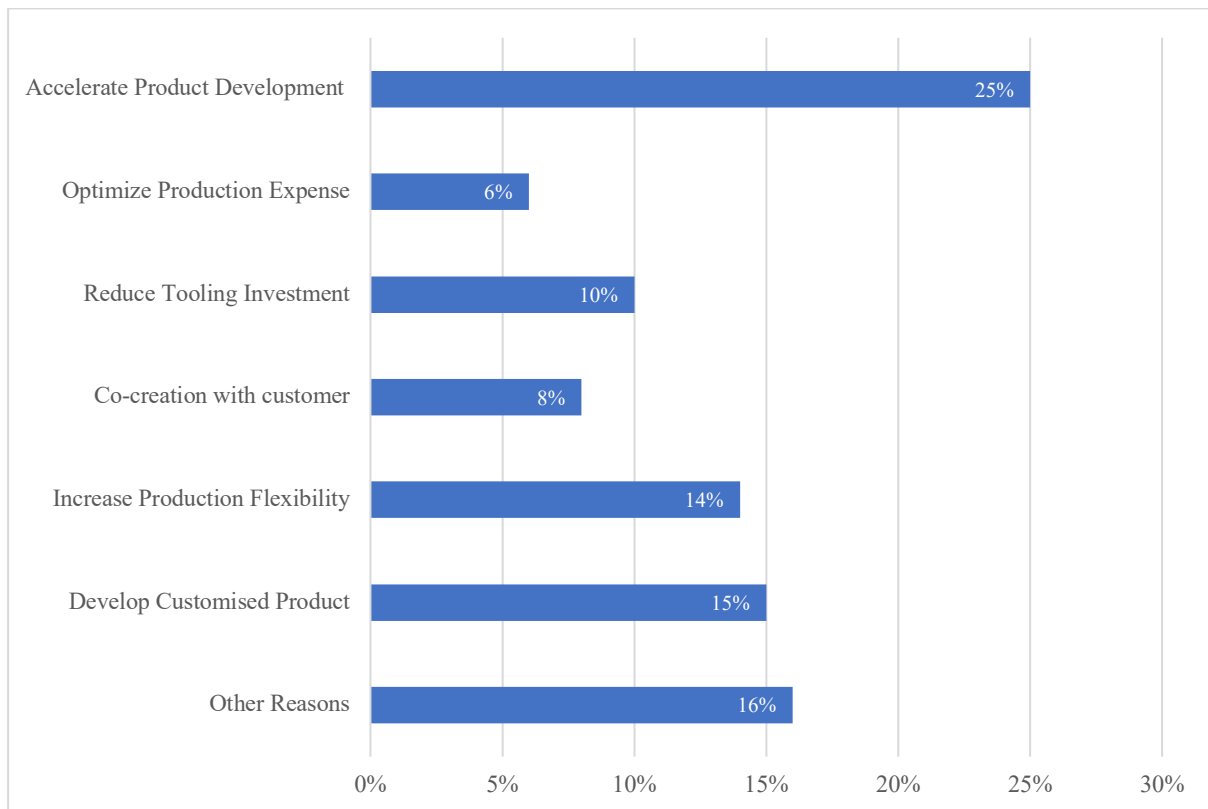
As shown by these statistics, businesses applying 3D Technologies may benefit the most from them to speed up the process during which a product may be designed, created, and commercialized, keeping the costs and expenses at their lowest. An essential aspect worth mentioning is the ability, facilitated by 3D Technology, to manufacture personalized products, guaranteeing a diversification of outputs.

Given these benefits that may seem appealing, it's important to report the challenges and limitations associated with them.

Additive Manufacturing, 3D Scanning, and 3D Modeling processes and their initial investments can be highly costly, not including the cost of other equipment and operational materials. They also require a certain level of technical expertise and high-quality software.

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[17] *Source: Mind Commerce. 2022. 3D Business Benefits. Web. Market Research Blog.*
https://blog.marketresearch.com/6-key-benefits-of-3d-printing-that-will-drive-adoption-in-the-business-sector.

Since these technologies always require data, supported by high-performance hardware and specialized software, processing them can be time-consuming, and developing proficiency in this field is not that easy.

Another problem that may arise from this type of immersive technology is that integrating AR and VR systems with existing infrastructures, software, and systems is challenging. Indeed, taking as an example the Medical Education and Treatment field, the main challenges are lack of face–to–face communication and relationship between the doctor and the patient; patient's reluctance and unfamiliarity with IT–based tools; specifying who is responsible for what during the treatment process, and make both therapists and patients aware of any potential hazards coming from such technology [18].

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[18] Tayebeh Baniasadi, Seyed Mohammad Ayyoubzadeh, and Niloofar Mohammadzadeh, "Challenges and Practical Considerations in Applying Virtual Reality in Medical Education and Treatment," *Oman Medical Journal* 35, no. 3 (May 15, 2020): e125, https://doi.org/10.5001/omj.2020.43.

3. Chapter II – The Use of 3D Technologies in the Preservation of Tangible Cultural Heritage

The transformative role of 3D Technologies is a fundamental tool in safeguarding and revitalizing our rich Cultural heritage. Now more than ever, there's an undeniable necessity to guarantee that the preservation and conservation of such historical legacy will keep up with the new technologies emerging from the current era of digitalization. By exploring the profound impact of 3D Printing, 3D Scanning, 3D Modeling, Virtual reality (VR), and Augmented Reality (AR), this chapter uncovers how these technologies not only breathe new life into our past but also pave the way for immersive experiences, wider accessibility, and innovative strategies for Cultural heritage preservation. Through a comprehensive examination of these technologies and their applications, we uncover the intricate connections between technological advancement and the preservation of our collective human legacy. Furthermore, understanding the significance of technological innovations will simplify the comprehension of their effect on businesses and organizations, and of their creation of economic value. The concluding segment of this chapter will be centered around the exposition of outstanding examples from the application of 3D Technologies to Cultural Heritage preservation, enhancing the clarity of their undoubted significance.

3.1 Exploring the Potential of 3D Technologies in the Preservation of Tangible Cultural Heritage

In recent years, 3D Technologies have played a pivotal role in the Cultural Heritage field, developing a major level in the accessibility toward artistic, archeological, and historical artifacts.

According to the UNESCO (United Nations Educational, Scientific and Cultural Organization), Cultural Heritage includes "artifacts, monuments, a group of buildings and sites, museums that have a diversity of values including symbolic, historic, artistic, aesthetic, ethnological or anthropological, scientific and social significance" [19].

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[19] "Cultural Heritage," UNESCO UIS, February 28, 2023, https://uis.unesco.org/en/glossary-term/cultural-heritage.

It's necessary, therefore, to make a clear distinction between Tangible and Intangible Heritage. The first stands for movable, immobile, and underwater assets, including artifacts, sites, monuments, paintings, sculptures, furniture, and buildings; the second represents oral traditions and expressions, performing arts, social practices, rituals and festive events, knowledge and practices concerning nature and the universe, and traditional craftsmanship [20].

Throughout this thesis, the research will exclusively concentrate on the exploration of the Tangible Cultural Heritage, providing a comprehensive analysis and understanding of the significance of its preservation.

In the subsequent subchapters, it will be shown the applicability of the already cited 3D Technologies to the cultural heritage works of conservation and preservation. Even though the traditional methods of restoration and reconstruction have shown themselves capable of donating a second life to historical and cultural "objects", it will be demonstrated how 3D Technologies provide additional advantages and benefits that mirror the era of digitalization we are witnessing.

3.1.1   3D Printing

Since 3D Printing allows the replication of existing and real-world objects in three-dimensional assessment, it represents one of the most reliable instruments capable of renewing ancient artifacts and monuments with missing parts. This assumes vital importance, especially in the context of historical sites that have been destroyed or damaged by time, wars, and factors of deterioration due to weather. 3D Printing found its first applications in tangible Cultural Heritage starting in the middle of the 1990s, being widely used by archeologists and researchers in the creation of physical replicas of ancient objects. By this time, its application has widened in different fields of cultural heritage, from Education to Research, from Virtual museums and exhibits to Restoration and Conservation.

