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Assessment of the Viability of using 3D printing for the Design and Prototyping of Historical Artifacts as Replicas

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Abstract. 3D printing is now being used in many different applications. Souvenir items and replicas of artifacts, which usually do not need to have high durability/strength, may be one of the possible applications of 3d printing. In this study, the researchers tried to manufacture keychains, refrigerator magnets, and display items from historical artifacts in the province of Bataan. Three experts (1 from the tourism industry, 1 BS Tourism Faculty, and 1 expert in 3d printing) were tapped to assess the viability of using 3d printing in the production of souvenir items. The items were particularly evaluated based on their quality, color, surface finish, cost, durability, authenticity, material, etc. Important considerations were obtained from 3d printing as well as from the insights/evaluation provided by the experts. Experts suggested modifying the thickness, color, and materials for added appeal. Reducing the price might also increase the market for souvenir items. Adding labels and descriptions has also been recommended. All these

improvements will inspire different emotions, create impact and make the design more memorable.

Keywords: Additive Manufacturing in Architecture, 3D Printing, Historical Artifacts, 3D Design and prototyping, Replicas

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1. Introduction

3D printing, more formally known as Additive Manufacturing, has gained considerable attention in the academic and research communities and is now being adopted by the industry. This is because cheaper and faster 3D printing technologies which can produce high print qualities are now available. Polymer materials for 3D printing also are now being produced with a wider range of properties. These advancements continuously change how the products are designed and manufactured and how they are used by consumers. Innovators and makers can now easily produce prototypes of their ideas as 3D printing greatly simplifies prototype production. The design and fabrication processes have been reduced from weeks to a few hours essentially allowing for innovation on the fly. AM could minimize production costs and improve the overall efficiency in the design and manufacturing sector. Moreover, AM provides solutions where complex designs are required, with short lead time and small lot sizes. AM is now being seriously considered to produce materials for several applications, namely: construction, apparel, agriculture, desalination, education, medicine, electronics, automotive, robots, military, oceanography, aerospace, satellites, oil & gas, architectural design, and many more [1-10].

3D printing can be used in producing souvenir items. 3D printing is ideal because it can do customization of souvenir items. Production of these replicas will help preserve the memory of historical artifacts. Additionally, it will inspire different emotions and create a lasting impact. However, important parameters have to be considered including the following: cost, quality, durability, authenticity, surface finish, color, the material used, overall quality and acceptability, and others.

Objectives of the Study

General Objectives

The main objective of the project is to assess the viability of using 3D printing for historical artifacts as replicas.

Specific Objectives

1) To generate designs of historical artifacts for the production of replicas
2) To 3d print replicas of historical artifacts
3) To assess the 3d-printed replicas

Literature Review

Souvenirs are considered to be a fundamental component of each human being's travel experience, as these objects tend to bring back special moments and experiences. It is solid proof that easily recognizes that special moment in their lives [11][12]. It can be a shirt, keychain, jewelry, sand, and scale models of a specific landmark. Souvenirs are often noticed due to their symbolic meaning and significance in a specific tourist location [13][14]. These small or big pieces of remembrance are psychologically important to many women tourists according to a study conducted in the North American regions [15].

Items such as souvenirs are deemed a major component in a tourism-based retail system as they can generate a lot of jobs for people who are involved in manufacturing, distribution, and sales [16][17].

Small to large-scale industries, and mass manufacturing firms that can distribute their products on a global scale are the leaders in the production of souvenir items [14]. Small to medium types of businesses have a team of artisans or craftsmen who specialize in locally produced items that are produced by traditional methods. Through such old methods of production, handcrafted souvenirs are believed to be able to retell the cultural stories of their origin. Meanwhile, mass manufacturing firms are known to embrace globalization more; settling for low-quality souvenirs that are products overseas thus lacking authenticity [18].

The use of any manufacturing or technological method in the interpretation of culture or creation has changed the perception of tourists toward how their experience is remembered [19]. A greater price or value is assigned to items that are compelling yet personalized, as these factors enable the consumers to be involved in the co-production of their souvenirs; a part of a very creative experience [20].

