Photogrammetry for Digitization and Digital Display as a Sustainable Way to Develop Vietnam's Museum Sector? A Co-Designed Action Research Project between RMIT University and the Vietnamese Women's Museum

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This paper explores how photogrammetry and free, open-source software can be used to sustainably develop museum sector capacity to digitize and publish Vietnam's cultural heritage online. This approach was developed and applied during a digitization project as a solution to overcome challenges experienced in Vietnam concerning a lack of human, technical and financial resources. This paper draws on findings from a co-designed action research project between RMIT University Vietnam (RMIT) and the Vietnamese Women's Museum (VWM) that developed an approach to create 3D (3 Dimensional) digital artifacts of their Betel Nut Collection using free, open-source software and applying the technique of photogrammetry. The aim was to co-design and co-produce a sustainable solution focused on readily available and easy-to-use digital technologies. However, not all artefacts could be digitized using this method, which sheds light on the challenges and opportunities of digitizing cultural heritage in the Global South. Overall, this sustainable approach can be applied by other museums and cultural institutions and can be a way to empower museums in the Global South to digitize and digitally display cultural heritage artefacts.

Keywords:
Museums, Vietnam Museum Sector, Photogrammetry, Cultural Heritage, Digitization, Co-Designed Action Research, Vietnam, Global South.

SDH Reference:
Emma Duester et al. 2023. Photogrammetry for Digitization and Digital Display as a Sustainable Way to Develop Vietnam's Museum Sector? A Co-Designed Action Research Project between RMIT University and the Vietnamese Women's Museum. SDH, 7, 1, 68-90.

https://doi.org/10.14434/sdh.v7i1.35960

This research project was funded by RMIT University, under the project name TRF-2022, from June 2021 until June 2023.
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1. INTRODUCTION

This paper investigates how far free and readily available technologies can be used as a sustainable way of digitizing and providing access to cultural heritage in the museum sector in Vietnam. This was tested in a digitization project paper as a suitable approach for museum digitization to help to overcome challenges in lack of financial, human, and technical resources faced by Vietnamese cultural professionals. It used free, open-source software to digitize cultural heritage artefacts in combination with free hosting digital platforms to display cultural heritage artefacts to the public. This paper draws on the process and findings from a co-designed action research project between RMIT University and the Vietnamese Women's Museum (VWM) from 2020 until 2023. This approach can be applied by other museums in Vietnam and other countries by sharing the opportunities and challenges of using free digital tools for the digitization of cultural heritage and this approach can empower museums to digitize and display cultural artefacts themselves. With this purpose in mind, this paper asks the question: how far can a process of photogrammetry using readily available technologies, as a free method of digitizing and displaying cultural heritage, be a sustainable solution for the museum sector in Vietnam?

Digitization for the preservation of cultural heritage has been taking place in the museum sector in Vietnam since the turn of the 21st Century, including the preservation of cultural collections and the creation of digital archives. For instance, state museums and cultural institutions have been carrying out digitization projects that focus on the preservation of folk arts and intangible cultural heritage and are supported by the Ministry of Culture, Sport, and Tourism (MoCST). However, many of these projects are not being made publicly accessible due to the country-specific challenges with lack of technical, human, and financial resources. In addition, there is a need for digital skills development and training in digitization techniques. This means that there are few digitized resources publicly available online. Instead, these resources are stored in digital archives within cultural institutions, having been digitized without being made publicly available online. While it is important to digitize cultural heritage for recording and preservation purposes as Vietnam faces climate erosion, it is also important to make this digitized cultural heritage publicly accessible to address a lack of available resources online. Hence, Vietnam remains at a disadvantage on a global scale in the digital transition of the museum sector. These challenges are hindering the pace of creating digital content, the quality of digital content, and effectiveness of digital platforms. Additionally, there are other challenges in Vietnam to do with internet speed, mode of access, and level of 'visibility' of digital content online. This highlights the timely importance of finding sustainable digital solutions.

The economic and social value of the cultural sector has been harnessed in many countries, including China, Korea and Japan [Su, 2015; Yim, 2002; Lim & Lee, 2018; Oyama, 2019]. However, this is still a relatively new phenomenon in Vietnam. Cultural organizations have recently been acknowledged by the Vietnam Government as having a direct and value adding role in driving economic growth and national cultural development, with the Vietnam Government recently outlining a cultural industries development strategy and a digital transformation strategy for implementation towards 2030 [Vietnam Government, 2020]. This has been supported by the activity of international organizations and councils to position the cultural industries in Vietnam as key pillars of economic growth [British Council, 2018; Cameron et al., 2019; UNESCO 2019].

This paper contributes to discourse on the sustainability of digitization in the Global South [Pawelec et al., 2019; Boumans, 2021] by exploring possible digital solutions amidst challenges with resources, access, and inclusion. Such digital inequalities and the extent of digital in/exclusion have been highlighted and exacerbated during the covid-19 pandemic. This makes the creation of digital content and digital skills development in the museum sector in Vietnam timely and important. In particular, the covid-19 pandemic has exacerbated existing digital inequalities in terms of funding and resources in the museum sector. As ICOM (International Council of Museums) [2020] argues, "the crisis has highlighted some structural weaknesses in terms of resources and staff dedicated to digital activities and communication, and level of maturity of the content produced." While some opportunities have been presented since the covid-19 pandemic, such as technology companies providing support for developing countries by making their services open-access or free to use[1], the covid-19 pandemic has made divisions greater. The covid-19 pandemic and the resultant increase in digital museum content globally makes divisions greater because digitization requires technical, financial, and skilled human resources.