For what concerns the advantages, 3D Printing enables to maintain the integrity of items, while concurrently permitting researchers to handle and analyze them. Furthermore, the use of traditional methods and instruments to recreate the exact details of some artifacts or statues

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[20] UNESCO World Heritage Centre, "Intangible Heritage - Glossary - UNESCO World Heritage Centre," n.d., https://whc.unesco.org/en/glossary/40.

that may have missing parts would never be as great as the one deriving from 3D Printing. Indeed, it's much easier to duplicate delicate items, thanks to the supplementary work of 3D scanners, without running the danger of destruction. Finally, it represents a cost-effective solution since it doesn't require costly materials and labor resources [21].

3.1.2   3D Scanning

Scanning's fundamental task of recording objects' surfaces and forms at the highest possible resolution enables to monitor, study, and understand our shared cultural history [22]. In this way, 3D Scanning can guarantee visitors, researchers, and students the creation of exact facsimiles of authentic items. What's more, three-dimensional scanning technologies are essential for the work of restoration: they can detect previous touch-ups and restoration works and, additionally, they are fundamental for discovering artworks from earlier periods concealed within the same piece of art. By using 3D Scanning delicate artifacts can be virtually restored, rather than physically, saving costs while ensuring that the original artifact remains untouched. Furthermore, 3D Scanning permits to develop collaborative and joint projects, particularly between cultural heritage institutions and tech companies. The use of this technology has the potential to draw funds for research from both the public and private sectors.

3.1.3   3D Modeling

In the field of Cultural Heritage, when it comes to the requirement of replacing original works of art with copies and generating replicas for archiving and marketing purposes of museums, 3D Modeling plays a crucial role. As a result, it is essential to the process of digital restoration, which involves constructing 3D representations of damaged parts of artworks. This technology's key benefit is seen in its enhanced documentation efficiency: in-depth digital documentation of objects and heritage sites is provided by 3D models, which also optimize the cataloging and archiving process, increasing the effectiveness of inventory management.

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[21] Marcin Frąckiewicz, "The Benefits of 3D Printing for Cultural Heritage Preservation," *TS2 SPACE*, May 16, 2023, https://ts2.space/en/the-benefits-of-3d-printing-for-cultural-heritage-preservation/.

[22] Factum Arte SL, "Factum Arte :: 3D SCANNING FOR CULTURAL HERITAGE CONSERVATION," n.d., https://www.factum-arte.com/pag/701/3D-Scanning-for-Cultural-Heritage-Conservation.

The interactive models produced by this technology can involve a wide range of enthusiasts and tourists, increasing visitations and generating revenue for historical sites and local economies [23].

3.1.4 Virtual Reality (VR)

Virtual Reality has been integrated into the Cultural Heritage context as cutting-edge technology for the enhancement of the tourist experience. Indeed, Virtual Reality, together with Augmented Reality, has been found as an ideal technology to provide visitors with enhanced, personalized, and enjoyable information.

Virtual Reality technology is particularly used by museums to create immersive experiences and provide visitors the possibility to be physically engaged in works of art or ancient sites. The use of this technology is a game changer to capitalize on the opportunities to increase income, visitor engagement, and intentions to return [24].

Undoubtedly, its huge potential must be found in the Education field. Virtual Reality technologies used in the Cultural Heritage can offer to schools and educational institutions immersive exhibitions and experiences, generating revenues from educational partnerships.

3.1.5 Augmented Reality (AR)

Art galleries and museums have recently started to develop AR applications to increase engagement and provide an entirely new kind of exploration experience. These experiences are usually characterized by the overlaying of digital contents, such as images and videos, into the real-world environment viewed through a smartphone, tablet, or AR headset (a special type of virtual glasses). This technology enhances the viewer's perception of the physical surroundings by seamlessly blending virtual elements with the real world. In the context of Cultural Heritage, AR experiences can bring historical sites, artifacts, and artworks to life in

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[23] Massimiliano Pieraccini, Gabriele Guidi, and C. Atzeni, "3D Digitizing of Cultural Heritage," *Journal of Cultural Heritage* 2, no. 1 (January 1, 2001): 63–70, https://doi.org/10.1016/s1296-2074(01)01108-6.

[24] Timothy Jung and M. Claudia Tom Dieck, "Augmented Reality, Virtual Reality and 3D Printing for the Co-Creation of Value for the Visitor Experience at Cultural Heritage Places," *Journal of Place Management and Development* 10, no. 2 (June 5, 2017): 140–51, https://doi.org/10.1108/jpmd-07-2016-0045.

various ways: they result to be particularly effective, enabling the visitors to discover details that are usually invisible to the naked eye or to make them see missing parts of destroyed monuments and ancient historical sites [25].

3.2 The Impact of Technological Innovations on Businesses – Cultural Heritage and Value Creation

This chapter analyzes in detail the impact that technological innovations, particularly 3D Technologies, have on businesses operating within the realm of Cultural Heritage preservation. Following up on the continuous evolution of digitalization and innovation, businesses have an unprecedented opportunity to leverage cutting-edge tools to preserve Cultural Heritage, enhancing value creation and engagement.

According to Golinelli (2014), the concept of "culture" has experienced a shift in its interpretation over time. The *cultural good*, at first, has been viewed from an idealistic and aesthetic meaning, being seen primarily for its entertainment aim rather than for its potential to create human capital. Subsequently, the historical and artistic item has gained the meaning of "*bene culturale*" in the systemic and anthropological sense. Therefore, this shift has implied a more significant rearrangement in the perception of culture: from culture being viewed as a resource to be preserved, to culture being regarded as a resource to be leveraged for the creation of value and societal benefits. When talking about the "value" of the cultural good, we are referring to "the value of use derived from its setting as a systemic value that is achieved in terms of service". Under this assumption, the cultural good is categorized into three different phases: material, dynamic, and intangible. The material refers to its physical characteristics and its safeguarding through conservation; the dynamic feature refers to the potential enhancement of the cultural good for its enjoyment in time and space – in this phase the cultural good is subject to a marketing purpose, shifting to the idea of "product"; the intangible aspect is seen as considering cultural heritage not only material objects but traditions and customs, too [26].

[25] Lucio T. De Paolis, and Patrick Bourdot, ed. 2020. *Augmented Reality, Virtual Reality, and Computer Graphics*: 7th International Conference, AVR 2020 Lecce, Italy, September 7–10, 2020 Proceedings, Part I 2020. Springer International Publishing, https://doi.org/10.1007/978-3-030-58465-8.

[26] Gaetano M. Golinelli, *Cultural Heritage and Value Creation: Towards New Pathways* (Springer, 2014).

Hence, comprehending how technological advancements can reformulate the functions and objectives of cultural institutions and organizations, transforming them into creators and dispensers of cultural material, is of paramount significance. Furthermore, delving into the emerging business model is equally essential since some industries – including the cultural industry – are reshaping their business models due to digitalization.

In the Cultural Heritage field, the arrival of new 3D Technologies has prompted the sector to embrace a new transformation: offering services to clients is not enough, there must be a change in the type of experience presented to visitors. There must be a shift of the main concern of Cultural Heritage, from technological to managerial and customer focused. As a result of digitalization, Cultural Heritage has undergone substantial transformations in its patterns, particularly in aspects related to business and market dynamics. Therefore, to embrace technological advancements and capitalize on potential opportunities, Cultural Heritage organizations must adapt their business models [27].

Firstly, here is a brief review of the concept of the Business Model: it can be described as the framework showing how a company, organization, or business is implementing its strategies to capture, create, and diffuse its value. The framework we're going to describe is the Business Model Canvas, proposed by Alexander Osterwalder and Yves Pigneur, segmented into nine sections, each of which delivers a specific question regarding the relationship between the organization and its value creation:

1. *Customer Segments*: What is the target audience that the organization plans to offer value to?
2. *Value Proposition*: How does the customer value the organization, differentiating it from the competition?
3. *Channels*: How does the customer reach the organization and capture its value?
4. *Customer Relationships*: How does the organization build a relationship to reach out to its Customer Segments?
5. *Revenue Streams*: How does the organization generate revenues from the offering of its products and services?