As technological advances move beyond functional tooling to creative production activities, 3D printing technologies can be facilitated to develop co-creative activities focused on tourism products. These technologies had rapidly progressed in the last decade, and these advances made 3D printers capable of producing functional parts that are fully customizable [21]. It also allows the objects or landmarks to be scanned, converted, or manipulated to a 3D printing file such as .stl, and then shared to be printed anywhere [22].

Through sites such as Thingiverse, people gained access to a huge array of open-source designs. It also offered multiple opportunities for people with zero knowledge of 3D printing and design principles to design and print their objects which can be produced using a 3D printer [23]. Another website that is worth mentioning is MyMiniFactory.com, it features Scan The World – a community-built museum that aims to archive the world's famous sculptures, statues, artifacts, and even landmarks using 3D scanners and 3D printers. The section uses photogrammetry, the scanned objects are free to download for the sole purpose of giving access to people to cultural heritage, education, and cultural preservation. Landmarks such as the Parthenon in Greece, and Arc de Triomphe in France, and sculptures such as the La Pieta, Venus de Milo, and Moses can now be downloaded and printed for free [24].

3D printers were created for rapid prototyping purposes in engineering and manufacturing aspects. However, 3D scanners and printers are also used in cultural heritage and museums to remake digital copies of artifacts, landmarks, and other objects for educational and preservation purposes [25]. 3D printing has advantages over traditional manufacturing methods, and its foremost edge is its ability to produce customized products. Its method of production also lessens material waste, alongside the avoidance of the need for a large storage space to store products for future use and distribution [26]. AM can explore and focus on the co-creation of souvenirs through the adaption, modification, and transformation of existing designs to improve the tourism experience [23][27].

Hector Serrano wished to explore the potential of 3D printing as a manufacturing method for the production of souvenir products. He produced a collection for an exhibition about sustainable design. The project tackled how objects are produced using modern manufacturing methods and how alternative ways or methods can reduce their impact on the environment. It concluded with less carbon footprint due to the designs being sent through email and produced using 3D printers, thus gaining no carbon footprint from transportation or shipping [28].

As AM technologies are more accessible to the masses, the possibility that 3D printing can be a viable production method for souvenir items as it can promote co-creation activities; bringing an immersive experience to tourists, must be evaluated [29] [30].

2. Methods

The study has three phases namely the Design Phase, 3D Printing Phase, and Assessment Phase. The first phase will include the design of the models. The second phase will focus on the 3d printing of models based on the design. The third and last phase will be the assessment of the models by experts, the architects, through interviews. Please see the interview guide questions. Figure 1 shows the design process followed in the study showing all three (3) phases.

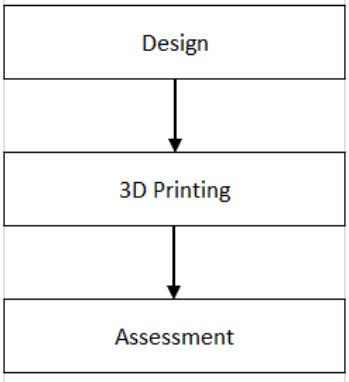

Figure 1. Research Methodology

The three phases will lead to Specific Objectives as enumerated here. The first specific objective is to generate designs of historical artifacts for the production of replicas. 3d modeling software such as Autodesk Inventor and Google Sketchup has been used to generate the models of the replicas. The second specific objective is to 3d print replicas of historical artifacts with the different 3d printers such as Zortrax M200 and Ultimaker 3 Extended have been used to produce the replicas of historical artifacts, also 3d printing materials such as acrylonitrile butadiene styrene (ABS) and Polylactic Acid (PLA) have been used for the replicas, and the post-processing such as sanding and cutting have been employed. The third specific objective is to assess the 3d-printed replicas. There were three (3) experts who have been interviewed/surveyed to assess the 3d-printed replicas in terms of their quality, color, surface finish, cost, durability, authenticity, material, etc.