2. METHOD

This research project was based on a co-designed action research project between RMIT and VWM from 2020 until 2023. The digitization project began by conducting 50 semi-structured interviews with cultural professionals in Vietnam between 2020 and 2021. The interviewees were recruited based on RMIT University's existing industry connections and continued through snowball sampling. The aim of the interviews was to find out the nature of digital transition occurring in the culture sector in Vietnam, what opportunities and challenges professionals were facing, and how they were using digital technologies. Interview findings identified specific challenges in digitization and particular needs for digital transition at museums. These findings were used to prepare and assess suitable digital solutions for the action research. This co-designed action research approach was chosen in response to findings from interviews.

VWM was selected for the digitization project as they clearly stated in interviews that they required assistance with digitization. This museum was selected based on their needs but also because it exemplified the whole museum sector in Vietnam that was facing similar challenges. As Bryman [2016: 62] states, this is a "typical case sampling" strategy that was chosen to "exemplify a broader category of which it is a member".

The aim of the digitization project was to co-design and co-produce a sustainable digital solution jointly with the museum and to use readily available and easy-to-use digital technologies. This was selected in preference to sourcing high-tech equipment and software as this would have inhibited museums' uptake and implementation operationally of this long-term. It was based on the museums' needs, which were shared in interviews and consultations. This was important to ensure the project itself was sustainable. Additionally, the selection criteria for which artefacts to digitize was based on the museum's preference to connect more to the younger generation. In response, RMIT researchers organized a workshop to bring together museum staff and students so that students could decide

[1] For example, SketchFab provides free subscription to museums in developing countries.

which collection to digitize and how to best digitize the collection. RMIT also asked VWM for information and stories around the artefacts to include with the 3D digital artefacts.

This was an experimental design and technique due to combining multiple methods and multiple stakeholders. This was suitable because VWM and RMIT shared the common concern for the lack of available resources online about Vietnamese cultural heritage. As Altrichter et al. [2002: 125] argue, action research is about a collaboration between people "with a shared concern and the motivation to address this shared concern." Another aspect of this action research design was that it involved multiple methods, including interviews, consultations, photogrammetry, and working with a scan company and an artist. The co-design action research design meant that RMIT and VWM worked together to plan and implement the project through in-person consultations during the project. Experts from different fields and organizations were included. Experts from communications, design, museum technology, digital technology, and curation were included from RMIT side and experts from communications, conservation, and collections departments were included from VWM side. As a result, co-design has provided a "whole-of-system view and transformative change at multiple scales" [Webb et al., 2018: 57].

In-person consultations took place with VWM to ascertain VWM's current state of digitization, their needs for digital skills and digital technology adoption, and how to make their digitization projects sustainable. Consultations took place regularly throughout the project and VWM were consulted at every stage of the process, with changes and adaptations to scans and display where required by VWM[2].

Photogrammetry was used as a practice-based research method to photograph, digitize, and publish the 3D digital models online. This was done using a smartphone to take photographs of every angle of the artefacts and using meshing software to render and blend the photographs together to produce one 3D digital model. As Pisa et al. [2011] argue, "ease, rapidity, low cost, and completeness of the documentation are the main advantages of this technique."

A Google Pixels 3XL mobile phone was used to take photographs, set at a high resolution of 3840 x 2160 Pixels Per Inch (PPI). Since a proper photography studio was not available, mid-afternoon outdoor lighting was selected to take the advantage of the wide spread of photography dynamic range with soft shadows. Auto white balance was applied to capture the warm tones of the artifacts. While auto-focus was applied to ensure textures were fully captured. Various angles such as high-angle, close-up, medium and low-angle shots were used to fully capture the artifact. An average of 50 to 180 shots were taken for each artifact to ensure sufficient visual information is provided for photogrammetry software to work effectively. JPEG (Joint Photographic Experts Group) image format was chosen due to its efficiency to store large number of images within limited storage space. Since photogrammetry programs rely on image metadata to help stitch the images together, JPEG was also suitable format due to its capabilities in storing EXIF (Exchangeable image file format) metadata. Professionals with structured-light Artec Eva 3D scanners were hired to accurately scan the artifacts that were not possible to digitize using photogrammetry.

[2] This research project also included surveys with the audience to find out their preference for digital content and the future of digital offerings at museums in Vietnam. This included museum visitors from Vietnam and expats living in Vietnam. These are not included in this paper due to its focus.

For each artifact going through the photogrammetry process, an average of 50 to 180 photographs were imported into Alice Vision's Meshroom. AliceVision is a Photogrammetric Computer Vision framework for 3D Reconstruction and Camera Tracking[3]. Although photogrammetry software is able to reconstruct 3D objects from 2D photographs, post-processing is required. This step helps improve the quality and accuracy of the reconstructed 3D model[4]. As an example, a basic cylinder 3D artifact constructed through photogrammetry can have up to millions of triangle mesh. Throughout our experience, to have this model displayed online efficiently without compromising performance, the meshes need to be lowered down to get a smaller byte size while retaining the artifact's aesthetic shape. This requires a lot of trial and error lowering down the meshes while considering the aesthetic shape. Artifacts scanned with professional structured-light 3D scanners had the same issue comprising of unnecessary extra meshes. In Blender, the Decimate modifier is used to lower down the meshes. Besides considering the correct amount of 3D meshes for storge and online performance purposes, textures affect visual aesthetics and performance[5].

This partnership also included generating an ethical research protocol, which was devised jointly between RMIT and VWM in consultations. This was to ensure common agreement on authorship and copyright. RMIT researchers made sure to maintain the copyright of the VWM as well as platform policies of Sketchfab, Blender, and Meshlab to know use of these platforms would not compromise VWM's copyright. This was officiated by gaining a MOU (Memorandum of Agreement) and A Letter of Agreement to set professional working standards for this partnership on this specific digitization project, and to clarify VWM's expectations versus RMIT's expectations. Another aspect of the ethical consideration was in the project's sustainability, which is why RMIT researchers wanted to make sure the project was sustainable enough for VWM to take on afterwards.