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[27] Tiziana Russo Spena et al., "A Digital Business Model: An Illustrated Framework from the Cultural Heritage Business," *International Journal of Entrepreneurial Behaviour & Research* 28, no. 8 (February 18, 2022): 2000–2023, https://doi.org/10.1108/ijebr-01-2021-0088.

6. *Key Resources*: What are the main intellectual, physical, human, and financial assets that the organization must capture to create value?

7. *Key Activities*: What are the main actions that the organization implements to capture value?

8. *Key Partners*: What are the relationships the organization builds with other entities to succeed?

9. *Cost Structure*: What are the overall costs that the organization incurs to create value?

Primarily, digitalization allows businesses to reach a wider audience, beyond geographical boundaries. Indeed, the application of Virtual Reality and Augmented Reality is useful to guarantee cultural experiences for all students, researchers, and academics globally and expand the market that aims to serve. Taking as an example the American Museum of Natural History (AMNH) in New York, it can be stated that its customer segment was mainly represented by culture enthusiasts and researchers. Thanks to the support of 3D Technologies, the AMNH has recently added some Virtual Field Trips, to engage students in a virtual exploration of the museum. By doing so, the customer segment has expanded from a niche portion of the market to a more diversified audience.

Moreover, changing the way a service or a product is offered requires a significant revision in the value proposition: with the use of 3D Technologies a cultural item, artifact, or monument will be experienced differently by the customer. This change should also be reflected in the core of the organization that is offering the product, clearly communicating the additional benefit that the audience will get advantage from.

Traditionally, the channels through which an organization may communicate with its client in the Cultural Heritage field are represented by physical exhibitions, gift shops, and events to create awareness about the organization's activities and collections. Thanks to 3D Technologies, it's now possible to create faster and more accessible communication. Thanks to mobile apps and online channels, the customer can get in touch with historical and cultural exhibitions, or experiences, or events saving time, and most of all, saving geographical distances. This last concept strongly correlates to how new customer relationships are shaped by digitalization. The organization can better build a strong relationship with the customer if the customer herself can be integrated into the creation of products and services. In this case, we talk about "*co-creation*". This type of relationship is based on sharing the process of production of a service or a product with the customer, letting her actively participate to create value. With relation to the 3D Technologies in the Cultural Heritage field, visitors can immerse

themselves in the virtual environment thanks to the use of Virtual and Augmented Reality and become the main characters of the cultural experience. The connection is based on the interaction between the physical and the virtual world, the personalization of avatars or personalized characters, and gamification – the application of typical objects from games to a context to enhance the engagement of customers. Three-dimensional technologies enhance the co-creation of experiences by supporting enterprise and tourist interactions, encouraging their participation and the sharing of experiences among visitors [28].

A great example of the co-creation concept comes from the project Minecraft Education, an educational version of the popular video game Minecraft, that offers a unique and engaging way for educators to incorporate game-based learning into their teaching strategies. Thanks to this new type of education, teachers can benefit from gaining the attention of students who are more engaged during the lessons, but at the same time, students can re-build ancient monuments and better understand their construction and structures.

Moreover, Revenue Streams diversify with digitalization. Traditionally, the income-generating activities in the Cultural Heritage sector came from historical site visitations, ticket sales, and revenues from souvenir shops. With the outset of new technologies, additional opportunities to create revenue streams from digital assets have been opened. In particular, the new ways of utilizing digital assets to generate income may include the following activities: digital replicas, partnerships, and collaborations, and *freemium* – a business strategy in which a basic version of a product or service is offered to customers for free, while advanced or premium features are available for a fee. Indeed, a wide range of important museums, including the British Museum in London, is collaborating with technology companies and 3D software developers to provide 3D representation of artifacts from museums' collections. Visitors may download for free the three-dimensional scans of the items or get a high-resolution 3D print of the items, paying for the service.

By doing so, Cultural Heritage organizations and museums can offer new and engaging experiences to the audience, while generating new revenue streams to support their initiatives. With relation to resources, the integration of 3D Technologies requires significant changes in the assets used to create value. To guarantee the digital preservation and conservation of historical artifacts and cultural sites, specialized hardware such as high-resolution 3D scanners and cameras are necessary; nevertheless, the adoption of such technologies can only be applied

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[28] Tanvi Panhale, Derek Bryce, and Eleni Tsougkou, "Augmented Reality and Experience Co-Creation in Heritage Settings," *Journal of Marketing Management* 39, no. 5–6 (September 26, 2022): 470–97, https://doi.org/10.1080/0267257x.2022.2120061.

thanks to investments in equipment, training, and staff, that is only possible after obtaining funds.

Besides the traditional maintenance of physical sites and collections in museums, businesses need to manage the digital transformation bringing some changes to the pre-existing key activities. Regular updates to virtual exhibits, interactive elements, and online learning materials become essential, but most of all the support of Research and Development (R&D) is the key factor. An organization or a business needs to be continuously engaged in research for technological innovations to create more value and offer new experiences and services.

Moreover, as already cited, partnerships between cultural organizations and technology companies are essential for the digitalization process. The partnerships may include Strategic, Research, and Education Partnerships. An example is Europeana, an initiative of the European Union financed by the European Union's Connecting Europe Facility and European Union Member States to empower the cultural heritage sector in its digital transformation. Europeana's mission is to engage the audience with cultural heritage, building significant partnerships with diverse organizations, both non-profit and corporate ones [29].

Lastly, costs related to digitization, technology adoption, and online operations are added to the traditional Cost Structure. Fixed costs may include investments in hardware and software, while variable costs might represent the overall expenses on materials for 3D Printing and 3D Scanning, equipment maintenance, and exhibitions and events. Overall, the organizations involved in Cultural Heritage are value-driven, meaning that their goal is to invest in 3D Technologies to enhance the quality of preservation, visitor experience and education, while improving resources to achieve a higher level of engagement and interactivity with cultural heritage.

3.3 Notable Examples of Cultural Heritage Preservation Using 3D Technologies

The following chapter presents two noteworthy exemplifications, showcasing the tangible impact and potential of 3D Technologies in the realm of Cultural Heritage preservation.

The first example worthy of being illustrated is the collaboration between Stratasys – a 3D printer company -   and Google Arts and Culture aimed at creating 3D replicas of the world's

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[29] "Partnerships | Europeana PRO," Europeana PRO, n.d., https://pro.europeana.eu/about-us/partnerships.

historical monuments and artifacts using both digital printing and modeling techniques. The Stratasys J750 printer has been used to support the work of re-creation of cultural heritage items and explore iconic locations in a three-dimensional environment. Thanks to the help of CyArk – a non-profit organization focused on the digital preservation of cultural heritage – it has been possible to document and scan architectures in heritage sites, not only increasing the accessibility of culture but also allowing the downloads of scanned artifacts, helping researchers and in general culture enthusiasts.

Figure 3 shows the 3D reproduction of the Wat Phra Si Sanphet temple, in Thailand. Following a significant flood in 2011, when the archeological complex was dangerously damaged, CyArk started its mission: to support UNESCO and the Fine Arts Department (FAD) of Thailand in mapping the site and providing detailed documentation surrounding the subsidence of the monuments [30].

