UTILISING SMART TECHNOLOGY FOR HERITAGE PRESERVATION: A SYSTEMATIC REVIEW CASE STUDY MALAYSIA AND TÜRKIYE

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ABSTRACT

Conventional heritage preservation faces physical, social and technical challenges. This systematic review examines the use of smart technology to overcome those challenges through a case study and rapid reviews comparing the heritage preservation method in Malaysia and Türkiye. Given both generic and Islamic-specific contexts of the two countries' comparison, the study aims to understand how well both countries attempt to resolve conventional heritage preservation using several smart technologies applications using augmented reality (AR), virtual reality (VR), the Internet of Things (IoT), and drone technology. The finding carefully outlined the benefits, challenges, and limitations of smart technology techniques for better smart heritage governance direction in the future. It highlighted their significant role in smart heritage initiatives, including robotics, automation, 5G, and augmented reality in museums. These technologies enhance safety, prevent damage, and provide immersive learning experiences, helping policymakers and historical preservationists better understand the potential of smart technology.

Keywords: Smart Technology, Heritage, Preservation, Malaysia, Türkiye

1.0 INTRODUCTION

Heritage is considered an invaluable resource that needs to be preserved. Heritage preservation refers to the efforts to protect and conserve cultural, historical, and natural heritage for present and future generations (Lowenthal, 2013). It encompasses preserving historic buildings, archaeological sites, cultural traditions, artefacts, natural landscapes, and intangible heritage such as languages and traditional knowledge. However, the preservation of heritage faces several challenges, such as physical limitations due to the location of heritage (Barrado-Timón et al., 2019), restrictions of geographical area (Ribeiro et al., 2018), loss of sociocultural identity due to urban development (Abdrabo, 2020) and to saving an important historical structure or building due to deterioration effect (Khalil et al., 2021).

In practice, both government and private sectors play a role in protecting historic structures (Macdonald & Cheong, 2014). These precious heritage sites and traditions testify to the collective heritage and provide invaluable insights into the past. Inefficiency in heritage preservation such as Cairo's old city center listed as one of UNESCO's World Heritage Sites (Shehata & Moustafa, 2015) was found due to old technology used to preserve the built heritage. Despite the obstacles posed by extensive development and the effects of climate change on many types of disasters, efforts were made to identify the optimum method of integrating smart technology.

In recent years, integrating smart technology has revolutionised various aspects of our lives and heritage preservation. The Internet of Things (IoT), artificial intelligence (AI), and data analytics are just a few examples of smart technologies that have created exciting new opportunities for the advancement of preserving and promoting cultural heritage. China adopted the technical application of 3D LiDAR to protect their built heritage by performing 3D scanning, high-precision measurement, and reconstruction (Li et al., 2023) and integrating IoT tools to improve

the resilience of the built heritage (Elabd et al., 2021). By utilising these technologies, it is possible to guarantee the cultural heritage's long-term preservation and promotion, opening it up to a wider audience while keeping it alive for future generations. Amid recent environmental disasters such as floods and earthquakes, capturing the heritage site and built environment helps minimise the risk for future mitigation action and educational awareness (Cremen et al., 2023). With frequent climate change events, it is crucial to evaluate to what extent smart technology preserves heritage sites. Using the case studies method through the lens of smart technology, the paper evaluates the heritage site and built environment in Malaysia and Türkiye with the aim of co-learning spirit. Further, the need for real-time information for decision-making in heritage management organizations in both countries was justified. The involvement of smart technology in providing the best information to minimise the degradation effect on the heritage site and built environment amid environmental disasters of the sites will be emphasised. In the end, the benefits, challenges and limitations of smart technology in heritage preservation will be outlined to identify the recommendations of potential prospects and the emerging trends and future directions given for related policymakers and heritage preservation organisations.

2.0 UTILIZING SMART TECHNOLOGY FOR HERITAGE PRESERVATION

This section is structured according to selected smart technology applications in the context of heritage preservation efforts.

Using smart technology to protect and promote cultural assets has emerged as a possible method. Through modern imaging techniques such as high-resolution imaging, 3D scanning, and photogrammetry, smart technology helps the digitisation and preservation of historic artefacts and sites. These techniques allow for the accurate and detailed portrayal of cultural objects and settings. Furthermore, data management solutions, such as databases and cloud-based platforms, make it easier to store, organize, and disseminate heritage information (Bertacchi et al., 2018).