3. LITERATURE REVIEW

While a lot of research has been conducted on the use of photogrammetry for the recording, documenting, and archiving of cultural heritage [Pisa, Zeppa and Fangi 2011; Yilmaz et al 2007;

[3] Meshroom starts by analyzing the images to find common features and match them across different photos. It uses feature detection and matching algorithms to determine corresponding points in the images. A dense point cloud representation of the artifact is then generated. Based on the dense point cloud, Meshroom generates a 3D mesh, which represents the surface of the reconstructed artifact. Once the 3D mesh is generated, Meshroom applies texture mapping to the mesh. This duration of this process will depend on the complexity of the 3D artifact and individual computer's CPU (Central Processing Unit), RAM (Random Access Memory) and Graphics Processing Unit (GPU). Based on our setup of an i7-8750H CPU, 32GB RAM and NVIDIA GTX1060, an average time to construct a 3D artifact will take from 20 minutes to 3 hours.

[4] Meshroom provides tools for cleaning up the mesh, removing noise, filling holes, and optimizing the geometry. We were particularly concerned with the visual aesthetic to represent the actual physical artifact. There were also issues in terms of unnecessary extra meshes in the constructed 3D artifact that could take up storage space and affect interaction performances when distributed online. By default, Meshrooms will save the constructed 3D artifact into a Wavefront OBJ 3D model exchange format. To enhance the 3D artifacts visual aesthetic and lessen the meshes for efficient storage and online interaction performance, the OBJ 3D models are brought into Blender, a free and open-source 3D creation suite.

[5] 3D artifacts from photogrammetry or professional scanners are normally captured at high resolution. This enables more pixel information to create a high-quality, crisp image. However, high resolution images will take up more storage space, thus affecting online performance original textures from scanned 3D artifacts were scaled down in Adobe Photoshop while careful consideration was put into maintaining the visual aesthetics. This requires multiple trial and errors to get a smaller byte size without comprising the visual aesthetic.

Aicandi 2018], there is still a gap in exploration of this method for publishing digital cultural heritage online and how far this can be a sustainable solution for a developing country in order to overcome challenges in terms of available human, technical, and financial resources. As Yilmaz et al. [2007] argue, photogrammetry can help with preservation, restoration, and creation of detailed data. Additionally, there is a set of literature on digitization [Astle & Muir, 2002; Yilmaz and Celic, 2011; Kucuk and Soydal, 2003] that focuses on digital content creation and digital storage. Hence, there is a gap in terms of discussion on making digitized content accessible and engaging to audiences amidst challenges, which is especially an issue in the Global South. This demonstrates how much discussion is about preservation of cultural heritage but not so much about publishing this content online. This is vital for providing digital inclusion and redressing digital inequalities and the imbalance in amount of cultural content online in Vietnam. Moreover, the use of photogrammetry as a valid research method within an action research design has yet to be fully explored in the literature.

There is a lot of discussion on the covid response in the museum sector at larger art museums in Western countries, with reports on museums' responses to the Covid-19 Pandemic as well as guidelines on digital solutions across Europe [Ciecko, 2020; Heritage Fund, 2020; International Council of Museums, 2020; Parry et al., 2018; UNESCO, 2021; Network of European Museums Association, 2020][6]. There was also work in Europe on how the online experience could bring more people into physical museums after the Pandemic [Hoffman, 2021; Noble, 2021]. For instance, there has been a lot of discussion on best practices learnt from the pandemic and opinion on how museums should adapt for the future [Gurian, 2022; Redman, 2020]. Many studies on digital technologies at museums during covid discuss digital innovations, adaptations, and pivots due to new circumstances. Digital innovations include new digital galleries, VR/AR applications for virtual tours and games [Decker et al., 2021; Bertrand et al., 2021; Cecotti, 2021; Kang & Yang, 2022], how to better engage the audience [Siwalette & Suyoto, 2020; Damayanti et al., 2021], and how to use photogrammetry or new types of digitization [Apopei et al., 2021; Aquino et al., 2021]. To illustrate, Apopei et al. [2021] discusses their use of cross-polarized light photogrammetry to generate a comprehensive virtual 3D collection of mineral and rocks in Romania. Aquino et al. [2021] also analyses the use of photogrammetry in 3D modelling, focusing on its pros and cons as a rapid, low-cost tool, which makes artworks virtually accessible to the public.

Since the covid-19 pandemic began in November 2019, many studies have focused on new technologies of display utilized to better engage the audience either in physical or virtual museum spaces. As Oyelude [2022b: 14] argues, "in museums, the technologies post-pandemic are becoming more geared towards keeping the patron in the museum, but at a distance." Proposed technological solutions have now been implemented in many museums, such as tour guides using QR (Quick Response) code, mixed realities (MR), artificial realities (AR), and virtual realities (VR). These technologies can deliver immersive experiences to museum visitors, both in physical and virtual

[6] At a European level, for instance, the Network of European Museum Organizations (NEMO) released the results of a survey that took place between March and April 2020 with responses of around 1000 professionals from museums in 48 countries. In this survey, museum officers reported that social media, educational material, videos and films and collection-related content were amongst the most popular ones for audiences. NEMO's report concludes by emphasizing the need to invest in digital services, infrastructure, and digital skills acquisition (Network of European Museum Organizations 2020). This was used to create formalized guidelines on how to work during the Pandemic for museums across Europe.

spaces [Decker et al., 2021; Bertrand et al., 2021; Cecotti, 2021; Kang & Yang, 2022; Gatto et al., 2021; Puspasari et al., 2021]. Kang and Yang [2022] found that VR is the most used new digital technology by museums. For instance, Giuffrida et al. [2022], Gabellone [2022] and Siniscalco and Appolonia [2021] describe various experiments of applying VR technologies to digitize heritage sites in Italy and made available to the public audience via a digital platform. These technologies in general have been extensively applied worldwide to enable virtual tours and they continue to be developed [Guazzaroni, 2022].