Figure 3: 3D Reconstruction of the Wat Phra Si Sanphet in Thailand [31]
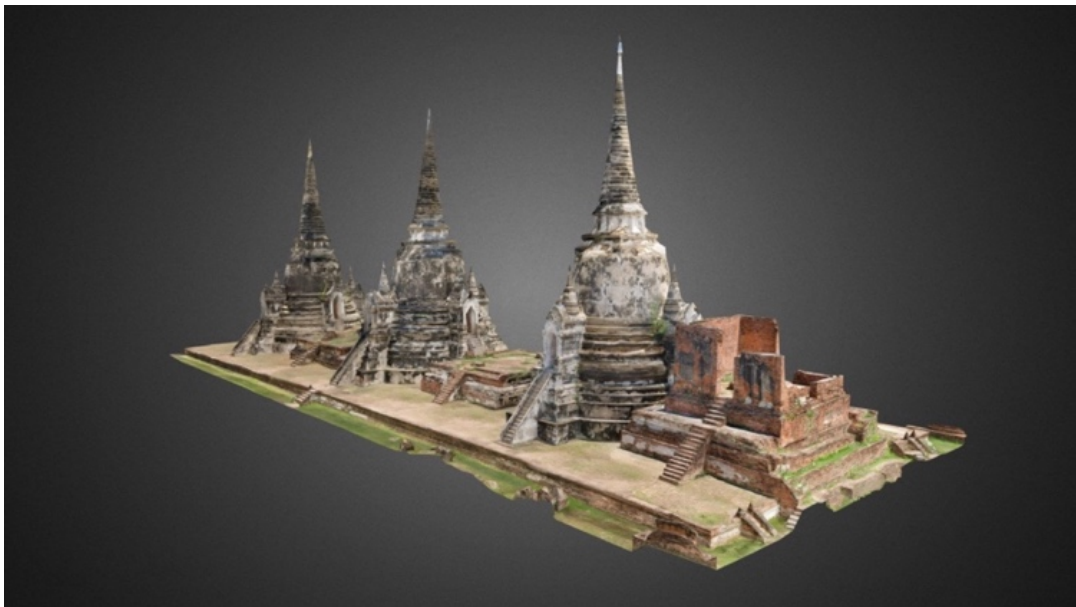
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[30] CyArk 2018: Ayutthaya - Wat Phra Si Sanphet - Photogrammetry, LiDAR - Terrestrial . Collected by CyArk . Distributed by Open Heritage 3D. https://doi.org/10.26301/taz6-n215

[31] Source: 2022 Cyark & Partners. n.d. *Wat Phra Si Sanphet - Ayutthaya, Thailand.* Edited by CyArk. Accessed June 19, 2023. https://www.cyark.org/projects/ayutthaya/3D-Explorer.

Another notable example is the Rome Reborn project, dated 2018. This project aims at re-creating the monuments, buildings, and streets of Ancient Rome – specifically Rome in 320 AC – using Virtual Reality technology. Rome Reborn offers the opportunity to look back at Rome under Constantine the Great's Empire and, through the two apps *The Roman Forum* and *Flight Over Ancient Rome,* everyone is free to walk around the city as an ancient Roman. The virtual reconstruction includes some of the most stunning monuments in Rome, such as the Colosseum, the Roman Forum, the Imperial Fora, the Pantheon, the Maximum Circus, the Mausoleum of Augustus, and the Pyramid of Cestius. Researchers and international technology experts have managed to work on 3D Virtual Reality models, giving a second life to Ancient Rome.

The project underscores the value of 3D Technologies in bridging the temporal gap between the modern world and the rich tapestry of human history.

As illustrated in Figure 4, the Rome Reborn project gives the users of the applications the opportunity to look at the Roman Forum, as it has never been seen before. In this way, the project facilitates accessibility to a global audience, breaking down physical barriers and offering individuals from diverse backgrounds the possibility to virtually visit and engage with the splendor of ancient Rome.

Figure 4: Rome Reborn Project [32]

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[32] Source: Flyover Zone. n.d. *Rome Reborn*. Edited by Flyover Zone. Accessed June 20, 2023.
https://www.flyoverzone.com/roman-forum-remastered-info-on-microsoft-store/.

4. Chapter III – Digital Restoration of UNESCO World Heritage Site of Palmyra, Syria

The following chapter delves into a comprehensive exploration of the case study centered around the digital restoration of the UNESCO World Heritage Site of Palmyra, in Syria. Through an accurate analysis of the use of 3D Technologies for the reconstruction of destroyed parts of the Syrian archeological site, we aim to uncover insights and draw meaningful conclusions about the benefits and drawbacks derived from the digitalized process applied to Cultural Heritage.

4.1 Brief Overview of the UNESCO Organization and the Palmyra Site

UNESCO is the United Nations Educational, Scientific and Cultural Organization, aimed at promoting peace and security through international cooperation in education, sciences, culture, communication, and information. The idea of developing a project designed for the establishment of an educational and cultural organization was born during wartime – in the early 1940s – when the European Countries met at the Conference of Allied Ministers of Education (CAME) in the United Kingdom. After globally diffusing their intention to rebuild the EU countries' education system afterwar, the United States decided to join in and on the 16th of November 1945, UNESCO was born in London, UK. Countries joining UNESCO committed to fostering a genuine culture of peace, with the hope of establishing a sense of "intellectual and moral solidarity of mankind", thereby preventing the recurrence of a global conflict like the World Wars [33].

The mission of UNESCO in preservation is to safeguard, protect, and promote Cultural Heritage worldwide, both tangible and intangible, and to raise awareness about the significance of Cultural Heritage, encourage its appreciation, and provide guidance to member states in the preservation and sustainable management of their historical legacy. Additionally, UNESCO seeks to foster international cooperation to ensure that Cultural Heritage remains a source of inspiration, knowledge, and mutual understanding among diverse societies.

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[33] "UNESCO in Brief," *UNESCO*, July 11, 2023, https://www.unesco.org/en/brief.

UNESCO's World Heritage List contains a compilation of cultural and natural heritage sites, recognized for their unique value and significance to humanity. Being included in the World Heritage List brings international recognition and often leads to increased efforts for the conservation and preservation of these sites.

One of the historical sites contained in UNESCO's list is the Palmyra Site, the ruins of a large city that was one of the most significant cultural centers of the ancient world, in the Syrian desert to the northeast of Damascus. The architecture of Palmyra is an existing testimony of the marriage between Greco-Roman techniques and Persian influences.

Unfortunately, from the year 2013 UNESCO included the Palmyra Site in the List of World Heritage in Danger, a collection of cultural sites considered to be facing significant threats to their integrity, due to wars, natural disasters, urbanization, and pollution [34].

Indeed, the terrorist organization of the Islamic State of Iraq and Syria destroyed some of the most stunning monuments in the Syrian historical site, including the Temple of Bel, the Temple of Baalshamin, the Arch of Triumph, and other parts that were critically damaged in August 2015. After almost a year, in March 2016 the Syrian army and the Russian troops reached the area of Palmyra, liberating it from the ISIS' forces. Previously to the ISIS occupation, Palmyra was once a prominent tourist destination in Syria and its liberation has restored the hope for reconstructing the historical parts that have been destroyed. After garnering global interest, certain countries including the UK, Germany, and Russia have demonstrated their willingness to contribute to a reconstruction project.

The support of other countries in the conservation of Palmyra's cultural legacy represents a game changer in the Syrian economy and its Tourism Sector. As a matter of fact, looking at the retrieved data from UNWTO (United Nations World Tourism Organization), it's undoubted the effect that the ISIS attack has had on the number of tourists visiting the historical site.

As shown in Figure 5, from 1995 to 2010, the total number of tourist arrivals in the Syrian Arab Republic – including overnight visitors and same-day visitors –, experienced an enormous increase, reaching 10,970 visitors in 2010. The following year represented a drastic decline that lasted until 2016: from 6,476 visitors in 2011 to 1,043 in 2016. As the data elucidates, the number of tourists who visited Syria during that period mirrors the poignant political circumstances the country was undergoing.

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[34] UNESCO World Heritage Centre, "Site of Palmyra," n.d., https://whc.unesco.org/en/list/23.

