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3D printing in tourism: an answer to sustainability challenges?

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Abstract

Purpose - The paper aims to explore the opportunities to use 3D printing technology as a more sustainable tool in various areas of the tourism and hospitality industry in Cyprus.

Design/methodology/approach - For the purpose of this study, a qualitative study was conducted to explore the current state and opportunities of 3D printing technology in Cyprus, specifically for the tourism and hospitality industry. Interviews were conducted with industry professionals and practitioners using a snowball sampling method.

Findings - The tourism and hospitality industry currently uses 3D printing technology mainly to restore cultural heritage sites; however, there is very high potential to implement 3D printing for buildings, souvenirs, and food items.

Originality/value - This paper explores the current state and opportunities to use 3D technology to print concrete/ buildings, restoration of cultural heritage, souvenir and food printing that together has the potential to contribute to a more sustainable tourism and hospitality industry in Cyprus.

Keywords - 3D printing, additive manufacturing, sustainability, cultural heritage, tourism.

Paper type - Interactions with practitioners/ practical solutions

Introduction

There has been an increasing interest in innovative technology such as the Additive Manufacturing (AM) process in recent years. This technique was known as rapid prototyping, which is well known as 3D Printing. According to the technical committee at ASTM (American society for testing and materials), the new terminology and standard are adopted, and it is now called Additive Manufacturing technology(Gibson *et al.*, 2014). Chars Hull was one of the first people to invent the Stereolithography (SLA) patent in 1986, which led to the introduction of AM technologies. Since then, AM technique has made a new revolution in different industries over the past two decades due to the advantage of manufacturing complex parts, freedom in design, less time to

produce, and lower cost (Tamez *et al.*, 2021). In recent years, innovation and technology have become essential topics for discussion.

Printers have been able to "print" three-dimensional physical items for almost two decades and have started to grow into a whole new range of digital manufacturing capabilities. The future of tourism, funded by the latest 3D printing (industrial) innovations, will be an exciting one, given that there is a wide and unlimited variety of printers that can be used. AM is a process to manufacture the desirable 3D parts using digital models such as computer-aided -design (CAD) by joining raw materials layer upon layer to produce metallic or polymeric parts(Smith and Rennie, 2010). The thickness of each layer is limited to some extent to produce the final cuts. In other words, as long as the materials in layers are thinner and more delicate, the desirable parts with correct dimensions and better surface quality can be manufactured (Gibson *et al.*, 2014). It is worth mentioning that, in this novel technique, the final parts are created by adding raw materials layer upon layer during the process.

In contrast, the conventional method is based on removing materials. Therefore, in the AM process, low waste materials and lightweight components can be generated, and lightweight components can be developed. The AM process is one of the most widely used industrial applications and the consumer market. These included aerospace, automotive, medical and accessories applications such as GE Aviation fuel nozzle, turbocharger wheel, prosthetics, construction of electric machines, titanium jaw implant, hearing aids, jewellery, art, and food as souvenirs(Gibson *et al.*, 2014; Juechter *et al.*, 2018). The expansion of additive manufacturing (3D printing) creates opportunities for custom-made souvenirs and tourist attractions, such as a 3D printed map of the city attractions.

On the other hand, perhaps the most serious disadvantage of this novel technology is built orientation. This is a critical problem since it is correlated with the item's precision, support level, and processing period to manufacture the object. Picking the AM's ideal construction orientation will lead to significant construction savings and enhance the item's precision. Further research should explore the build orientation in AM(Rocha *et al.*, 2018). Another major drawback of this technology is that the process parameters during AM can produce undesirable voids known as porosity. This can be implemented purposely or unintentionally to produce parts with inner porosity. Forming porosities is undesirable during AM processing, especially in some crucial parts in different applications such as aerospace and medical, because porosity might contribute to catastrophic failures and severe damage during service. Raw materials such as powder in the AM process have also been crucial in the final product quality. The powder should not have been exposed to light, any contamination as well as excessive moisture. Generally speaking, pollution prevention during processing leads to higher output and increases the parts' lifespan. Therefore, it is vital to prevent this kind of contamination (Gibson *et al.*, 2014).

Despite several drawbacks and risks, the global 3D market has been increasing rapidly over one decade to support environmental regulation to overcome issues such as producing parts in sustainable methods and controlling pollution in production routes. Since 2013, this has contributed to a 12-17 per cent rise in industry sales per year to an estimated US$ 44.6 billion by the end of 2027. The demand for 3D printing is forecasted to have an economic effect of between US$ 230-550 billion by 2025. Among all components, the latest development of metallic 3D printing is widely emphasised by all industry models. However, ceramic and composite printing is trying to overtake the industry(Gibson *et al.*, 2021; Kellens *et al.*, 2017; Tamez *et al.*, 2021).