Next, Augmented Reality (AR) technologies provide interactive and immersive experiences that help to preserve history and engage visitors. Several studies (Anastasiou et al., 2020; Papagiannakis & Christou, 2018) demonstrate the potential of AR applications for superimposing digital content on the physical environment. Users can interact with virtual reconstructions, historical material, and multimedia content, enhancing their understanding of heritage locations. Then, Virtual Reality (VR) technology has demonstrated tremendous potential for safeguarding cultural heritage. Research (Liarokapis & Zabulis, 2018; Papadopoulou et al., 2021) shows that VR can be used to build immersive replicas of historical periods and vanished heritage locations. Users can explore and engage with rebuilt heritage sites using VR experiences, which improves teaching, research, and visitor experiences. Furthermore, virtual tours provide remote access to inaccessible or vulnerable heritage sites.

Other than that, the Internet of Things (IoT) plays an important role in heritage preservation by connecting physical objects equipped with sensors and actuators. These sensors allow for real-time monitoring and data collection in heritage sites, aiding in environmental monitoring, conservation activities, and risk management. According to a research (Papadopoulou et al., 2021), IoT solutions are important in asset monitoring, visitor management, security systems, and crowd monitoring. Lastly, drone technology has shown to be a great asset in a variety of industries, including heritage preservation. Drones are a cost-effective and efficient way to capture aerial pictures and movies of cultural monuments. They enable the creation of detailed 3D models, orthomosaic maps, and digital reconstructions (Wang, et al., 2019). Heritage professionals may document places from numerous angles and perspectives using drones, resulting in accurate and comprehensive documentation. Drones offer distinct advantages for

monitoring and surveillance in historic sites. They provide real-time video feeds and are equipped with modern sensors and cameras, allowing remote surveillance of sensitive locations and increasing security measures. Drones also make it easier to monitor environmental elements, which aids in preservation and conservation initiatives.

2.1 Augmented Reality (AR) Applications

Augmented reality, or AR, has gained popularity in recent years due to the ability to superimpose digital content over the real world, resulting in interactive and immersive experiences. AR applications use computer-generated sensory input to improve users' perception of their surroundings. Firstly, AR has transformed education by providing interactive and engaging learning experiences. Kang and Radu (2019) have highlighted the potential of AR to boost student comprehension and information retention. AR apps make complicated concepts more concrete and accessible by providing virtual simulations, 3D models, and real-time data visualisation. AR-enabled gadgets enable students to immerse themselves in areas such as science, history, and geography. This promotes active learning, collaboration, and student engagement for future generations.

AR applications have had a tremendous impact on the gaming industry. Popular games such as Pokémon Go (Kok, 2018) have demonstrated the power of AR in developing location-based and participatory gaming experiences. AR-enabled smartphones and wearable gadgets enable users to merge the virtual and physical worlds, immersing them in real-world settings. AR gaming promotes physical activity, social connection, and discovery, creating a one-of-a-kind and dynamic game experience. Then, AR improved medical training, surgical planning, and patient care, transforming healthcare procedures. The work of Azuma et al. (2020) and Garca-Betances et al. (2018) demonstrated the benefits of AR in visualising complex anatomical structures, overlaying diagnostic information, and simulating medical procedures. AR-based applications help medical practitioners improve precision, reduce errors, and improve patient outcomes. During surgical procedures, surgeons can use AR visualisation to aid in real-time guidance and visualisation of key structures.

Further, AR has been acknowledged as a revolutionary technology in the architecture and design professions. Schall et al. (2019) and Zalama et al. (2018) have highlighted the ability of AR to visualise and manipulate 3D models in real-world settings. AR apps can be used by architects and designers to present their concepts to clients and stakeholders, allowing them to experience proposed structures and assess spatial linkages. This improves communication, speeds up the design process, and allows more informed decision-making.