Figure 5: Total Tourist Arrivals in the Syrian Arab Republic (1995-2016) [35]
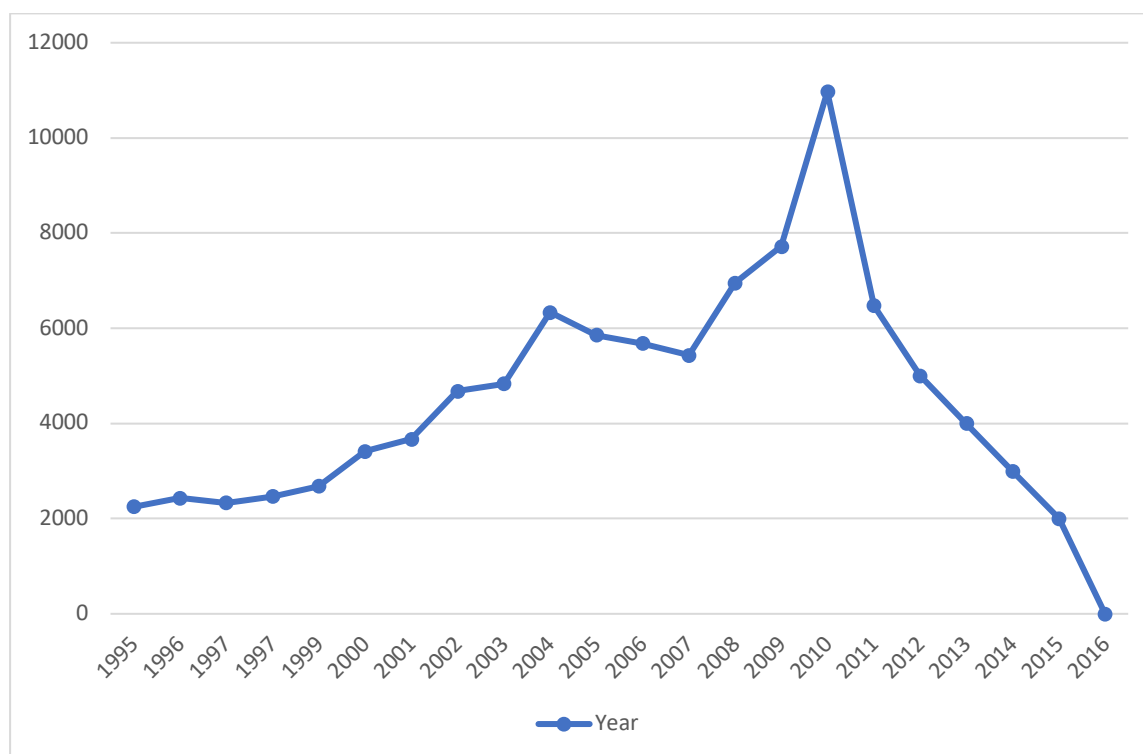
UNESCO immediately took action as a response to the tragic destruction: along with international partners and the Syrian government assessed the damage, documented the destruction, and planned the site's recovery. Moreover, UNESCO managed to raise awareness about the Palmyra attack and the importance of safeguarding the global cultural heritage. Indeed, thanks to significant collaborations between UNESCO and other organizations, it was possible to give a second life to the historical monuments that were unfairly deprived of their universal value.

4.2 Application of 3D Technologies for the Reconstruction of the Archeological Site

After illustrating how the destruction of one of Syria's most significant attractions led to a marked downturn in the national economy, specifically within the domain of tourism, the following chapter focuses on presenting two major projects. These initiatives, utilizing 3D

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[35] UNWTO. 2022. "Basic Tourism Statistics." Www.unwto.org. December 22, 2022.
https://www.unwto.org/tourism-statistics/key-tourism-statistics.

Technologies, have contributed to the reconstruction of the devastated monuments. In particular, the analysis will be focused on the project of archeologists from Vorderasiatisches Museum of the Staatliche Museen zu Berlin, aimed at creating a 360° and three-dimensional film of the Palmyra Site, and the collaboration between UNESCO and Oxford's Institute of Digital Archaeology (IDA) whose mission was to construct a three-dimensional replica of the destroyed Arch of Triumph.

4.2.1 Ancient Palmyra in 360° and in 3D: A Collaboration with the Vorderasiatisches Museum

The project of a 360° and three-dimensional film of Ancient Palmyra was born from the collaboration between the Vorderasiatisches Museum and the company men@work Media Services S.R.L. and produced by Stein Film Produktion in cooperation with ZDF and the Stiftung Preussischer Kulturbesitz [36]. The aim of the project is to enable the viewers of the film to follow three guided tours through the most important attractions of the ancient city:

i.   Tour 1: The Agora, the Roman Theatre, and the Tetrapylon;
ii. Tour 2: the Colonnade, the Hadrian's Arch, the Temple of Nabu, and the Diocletian Baths;
iii. Tour 3: The Temple of Bel.

This unique experience offers the possibility for scholars and visitors to explore the city's majestic ruins as if they were standing on its ancient streets, thanks to the work of archeologists and scanner experts who meticulously recreated every detail.

Mainly, the 3D Technologies that have been used for this project are 3D Scanning, 3D Modeling, Virtual and Augmented Reality. Indeed, the employment of high-precision 3D scanning enabled to capture detailed measurements of the city's ruins, and the implementation of 3D models to capture the scanned data and create from them an accurate representation. While, for the virtual and interactive experience Virtual and Augmented Reality played a significant role, empowering the visualization of the historical site.

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[36] Berlin, Staatliche Museen zu. n.d. "Experience Ancient Palmyra in 360° and in 3D." Www.smb.museum. Accessed September 1, 2023. https://www.smb.museum/en/whats-new/detail/experience-ancient-palmyra-in-360-and-in-3d/.

Figure 6 and Figure 7 represent some of the most stunning results from the 360° and 3D Films of the Palmyra Site. The graphical reconstructions that have been created by the collaboration between archaeologists and technology experts not only serve as a tribute to Palmyra's historical heritage but also contribute to its preservation, by fostering global awareness and appreciation of its cultural legacy. Additionally, this project testifies the importance of partnerships, as we have already mentioned in this thesis and its crucial role when it comes to the implementation of digital tools for the preservation and conservation of Cultural Heritage. These collaborations are essential for securing funding, expertise, and resources from various stakeholders, and they offer opportunities for revenue generation from tourism and educational programs.

4.2.2 The 3D Printed Replica of the Triumphal Arch of the Temple of Bel: The Institute of Digital Archaeology (IDA) and UNESCO Project

The Institute of Digital Archaeology (IDA) is an organization aimed at harnessing technology for the documentation and recreation of historical artifacts. Its project of giving a second life to the Arch of Triumph from Palmyra's Temple of Bel was supported using 3D scanners and their modelization was possible thanks to the collaboration with Tor Art – an Italian company specialized in robotics and the application of technologies to sculpture, design, and architecture – that created the three-dimensional replica with its 3D Italian Printer D-Shape.

First, the project gathered a huge number of volunteer archaeologists from all over the world to support the Million Image Database Project by IDA and to use their 3D digital cameras to take images of the historical monuments to be reconstructed in the future. Then, cutting-edge 3D scanning and modeling technologies were used to meticulously capture the architectural details and intricacies of the original Triumphal Arch, which had once graced the ancient city. These digital reproductions served as the blueprint for the creation of an exact 3D-printed replica.

Figure 8 illustrates the meticulous efforts invested in the restoration of the Arch of Triumph. On the left side of the illustration, there's the arch in its original form, previously to the destruction caused by the ISIS attack, which was set before the colonnades that crossed the ancient city. On the right side we can see the 3D reproduction of the arch, conceived through

cutting-edge 3D scanning and printing techniques, displayed in the heart of Washington D.C., a testament to human resilience and the enduring value of our shared history.

Figure 8: The Arch of Triumph before the destruction at Palmyra Site vs. the 3D Printed Replica of the Arch of Triumph, exposed in Washington D.C. in 2018

4.3 Discussion of Benefits and Challenges of Digitalization: Is it Truly Valuable?

After introducing the reconstruction projects for culturally significant tourist attractions in Syria, the following chapter delves into an in-depth examination of the gains and drawbacks associated with the utilization of 3D Technologies in cultural heritage preservation. On one hand, acknowledging the value that technological innovations bring to the realm of arts and culture as a social asset, allows us to capture the importance of digitalization for the purpose of creating a public value. On the other hand, certain issues arise regarding the potential lack of authenticity and both ethical and legal issues. In this case, the key concern should raise the following question: is digitalization always the most beneficial solution?

The advent of digital technologies has opened up fresh avenues for arts and cultural organizations to leverage their cultural assets and generate greater value. Taking to consideration that the sector of the arts encompasses a diverse range of entities, from small

ventures to larger cultural institutions – in both profit and no-profit domains – there's a growing awareness among policymakers that these entities play a pivotal role in the creative industries, serving as contributors of innovative concepts and talent that enrich the broader creative landscape and extend its influence [39].