In Cyprus currently, 3D printing is widely used in interior design and engineering parts. An area that is rapidly growing is the development of art pieces, as local artists are interested in the technology and try to implement it into their workflow. There is broad interest in 3D printing in the tourism sector too. Several companies in Cyprus are already using 3D printing technology for printing parts for tourism and cultural purposes. Although individuals and groups of experts have undertaken many initiatives and projects, there is no common understanding of the implementation of AM technology and its opportunities in Cyprus. Therefore, the primary purpose of this article is twofold: to explore the current stage of 3D printing in Cyprus; to investigate the opportunities on how 3D printing could support the sustainability of the tourism industry in Cyprus.

3D printing and sustainability: literature review

During the last decade, the attitudes towards sustainable design practice have changed. While sustainability has always been an issue, 3D printing can contribute to it (Aldoy, 2020). Several studies suggest that 3D printing could provide a variety of options that have the potential to contribute to product sustainability, for example, to substantially benefit designers (Diegel *et al.*, 2010). From the standpoint of sustainable design, 3D printing may be a valuable weapon in the armoury for bringing about the sustainable design of consumer items. With the developments in manufacturing technology in the current age, academics and industry have taken a greater interest in smart manufacturing to reap the benefits of making their production more sustainable and effective (Majeed *et al.*, 2021). Significant smart manufacturing, sustainable manufacturing, and additive manufacturing processes are integrated to provide a single phrase of sustainable and smart additive manufacturing (SSAM). Furthermore, it can meet the rising need for personalised goods while reducing environmental impact by eliminating production waste (Son *et al.*, 2021).

However, one of the significant implications of 3D technology on sustainability is the use of materials that helps 3D printing to be more sustainable. Because the importance of sustainability in human health is growing, several kinds of research have been conducted in recent years to make it a sustainable manufacturing technology (Jiang and Fu, 2020). The potential benefits include reduced material waste, decentralisation of the manufacturing process and cost savings from transportation and storage, production of products that would be difficult or impossible to produce using traditional subtractive manufacturing, and mass customisation of components. Aluminium,

plastic, paper, wax, steel, gold, concrete, chocolate, and sugar are just some of the materials utilised in additive manufacturing (Chen *et al.*, 2015); (Aldoy, 2020). The usage of plastics is a concern with 3D printing, although certain plastics are biodegradable. Touchless noted that printing spare parts on-demand with less waste enables becoming more sustainable (Aldoy, 2020). 3D printing has the potential to minimise waste and use less energy when producing final objects. Manufacturing products by AM could be used in clean energy technologies, which results in decreasing the carbon footprint and improving climate change.

There are several challenges that 3D printing may face soon. For example, legislation in Europe has been a driving force for reform, with manufacturers increasingly held accountable for end-of-life items. Design for disassembly and goods that can be fixed by the manufacturer or even the consumer is becoming more common, and product service system thinking is replacing the cradle to grave design paradigm. If 3D printing and digital communication continue to advance at their current rates, not only will all goods need to be redesigned, but the whole way design is structured and products are delivered will need to be rethought (Kalemis, 2018).

Methodology

The current study aims to explore the question "3D printing in tourism: an answer to sustainability challenges?". For this study, nine interviews with practitioners and industry professionals were conducted. The 3D printing industry in Cyprus is scattered. Several EU projects on AM, private companies doing 3D printing, industry enthusiasts working on implementing 3D, but not yet any association or links amongst those. Therefore, researchers used a snowball sampling method to select respondents for the interviews (Parker *et al.*, 2019).

Respondents were invited for an interview via a phone call and after e-mail to participate in the research. Questions were shared with the interviewees before the interview to obtain their informed consent and be better prepared. The interviews were carried via Zoom and face-to-face to gain detailed insights and clarify opinions into their perceptions. The interview questions included general and specific information about 3D printing in Cyprus, their standpoint on the 3D industry in Cyprus and their companies, the potential and opportunities for particular sectors of application of 3D printing technology, along questions focused on sustainability. Interview protocols were produced for the recorded interviews, and content analysis of the transcripts was done to help obtain the findings identified.

