POMPEII

28

E-Journal

Scavi di Pompei

18.12.24

The Pompeii sustainable management model

*Gabriel Zuchtriegel [1], Luigi Petti [2] *, Vincenzo Calvanese [1], Constanza Maria De Gaetano [2], Carmine Lupo [2], Arianna Spinosa [1], Alessandra Zambrano [1]*

Abstract

The Archaeological Park of Pompeii, a UNESCO site located in Southern Italy, stands as a site of immeasurable value, which demands preservation and protection. The effectiveness of measures designed to safeguard and enhance public access and understanding of the site, however, rests not solely upon the technical solutions available at any particular point, but fundamentally upon the overarching management framework. The Great Pompeii Project (GPP, 2012-2022), one of the most extensive 'rescue' interventions undertaken in the field of archaeology, unequivocally demonstrated that the cornerstone of its success lay in the robust organisational structure and the seamless integration of activities pertaining to research, conservation, accessibility, communication and public engagement.

To sustain and further elevate the quality standards attained by the GPP, an innovative "Sustainable Management Model" for Pompeii was devised. This model is based on the judicious utilisation of economic and human resources to facilitate the preservation and accessibility of the ancient site through the implementation of tailored development and maintenance strategies. The development plan aims to cultivate a diverse range of initiatives empowering Pompeii to achieve greater autonomy and mitigate the detrimental impact of overtourism. Concurrently, the maintenance plan aspires to implement pragmatic strategies for the monitoring of the site's condition using various scales of investigation at different levels of detail.

Keywords: *Cultural Heritage Maintenance, Proactive Maintenance, Sustainability Strategies*

fig. 1 A view of the Archaeological Park of Pompeii.

1. Introduction

The preservation of Pompeii, a UNESCO World Heritage Site, has presented a formidable challenge for those entrusted with its management, safeguarding, and enhancement. The city encompasses an area of 66 hectares, of which slightly more than two-thirds has been unearthed, Pompeii is an intricate and delicate archaeological site. It boasts remarkably well-preserved structures, frescoes, artifacts, mosaics, and infrastructure, a testament to the devastating eruption of Mount Vesuvius in AD 79. Over the centuries, Pompeii has served as a world stage for the pioneering of new methods of archaeological investigation, restoration and conservation. However, the effectiveness of these efforts has depended not only on technological advances, but also on the administrative frameworks implemented by the governing body. A prime example of this dynamic is the Great Pompeii Project (GPP), which was conducted from 2012 to 2022. The success of this project can be attributed to the organisational structure and integrated management model that has been put in place, encompassing protection, research, conservation, access, and public understanding of the site. [1, 2, 3].

[1] Archaeological Park of Pompeii (PAP), Ministry of Culture (MiC), Via Plinio, 80045, Pompeii, NA, Italy;
[2] Department of Civil Engineering, University of Salerno, Via Giovanni Paolo II, 84084, Fisciano, SA, Italy;
** Correspondence: Luigi Petti, petti@unisa.com*

A "Sustainable Management Model" is a nontrivial solution for implementing effective management in a complex site such as Pompeii. Sustainability necessitates an interdisciplinary approach and demands its recognition as a multifaceted value within a holistic framework. [4]. The challenge for Pompeii is to maintain and improve the high standards of conservation, restoration, access, and education achieved by the GPP through a continuous and sustainable management process. The proposed model aims to integrate these aspects with economic sustainability and an increased capacity for self-financing.

As outlined in the UNESCO publication on managing cultural heritage [5], sustainable development entails the responsible application of limited resources that strikes a balance between fundamental human needs and those resources available to future generations. Regarding cultural heritage, the issue of sustainable development can be understood in two ways:

1. Intrinsic: as a concern for maintaining the heritage, considered as an end in itself;

2. Instrumental: as the possible contribution that heritage and its preservation can make to the environmental, social, and economic dimensions of sustainable development.

The first approach is founded on the assumption that cultural heritage and the ability to understand history through its material remains, as attributes of cultural diversity, play a fundamental role in encouraging resilient communities, supporting the physical and spiritual well-being of individuals and promoting mutual understanding and harmony. The second approach acknowledges that the heritage sector should accept its share of responsibility for sustainability on a global scale, given the growing pressure from human activities, limited financial and environmental resources, and climate change.