The difficulties on assessing the benefits from the digitalization of Cultural Heritage lies on the lack of research methodologies and studies, which traditionally prioritize measurable economic gains without taking to consideration the unmeasurable cultural values. According to Bakhsi and Throsby in the "Culture of Innovation. An economic analysis of innovation in arts and cultural organizations" (2010), a useful framework that supports the theory of value creation in the creative industries, both from an empirical and theoretical view, is based on identifying the concept of innovation in four main categories: Innovation in artform development, Innovation in value creation, Innovation in business management and government, Innovation in audience reach.

The *innovation in artform development* is related to the work of cultural institutions on fostering new and experimental works within their programming while contributing to the evolution of the art forms they present. This means shaping existing artistic trends and developing new approaches to arts. In the field of art galleries, for instance, this concept translates on the ability to deepen the audience's comprehension of the artistic trends. Within the 3D Technologies domain, this type of innovation requires cultural entities to embrace digital tools, creating online platforms and immersive experiences that engage the audience in new ways. Innovation may be generated by product portfolio innovation, where new products are introduced or existing ones are modified, and by radical product innovation, which involves the introduction of entirely new and groundbreaking products. In terms of innovation in artform development, cultural institutions can also engage in interdisciplinary collaborations, leading to innovative and hybrid art forms. For instance, each year the Exploratorium in San Francisco, USA, a science museum, supports a wide number of artists working at the intersection of art, science, and education. The Exploratorium blurs the lines between science and art, creating exhibitions and installations that encourage visitors to engage in the creation of their own art by scientific properties. The *innovation in value creation* concerns the exploration of innovative approaches

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[39] "The Economy of Culture in EUROPE: Study Prepared for the European Commission (Directorate-General for Education and Culture), October 2, 2006, accessed September 1, 2023. https://ec.europa.eu/assets/eac/culture/library/studies/cultural-economy_en.pdf.

to quantify the economic and cultural impact that cultural institutions generate for their customers. It is also an essential process since it's strictly related to the work of policymakers, funding organizations, and private investors, who support cultural heritage by securing a financial assistance and the allocation of resources within the field of Cultural Heritage. Here, what's fundamental is the identification of the beneficiaries of the cultural value: the value is captured not only by the customer who is directly engaged with it, but also by stakeholders, potential audience, and sponsors. Furthermore, within the realm of preservation and conservation of Cultural Heritage, future generations may benefit from the cultural value thanks to the safeguarding of our global cultural legacy. From a theoretical perspective, the digital conservation of Cultural Heritage guarantees an "unmeasurable" cultural value, which translates into helping nations and countries to maintain their unique identities, while enhancing their attachment to and engagement with the community; providing opportunities for education and research; involving international cooperation to protect Cultural Heritage from threats like wars or natural disaster. From a financial perspective, the use of 3D Technologies generates "measurable" tourism and economic benefits [40]. In order to analyze this aspect, it's necessary to focus on the change of consumer behaviors toward a more digitalized culture, analyzing the concept of Active Cultural Participation. In this sense, it signifies a scenario where individuals do not passively gather the cultural stimuli, but rather are driven to actively apply their skills, being keener to cultural participation. Furthermore, the acquisition of cultural skills generates the willingness to transmit new content, including co-creation, use of online platforms, and participation in immersive experiences [41]. In essence, Active Cultural Participation creates a dynamic cycle where individuals' involvement in cultural activities not only enriches their cultural lives but also drives economic effects, nurturing entrepreneurship, spurring tourism, and fostering the growth of creative industries. This interplay underscores the evolving relationship between cultural engagement and measurable economic benefits in the context of 3D Technologies and digitalized cultural experiences.

The *innovation in business management and government* represents the effect of digitalization on Cultural Heritage at a business level. Due to the introduction of technological innovations, cultural organizations must face strategic management challenges, making changes in their business models and adapting their financial strategies to the evolving funding environment.

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[40] David Throsby and Hasan Bakhshi, "Culture of Innovation: An Economic Analysis of Innovation in Arts and Cultural Organisations," *NESTA*, June 4, 2010, https://apo.org.au/node/21548.

[41] Pier Sacco, 2011. "Culture 3.0: A New Perspective for the EU 2014-2020 Structural Funds Programming." https://www.interarts.net/descargas/interarts2577.pdf.

Indeed, within cultural entities there must be the urge to move toward audience development rather than product development, prioritizing the role of the customer within the organization [42].

Taking a look at Figure 9, which shows the traditional Cultural Value Chain, is a helpful tool for the analysis of changing the business models within cultural institutions. As shown in the figure, the objective of organizations within the realm of Cultural Heritage is the balancing of the three dimensions for the implementation of the cultural product, creating value at each stage: Production, Distribution, and Consumption. What's more, this task becomes more challenging as new digital tools, such as 3D Technologies, are employed within cultural organizations. Keeping business models updated implies a re-arranging of revenue sources, and promotion of content, such as merchandising and production of audio-visual materials and media. Since the collaborations are fundamental for the implementation of a great business strategy, organizations need to reorganize their relationships with funding providers, including sponsors, individual donors, and partners.

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[42] Throsby and Bakhshi, "Culture of Innovation: An Economic Analysis of Innovation in Arts and Cultural Organisations."

Figure 9: The Value Chain for Cultural Institutions [43]
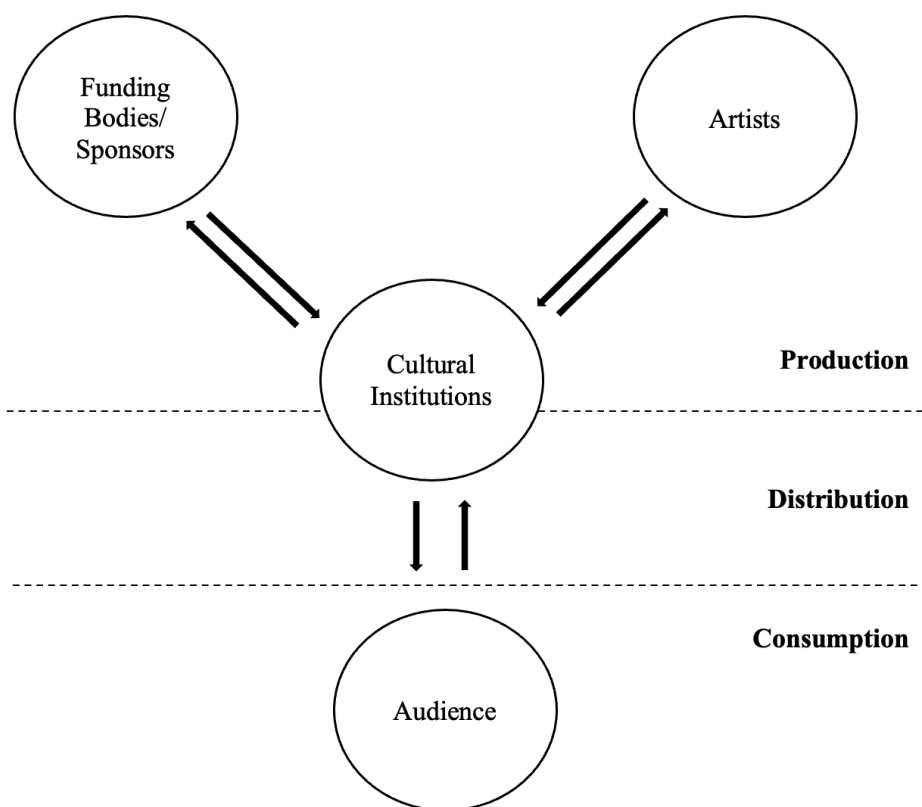
The *innovation in audience reach* refers to the generation of new creative ways to engage and expand a wider audience in the cultural experiences. Within the context of 3D Technologies, it refers to the initiatives that help create immersive and more appealing experiences for the consumer, such as Virtual Tours, Online Learning Resources, Interactive Exhibitions, and Online Collections. The question is: How can a cultural institution or organization increase participation [44]?