The current state of 3D printing in Cyprus

In Cyprus, 3D printing technology has existed for many years and is progressing rapidly in different sectors. Industry practitioners admit that "*in the last two years, there is a high increase in 3D printing businesses and individual makers. Product development has led to an increase in prototyping needs and therefore 3D printing has become the main service for fine-tuning the products"*. Multiple companies are providing 3D printing technology.

3D printing technology can create a massive manufacturing sector for customised products in the Cypriot market. It is a technology that can penetrate several sectors because it can be used as a development tool and also as a final product manufacturing method. 3D printing companies in Cyprus understand the value and the importance of the technology and mention that *"3D printing has been receiving acknowledgement more and more in Cyprus. We need to invest in educating professionals on their strengths and potentials to fully realise the benefits one can have"*.

Concerning the tourism industry, 3D printing experts admit that *"3D printing for tourism development already exists in Cyprus in various fields such as religious tourism, archaeological monuments and artefacts restoration as well as a tool for artists that craft new designs and also alterations to ancient and modern art pieces"*.

Another local company, CYENS - the Research and Innovation Centre on Interactive Media, Smart System and Emerging Technologies – Centre of Excellence empowers knowledge and technology transfer in the region. This company has a lot to offer to tourism in Cyprus in terms of technology and innovation. They currently collaborate with CYENS ITICA MRG and CMMICyprus (Cyprus Larnaca Tourism Board). One of the current projects involves planning several driving routes in the underwater coastline of Larnaca to recreate it in 360 videos virtually. The representative from the company was very positive about 3D printing technology in the tourism industry and stated that: "*3D printing technology gives the benefit for design freedom and therefore ideas on how to use it can only be limited by the user's imagination"*.

One of the main benefits outlined by the respondents were unlimited opportunities on how and where 3D printing could be applied. As practitioners are saying, *"Reverse engineering and product development have the lead. 3D printing machines are the ideal tools for the designer, the hobbyist, the engineer, the inventor and the artist. Each and everyone can bring their ideas to a physical form without the need for expensive and time-consuming equipment. 3D printing can support and facilitate research, design, and prototyping in any field or industry. I would encourage professionals to introduce this practice in their professional environment as in combination with other specialities can result in great results"*.

Industry professionals also see the opportunity of 3D printing technology contributing to more sustainable tourism industry. Still, they admit that "*3D printing will become unavoidable at some point (see the reduce, reuse, and recycle model, for example). However, this needs careful planning and trained personnel that realises the appropriate use of such technology"*. Several respondents raised concerns about a low understanding of the technology, low familiarity, and a limited number of professionals who can use the technology, limiting the industry to reach its full potential.

Opportunities to use 3D technology in concrete/ building printing

One of the products that 3D printing offers nowadays is concrete printing. 3D concrete printing has grown in popularity in recent years. The usage of cement and concrete materials in combination with 3D printing is becoming more common. The technique began with modest non-structural applications and progressed to big-scale constructions with the help of significant firsts that accepted and established the 3D Printing Method (Hussein, n.d.). This technology provides many mass customisation options to the construction sector, which has traditionally been thought to be a low-mass modification business. Lightweight components can be generated, and AM process's, to traditional techniques limiting architects' innovation; the building business can be opened up to various product customisation. Several factors determine the effectiveness of this technique, such as the nature of the consumer's demands and the degree of the customer's desire. The primary benefit of 3D printing concrete buildings is that no formwork is required, and complicated structures may be constructed quickly. Another advantage of 3D printing concrete buildings is that it speeds up the construction process and saves on-site personnel (Han *et al.*, 2021). With a growing emphasis on sustainability, 3D printing construction and recycled concrete have piqued the imagination of many as innovative construction technologies and unique building materials.

3D concrete printing is not limited in its options. The concept of customising buildings has grown into a thriving worldwide trend (Han *et al.*, 2020). WinSun Company in China successfully printed a number of houses in less than 24 hours in 2014 (Wu *et al.*, 2016). Buildings, such as houses, offices, bridges, pavilions, shelters, residential buildings, hotels and many more, are printed nowadays with advanced technology (Hossain *et al.*, 2020). There are many examples of such buildings; one example is during the Solar Decathlon Competition in China in the summer of 2018, a display house was planned and built by team WashU ("2018 LOTUS HOUSE", n.d.); ("Solar Decathlon China", n.d.). During the building phase, the WashU team concentrated on decreasing CO2 emissions and material waste. In this project, 3D printing was used to create surface moulds for the walls, which were subsequently cast with concrete. The lotus blossom, a natural emblem of purity and beauty, served as inspiration for the architectural style. Its petals, which were free-form, were abstracted as curving walls. Its rounded planar design was appropriate for detailing as a residential dwelling layout (Han *et al.*, 2020).