While this discussion mostly pertains to what happened at museums in the West, what happened in the Global South requires more investigation. A few examples include Plasencia et al. [2021] who discuss the design and implementation of a VR mobile application integrating 3D modelling technologies in Ecuador. Similar prototypes for 3D modelling and VR applications are being developed and tested in Indonesia [Sulistiono et al., 2021], in Malaysia [Samah et al., 2021], and in Peru [Mandros et al., 2021].

The covid-19 pandemic has provided more opportunities whilst also making divisions greater. For example, some companies are giving more support to developing countries and making their services open-access or free to use. However, it also makes divisions greater because digitization requires resources - and the pandemic has emphasized the divisions in resources between countries. The disparities among regions in terms of digitization of museums' offerings can also be seen from this systematic review. A text-mining analysis of the articles' full text reveals the extent to which different regions are referred to by researchers studying museum digitization. Unsurprisingly, the most mentioned countries are the USA, UK, Italy, France, Germany, and China as can be seen from the figure below.

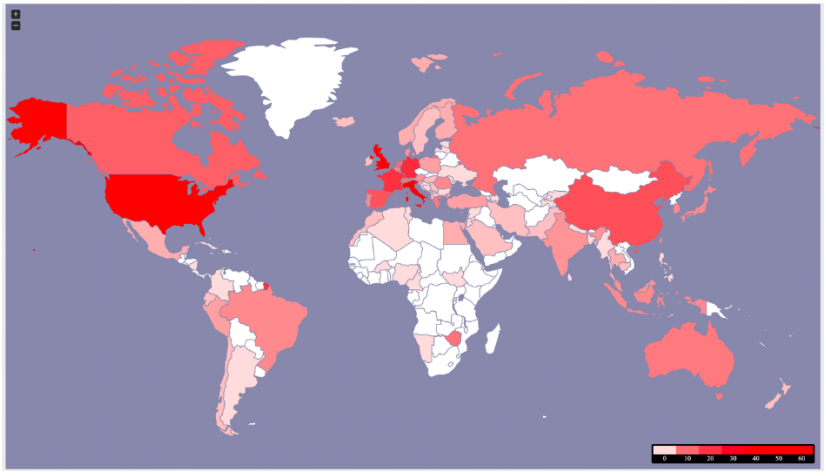

Figure 1. The frequency of 'mentions' of different countries in the literature on museum digitization through the covid-19 pandemic

In terms of the number of case studies on specific digitization initiatives, there is also disparity between the 3 top countries of Italy, USA and UK in comparison to the other countries, as shown in Table 1.

Table 1. Countries and number of reports published on covid response in the cultural heritage sector.

Countries	Number of case studies
Italy	25
USA	20
UK	19
Indonesia	8
Spain	6
France	5
China	5
Portugal	4
Romania	4
Russia	4
Poland	3
Australia	3
Netherlands	3
Greece	3

Globally, there have been reports on museums' responses to the covid-19 pandemic as well as guidelines and training guides for digital transition across Europe [Cieko 2020; Heritage Fund 2020; International Council of Museums 2020; Parry et al. 2018; UNESCO 2020; Museums Association. 2020]. For instance, the Network of European Museum Organizations (NEMO) released the results of a survey that took place between March and April 2020 with responses from around 1000 museum professionals in 48 countries. NEMO's report emphasizes the need to invest in digital services, infrastructure and digital skills acquisition [Network of European Museum Organizations 2020]. This has been used to create formalized guidelines on how to work during the covid-19 pandemic for museums across Europe.

However, there are concerns around the digital transition and the ability of museums in the Global South to digitize cultural heritage adequately and appropriately. There is insufficient discussion about ways to overcome challenges in developing countries in the Global South and how to overcome the issues that are hindering digitization for display and access of cultural heritage and discourse to highlight the need to find accessible and affordable solutions. This is much more of an issue in developing countries where the challenges of a lack of human, technical, and financial resources are preventing them from harnessing digital technologies, platforms, and applications.

The digital divide, understood as the inequalities arising in terms of digital infrastructure and digital literacy, is nothing new [Clerkin and Taylor, 2021]. However, the true scale of the problem has been highlighted with the forced digitization of all aspects of social life during the pandemic. There are huge disparities across different regions of the world in terms of access to the Internet. Half of the

world's population has no access to digital technologies at all [Lerario, 2021], which means that the virtual world of museums is just out of question for certain groups of people. Ostrowska-Tryzno and Pawlikowska-Piechotka [2022] report that digital activities of museums were almost absent in the continents of Africa, Latin America, and small Pacific islands. The situation is completely different in developed countries where the audience can enjoy the privilege of cultural representation and being served by a far greater number of well-equipped museums with considerable experience gleaned in implementation of digital projects and possessing a huge amount of already developed digital resources. Poor access to the Internet means that some are deprived of online access to cultural resources and education. As an example, economically and technologically advanced countries such as the USA, United Kingdom and China still dominate the application of AR and VR technologies. In general, the applications of MX and extended reality technologies are mainly limited to countries like China, UK, and US, while museum professionals in less developed countries might not have sufficient resources [Kang & Yang, 2022].

The research contributes to discourse on the ethics and sustainability of digitization in the Global South [Pawelec et al., 2019; Boumans, 2021] by exploring possible digital solutions amidst challenges with resources, access, and inclusion. Thus, the paper also links to critiques on issues concerning digital ex/inclusion [Flores-Fuentes & Navarro-Rangel 2020; Lowry 2019], the ethics and sustainability of digitization in the Global South [Džikić & Radin 2019; Pawelec et al. 2019; Boumans, 2021], and the appropriateness of digitization using western software and platforms for cultural preservation in the Global South [Duester, 2023; Džikić & Radin 2019; Flores-Fuentes and Navarro-Rangel 2020; Lowry 2019; Pawelec et al. 2019]. However, there is insufficient discussion about ways to overcome challenges in developing countries in the Global South and how to overcome the issues that are hindering digitization for display and access of cultural heritage and discourse to highlight the need to find accessible and affordable solutions[7].