2.2 Virtual Reality (VR) Applications

Virtual reality uses computer technology to create simulated environments where users can interact. VR applications use specialised headsets and motion-tracking equipment to give users a sensation of presence and immersion in virtual environments. Firstly, VR has transformed the game business by providing immersive and engaging experiences. The work of Griffiths et al. (2020) and Weech et al. (2019) have shown that VR gaming has the potential to improve player involvement, immersion, and enjoyment. VR platforms allow users to physically interact with virtual worlds, resulting in a more realistic and dynamic gaming experience. VR gaming provides a variety of intriguing experiences, ranging from action-packed adventures to simulation-based games.

Next, by providing immersive and interactive learning experiences, virtual reality has the potential to revolutionise education. Studies showed that VR apps improve student engagement,

knowledge retention, and understanding of complicated subjects (Akçayır & Akçayır, 2017; Sánchez et al., 2020). Virtual reality allows students to explore previously unavailable virtual settings, historical places, and scientific phenomena. This hands-on learning technique encourages active engagement and increases conceptual knowledge. Then, VR has proven to be useful in healthcare, particularly in medical training, therapy, and pain management. VR simulations can improve medical abilities, reduce errors, and provide realistic training settings (Freeman et al., 2017; Soares et al., 2021). VR therapy has also demonstrated promising outcomes in treating phobias, PTSD, and chronic pain. Because of the immersive nature of VR, patients can confront and overcome their phobias in safe and controlled surroundings.

Additionally, virtual reality has transformed training procedures in various areas, including aviation, military, manufacturing, urban planning and heritage preservation. VR simulations improve training efficacy and decision-making abilities and lower expenses associated with in-person training (Kersten et al., 2019; Seo et al., 2020). VR provides realistic and immersive settings that match real-world circumstances, from flight simulators to equipment handling and emergency response training for planning smart, sustainable cities (Jamei et al., 2017). Finally, virtual reality has created new opportunities in entertainment virtual tourism and heritage preservation, such as reconstructed 3D models of historical establishments (Ahmed et al., 2019). Virtual tours of famous places, virtual museums, live events, and immersive storytelling experiences are available to users. Lin et al. (2020) and Rosenbaum et al. (2019) have demonstrated the promise of VR in developing compelling and interactive entertainment content, allowing consumers to enjoy unique and unforgettable experiences.

2.3 Internet of Things (IoT) Applications

The protection and conservation of historical sites, cultural artefacts, and intangible heritage are all part of heritage preservation. By offering real-time monitoring, data collecting, analysis, and interactive visitor experiences, IoT technologies have the potential to transform heritage preservation completely. This review examines several research, projects and efforts that have used IoT to preserve cultural heritage and examines their advantages, difficulties, and potential future applications.

Maksimovic (2019) cited that the Internet of Things (IoT) and other contemporary ICTs have already demonstrated their enormous potential when used to monitor cultural heritage sites. The IoT has been applied to preserving and reviving cultural heritage, monitoring the structural health of buildings, and enhancing visitor experiences in cultural settings. IoT technologies can be used in various use cases related to cultural heritage protection. From Wireless Local Area Network (WLAN) technologies for mid-range communication to Wireless Personal Area Network (WPAN) technologies based on a more infrastructure-free method, Low Power Wide Area Network technologies use a long-range cellular infrastructure (Astorga, et al. 2022).

This extensive study attempts to offer insights into the current state of IoT applications in historic preservation by reviewing available literature. It draws attention to the possibilities, difficulties, and advantages linked to using IoT technology in this field. Researchers, practitioners, and policymakers can use the findings of this review to help them when building and putting into practice IoT-based solutions to protect and advance the cultural heritage.

2.4 Drone Technology for Documentation and Surveillance

Drones have been employed in various industries during the past ten years, including mining, building and infrastructure, agricultural, environmental monitoring, and GIS. Daniela (2021) reported that drones are now being used to investigate cultural assets, allowing researchers to fly

over heritage sites and monitor them from the air while incurring little operational costs. They do, in theory, provide photogrammetry services, however, the applications could include remote investigation and sensing activities in archaeological sites rather than human workers.

The field of photogrammetry is now being expanded by digitisation to include picture analysis and processing based on mathematical and geometric models with software-implemented algorithms. Drones can give enormous volumes of data through mobile scanning over areas of interest, which is used in automatic picture processing (Daniela, 2021). Drones with high-resolution cameras and sensors may take precise aerial photos and films of historical places from various perspectives and altitudes. As a result, 3D models, and virtual tours of cultural heritage sites can be made by archaeologists, historians, and preservationists that are precise and in-depth. For the sake of conservation, research, and public outreach, this record is crucial.