Here are the short profiles of three (3) experts as respondents to this study. They are Ms. Lucille Marcelo, Engr. Brian Tuazon, and Ms. Danica Lolita Tigas. The several organizations, educational attainment, skills, eligibilities, working experience, published papers, oral and poster research presentations, seminars, and training attended considered our respondents knowledgeable in tourism trends, 3D printing, and tourism industries, respectively.

Ms. Lucille Marcelo is a Tourism faculty instructor at the Bataan Peninsula State University since August 2016, taking up a Master of Science in Hospitality Management major in Tourism Management from Centro Escolar University in Manila Campus in 2017 up to the present. Ms. Marcelo is a regional tour guide of the Bataan Peninsula Tour Guide of Bataan Tourism Center, a member of the Philippine Association for Tourism and Hospitality, and a member of the Association of Tourism Officers of Central Luzon of the Department of Tourism in Region III. The first expert started attending related seminars and training in 2012 and among these were Tour Guide Seminar Techniques, Actual practice and Workshop in Laoag City, Ilocos Norte; InfiniTHI Eco-Tourism, Tourism Planning as a Profession and Career opportunities in the Local and national Government, Global Trends and Tour Products in Balanga City, Bataan; Expose – Seminar on Global Tourism in Balanga City also; Bataan Tourism marketing and Strategies Seminar; Seminar on Career Opportunities in the Tourism Industry; Tourism Entrepreneurship: Training Workshop on Simplified Accounting and Agripreneurship; Cultural Guiding Seminar in Balanga City, Bataan; 3rd International Creative Tourism Design Conference 2016 in SM North Edsa, Quezon City and more.

The second respondent is Engr. Brian Tuazon, a 3D printing expert, a permanent instructor at the Bataan Peninsula State University since 2014, a licensed Mechanical Engineer, a registered master plumber, and graduated Master of Science in Mechanical Design and System Engineering with a full

scholarship from Andong National University, Republic of Korea. This second expert became a Research Assistant in the Materials Behavior Measurement and Evaluation Laboratory during his stay at Andong National University from October 2012 to August 2014 in Andong, Kyungbuk, Republic of Korea. This respondent is a Board of Directors Member of the Philippine Society of Mechanical Engineers Bataan Chapter since 2018 up to the present, and a regular member of the Mechatronics and Robotics Society of the Philippines, Inc since 2018 also. Among his related training and seminars attended from 2009 to 2019 were the 24-Hour Training Workshop on 3D Studio Max 2019 at the Bataan Peninsula State University; the Design Thinking Workshop in Central Luzon State University, Nueva Ecija; Computer Aided Sprinkler System Design from CADVision Engineering Technologies in Sampaloc, Manila; the Operation, Programming and Functionality of Intelitek SCORBOT ER 4u from State Alliance Enterprises Inc. in Balanga City, Bataan; and 2009 3rd Quarter Technocon and Innovention Contest of the Philippine Society of Mechanical Engineers Bataan Chapter, Balanga City Bataan.

The third expert is Ms. Danica Lolita Tigas, MSHM-TM, a Tourism industry practitioner. Ms. Tigas is a Tourism Operations Officer 1 at the Bataan Provincial Tourism Office since November 5, 2015, up to the present and a graduate of Master of Science in Hospitality Management major in Tourism Management from Centro Escolar University, Mendiola, Manila in March 2018. Among the training and seminars attended by the third respondent from 2013 to 2018 were the 19th Association of Tourism Officers of the Philippines national Convention in Cagayan de Oro City, Advanced Tourism Statistics Training, Tourism Marketing Seminar on Regional Branding in South Cotabato, 1st North Philippines Tourism Forum and Career Fair in Baguio City, 18th Association of Tourism Officers of the Philippines National Convention in Ilo-ilo City, International Conference on Cultural Statistics in Ermita, Manila, 6th UNWTO International Conference on Tourism Statistics: Measuring Sustainable Tourism in Pasay City, 3rd Leg of Pamana: World Heritage and Biosphere Reserve Nomination Series in Albay, Tourism Product Development Workshop and Tour package Development and Delivery Seminar in Balanga City.