This research contributes to literature on developments in digital transition in the museum sector in Asia, predominantly concerning China, Japan, and South Korea. In these three countries, many large-scale, state-funded digitization projects are being carried out for the preservation of cultural heritage. China is investing large amounts of state funding and personnel into digitization projects; this is country-wide from central to local level for the digitization of cultural heritage at state institutions. For example, there are state-supported and state-led activities to digitize intangible cultural heritage in some of China's second-tier cities like Nanyang and Kaifeng [Zhou, Sun, & Huang, 2019]. Meanwhile, there have been developments in Japan to create a common archive and a standardized procedure for retrieval of archival data for the purposes of cultural preservation [Togiya, 2013], specifically to preserve and share collective memories of national disasters.

There is an emerging set of literature on the digitization process and trialing new methods for digitizing art and culture heritage at museums in Southeast Asia. For instance, Milosz et al. [2020]

[7] This is much more of an issue in developing countries where the challenges of a lack of human, technical, and financial resources are preventing them from harnessing digital technologies, platforms, and applications. As Pinto (2021) states, this global disparity in resources is both in terms of capital resources (ownership and control of cables, servers and data) and intellectual resources (the most advanced technicians and research institutes); the other aspect is legal architecture, which blocks low-middle income countries in the Global South from adopting policies that favour the production and purchase of goods/services produced domestically.

provide methods, techniques, and recommendations on how to solve specific problems that interfere with the process of data acquisition during continuous access to the objects by tourists and the impossibility of turning the object off from the visitors. Samah et al. [2021] discusses the design and implementation of a VR mobile application integrating 3D modelling technologies in Malaysia and Puspasari et al. [2020] discusses the same in relation to Indonesia. Sulistiono et al., [2021] proposes the design of a VR system to enable visitors interact with the artefacts by natural hand gestures in Indonesia. There is also specific but smaller set of literature on digital policies for digitization in the cultural industries in Southeast Asia, such as in Malaysia and Singapore, which scholars state are taking place for the purposes of ensuring sustainable digitization projects, for developing international standards, and for boosting national economies with the use of culture[8].

4. THE VIETNAMESE WOMEN'S MUSEUM (VWM) ACTION RESEARCH

The VWM's mission is to highlight the role of Vietnamese women in historical and contemporary times, thus contributing to gender equality and the progress of women in Vietnamese culture. For today's situation, that means to provide innovative and engaging digital content for national and international audiences. Their goal today is to respond to the community's needs and maximize the value of cultural heritage in a contemporary context.

From early after its opening in 1987, the VWM realized that it had to continually develop to best serve the public at each moment through history. The museum has been evolving with digital transition and has been keen to adopt new, innovative ideas, to start to apply digital technologies, and to experiment with more interactive activities for visitors.

"During the past 5 years, the Vietnamese Women's Museum has had the following activities using digital technologies: Digitize and coding museum artifacts for archival and communication purposes, introduce the museum artifact story on YouTube and other social networking sites like Facebook, Twitter, Instagram, and the museum's website: baotangphunu.org.vn, upgrade the website of the Museum with a modern and friendly new interface[…]The museum uses digital platforms to serve the purposes of: communication, introducing photos of the museum on the mass media to attract more people to the museum; preserving artifacts, backing up and protecting artifacts information; and research, using digital technology to support the search process" [Interview with Head of Communications at VWM, 2020].

"It can be said that the current use of digital technology at the Vietnamese Women's Museum still has a few limitations due to the staffs have not been trained and updated with new technology; due to the limited budget. The above activities of the Museum are just at the beginning of the experiment and

[8] For example, in Malaysia, there has been a push by the government to connect both fields of digital technology and creativity, with the creative industries becoming a focus area for the Malaysian Government (Barker and Adrian 2017). In Malaysia, this is being developed effectively and systematically by the government, through putting standards and policies in place. In Malaysia, the government has begun to manage digital resources and has begun to create standard procedures that can adequately and effectively maintain and preserve digitized resources (ibid.). The Malaysian government has identified areas that need to be addressed to ensure sustainable and successful implementation of digitization projects. Hence, developments are taking place on digital culture policy and using digitization for preserving cultural heritage in the cultural industries in East Asia as well as other parts of Southeast Asia.

are being carried out on actual resources but have not yet achieved the desired goals." [Interview with Head of Communications at VWM, 2020].

For the future, their strategies include to continue to invest into the development of their website, to apply modern technologies, and to enhance international collaboration activities.

"In the future, we hope to utilize digital technologies in our exhibitions, we want to use technology to describe women's timeline through history. But it is hard to find budget[…]We hope to have more resources by next year." [Interview with Director of VWM, 2021].

"We want to build an online archive for educators. It is difficult to find budget and staff. No museum has invested in creating an online library. We want to do this, but we need money and experts. Now it is sporadic. It is the cloud storage that we want to do in the future. Building library archives is very safe for our collection. It is important to have the library protected. This is not only for protecting but curating (with themes and messages) and for giving access to educators and curators. (Interview with Head of Communications at VWM).

The museum's overall goal with using more digital technology is to "gradually familiarize and apply more digital technology in our activities so many people in many places know about the museum." [Interview with Head of Communications at VWM, 2020].

This can be done effectively through digitizing and digitally displaying collections that highlight women's cultural practices. The Betel Nut Collection is an important collection that highlights Vietnamese women's role and practices throughout history and in contemporary society. It is known as Trầu Cau in Vietnamese. Trầu refers to the betel leaves and Cau is the areca nuts. When they are chewed together, they produce a red color to the lips which is considered attractive in Northern Vietnam. The caskets were used to store the betel nut of dignitaries and wealthy families in Northern Vietnam. The more elaborate designs signify opulence and wealth, while ordinary wooden boxes were used by less wealthy families. The knife was used by women to peel and cut betel nuts. However, the traditional concept that 'the Betel Nut is the beginning of the story' is applied on the occasions of filial piety and joy, the full moon day, the first day of holidays and Tet (Lunar New Year).