Fig. 1 The lotus house (photo from ("2018 LOTUS HOUSE", n.d.))

Many researchers and firms think that 3D printing may positively impact the building sector, and some large-scale constructions have already been built in many countries worldwide. The project sought to exhibit an innovative, beautiful, and sustainable house by utilising 3D-printing technology in architectural design and construction (Pessoa and Guimarães, 2020).

Another example is a fully functional 3D printed office in Dubai (Carolo, 2020). This building is called "Office of the Future" and is recognised by Guinness World Records. It is the first 3D printed commercial building designed by the architecture firm Gensler for the United Arab Emirates National Committee as the headquarters for the Dubai Futures Foundation.

Fig 2. The “Office of the future” in Dubai (photo from

The world’s first-ever 3D printed hotel room is presented in Lewis Grand Hotel in Angeles City, Pampanga, Philippines (Tablang, 2015). It took over 100 hours to 3D print the 130-square-meter extension. The suite itself is concrete spread, is the world's first legally sanctioned and functioning commercial building constructed using 3D printing technology. Its most recent addition featured 3D printed bedrooms, living spaces, and a jacuzzi area.

Fig 3. Lewis Grand Hotel Extention (photo from ("3D Printed House: 20 Most Important Projects", 2020))

Although 3D technology in concrete/ building printing offers many advantages and could significantly increase and customise tourism offers in Cyprus, industry professionals admit that such large scale projects have not yet been undertaken in Cyprus. One of the respondents admits, "*3D printing of buildings in Cyprus would be great- think customised hotel rooms, boutique bungalows in mountain areas, but it needs large investment".* Such a massive project has not yet been undertaken in Cyprus. It still requires years of practice and technology implementation to develop a significant level in 3D printing. However, there is potential in this field of 3D technology, and there are opportunities for Cyprus to implement this technology. The 3D built houses would be a solution for a climate like Cyprus has (hot summer and cold winter). These houses can be designed to keep the warmth inside or to cool the temperature down. Also, it is a sustainable product.

Opportunities to use 3D technology for restoration of a cultural heritage

To be nominated for World Heritage status, properties must have "integrity" and "authenticity" and be of "outstanding universal value" (Alberts and Hazen, 2010). Identifying and preserving authenticity and integrity at cultural heritage places, on the other hand, are complex tasks. Furthermore, the variety of locations and the vast range of impacts on them necessitate specialised methods to preservation in many situations. Nonetheless, authenticity and integrity may serve as valuable guiding ideas in pursuing a systematic approach to conservation in various conditions.

In recent years, 3D technology for Cultural Heritage has shown positive protection, enhancement, and heritage transmission. The advent of 3D printers has opened new opportunities for the heritage industry (Kalemis, 2018). 3D models have a rather lengthy history in modern archaeology, primarily for public presentations, museum services, and involvement in educational programs (Hermon *et al.*, 2018). Restoration of cultural heritage, such as monuments, missing pieces of architecture and monuments, has been widely used for the past ten years worldwide. Preservation and restoration of the heritage dated 2000 or even more years back are not always easy and require much time, energy, and equipment. Mediterranean islands, including Cyprus, are rich in history and heritage. With so many wars and invasions, the heritage was ruined, and some has disappeared completely. 3D printing is already used by local engineering and manufacturing companies to restore and make a replica of famous architectural buildings and monuments. These companies have been establishing collaborations with Universities, Cultural Heritage professionals, architects, designers, marine research, and other creatives, and still, they are open to expanding this collaboration further.

One of the well-known and well-established 3D printing companies on the market in Cyprus is G LAB PROJECT 3D LTD. This company has contributed to many projects related to cultural heritage, such as the digitalisation of Cyprus monuments and artefacts using 3D scanning and

reverse engineering. These projects aim to preserve the artefacts and monuments of Cyprus cultural heritage in a digital form; 3D printing of artefacts from the Cypriot culture that was used for presentations as well as aids to help people with disabilities (for example, visually impaired people) to have interaction with the shapes of monuments and artefacts, creation of 3D art pieces using 3D modelling and 3D printing from just pictures or the artist's ideas. These art pieces can now be found in several museums, public places, monuments and parks. The company also helped develop souvenirs and small art pieces by local artists who used the technology to create their twist on known statues. The company's owner states, *"Digitizing of the culture can have several benefits such as virtual representation and tours, assist in restoration and preservation in case of natural damages and recreate mock-ups and accurate copies of artefacts through 3D printing and further post-processing".*

Many of these and more restoration projects are undertaken can be seen all over Cyprus. There are some examples of finished projects existing.