3. Results and Discussion

The researchers surveyed for the assessment of the viability of using 3d printing for the design and prototyping of souvenir items. The respondents are namely: a tourism faculty member, a 3d printing expert, and a tourism officer. Here are the results of the survey.

3.1. Bataan Map Keychain

Souvenir item number one (Fig. 2a) is the Bataan Map Keychain wherein we value the historical path. We can view also the shape of the province, the distance, and natural resources such as mountains and lands can be figured-out. The researchers design the map in a keychain to make it handy and can be used anytime. Table S1 shows the ratings for the Bataan Map Keychain made by the experts.

Experts Assessment: Respondent #1 pointed out that another design of the Bataan map can be better for Municipalities to easily identify that the keychain is from Bataan. Respondent #2 also said that it is better to enlarge, thicken, have additional color, and use other materials like plastic for the keychain to see the details of the Bataan map.

3.2. Bataan Map Ref Magnet

Souvenir item number two (Fig. 2b) is the Bataan Map Ref Magnet wherein aside from the historical path value of the design we can also keep important notes by sticking to our fridge door with this product. Table S2 shows the ratings for the Bataan Map Ref Magnet made by the experts.

Experts Assessment: Respondent #1 suggested the following, white color will be more attractive for the Bataan map ref magnet, Bataan map with towns will suit in memento and lower the price below

Php240 or if possible ranging from Php150 to Php180 for tourists. Respondent #2 advised using vibrant colors of filament to highlight the details of the Bataan Map.

3.3. Bataan Map with Town Names Ref Magnet

Souvenir item number three (Fig. 2c) is the Bataan Map with Town Names Ref Magnet where we can view easily the different municipalities and boundaries. Table S3 shows the ratings for the Bataan Map with Town Names Ref Magnet made by the experts.

Experts Assessment: Respondent #1 requested that the price may range from Php150 to Php200.

(a) (b) (c)

Figure 2. Photos of 3D-printed miniature maps (key chains and ref magnets)

3.4. Death March Marker Display

Souvenir item number five (Fig. 3a): is the Death March Marker Display where we can recall the historical event of the Bataan Death March has come to dominate the role that our country, the Philippines played in World War II.

Experts Assessment: Respondent #1 commented that for uniqueness and authenticity, put km00 and have an additional size on the base to look like more of a km marker. Price may range from Php150 to Php200. Respondent #3 and Respondent #2 urged to include some details in the marker like if it's 00 in Bagac or 0 in Mariveles for the Death March Marker display just to depict that this is from Bataan and not from Pampanga or Tarlac. Additional color will highlight important parts of the Death March Marker display as pointed out by 3d experts.

3.5. Philippine-Japanese Friendship Tower Display

Souvenir item number five (Fig. 3b) is the Philippine-Japanese Friendship Tower Display.

The site of the Philippine-Japanese Friendship Tower in Bagac, Bataan is ~200 meters from where the Bataan Death March of April 1942 started. The death march caused the deaths of ~10,000 war prisoners.

Experts Assessment: Respondent #1 suggested enlarging the size and having the additional weight of the Philippine-Japanese Friendship Tower display to sell at a range from Php300 to 350. Respondent #2 also advised having a label that will give information about the design and additional color to highlight important points and takeaways. Respondent #3 proposed changing the display to white color and including the important bell and the highlight of the tower.

3.6. Dambana ng Kagitingan Display

Souvenir item number five (Fig. 3c): is the Shrine of Valor (Dambana ng Kagitingan). This shrine is located in Mt. Samat, Pilar, Bataan. This shrine was built to remember and honor the gallantry of American and Filipino soldiers who fought against the Japanese Imperial Army during WWII.