According to McCarthy and Jinnett (2001), there are three possible ways: audience *broadening*, audience *deepening* and audience *diversifying*. The first refers to the ability to expand the existing market to a market made of consumers who are audience in the field of arts but not currently participants; the second represents the enhancement of the customer's level of

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[43] Hasan Bakhsi, and David Throsby. 2009. *The Value Chain for Cultural Institutions.* https://www.researchgate.net/publication/265748057_Innovation_in_Arts_and_Cultural_Organisations

[44] Throsby and Bakhshi, "Culture of Innovation: An Economic Analysis of Innovation in Arts and Cultural Organisations."

engagement; the third conceptualizes the act of expanding the market to those who are not usual consumers [45].

For a more comprehensive explanation of these concepts, here are a few real-life examples concerning cultural institutions, such as the following major museums, who have employed an increase in participation thanks to the audience strategies already cited.

The Louvre Museum in Paris has recently launched the project "Mona Lisa: Beyond the Glass", part of the 2020 Leonardo da Vinci exhibition, which is a Virtual Reality (VR) experience that can be displayed in a smartphone, using its own application. This project allows people who cannot physically visit the museum to enjoy the magnificent Italian artwork. In this way, the audience is broadened, from an audience composed of in-presence visitors to an audience made of culture enthusiasts who might not be engaged in this experience otherwise.

Moreover, since the degree of audience deepening can be measured through the number of attendances per year at a certain cultural institution or museum, the Cleaveland Museum of Art (CMA) in Ohio, USA, is a great example. The American museum has introduced the ArtLens application and three-room experience, which employs Augmented Reality (AR) and 3D Technologies to enhance the visitor experience, offering interactive tours and the possibility to create personal digital compositions. After having launched the project, the CMA released the findings of a two-year study on the correlation between digital technologies and customer engagement, to check whether ArtLens was effectively successful or not. The results, based on the period November 2017 – January 2018 were the following: of the total 36% of people visiting the ArtLens Gallery in the museum, 76% agreed that the ArtLens Gallery enhanced their overall museum experience, 74% that it encouraged them to look closer at the art. Also, the majority of the sample (78%) agreed that the virtual experience increased their perception of museum as innovative [46].

Furthermore, the strategy employing audience diversifying is referred to those institutions managing to make the cultural experience more inclusive, encompassing those groups of customers who are usually not included in the market as "common consumers". For this reason,

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[45] Kevin F. McCarthy, and Jinnet Kimberly, *A New Framework for Building Participation in the Arts*. (Rand Corporation, 2011), 53-54.

[46] Elizabeth Bolander, Hannah Ridenour, and Claire Quimby, "Art Museums and Technology Developing New Metrics to Measure Visitor Engagement", accessed September 3, 2023. https://www.clevelandart.org/sites/default/files/documents/other/CMA-18-18160%20Art%20Museums%20%26%20Technology%20White%20Paper_R5.pdf.

one of the initiatives that the European Union supported and it's worth to be mentioned is the ARCHES Project, in collaboration with VRVis (a research institute specialized in visual computing). The name stands for Accessible Resources for Cultural Heritage EcoSystems and it's focused on making cultural heritage more accessible to individuals with disabilities. In this way, the project guarantees inclusivity and accessibility, while diversifying the audience and catering to a group of people who may not have had the opportunity to engage with cultural heritage in traditional ways. Thanks to the support of 3D Technologies the project develops interactive tools as sign language video avatars, a museum-oriented tablet game for blind people, and the prototype of a portable visual perception 2.5D printer to allow people to feel the artworks through tactile sensations. All these digital services are now available on Google Play and Apple Store and will be displayed in major museums such as Museo Thyssen-Bornemisza in Spain, Victoria & Albert Museum in the United Kingdom, KHM-Museumsverband in Austria, Museo Lázaro Galdiano in Spain, The Wallace Collection in the United Kingdom, and Museo de Bellas Artes de Asturias in Spain [47].

Figure 10 shows one of the results of the ARCHES Project, illustrating the "*The Birdnester*" by the famous painter Bruegel. With 3D Printing technology, the experts created a meticulous replica of the artwork, allowing people with cognitive or physical impairments to be involved in the appreciation of the painting through tactile sensations.

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[47] European Commission and Cordis, Eu Research Results, "Technical Innovations Help Overcome Access Barriers to Cultural Spaces," cordis.europa.eu, February 24, 2020, accessed September 3, 2023, https://cordis.europa.eu/article/id/413505-technical-innovations-help-overcome-access-barriers-to-cultural-spaces.

Figure 10: The 3D Printing Replica of Bruegel's "The Birdnester" by VRVis [48]

After having analyzed the positive aspects that 3D Technologies produce within the sector of Cultural Heritage, there exist some drawbacks that may negatively affect the production of digital cultural "products" by the creative industries.

First, the main concern associated with the utilization of 3D Technologies is the risk of compromising authenticity. In the specific case of the digital reconstruction of the Palmyra Site, concerns have been voiced regarding the selection of materials used in constructing the Arch of Triumph replica and its capacity to authentically preserve the historical and cultural intrinsic value. Indeed, even though the reproduction of the building resulted to be almost identical to the original one, and managed to give a second life to it, some researchers claimed that many characteristics were not equally reconstructed as the old arch. Indeed, the color of the replica was accused of being smaller in scale and the material used was uniform yellow instead of its original Egyptian marble. Furthermore, the reconstruction of such a culturally significant historical site may be seen as an act of resistance against the attempters of the culture, but, most of all, as an act aimed at political gains. Indeed, the reconstruction of Palmyra was speedy incentivized by the political power of Russia, and the reason for the concern is hidden behind the fact that in the context of political conflicts, heritage is used as a weapon in propaganda battles. This concern was raised once the media reporters in Russia and Syria created strong

[48] VRVis. n.d. *ARCHES: How IT Can Make Art and Visual Art Education Inclusive*. Accessed September 4, 2023. https://www.vrvis.at/en/research/research-projects/arches.

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propaganda on the effectiveness of their Russian-Syrian alliance, compared to the less powerful Western forces. However, rebuilding historically valuable monuments or buildings should not be seen as an act of masking the true crimes that happened, but instead, it should be viewed as a necessary step by the entire community to preserve their collective memories [49].

The issue related to the lack of authenticity is strictly correlated to the concept of author rights and Intellectual Property Rights within the digital world. Copyright allows artists, writers, and authors to economically take advantage of their works, earning profits every time their production has been used, cited, or reproduced.

In 2019, the 27 European Countries have drawn up, together with the European Commission's Expert Group on Digital Cultural Heritage and Europeana (DCHE Expert Group) a list of 10 basic principles for 3D digitalization of tangible Cultural Heritage. The fourth principle concern the Copyright issue and is titled as follows: "Clarify Copyright aspects and plan for open and broad access". The 3D digitalization process itself may also produce new supplementary rights, held by other individuals or organizations. Therefore, the identification of the rights at stake and of the entities owning them is a necessary task prior to the beginning of production. The problem can be found in the case a country's regulations don't transfer the rights of a Cultural Heritage item to its digital replica. In that case, clarification and negotiation with the involved institutions should be made, with the aim of transferring any copyrights or associated rights and realizing digitalized replica in the public domain with no infringements. Furthermore, it is important to plan how the target audience will use the digital items. This means identifying the channels through which the customer will reach the products offered – virtually, online, via streaming, and in museums [50].

The era of digitalization has generated a shift from traditional Cultural Heritage production to a 3.0 model, involving three-dimensional technologies. This change, as already cited, has brought significant and enormous opportunities both in a social and economic sense. However,

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[49] Sarah Amawi, "Palmyra's Reconstruction: Importance and Discourses of Authenticity after Reconstruction - Observatory Patrimoine d'Orient," *Observatory Patrimoine d'Orient - Thinking the East differently* (blog), April 13, 2021, https://patrimoinedorient.org/index.php/en/2021/04/13/palmyras-reconstruction-importance-and-discourses-of-authenticity-after-reconstruction/#_ftn4.