Unique stone objects found at the Late Bronze Age site of Pyla-Kokkinokremos.

Pyla-Kokkinokremos is one of only three significant towns established in previously deserted areas during the 13th century BC. The village of Pyla-Kokkinokremos is considered a Late Bronze Age village and is located in southeast Cyprus on a high plateau overlooking Larnaca Bay (Brown, 2017). The archaeological site of Pyla-Kokkinokremos is the topic of an ongoing archaeological study that began in the early 1950s and continues until this day. The site is located 10km from Larnaca. Its unique nature, being short-lived while being highly rich in terms of diversity of material culture and industrial activity, is reflected by the range of items best defined as belonging to the larger Eastern Mediterranean cultural sphere of influence (Hermon *et al.*, 2018). The numerous excavation efforts produced a vast corpus of items that piqued the interest of scholars owing to their distinctiveness and possible contribution to the understanding of cultural processes that happened in the region towards the end of the Bronze Age.

A little stone item with a carved surface from bottom to top was discovered in a damaged archaeological setting at the Pyla-Kokkinokremos site in Cyprus. Given its early recognition as a one-of-a-kind artefact, an attempt was made to study it using scientific visualisation and 3D shape analysis on its 3D digital and physical duplicates for future research (Hermon *et al.*, 2018).

Fig 4. 3D printed replica of the object (photo from (Hermon *et al.*, 2018)

An archaeological study of an item was carried out using scientific visualisation and shape analysis tools on 3D digital and physical copies of the artefact. The authors state a few examples of scientific visualisation using 3D models of ancient artefacts for research purposes. In this specific study, aspects such as the object's history and manufacturing processes, handling, and potential usage were explored. The uniqueness of this study is in the systematic procedures used for its 3D documenting, followed by scientific visualisation and shape analysis, which was critically described to create a future framework and methodology for such archaeological artefact study. As a result, the study's findings may serve as a methodological foundation for future archaeological artefact interrogations based on 3D scientific visualisation.

The cultural heritage site of Asinou Church

Historically, recording architectural, cultural heritage sites have been time-consuming and labour-intensive (Themistocleous *et al.*, 2015). New innovative technologies provide an affordable and straightforward method of capturing cultural heritage sites. As a result, a more efficient and sustainable approach to the documentation of cultural heritage monuments and sites that architects, archaeologists, and cultural heritage experts can use for data acquisition and more. The church of Panayia Phorviotissa, better known as Asinou Church, is a 12th-century church listed under UNESCO World Heritage Site since 1985. (Gibson, 2020; Stylianou and Stylianou, 1997; Themistocleous *et al.*, 2015). It was constructed in the now-defunct hamlet and river known as Asine. The church was built in the scenic setting of the lower Troodos mountain in central Cyprus, approximately twenty kilometres from Nicosia, and served the monastery of Mother of God to Phorbion (Carboni, 2020). The church's interior walls are beautifully adorned, with frescoes dating from the twelfth (founding) to the early seventeenth century, reflecting and recording the life of an Orthodox monastery through three distinct regimes and statuses. The importance of the church physically and spiritually in the lives of the villagers was confirmed (Gibson, 2020). For this specific project, researchers from the Cyprus University of Technology have used aerial imagery for the 3D reconstruction of the cultural heritage site. These techniques provide a set of new tools for cultural heritage experts to capture, store, process, share, visualise and annotate 3D models in

the field (Themistocleous *et al.*, 2015). In addition, researchers employed a mix of aerial photos to create a 3D model of the cultural heritage site.

Fig. 5 3D model of Asinou Church (photo from (Themistocleous *et al.*, 2015).

Phantom 2 Quadcopter with GoPro Hero 3 camera was used to take over 1,000 photos were obtained at Asinou Church, which was then post-processed by eliminating lens distortion and processed using the Agisoft Photoscan Professional software. The image processing was carried out using the Agisoft PhotoScan and a software package developed by the Cyprus University of Technology, where the photos were input into the software. Such simple methods gave a practical and low-cost-effective solution (Febro, 2020). The goal of documenting the structure was to prepare it for future restoration and/or enlargement work. The aerial data that the UAVs collected was then integrated into the Agisoft software and the newly built 3D Reconstruction software platform at the Digital Heritage Research Lab to generate ortho-mosaics and 3D digital surface models in a quick and automated manner (Themistocleous *et al.*, 2015). The technologies used were highly beneficial in developing a high-resolution and accurate 3D model of the Church, which could subsequently be replicated using a basic 3D printer.