Furthermore, drones can be used for surveillance and monitoring of heritage sites to prevent illegal activities such as looting, vandalism, and encroachment. They provide a cost-effective solution for regular inspections, allowing heritage managers to identify potential risks or damage in real-time. Drones equipped with thermal imaging cameras can also detect structural weaknesses or temperature variations that might indicate areas of concern. In terms of accessibility, drones can reach places that are otherwise unsafe or difficult to access, such as rooftops, inaccessible or delicate architectural details, or distant archaeological sites. They do away with the necessity for actual access tools or putting workers at risk in dangerous places. This accessibility enables detailed studies of historic buildings, ensuring full evaluations and precise preservation strategies. In conclusion, drone technology offers an effective tool for cultural preservation documentation, monitoring, and surveillance. It enhances conventional techniques and makes it possible for more thorough, effective, and accurate preservation efforts, helping to ensure the long-term preservation of our cultural legacy.

3.0 METHODOLOGY

Using a qualitative systematic review, the research was based on international academic papers covering heritage preservation using smart technology comparing selected case studies from Malaysia and Turkiye. Addressing the fact that little work has been carried out comparing smart heritage preservation in both countries, the type of smart technology application is Augmented reality (AR) for interactive museums, Virtual reality (VR) photography for interactive visual media creation, IoT-enabled monitoring and preservation systems, drone-based mapping and surveillance of heritage sites (Abdelhai, 2022). Based on the four types of smart technology applications for heritage sites and built environments, rapid reviews were performed. The analysis involves several pieces of literature, which provide the overall quality or direction of the effect of the literature; a search for completeness, which is determined by time constraints; and a synthesis of the result displayed in typically narrative form (Pesce et al., 2019). All the data for this study was gathered from observations and textual analysis.

Data collection for this research is based on contextual detail from the previous research and case study. Existing case studies of the heritage site and the application of smart technology in Malaysia and Türkiye were carefully selected for the examination. This is to improve the various technology applications, which also demonstrate the crucial involvement of stakeholders in digitising heritage site management and its cultural preservation values (Pesce et al., 2019). Data were collected by the search strategy method (Aromataris & Riitano, 2014). Heritage, preservation, smart technology, and heritage sustainability were combined as search terms to help find relevant literature for this research. By conducting a string search using numerous keywords, researchers could focus on the titles, abstracts, and full texts of the pertinent research publications.

4.0 RESULT AND FINDINGS

The study results are presented in a case study approach comparing the type of smart technology application in heritage sites and built environments in Malaysia and Türkiye.

4.1 Case Study 1: AR-based Interactive Museum Exhibits

AR is one of the initiatives to preserve the country's heritage. The fusion of digital data with the user's surroundings in real-time is known as augmented reality (AR). AR users encounter a real-world environment with created perceptual information superimposed on top of it, unlike virtual reality (VR), which entirely artificially recreates the scene. Through a device like a smartphone or glasses, augmented reality (AR) provides the user with visual elements, sound, and other sensory information. To provide a seamless experience where digital information modifies the user's view of the actual environment, this information is layered onto the device.

The use of modern technologies in museum exhibitions in Malaysia is still lacking, even in the context of AR, even though science and technology are thriving nowadays (Hashim et al., 2014; Mohd Isa et al., 2020). In Malaysia's national museums, most exhibits employ passive and traditional information display techniques. The "Virtual Maritime Museum" at the Maritime Museum in Melaka, Malaysia, is a remarkable case study of AR-based interactive museum exhibitions in that country. The Maritime Museum is housed in a replica of the Portuguese ship "Flor de la Mar" and showcases Malaysia's maritime history. Maritime Museum's official opening was on June 13, 1994 (Abd Razak et al., 2017). The AR-based exhibits at the Virtual Maritime Museum changed the visitor experience by making it more engaging, immersive, and instructive. The museum gave visitors a distinctive and exciting approach to learning about Malaysia's nautical heritage using AR technology.