The EU Framework for Action on Cultural Heritage recognises sustainability as a fundamental component of its five pillars [6, 7]. The recognition of cultural heritage as positively affecting social, capital, and economic growth, as well as environmental sustainability is well-established. The five pillars of this Framework for Action are:

1. Cultural heritage for an inclusive Europe: participation and access for all.

2. Cultural heritage for a sustainable Europe: smart solutions for a cohesive and sustainable future.

3. Cultural heritage for a resilient Europe: safeguarding endangered heritage.

4. Cultural heritage for an innovative Europe: mobilising knowledge and research.

5. Cultural heritage for stronger global partnerships: reinforcing international cooperation.

Managing cultural sites can be significantly challenging when hazardous conditions are present [8], such as the complex environment of Pompeii. Recent meteorological phenomena have highlighted the fragility of this territory, which is generally still not prepared for such challenges [9]. The development of a management model must consider the hazards and risks that can threaten the preservation of heritage according to a sustainable approach. The implementation of strategic plans that anticipate potential damage and catastrophes demonstrates an efficient and effective use of resources to safeguard and protect heritage with a proactive approach.

The recent literature review [9] on the impact of climate change on cultural heritage emphasises the significance of variations in temperature, precipitation, and wind. The available studies indicate significant impacts on archaeological sites, including:

- An increase in precipitation and humidity, coupled with higher temperatures, may result in several forms of material damage such as corrosion, biological deterioration, distortion, and cracking, as well as the formation of salt crystals causing efflorescence and subflorescence;

- The intensification of wind, particularly when associated with sand, salt, and atmospheric

contaminants, could result in surface erosion, increased water infiltration, structural damage, and the potential collapse of structures;

- An increase in temperature could lead to more freeze-thaw cycles or greater temperature fluctuations throughout the day. These would impact the frequency of thermoclastism phenomena, potentially causing increased physical weathering damage to stone and ceramic materials;

- An increase of temperature and humidity could intensify biological degradation due to the creation of favourable conditions for mould growth and insect activity.

Within a sustainable management model, it would be beneficial to distinguish between the effects caused by fast weather changes and ones following very extreme events, both of which are related to effects of climate change. While the first has a tendency to lead to a slow but constant decay, the second could produce a sudden impact with heavy damage. As a result, the effects due to fast weather changes can be fully controlled through proactive maintenance procedures, while the effects of extreme events can be properly mitigated. Earthquakes, floods, conflicts and the outbreak of disease cannot be entirely prevented but mitigation measures can effectively reduce the risk that these factors can present [10].

The objective of this paper is to provide a description of the challenges faced and the strategies implemented to manage the Archaeological Park of Pompeii after the GPP, which include consideration of an innovative monitoring and maintenance process according to codified international maintenance standards [11, 12] together with a sustainable approach to public access and understanding of the site.

2. Site context

The Archaeological Park of Pompeii is a local organisation belonging to the Ministry of Culture of Italy. In addition to the site of Pompeii, the Archaeological Park comprises other museums and cultural heritage sites. These include the Antiquarium of Boscoreale, the Castle of Lettere, the Archaeological Park of Longola in Poggiomarino, the archaeological museum at Quisisana in Castellammare di Stabia, the archaeological sites of Oplontis in Torre Annunziata, the villas of Stabia in Castellamare di Stabia, Villa Regina in Boscoreale, and the Former Royal Bourbon Powder Factory in Scafati.

In January 2014, the 'Special Superintendency for the Archaeological Heritage of Naples and Pompeii' was divided into two bodies by the Decree-Law no. 91 of 8th August 2013 [13], and Law no. 112 of 7th October 2013 [14]. One institution was responsible for Naples, the Campi Flegrei area, and Caserta, while the other, the 'Special Superintendency for the Archaeological Heritage of Pompeii, Herculaneum and Stabiae was responsible for the Vesuvian sites of Pompeii, Herculaneum, Stabiae, Oplontis, and Boscoreale. In 2016, this institution was renamed as 'Superintendency of Pompeii', and with the adoption of Ministerial Decree on 12th January 2017 (OJ 10/03/2017) [15], it was rebranded as the 'Archaeological Park of Pompeii' in line with international standards for cultural institutions and sites. That same year, Herculaneum was separated from Pompeii to become the 'Archaeological Park of Herculaneum'.