The archaeological site of Curium - 3D model for visually impaired people

3D printing is used in the restoration and preservation of archaeological sites and for a display at the museums of galleries. Such an approach can be used for visually impaired people. Many visitors, especially those with learning disabilities, youngsters, and those who are blind or visually impaired, require the use of all of their senses to comprehend art and cultural heritage (Neumüller *et al.*, 2014). There is a need to make cultural heritage sites accessible to all individuals. The ability to touch exhibitions and the availability of guided touch tours can assist these art enthusiasts in appreciating works of art. Tactile instructional items, particularly for archaeology and cultural heritage sites, are required to teach the blind and visually impaired. Touch tours have grown in popularity to improve the museum experience for the blind or visually impaired (Themistocleous

et al., 2016). The industry practitioners are saying that *"Digitizing of the culture can have several benefits such as virtual representation and tours [..] as well as aid to help people with disabilities (for example blind people) to have interaction with the shapes of monuments and artefacts."* Researchers from the Cyprus University of Technology, using low-cost 3D printers, have made a model of a Curium archaeological site (the Curium Amphitheatre) that is displayed in the foyer of the Curium site's visitor centre, with Braille annotations and descriptions, to allow individuals with visual impairments to connect with the Curium's history.

The research was carried out in Cyprus at the archaeological site of Curium, which is located just outside the contemporary city of Limassol. The peak of Curium, on which the ancient city-kingdom grew, dominates the seashore 4 kilometres southwest of the town of Episkopi in the Lemesos region (Themistocleous *et al.*, 2016). The city has gone through several stages, including the Hellenistic, Roman, and Christian eras. The area is well-known for its beautiful Greco-Roman theatre (Bowman *et al.*, 2021; Themistocleous *et al.*, 2016). The Curium amphitheatre site was chosen, and Ground Control Points (GCPs) were placed around it. At the height of 125 meters, the UAV flew over the location. The pictures were analysed to produce a 3D model, which was then made on a 3D printer.

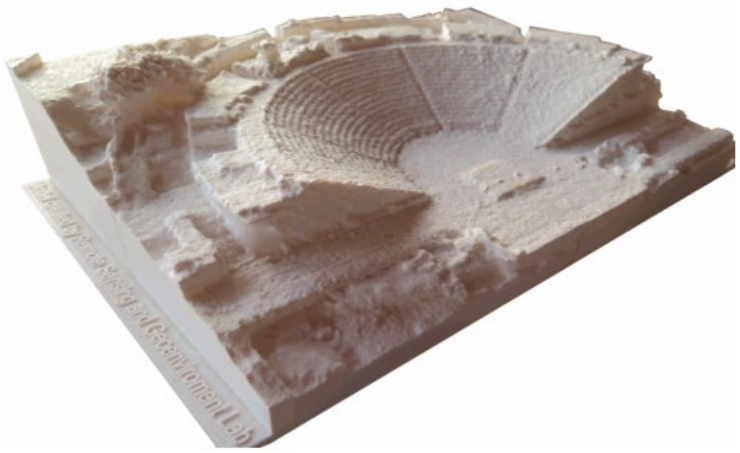

Fig. 6 3D model of a Curium amphitheatre

GCPs were positioned and measured across the whole region before the flight to perform the necessary adjustments during picture post-processing. These adjustments are required to assure the model's correct scale, which is essential accurately to print the model in scale. The UAV's flight planning software offered a predetermined flight route to be followed, guaranteeing considerable picture coverage and overlap to create stereo-pairs of photos. The UAV camera captured pictures with a 60% overlay within each image. To rectify distortions and construct a 3D model, single pictures were automatically assembled into an extensively detailed map (Themistocleous *et al.*, 2016). A total of 331 shots were captured and post-processed with the Agisoft PhotoScan program. The 3D model was exported to clean it up, repair it, modify it,

optimise it, and prepare it for 3D printing. A 3D model of the theatre was also created for visualisation reasons.

Currently, 3D technology for the restoration of cultural heritage is widely used in Cyprus. It provides unlimited opportunities to expand, for example, restoration of architectural sites, churches, the printing of missing parts of the monuments or making replicas of its restoration of important historical sites and many more.