A case study in Türkiye is the Topkapi Palace. The Topkapi Palace Museum in Istanbul features interactive exhibits that utilise augmented reality, showcasing the advantages of doing so (Bozkuş et al., 2014; Çıldır & Karadeniz, 2014). Turkish museums may use the interactive and immersive qualities of AR to increase visitor engagement, add to historical context, and create fun and informative experiences for visitors of all ages. These technological developments can potentially change conventional museums into lively, interactive learning environments that draw a larger audience and promote cultural heritage.

4.2 Case Study 2: VR-Based Virtual Tours of Heritage Sites

Virtual reality (VR) photography is an interactive visual media creation, especially in panoramas and object movies. VR can be interpreted in three dimensions: the multisensory, immersive, and interactive digital environment, which has sparked a broad imagination of future technologies for dominating work, education, and leisure (Roussou, 2004).

On July 7, 2008, the United Nations Educational, Scientific, and Cultural Organisations (UNESCO) designated George Town, Penang, as a world-historic site. This site was chosen to develop a demonstration system for a game, which is an application of virtual reality to heritage site research on a mobile platform that includes the game M-Heritage Hunt. The main objectives of this game are to develop a setting that offers a panoramic perspective of many heritage landmarks, to draw visitors to and advertise a specific heritage region and to improve learning opportunities in George Town, Penang, Malaysia. A unique game called M-Heritage Hunt combines Monopoly and treasure hunting in a single package. The game, which combines virtual reality with the classic Monopoly and treasure hunt games, can increase awareness of and draw visitors to a specific heritage region. Malaysia can promote cultural preservation, tourism, and education by implementing a VR-based virtual heritage project for George Town. It provides an

immersive and accessible way for people to experience the city's rich heritage, even if they cannot visit in person. Virtual reality (VR) has become an innovative tool for preserving and showcasing cultural heritage.

In Türkiye, with its rich history and diverse heritage sites, VR-based virtual tours and experiences can play a significant role in promoting tourism, education, and preservation efforts. There is a project of VR-based virtual heritage in Türkiye named “Journey Through Time: Exploring Türkiye's Cultural Heritage”. One of the heritage sites chosen to be in this project is the Ottoman World. The 'imaret' complex, a charity structure constructed on the devout principles that underpinned the growth of Ottoman cities, is the subject of the article (Ibrahim et al., 2007). Türkiye can build engaging and immersive virtual heritage experiences that engage audiences, protect cultural heritage, and improve tourism by utilising the power of virtual reality. These initiatives could improve educational possibilities, raise public awareness, and support the long-term growth of Türkiye's cultural heritage industry.

4.3 Case Study 3: IoT-enabled Monitoring and Preservation Systems

The George Town World Heritage Site in Penang is one of the case studies in Malaysia for IoT-enabled monitoring and preservation systems for heritage. To preserve, safeguard, and promote the George Town World Heritage Site (GTWHS), George Town World Heritage Incorporated (GTWHI) has created an Integrated Heritage Database System (IHDS) employing smart mapping technology, sometimes referred to as Geographic Information System (GIS) technology. The George Town World Heritage Site management has improved because of the deployment of IoT-enabled monitoring and preservation tools. Authorities can prevent potential threats and preserve historic sites for future generations by utilising real-time data and automation. This case study shows how IoT technology can successfully maintain and safeguard historical sites.

The Hagia Sophia Museum in Istanbul serves as a showcase for the usage of IoT-enabled monitoring and preservation systems in the context of heritage in Türkiye. The Hagia Sophia is a magnificent piece of ancient architecture that has undergone numerous changes throughout its life, acting as a cathedral, mosque, and museum at various points. In recent years, with advancements in IoT technology, the management of the Hagia Sophia Museum has integrated smart monitoring systems to ensure the preservation and safety of the structure. The Hagia Sophia Museum's adoption of IoT-enabled monitoring and preservation technologies serves as an example of the potential advantages of incorporating technology. These technologies aid in the long-term preservation and sustainability of cultural treasures by delivering real-time data, actionable insights, and improved security.