The Park's sites are located at the foot of Vesuvius and in close proximity to the area of Campi Flegrei, one of the most hazardous volcanic sites in the world. Even if the hazard linked to Vesuvius appears to be the highest when considering these sites, the Campi Flegrei caldera, a complex and resurgent volcano, has experienced intense volcanism with eruptions concentrated in temporal clusters known as epochs [16]. Both Vesuvius and Campi Flegrei refer to a single deep magma system, which also feeds magma to Ischia. In addition, the ancient city of Pompeii is situated within a widely recognised seismotectonic context [17] that characterises Southern Italy with high to medium seismic activity. The local seismicity of Pompeii has been extensively studied [18], mainly through an investigation of the effects of the great earthquake of AD 62/63. Hydrogeological hazards are equally significant, as they affect the stability of the existing walls and the conservation of the site as a whole.

The wonders of the site of Pompeii and the complex problems that characterise its conservation and management have long attracted the attention of the international community. The most notable of these was in November 2010, following the collapse of the Schola Armaturarum, which was attributed to a lack of maintenance and the effects of hydrogeological instability - a factor emphasised in recent years by significant climate changes.

The Great Pompeii Project was conceived in response to this collapse, thanks to the joint action of the Ministry of Cultural Heritage and Tourism and the Presidency of the Council of Ministers, with the aim of halting the degradation and improving the conditions of conservation of ancient Pompeii. In January 2012, the aforementioned Ministry drew up an exceptional and urgent program of restoration for the archaeological site of Pompeii. In this context, the Great Pompeii Project was proposed as a "major community project" and subsequently approved by the European Commission, that authorised funding totalling 105 million euros, of which 78 million came from the European Regional Development Fund (ERDF), within the interregional operational program "Cultural, natural actuators and tourism", and 37 million euros from national funds.

A massive programme, composed of 76 interventions organised into 5 plans, was carried out in two "phases" of financing: the first was an instalment of 39.7 million euros (based on the POIn Cultural Attractors 2007-2013 programming cycle); the second was 65.3 million euros (valid for the next financial planning cycle, Axis I of the NOP Culture and Development 2014-2020).

In table 1 the details of the 5 plans are summarised.

PLANS	*ACTIONS*	*COST*	
		Amount by sector	*Total*
Knowledge plan	Surveys, investigations and diagnoses, needs analytical identification	8.200.000	8.200.000
Plan of works	Works with advanced planning	47.000.000	85.000.000
	Works to be designed	38.000.000	
Plan for the use improvement of services and communication	Adaptation of services to the public	5.000.000	7.000.000
	Promotion and communication	2.000.000	
Safety plan	Remote surveillance	700.000	2.000.000
	Plant safety	1.300.000	
Technological strengthening and capacity building plan	Technological adaptation	1.000.000	2.800.000
	Capacity building	1.800.000	
	TOTALE	**105.000.000 €**	**105.000.000€**

The precarious state of the site prior to the GPP was primarily attributable to its vast scale, the significant damage inflicted by the 1980 earthquake, and prolonged periods of inadequate maintenance. [19].

The so-called " Knowledge Plan" allowed the development of the Information System (SiPompei), which is a unique tool that describes and catalogues the entire ancient city of Pompeii. The principal aim of the SiPompei platform is to support the maintenance management through a georeferenced relational database to monitor the most vulnerable elements [3].

More recently, the open-access digital archive, Open Pompeii [21], was developed to facilitate access, foster public understanding, and enable the dissemination of site data. Open Pompeii is linked to the SiPompei platform, to the Archaeological Information System of the Vesuvian Area (SIAV), and to the photographic and historical archive of digital documentation system, Tolomeo. SIAV, in particular, was developed between 2001 and 2007, prior to the GPP, with the objective of integrating archival materials pertaining to the Vesuvian region. This initiative aimed to facilitate online management, implementation, and consultation of these materials, enabling both topographical and catalogue-based searches through user-friendly interfaces. [22].

Concerning overall site safety, the Smart@ POMPEI project was launched recently. This initiative aims to effectively manage and mitigate safety risks for both visitors and monuments, encompassing both routine operations and emergency scenarios. This project was established following a collaborative agreement signed in May 2015 between the Ministry of Cultural Heritage and Tourism (MiBACT) and the National Research Council (CNR). The Smart@POMPEI project developed a platform integrating video surveillance, access control, anti-intrusion systems, and environmental monitoring by means of sensors, drones, etc. [23].