As a result, RMIT decided to choose a sustainable method to digitize VWM Betel Nut Collection due to its cultural significance to women in Vietnam as outlined by the VWM and the potential to engage a younger audience that emerged from workshops with students. The digitization project began by taking photographs of 4 artefacts from the Betel Nut Collection. The aim was to digitize all 10 artefacts from the Betel Nut Collection using the same method of photogrammetry, free blending software, and free hosting platforms. The process started by photographing the artefacts from every angle using a smartphone. The next process was to stitch together these photographs using MeshLab and Blender, providing free-to-use software programs that could render and mesh together multiple photographs into one 3D digital model. The 3D models were then uploaded onto Sketchfab, a free hosting platform, from where the 3D models could be published for free and made accessible to the general public. Icons were added to parts of the Kinh Lime Pot to provide more information and stories around the artefact, as shown in Figure 1; this was added to all artefacts in the Betel Nut Collection on SketchFab. A watermark was also created for 3D digital display above the artefacts, which hovers and turns when the audience turns and zooms into the artefact. As a result, 4 out of 10 artefacts from the Betel Nut

collection were digitized using this method. These were the Kinh Lime Pot, Kinh Casket, Hep La Casket, and a Brass Betel Nut Leaf Case.

Figure 2. Screenshot of a 3D model of a 16th century Kinh Lime Pot. Image credit: RMIT Research Team, Emma Duester, Ondris Pui, and Michal Teague in connection with the Vietnamese Women's Museum Betel Nut Collection artifacts (2022).

Figure 3. Screenshot of a 3D model of a Betel Nut Knife hosted on SketchFab. Image credit: RMIT Research Team, Emma Duester, Ondris Pui, and Michal Teague in connection with the Vietnamese Women's Museum Betel Nut Collection artifacts (2022).

Figure 4. Digital Image of the 3D model of a Kinh casket, 19th Century. Image courtesy of Ondris Pui and courtesy of the VWM.

6 out of 10 artefacts were too complex and intricate for the free photogrammetry method. The aspects that could not be captured were the intricate edges on the Northern Casket, the densely woven and dark coloured material of the betel nut bag, and artefacts with reflective textures or translucent surfaces.

Figure 5. Digital Image of the 3D model of a Northern Casket that was scanned and digitized by VietNam ScanTech. Image Courtesy of Ondris Pui and courtesy of VWM.

In response, a commercial scan company was employed to digitize the remaining 6 artefacts of the Betel Nut Collection. The scan company, VietNam ScanTech, was chosen as it was one of few who used a 3D portable scanner. However, VietNam ScanTech had no prior history of working with art and cultural heritage. Instead, they had experience in scanning interiors and architecture. They were chosen because they were the only place in Hanoi to have this particular scanner. This lack of experience and trial-and-error approach meant there were setbacks encountered with the appearance of size, colour, definition, and detail on the object in their first iterations. Yet, this experience upskilled the tech sector and made them want to do more for this sector in future.

Figure 6. Digital Image of the 3D model of the Betel Nut Bag from the Tay Ethnic Group that was scanned and digitized by VietNam ScanTech. Image Courtesy of Ondris Pui and courtesy of VWM.

However, there were also limits to what VietNam ScanTech could digitize. One bowl had to be substituted with another bowl with a thicker surface in order for the scanner to capture it. Furthermore, the string on the Betel Nut Bag was too thin for the 3D scanner to 'read', so it was not possible render and blend it together properly once processed on digital software. Hence, the string straps had to be deleted from the final 3D digital model.

An additional concern held by RMIT and VWM was how to extend the novelty of 3D digital objects beyond solely turning them around and zooming in and out. There was little context or narrative around the content. The museums wanted content that was curated and engaging for audiences; they did not want standalone digital 3D models.

Figure 7. Screenshot of a virtual exhibition created using Mozilla Hubs featuring 9 digital 3D models of the Betel Nut Collection from the Vietnamese Women's Museum and additional contextual multimedia content. Image credit: RMIT Research Team, Emma Duester, Ondris Pui, and Michal Teague in connection with the Vietnamese Women's Museum Betel Nut Collection artifacts (2022).

In response, RMIT researchers created a virtual exhibition space on Mozilla Hubs, a free virtual exhibition platform, to create a virtual exhibition environment in which to place the 3D digital models that were hosted individually on Sketchfab, titled 'The Vietnamese Betel Nut Village'. RMIT researchers made sure to respect local communities who made and used these artefacts by creating a Vietnamese style environment and an environment where the 3D models are positioned alongside information, videos, silhouettes (to show artefact scale), and maps to show the origin of the artefacts. Visitors can walk around this environment with an avatar and can engage with the story and cultural context. The digital environment created on Mozilla Hubs provided cultural context and immersion by positioning the digital 3D models in a relevant context with a temple and landscape familiar to Vietnam, rather than a white wall exhibition space. Instead, there is a temple setting, it is located

outside, and there are trees and nature surrounding the 3D models. The objects float and the audience can interact with the models in novel ways. The audience can 'toss' them away and spin them around. They are floating rather than placed on plinths because this would have been too much like a traditional, physical exhibition space and is not relevant or authentic to Vietnamese culture. The digital does not need to copy the physical and must not continue to intimidate audiences. It was also important to create digital content that respects and acknowledges all people involved. Hence, there is a temple-like information board at the start just after entrance to temple. This has two clear logos of RMIT and VWM. There is also a range of information with each artefact, including name, origin, location, and community. The virtual exhibit was awarded the 'Beyond Borders Project' in the recent Built with Bits, a Europeana mentoring programme and educational challenge. RMIT researchers have since created and launched a website so that the Mozilla Hubs virtual exhibition is embedded in a particular digital space and surrounded by context. As such, it is easier for the general public to find, access, and understand.