4.4 Case Study 4: Drone-based Mapping and Surveillance of Heritage Sites

The case study chosen is the As-Solihin Mosque at Melaka. According to Sauti et al. (2018), historical structures should be preserved in every nation because of their great emotional, cultural, and practical qualities. Without proper ongoing preservation, there is a fear that these ancient structures would disappear and be consumed by time. Unmanned Aerial Vehicle (UAV) are chosen as an alternative tool for visually inspecting Solihin Mosque at Melaka. According to Norhisham et al. (2023), this technology comprises a camera that can take clear pictures in addition to movies. The damage to the building's exterior could be seen by using a micro-UAV. As-Solihin Mosque is a historical building in Melaka; this study illustrates the visual assessment procedure for dilapidation work. The purpose of this investigation was to have a comprehensive understanding of the mosque's roof structure's actual damage. This case study highlights the advantages of this technology while demonstrating its potential to strengthen conservation tactics

and save the nation's cultural heritage. Malaysia can preserve its priceless cultural assets more successfully and sustainably by utilising contemporary tools and methods.

The area selected as a case study in Türkiye is Gobekli Tepe. Known as one of the earliest known man-made constructions, Göbekli Tepe is a prehistoric archaeological site in southeast Türkiye. It is said to have been created around 11,000 years ago during the Neolithic period and is extremely important for comprehending the evolution of early civilizations as well as the history of humanity. Due to its size, some areas of Göbekli Tepe may be difficult to reach on foot. Drones can offer an affordable and effective way to explore and record these inaccessible locations. Archaeologists and scholars can investigate various areas of the site without physically entering the area by taking aerial photographs, which reduces the chance of damaging sensitive structures. There are several advantages to using drones to map and monitor historical sites like Türkiye's Göbekli Tepe. Accurate recordkeeping, site monitoring, accessibility, participation from the public, and research opportunities are made possible.

5.0 DISCUSSION

The following sub-section outlines the benefits, challenges and limitations of smart technology implementation in heritage preservation in Malaysia and Türkiye, with its subsequent effects on heritage professionals, policymakers, and visitors.

5.1 Benefits of Smart Technology in Heritage Preservation

Smart technology has developed as a potent tool in cultural preservation, with numerous advantages. Smart technology has the potential to transform the way we maintain and appreciate our cultural heritage, from improved conservation methods to enhanced visitor experiences. Conservation and restoration of heritage sites, antiques, and artworks are aided by smart technology. According to Liarokapis et al. (2021), “High-resolution imaging techniques, 3D scanning, and augmented reality (AR) can be utilised to document, analyse, and recreate damaged or lost elements”. These technologies allow professionals to digitally restore and conserve cultural artefacts without inflicting additional damage. These technologies enable the precise and detailed digital preservation of Türkiye's and Malaysia’s cultural assets, resulting in comprehensive recordings that may be used for research, restoration, and education.

Next, smart devices and sensors deployed in heritage sites allow for real-time data collection on parameters such as temperature, humidity, light levels, and air quality (Delin et al., 2018). This information is useful for monitoring environmental conditions and identifying potential threats to the preservation of artefacts or structures. Heritage professionals may make informed decisions, adopt preventive measures, and intervene quickly to prevent harm or degradation by examining this data. Other than that, smart technology improves the visiting experience at heritage sites significantly. Mobile applications, interactive displays, and virtual reality (VR) experiences provide visitors with immersive and interactive ways to engage with history, stories, and artefacts (Diara et al., 2019). These innovations bring heritage to life by providing multimedia information, guided tours, and interactive exhibits. Such encounters not only educate visitors but also build a greater appreciation for and relationship with the legacy, encouraging its long-term preservation.

According to Styliani et al. (2019), “Smart technology enables the creation of digital replicas and virtual models of heritage sites, monuments, and artefacts. These replicas may be accessible remotely, allowing individuals from all over the world to explore and enjoy cultural heritage even if they cannot visit the place in person”. Using virtual tours, online archives, and digital displays expands the scope and impact of cultural preservation activities. They promote awareness, garner

support, and make research and educational opportunities possible. Then, smart technology improves heritage site security and risk management. Advanced surveillance systems, including video analytics and motion sensors, can detect and alert authorities to potential threats such as theft, vandalism, or natural disasters (Quercia et al., 2020). Furthermore, smart technologies can help with emergency response planning and speedy emergency intervention. Smart technology improves the safety and conservation of cultural assets by providing real-time monitoring and notifications.