Opportunities to use 3D technology for souvenir printing

Printing and prototyping parts at home, in-office, and even on the lab scale are accessible these days. This has fundamentally changed the 3D industry and encouraged all producers and consumers to switch from conventional applications for prototyping methods in different industries. For example, the global hospitality industry can be affected by 3D printing technologies. This is undoubtedly true in the case of tourist souvenirs. It has been claimed that by many researchers, buying souvenirs and gifts allows tourists to turn the intangible experiences they witness into meaningful experiences during their vacation. This can extend the link to the visiting location far beyond the trip itself and be the centre of tourist attraction. However, it is an expensive and time-consuming procedure to produce tourist souvenirs in conventional methods. It is also required to have enough storage space and delivery of the souvenir to the gift shops, and all come at environmental costs(Anastasiadou and Vettese, 2019; Tamez *et al.*, 2021).

In addition to that, the market has changed steadily for tourist souvenirs based on visitor requests and demands. Therefore, new technological innovation processes such as 3D printing can change the travel and hospitality industry due to less time to produce items. Savouries manufactured parts are inexpensive, complex objects can be printed, and less space is required for 3D printing machines; it can also generate significant income for local people and identity. In addition to the advancement of 3D printing technologies, it is mainly discovering new materials that lead to substantial innovation in 3D technology. Therefore, additive manufacturing is an ever-changing field associated with manufacturing novel materials to meet modern applications' demands. The variety of 3D printing materials produced since 2015 has almost doubled. However, the most significant issues of the process are its diverse dependence on technology developments such as material modelling, software development, simulation, materials quality and design engineering(Anastasiadou and Vettese, 2019; Tamez *et al.*, 2021).

3D printing of souvenirs is a well-known technique that helps to promote tourism in many countries and provinces. A study by Yun FAN uses the development of red tourist souvenirs in Gansu Province in China as an example to investigate the relevance of combining industry and education with 3D printing technology (Fan, 2020). Traditional tourism crafts and souvenirs can no longer fulfil the demands of tourists due to the continual development of people's living standards, and new design and innovative materials are continuously integrated into the design of creative tourism goods (Du, 2020). Tourist handicrafts, souvenirs, and tourist goods are among the

innovative products of intangible cultural heritage that may be made using the technology of 3D printing. When the benefits of 3D printing are combined, creative goods or immaterial culture and tourism may be developed. For example, the ideal souvenir would be a delicate 3D printed souvenir with a polished and projected image of the area (for example, a city of the country where tourists stayed) or a cultural heritage (for instance, a monument or a statue), as well as personalised customisation.

Another interesting idea that can easily attract more holidaymakers to Cyprus is the 3D printed Wedding invitation. Cyprus is considered a resort island and an island that holds most weddings annually, especially in the high season. This would be an exciting and progressive approach.

Fig. 7 3D printed message bottle with the paper invitation inside (photo from (novio3dprinters, 2016)

3D printing companies are helping in the development and promotion of souvenirs in Cyprus. A local 3D printing company representative has pointed out that *"Our company helped develop souvenirs and small art pieces by local artists who used the technology to create their twist on known statues".*

The majority of traditional souvenirs sold in Cyprus are cups, magnets, personalised key-chains or scenery from Cyprus, but produced in China. The same souvenirs can be found in every tourist location around the world, just with specific scenery. 3D printing technology offers unlimited opportunities to make customised, engaging, innovative souvenirs that tourists would be willing to purchase and use. Such souvenirs could be

3D food printing

As the world's population grows, so does the need for food. To meet this rising need for food, agricultural lands must be expanded for food material production. However, one of the applications of AM can be in the field of food and hospitality industries. This is less expired but provides many opportunities, such as printing complex chocolate objects with the lowest cost. Chocolate's properties, such as melting at a specific temperature and fast solidifying upon adhering to the preceding layer, are critical in 3D printing. Because of cocoa butter, chocolate is a temperature-sensitive substance that is simpler to print on (Mantihal *et al.*, 2020).

Furthermore, this novel technology can be beneficial to create individualised cakes for specific events such as birthday or wedding cakes. Therefore, the food printing demand is expected to multiply in the next few decades due to freedom of design, efficiency, and creating different objects with the highest complexity shape. However, there are also some disadvantages to AM that must be acknowledged. Firstly, the extruder (part of the AM machine) during the process requires it to be firmly rigid and well designed. Secondly, an active cooling system is necessary to decrease the chocolate temperature to avoid melting (Lanaro *et al.*, 2017).