5. DISCUSSION

An action research design was used to carry out the digitization project. This approach arose in response to constraints expressed in interviews and consultations with VWM. In response, RMIT researchers co-designed a low cost or no-cost process using smart-phones and free open-source apps. Hence, this research project applied a co-designed action research project that could take the next steps of applying interview findings (in)to practice. The digitization project found and implemented sustainable digital solutions to overcome challenges in lack of technical, human and financial resources. RMIT researchers also used co-design action research to build capacity in the sector to support digitization developments in the sector longer-term, including connections to the tech sector and between national museums and independent artists. As a result of the project, museum staff now know how to use these free, open-source technologies to create and publish 3D digital artifacts, which they can select and curate. It was also important to build skills to hand over this digitization project to VWM. Additionally, it was important to create a long-term, sustaining project that was also meaningful and empowering for VWM. Co-design also allowed RMIT researchers to alleviate the inherent power balance in research. Also, it was important to be mindful of our position as non-Vietnamese academics working at an English-language Australian University in Vietnam.

The key learnings from this project are that there are both opportunities and challenges in digitizing cultural heritage. Even with its limits due to technical, financial, and skilled human resource constraints, it is sustainable for the development of Vietnam considering how these 3D models and gamified virtual exhibitions can help to engage the next generation who are digital natives. Subsequently, this can increase the amount of people accessing Vietnamese cultural heritage and can encourage Vietnamese people to value their own culture through use of digital technologies to represent and present their culture. It is also positive for boosting tourism, which is a vital element of Vietnamese culture and economic development. The project also developed better understanding of the dividing line between and the factors that determine what can and cannot be digitized properly using the photogrammetry method and readily available technologies. This has to do with the artefacts' material qualities, such as the thickness and translucency of the surface, and the intricacy

of the edges. Another country specific challenge with the digitization process was that the digital 3D models need to be tailored for Vietnam's specifics such as slower/unstable internet speed, museums' low-weight websites, the general public's use of social media platforms, and their use of smartphones for access. Together, this paper has provided a critique of the process and limitations of action research and photogrammetry method, the limitations of free software for hosting and displaying artefacts, and challenges in Vietnam with lack of resources and need for content to be smartphone-friendly.

A challenge of using Mozilla Hubs was that most people in Vietnam access content via smartphones and the limited internet speed means it is slow to load. There was also a compression issue when transferring the digital 3D models from Sketchfab to Mozilla Hubs. While the digital objects can be uploaded and published at the highest quality possible on Sketchfab, they must be compressed on Mozilla Hubs as many people are visiting the platform simultaneously and there is a lot of digital content housed in one space. This meant the size of the digital models had to be decreased so that access could be more convenient for the audience, but this necessarily affected the quality of the digital 3D models, especially on the Mozilla Hubs virtual exhibition. In addition, the content cannot be too heavy as the museum websites cannot take heavy data, programs, or apps. Compatibility between programs and applications is also a concern, as Mozilla Hubs has its own software called Spokes, which means it is not easily transferable from Sketchfab, which also has its own software. This means the balance between image quality and accessibility had to be carefully considered throughout the research process. This is an important point for future digitization projects at Vietnamese museums.

There are some learnings and considerations for future digitization projects at Vietnamese museums. A modest amount of learning and training took place on this project as this was a small-scale project. This means there is still a need for more digital skills development. For example, learning and training in how to use of free software like Sketchfab and Mozilla Hubs. There are challenges of 'digital work' not being fully embedded into the cultural sector's overall operational strategy, as many museums do not have dedicated teams or staff for this purpose. Digitization and accessibility are yet to be viewed as a central part of museum activities, which means that digitization projects take place on an ad hoc basis. Hence, it is not yet sustainable. A lot more developmental work is needed with skills capacity training and creating dedicated teams. Moreover, as technologies are constantly changing and developing there needs to be continued training at museums. This is the beginning of the process to make this kind of work part of the daily activities and annual strategies of national museums.

It was not possible to digitize all artefacts with the free method, which shows the limits of this free method. Thus, the project went against its original aim to be free and sustainable. However, this allowed other sustainable approaches to be trialed such as collaborating with a professional artist, which led to a sustainable connection between the national museum and an independent artist and the pooling of resources. Even though photogrammetry is not an entirely sustainable method in terms of being free, sustainability in the museum sector is also about collaboration and cross-sector work partnerships. Therefore, this method is suitable for showing a way forward in the museum sector in terms of co-design and co-production approach. This was innovative as it included different perspectives from professionals, institutions, students, researchers, and tech companies.

There are limitations and concerns for the future of digitization projects in the Global South that need to be taken into consideration. This comes in response to the findings from this project on the limitations in the digitization project with using the free photogrammetry method and with using a professional scan company. Hence, some of the authenticity and 'information' about the object is lost in the creation of the digital model. This is a key issue to consider for the future and the digital as a copy and as a representative of the physical artefacts. There were also problems with parts that were translucent, dense and dark, reflective, or too thin, as the scanner could not detect the surface accurately. As a result, some artefacts in Vietnam might not be able to be digitized with the scanning equipment currently available, hence leaving gaps in history and knowledge. Broadly speaking, maybe the digital cannot capture or achieve everything, hence, there will be some artefacts that remain un-digitized and therefore invisible.