Smart technology provides prospects for long-term heritage preservation. Energy-efficient systems, such as smart lighting and climate control, minimise the environmental impact while ensuring the preservation of artefacts and structures (Yoon et al., 2018). Furthermore, digital documentation and online archives lessen the demand for physical storage space, which helps to conserve resources. By implementing smart technology, heritage preservation may connect with sustainable practices and reduce carbon impact. Lastly, according to Pérez-Valverde et al. (2020), "Smart technology enables collaboration among experts, researchers, and heritage professionals across different geographical locations". Digital platforms, virtual conferences, and online databases allow the exchange of historic preservation information, research findings, and best practices. This collaboration hastens the development of innovative preservation solutions. In the field, smart technology acts as a driver for interdisciplinary collaboration and knowledge sharing. These benefits show how smart technology may help preserve history in Türkiye and Malaysia by supporting conservation, increasing visitor experiences, fostering sustainability, and creating economic opportunities.

5.2 Challenges and Limitations of Implementing Smart Technology

Implementing smart technology into heritage preservation benefits considerably, providing benefits like conservation and restoration, increased visitor experiences, and data-driven decision-making. However, it is critical to recognise the problems and limitations connected with smart technology deployment in this setting. The considerable upfront expenses associated with using smart technology in heritage preservation are one of the key concerns. The installation of sensors, monitoring systems, and infrastructure, as well as the development of specialized software and applications, can require substantial financial investment (Pattanayak, 2019). Smaller heritage sites or groups with limited funding may find it especially difficult to fund these technological developments.

The technical integration of several smart technology systems and maintaining their interoperability might be challenging. Heritage professionals and staff may require training and support to effectively operate and maintain these solutions (Ballarin et al., 2018). The technical competence required for successful smart technology deployment and administration may be a barrier for some firms, particularly those without dedicated IT departments. Also, collecting and analysing real-time data from heritage sites presents privacy and security concerns. Sensitive information about visitors, artefacts, and the site itself needs to be protected from unauthorised access, hacking, or misuse (Lazaroiu et al., 2020). To protect the integrity and privacy of data, it is critical to employ strong security mechanisms and protocols.

Smart technology systems require constant maintenance, upgrades, and repairs to function properly. According to Pérez-Valverde et al. (2018), “Hardware components, software applications, and networking infrastructure may need periodic upgrades or fixes”. Ample resources and trained employees must be available to meet maintenance requirements and fix any emerging technical issues. While smart technology can improve visitor experiences, it can also create accessibility challenges for some people. Not all visitors may have access to smartphones,

tablets, or VR devices necessary for interactive experiences (Hornecker & Ciolfi, 2022). It is critical to consider inclusive design principles and provide alternate options to ensure that everyone, regardless of technology capabilities, can participate in the cultural site.

Lastly, using smart technology to preserve history should be done with cultural sensitivity. Cultural practices, beliefs, and traditions are all protected and preserved as part of heritage preservation. It is important to engage stakeholders and local communities in the decision-making process to address concerns or conflicts that may arise regarding the integration of technology in heritage spaces (Pattanayak, 2019).

6.0 FUTURE PROSPECTS AND RECOMMENDATIONS

6.1 Emerging Trends and Future Directions

Among the approaches that can be used in the future include the integration of Internet of Things (IoT) sensors to collect real-time data on environmental conditions and visitor behaviour, as well as the use of artificial intelligence (AI) and machine learning algorithms for automated analysis and predictive modelling, are examples of such innovations. Next, virtual and augmented reality (VR/AR) technologies are gaining popularity because they provide immersive experiences and virtual repair options. Then, digital documentation and preservation efforts such as high-resolution imaging and 3D scanning facilitate remote access and research. Next, big data analytics provide insights into usage trends and conservation needs, while mobile applications and geolocation services improve tourist experiences. Lastly, the public is involved in cultural preservation efforts through collaborative platforms and crowdsourcing projects. Embracing these trends can transform heritage preservation in Türkiye and Malaysia, opening up new conservation, education, and sustainable tourism avenues. Both countries can uncover new conservation, education, and sustainable tourism prospects by adopting these technologies and promoting cooperation between heritage specialists, technological experts, and local people.