[50] Review of *Expert Group on Digital Cultural Heritage and Europeana Basic Principles and Tips for 3D Digitisation of Tangible Cultural Heritage for Cultural Heritage Professionals and Institutions and Other Custodians of Cultural Heritage*. 2019. *Europa.eu*. European Commission: EUROPEAN COMMISSION DIRECTORATE-GENERAL FOR COMMUNICATIONS NETWORKS, CONTENT AND TECHNOLOGY. https://digital-strategy.ec.europa.eu/en/library/basic-principles-and-tips-3d-digitisation-cultural-heritage.

digitalization has its own costs. While cultural institutions feel the need to continuously diffuse cultural goods for a public purpose, they are challenged to keep up with the digitalization diffusion and adapt their business models to it. This introduction of entrepreneurial activity to the cultural domain has certainly had a huge impact on the economic industry environments. The necessity of creating new business models generates additional pressure on those institutions that are engaged in "producing" cultural goods, such as galleries, libraries, and museums (GLAM institutions) to adopt this recent digital transformation and adapt to the marketplace. Still, the ability to make use of 3D Technologies in a beneficial manner requires GLAM entities certain resources for the implementation of technology, including Research and Development (R&D), Storage and Data Management, and hardware and software equipment. Furthermore, the ongoing innovations in Cultural Heritage may be of significant cultural, creative, and imaginative value but don't contribute to societal growth. The key point here is to create a balanced connection between innovation and creative industries, responding to social issues and needs and delivering to customers the right value [51].

According to Bugine et al. (2019) Cultural Heritage sector faces two main obstacles in the implementation of technological–based goods: the lack of sufficient infrastructure and democratic access to the digital economy and the cost and complexity of implementation of digital tools. The main problem related to implementing digital tools is the insufficient access to the internet for almost half of the global population - 3.6 billion individuals aren't connected – and the cost associated to e-insurance are large. Looking at the industry environment, the digitalization has reached only less than 40% of the global industries, due to the necessary transformation required at a strategic level [52]. Therefore, new types of skills are required to the employees inside the business, and new mindsets to entrepreneurs to achieve this new implementation. What's more, once an organization has developed and upgraded its business model, the integration of technologies into the company's process may be challenging. To obtain the necessary skills, an organization must improve its own adaptive learning programs, balance a sufficient connection between business and public sector, and implement training programs for the use of three-dimensional technologies. Unfortunately, there is a wide range of

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[51] Melissa Terras et al., "The Value of Mass-Digitised Cultural Heritage Content in Creative Contexts," *Big Data & Society* 8, no. 1 (January 1, 2021): 205395172110061, https://doi.org/10.1177/20539517211006165.

[52] Jacques Bughin, Laura LaBerge, and Anette Mellbye, "The Case for Digital Reinvention," *Mckinsey.Com*, February 9, 2017, accessed September 1, 2023, https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-case-for-digital-reinvention.

economic sectors or industries that would significantly benefit from the implementation of 3D Technologies but that still, due to their high costs, cannot make use of them, including small start-ups, entities with limited budgets as nonprofit organizations and some traditional manufacturing sectors [53].

[53] Jacques Bughin et al., "Tech for Good: Smoothing Disruption, Improving Well-Being," *Mckinsey.Com*, May 15, 2019, accessed September 1, 2023, https://www.mckinsey.com/featured-insights/future-of-work/tech-for-good-using-technology-to-smooth-disruption-and-improve-well-being.

5. Conclusions

In the preceding chapters, we have developed an extensive analysis of the convergence between Cultural Heritage and 3D Technologies, with the common aim of preserving and conserving our cultural legacy. We aimed to undertake an investigation, merging the concept of technological innovations and entrepreneurship, within the realm of business organizations, discovering a scenery full of challenges and opportunities. In this concluding section, we will summarize the main takeaways from this study, discuss their relevance to the field of Cultural Heritage, and reflect on their implications.

Returning to the central question that guided our research, the main issue was to understand how technological innovations and Cultural Heritage may work together to create value for individuals, both in an economic and social meaning. Indeed, as individuals we intended the direct beneficiaries of Cultural Heritage experiences – so, the audience – and the indirect beneficiaries, who work behind – the organizations and businesses.

The path of this research has started with an overview of the 3D Technology Market, together with an explanation of the most used 3D Technologies and their associated benefits and costs in the realm of businesses. In doing so, we wanted to offer a sufficient background knowledge of how these technologies technically work and how the market is answering to the increasing demand of digitalizing organizations, businesses, products, and services. As we showed in the Technology Regional Market Share graph from 2019 (Figure 1), it is clear that the global market for digitalization is gradually expanding among countries, but also among different industries. This significantly represents the need of economic sectors, from Healthcare to Automotive, from Education to Aerospace, to welcome 3D Technologies and gather all the benefits that they may offer.

Subsequently, the key findings from the analysis of the correlation between value creation and business models in the Cultural Heritage have shown that if there's a change from the outside – in this case, the need to make customers more engaged with virtual cultural experiences or encourage for a more digitalized form of preservation of artifacts – it should be adopted in the organization itself. Looking at the Business Model Canvas, we discovered that capturing, creating, and diffusing value in the digitalization era must necessarily update the channels, activities, and key partners through which the cultural value is perceived by customers.

Moreover, researching the literature whose main concern is to analyze how value is created and addressed to audiences within the field of Cultural Heritage, we have found that there's a lack of methodologies that address the cultural value of digitalization in this sector, while a wide range of authors primarily discussed the economic aspect. Thanks to the Innovation Methodology Analysis from Throsby and Bakhshi (2010), we examined how innovation brings changes both from an economic and cultural perspective. Our findings showed that beyond offering new ways of engagement with Cultural Heritage to customers, digital tools can also give rise to new artistic trends, gathering a portion of the market customers who were not the usual target audience. This represents a significant change in the way we approach Cultural Heritage, not being just "passive" watchers of our historical legacy but becoming the main characters in it.

What's more, through the analysis of the Value Chain for Cultural Institutions (Figure 9), we concluded that there's a continuous correlation between the main actors that take part in Cultural Heritage production, which are: funding providers, artists, cultural institutions, and the audience. This means that there cannot be divisions between the economic initiatives of cultural organizations - managerial and strategic activities – and the cultural purposes aimed at reaching the audience and creating cultural value. Their actions take part in a common plan, whose objective is balancing the inputs and the outputs throughout the main three steps of the value chain: Production, Distribution, and Consumption.

However, the main objective of this thesis was also to take into consideration all those drawbacks that are correlated to the implementation of 3D Technologies to Cultural Heritage Preservation. Not all technological innovations culminate in favorable outcomes, and many of them may fail. In the specific case of Cultural Heritage Preservation, with a particular look to the case study that we analyzed - Digital Reconstruction of Palmyra Site, in Syria – we examined when digital tools are not greatly welcomed by organizations and customers. The issue of digitalized culture is strictly related to compromising its authenticity and originality, and even though the use of 3D tools can reconstruct destroyed or missed parts of artifacts and buildings, it still generates controversial opinions among researchers and cultural enthusiasts. Addressing the research question posed at the outset of our thesis, we think that recognizing the enormous contributions derived from 3D Technologies applied to Cultural Heritage is only possible if the conception of "culture" changes. Culture should not be considered only the action of "doing" arts, limited to the artistic and creative application. Expanding the meaning of culture

from its conventional meaning to a wider one allows us to capture its significant value. Cultural Heritage represents the promoter of the production and distribution of cultural socially desirable goods and services, both in economic and social areas; it becomes the sector of the Cultural and Creative Industry suitable for welcoming cutting-the-edge technologies and reaching a significant relevance among other economic sectors that have been previously digitalized; it becomes a resource that needs to be efficiently allocated to capture its intrinsic societal and economic value. The implementation of 3D Technologies in the preservation of Cultural Heritage guarantees the increase of present and future tourism, museum visitors, researchers, and students, expanding the target audience of a sector that has been often associated only with culture enthusiasts. Digitalization will open an enormous number of opportunities, which will require at the same time significant investments and funding, but that will create a more democratic Culture, making it accessible to a wider and more diverse audience.

As we stand on the cusp of the digital revolution, this is just the beginning of what hopefully will be the journey of Cultural Heritage within the realm of technological innovations and three-dimensional tools. In following this path, we will have the opportunity to revitalize the past, give a second life to its cultural legacy, and ensure that future generations capture the value of the cultural treasures left behind by our predecessors in our world.

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7. List of Figures