6. CONCLUSION

This action research project has both documented and contributed towards the development of digitization in the cultural sector in Vietnam, highlighting a paradigm shift in tools and processes of preserving, promoting, and displaying museum collections. It has highlighted how Vietnam remains at a disadvantage due to country-specific challenges in digitization, which are hindering the pace, quality, and effectiveness of digitization projects. This comes at a crucial time in Vietnam, as there is an emergent digital culture in the art and cultural sector in Vietnam, which is producing a shift in the nature of work for cultural professionals, the way of preserving and displaying art collections as well as the nature of international connections. This is an important shift in this sector because digitization processes provide an increased agency for cultural professionals to present their own image of Vietnamese culture to an international audience. Cultural professionals are now the 'mediators' of Vietnamese culture on an international scale, acting as an important source of access to and education about art and culture globally. Digital platforms allow more international connection and the ability to raise awareness internationally on, for instance, Vietnamese photography and Vietnamese women. This includes subject matter that is not so often seen globally online, as compared with commonly shared images related to tourist hotspots, traditional clothes, and customs as well as conflict. This digital shift can also help to improve the international standing of the Vietnamese art scene, allowing the development of the art market, and providing a way of attracting foreign investment.

This article has developed understanding on the challenges and opportunities associated with digital heritage in the Global South. In addition to the challenges presented in the article, there is a need for further discussion and critique into other related challenges, such as how to present, interpret, and educate on cultural heritage in the context of a digital gap in societies of the Global South, particularly in Vietnam. Ethnic minorities, local communities in rural areas do not have ready access to the internet as in the cities. It is important to note that within societies like Vietnam that have limited access to digital technology, not all members have equal access, and there may be various gender and social inequalities in access. This case study focuses on the Vietnamese Women's Museum, which has been helpful in illuminating the role of women through digital storytelling and exhibition technologies. The Mozilla Hubs exhibition went some way to present women's culture and history via digital storytelling, with mixed media including 3D models, sound, motion, interaction, and audio

narration of the collection. Together, this kind of mixed-media digital storytelling can offer a powerful way of engaging and empowering women and other marginalized groups, while also facilitating the preservation and promotion of cultural heritage.

This paper has intervened in literature on digitization for cultural preservation and content creation, which focuses on the production of digital archives and the quality of digital copies. This paper contributes to literature on digitization in Asia for the preservation of cultural heritage collections. It has combined discussion on the technical side of digitization with discussion from the cultural side of digitization from the cultural studies and cultural heritage fields, including work on digitization of cultural heritage. While there is a lot of literature on the technical side of digitization, focusing on digital content creation and digital storage, there is a gap in terms of discussion on making digitized content accessible and engaging to audiences. This is vital for providing digital inclusion and redressing the imbalance in the amount of cultural content online in Vietnam. Furthermore, there is a need to connect literature on digital technology and the cultural sector, as the digitization of art and culture is distinct, including aesthetic quality, personalization, and copyright protection.

Looking towards the future, the regained physical access to museums' collections will not eliminate increased attention to the online platforms of museums. The increased digital approach is one of the permanent consequences for museums connected to the pandemic with museums reluctant to revert to previous approaches, mostly because of undeniable benefits and advantages proffered by digital technology. This includes preservation, storage as well as cultural promotion, education, and research. There is also enormous potential with digital technologies for the creation of new audiences and new ways to bring art and history alive.

In the future, exhibitions will likely be made available both online and in the physical sense, by having a range of digital technologies for access and engagement during the physical visit. This reflects the changes accelerated during the covid-19 pandemic and developments made by both museums and audiences. These hybrid models will safeguard museums' sustainability and permanence in the future as well as securing the broadest possible access to culture for the audience.

Since the pandemic, the challenge for museums globally is to reinvent themselves, to redefine their mission and to find new justifications for their existence, both in the digital and physical sense. What museums must do in the future is to cultivate relationships with the community and provide educational resources so that arts and culture are available to the public. By shifting their narratives from object-centric to people-centric and transitioning from inert physical places into living hybrid physical-digital spaces. The digital and physical experiences will need to co-exist more than ever in post-pandemic museums. There will be hybrid versions of online and offline offerings, blending digital and physical experiences. This makes it important to create engaging and sustainable digital content that can be used in the physical museum exhibits that are now open to the public. This will ensure that visitors will return to physical spaces.

For post-covid recovery, museums will also need to consider new business models which allow them to include digital offerings. These new business models must account for revenues potentially generated by digital activities. The willingness to pay, as expressed by some museum visitors, for access to quality digital contents in a live mode, with museum directors or curators available to provide explanations and insights in real time, is noteworthy. These new revenue streams from

digital offerings could help to alleviate museums' financial circumstances which have deteriorated during the pandemic as well as the long-term challenges experienced by the sector in Vietnam as mentioned previously in this paper concerning a lack of human, technical and financial resources. Museums' attractiveness must also be measured in terms of not only the number of people visiting exhibitions physically, but also by the number and the intensity of digital visitors who 'consume' the museum collection through digital experiences. With more available budget for digital offerings, there might be more scope for paying for professional services for digitizing those artefacts that are too complex to use the free methods.

This project has helped to ensure cultural sustainability by preserving objects that might be destroyed or damaged and promoting them and attracting local and international tourists more effectively. The significance of this is that it has helped to develop capabilities in digitization to ensure digitization is not only for preservation but can also be for cultural promotion and engagement. This model can be applied to other museums to develop the museum sector across Vietnam and the Global South. This project has provided more accessible resources to balance the amount of cultural content online and boost the tourism industry by making their collections more visible online and empower museum staff through training on the digitization process, digital storytelling, and digital marketing.

Overall, this project has enabled more fragile and culturally significant artefacts to be captured and preserved for digital access. This can help to ensure the survival of the VWM post-pandemic; the co-designed action research project created resources to engage new audiences in Vietnamese art and culture, built the culture sector's human resources and technical capacity, and boosted current and future local and international cultural tourism to the museum sector. Other museums can replicate this process due to being easy-to-follow and through understanding the opportunities and challenges. Together, this research exploited the opportunities of digitization for increased access, creation of digital resources, and rebalancing the discourse and amount of content online on Vietnamese art and culture.

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Received March 2023; revised July 2023; accepted Sept 2023.