6.2 Recommendations for Policymakers and Heritage Preservation Organizations

The Ministry of Culture and Tourism (Kültür ve Turizm Bakanlığı) is responsible for formulating policies, regulations, and strategies related to cultural heritage preservation in Türkiye. It oversees the protection, restoration, and promotion of cultural heritage sites and monuments in Türkiye. In Malaysia, the Department of National Heritage, which is part of the Ministry of Tourism, Arts, and Culture (MOTAC), is responsible for identifying, protecting, and managing Malaysia's national heritage. The agency develops historical preservation policies, standards, and plans, as well as oversees heritage-related activities. The recommendations include creating complete digital preservation methods for cultural heritage, including digitising rules, metadata standards, and long-term data storage. Encourage collaboration between historic institutions and technology specialists to ensure that digital archives are implemented and maintained effectively.

This organisation must improve digital infrastructure and connectivity at heritage sites to support smart technology implementation. Improve Wi-Fi connectivity, install sensors, and build data centres or cloud storage facilities to support real-time data collecting, remote monitoring, and digital preservation activities. Investing in education and training programs for heritage professionals, museum employees, and technology specialists allows for cross-disciplinary collaboration and knowledge exchange, creating a thorough understanding of historic preservation principles and emerging smart technology applications.

Next, the government should allocate resources and financing for smart technology research and innovation for heritage protection to encourage research institutions, universities, and technology companies to investigate and create cutting-edge solutions such as artificial intelligence-based

conservation algorithms, sophisticated imaging techniques, and interactive visitor experiences. Policymakers and heritage preservation organisations in Türkiye and Malaysia can effectively harness the potential of smart technology to safeguard their cultural heritage, enhance visitor experiences, and ensure the long-term preservation of their valuable assets by implementing these recommendations.

7.0 CONCLUSION

Based on this study, it can be concluded that smart technology can be used to preserve heritage. Undoubtedly, technology is incredibly capable of restoring and protecting humanity's cultural heritage. Technology plays an even more significant role in the years to come as our digital society develops in this regard. Robotics and automation could monitor and protect historically significant places prone to theft, and 5G could connect remote IoT sensors that could notify authorities of tourist-related damage. The museum visitor experience can now be improved with interactive, augmented reality-based exhibits. These displays provide a distinctive and engaging approach to learning about art, history, science, and culture by fusing the real and virtual worlds. Interactive museum exhibits based on augmented reality (AR) have several advantages, such as improved engagement, immersive learning, personalised experiences, accessibility, preservation of artefacts, dynamic content updates, visitor analytics, and increased reach. These results demonstrate how AR technology has improved museum experiences by making them more interactive, educational, and inclusive.

Moreover, virtual tours provide educational opportunities by offering detailed information about the heritage site, including its historical context, architectural style, and cultural significance. This allows users to understand better and appreciate the location's heritage and cultural value. Users may explore and learn about culturally significant areas from anywhere in the world thanks to VR-based virtual tours of heritage sites, which provide an immersive and informative experience. They are an important tool for fostering respect for and knowledge of cultural heritage since they offer accessibility, preservation, and educational benefits. In conclusion, smart technology is revolutionising heritage preservation by improving conservation practices, promoting wider access and engagement, and facilitating sustainable management of our cultural heritage. It empowers us to safeguard the past while embracing the possibilities of the digital age.

Heritage preservation is critical in Türkiye and Malaysia, as both countries have rich cultural legacies and historically significant sites. Introducing smart technology has significant consequences for these countries' cultural preservation strategies, providing distinct benefits and opportunities. One significant implication is enhanced conservation and preservation. Thanks to its unique cultural heritage, Türkiyee can use innovative technology to maintain and preserve its historical landmarks, artefacts, and customs. Using real-time monitoring systems with advanced imaging techniques ensures that Türkiye's cultural assets are preserved in the best possible conditions. Similarly, smart technology can help Malaysia preserve its distinct cultural assets, such as traditional crafts, architectural structures, and indigenous knowledge. Both countries may proactively monitor and maintain their cultural property by deploying smart technology solutions, reducing the danger of harm or deterioration.

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