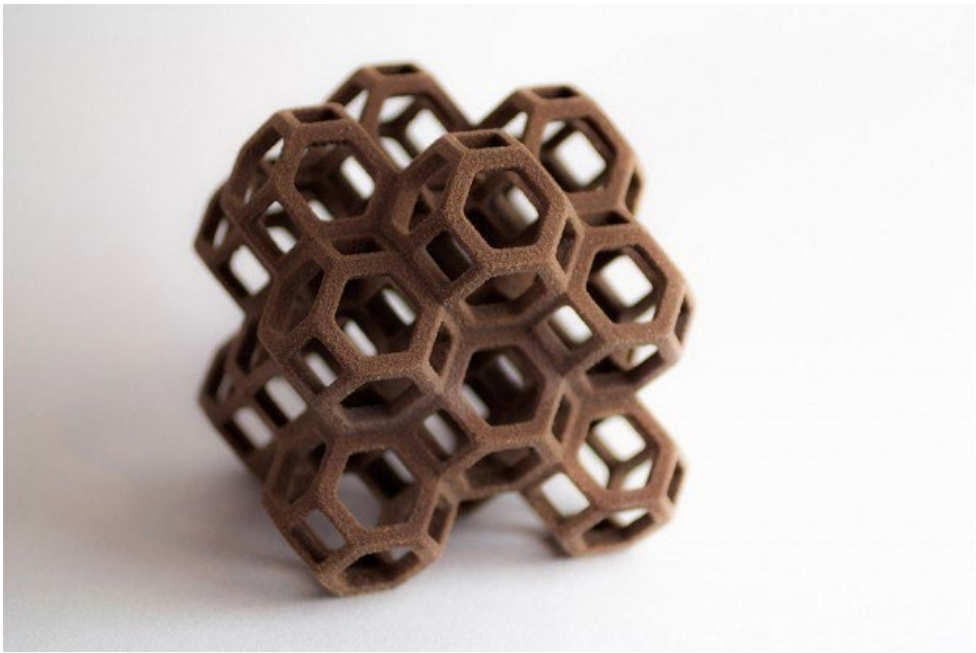

Fig. 8 3D printed chocolate design (photo from ("chocolate Archives - Perfect 3D Printing Filament", n.d.)

There are more applications that AM could provide for the hospitality industry. For example, recent cases reported by Jeffrey Lipton (2015) support that AM can manufacture complex shapes with the lowest cost. To demonstrate that, they produced a dinner service that was entirely manufactured by AM technology. This included the table setting consisting of cutlery and

kitchenware items: fork, knife, spoon, bowl, wine glass. This creating a Local illustrates the great potential of this noble process in the food safety industry based on experimental evidence. Still, it would be beneficial for manufacturers to take advantage of this technology to satisfy consumers and generate revenue (Lipton *et al.*, 2015).

Not only is 3D food printing technology important for HoReCa businesses, but it is also essential for the health industry, notably in the realm of special diets and drugs. For these reasons, using 3D food printing can enhance cost-effectiveness, efficiency, and sustainability, helping both the food industry and the hotel and tourism sectors (Zsarnoczky, 2018).

Currently, 3D practitioners admit that "*food printing is not our priority, I guess because everybody is afraid that customers would not be on board to try and use it*". However, using food printing technology in Cyprus, tourists can benefit from unique products that were not just made at the factory but printed using 3D technology.

Conclusion

Currently, the 3D printing industry in Cyprus is developed to the extent that it is widely used for the restoration of historical and archaeological sites, monuments, buildings. However, more opportunities could be explored in the tourism and hospitality industry, contributing to a more sustainable industry overall.

One of the areas of great potential is the 3D printing of buildings and sites. There is currently not a large-scale 3D project undertaken in Cyprus. Still, with the penetration of new technology in the market and sponsorship, these projects can become real soon because they can provide creative and customised solutions that attract tourist attention, such as individualised hotel rooms and boutique hotels.

Another area 3D printing could support the tourism industry is the printing of souvenirs. For example, small projects have been undertaken, such as the development of souvenirs by local 3D printing companies in collaboration with arts and crafts artisans. Still, there are more opportunities to provide customised souvenirs, increasing the tourist satisfaction and usage life of a unique souvenir.

Finally, 3D printing technology that currently is not applied in Cyprus is printing food items. In general, this is the area that industry professionals expect the most resistance from the customers and therefore are not undertaking any projects; however, with the expansion of the hospitality and tourism industry and customers that search for unique experiences, these projects can provide recognition at international level. For example, culinary competitions or exhibitions organised worldwide can make Cyprus more attractive and visible internationally.

To conclude, 3D printing has great potential in Cyprus to be used in various areas and aspects of the tourism and hospitality industry.

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