Experts Assessment: Respondent #1 recommended a thicker size of the display to look the same as the Shrine of Valor in terms of authenticity and additional thickness below the part to look heavy. Respondent #2 proposed to include the landscape of Mount Samat in Pilar to recognize easily the Mount Samat National Shrine. Respondent #3 was encouraged to include the Nabiag Na Bato in the lower part of the cross and include or replicate the glass on the arms of the cross

(a) (b)

(c)

Figure 3. Photos of 3D-printed replicas of historical markers

3.7. Morong Church Display

Souvenir item number four (4a) is the Morong Church Display where we can view easily the place of worship and church members or religious communities will love this product.

Experts Assessment: Respondent #1 as well as Respondent #2 asked to put the label with the name of the church to identify easily. Respondent #2 also recommended having additional colors in the design to highlight the beauty of the church. Respondent #3 emphasized that this Morong church display was her favorite among the souvenir items because it shows the uniqueness of Morong Church. However, she was also encouraged to include the St. Dominic Cathedral of Abucay which is the oldest church in Bataan, and also to coordinate the use of the churches as souvenir items with the Diocese of Balanga. She also advised to lessen the price and include a short description about the destination, or even the name and the location to use the item as a promotional platform, as well.

3.8. Bataan Provincial Capitol Display

Souvenir item number four (4b) is the Bataan Provincial Capitol Display.

Experts Assessment: Respondent #1 proposed additional stairs around the façade of the Bataan Provincial Capitol display. Respondent #3 praised the display as 99.9% or close to perfect. However, she and Respondent #2 preferred to include a label for future customers who don't know what the place is and lessen the price. Respondent #2 also advised having additional colors to highlight the design.

3.9. Bataan Map Display

Souvenir item number five (5) is the Bataan Map Display

Experts Assessment: Respondent #1 advised thickening and having additional weight to the Bataan map display while Respondent #2 recommended having additional color to inspire different emotions, create impact, and make the design more memorable.

(a)

(b)

Figure 4. Photos of 3D-printed replicas of historical sites

(i)

Figure 5. Photo of a 3D-printed replica of the Bataan map for display

4. Conclusion

3d printing is now being used in many different applications. Therefore, souvenir items and replicas of artifacts, which usually do not need to have high durability/strength, may be one of the possible applications of 3d printing. In this study, the researchers tried to manufacture keychains, refrigerator magnets, and display items from historical artifacts in the province of Bataan. 3 experts (1 from the tourism industry, 1 expert in 3d printing, and 1 BS Tourism Faculty) were tapped to assess the viability of using 3d printing in the production of souvenir items. The items were particularly evaluated based on their quality, color, surface finish, cost, durability, authenticity, material, etc. Important considerations were obtained from 3d printing as well as from the insights/evaluation provided by the experts.

The experts suggested modifying the thickness, color, and materials for added appeal. Reducing the price might also increase the market for souvenir items. Adding labels and descriptions has also been recommended. All these improvements will inspire different emotions, create impact and make the design more memorable. Below are further detailed suggestions from the experts.

First, a keychain design was suggested to contain the names of the municipalities to easily identify that the product is from Bataan. As for other designs, labels were also suggested. Second, the thickness and colors of the souvenirs should be altered and improved to create a greater impact, making them more memorable and aesthetically pleasing. Third, the selling price of the items is also suggested to increase. Forth, the experts suggested the coordination between the manufacturer and the Diocese of

Balanga; the inclusion of the St. Dominic Church as a souvenir as it is the oldest church in Bataan. Lessen the price, according to Respondent #3, and include a short description of the destination. Fifth, enlarge some of the designs and increase the weight. Sixth, the inclusion of Nabiag Na Bato in the lower part of the Dambana ng Kagitingan or Shrine of Valor, the landscape of Mt. Samat, and replicating the class on the arms of the cross. Seventh, additional stairs for the façade of the Bataan Provincial Capitol display. Eighth, add more colors to the design, and always label the souvenirs; labels should contain the place's or landmark's history.

The experts agreed that 3d printing is a viable manufacturing process for the production of replicas of historical artifacts.

Supplemental Information

Supplemental information for this material is provided in a separate word file.

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