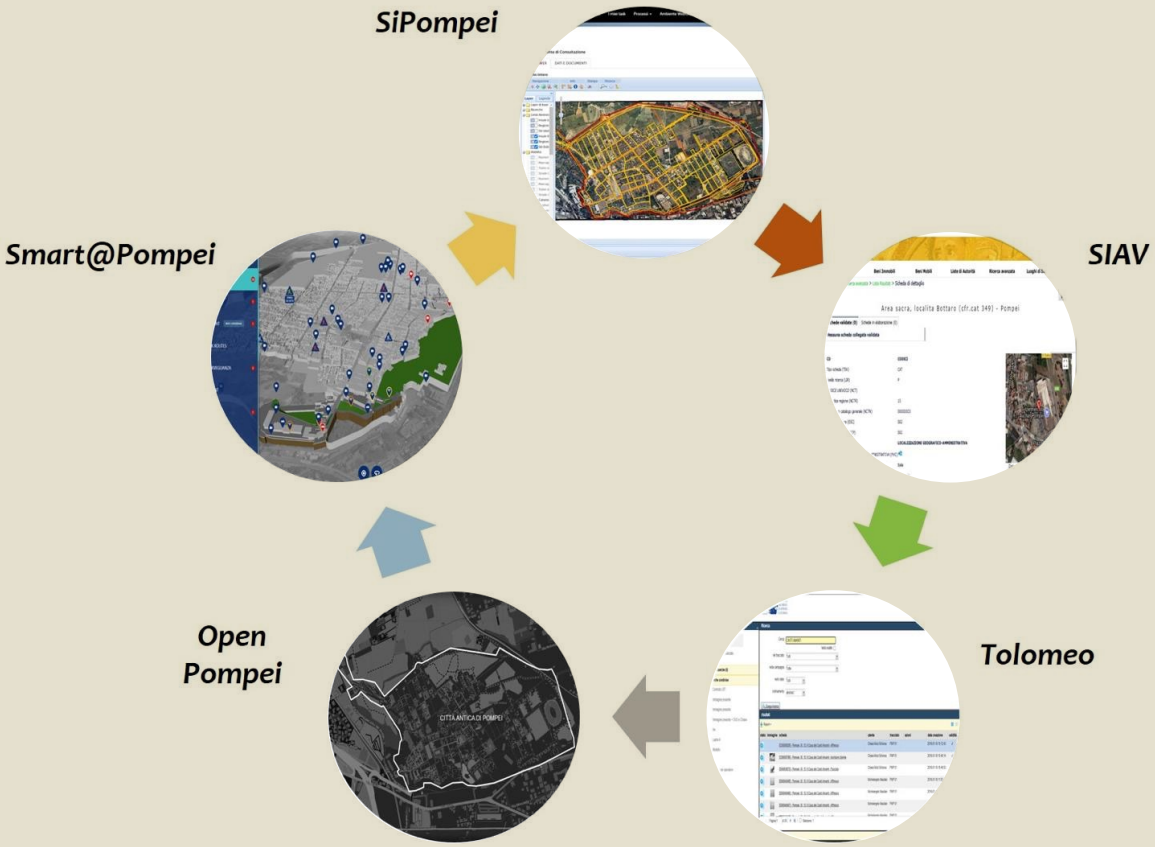


Figure 2 describes the map of the Informative Systems of Pompeii.

3. The Sustainable Management Model of Pompeii

In the field of cultural heritage, preservation is increasingly perceived as a major challenge. Nowadays there are numerous approaches to conservation, restoration and renovation. However, it is necessary to bear in mind that there are substantial differences between these concepts [24]:

• Conservation means consolidating and preserving structures. Preservation lies at the heart of the concept of conservation. Together with consolidation and safeguarding measures, conservation aims to protect the fabric of a monument and to prevent further loss;

• Restoration means restoring a building or painting to its original condition. Restoration aims to accentuate aspects of a monument that are hidden (for whatever reason), disfigured or impaired. It is concerned

with the overall appearance of the monument as historical and artistic evidence. Following on from the consolidation and conservation of the original fabric, restoration adds new elements without impairing the original ones;

• Renovation means to renew. Renovation aims to achieve aesthetic unity in a monument in the sense of "making new again".

Conservation, restoration, and renovation constitute a graduated system of preservation measures which are interconnected. According to the circumstances, they may be carried out one after the other or simultaneously. Among the measures that contribute towards preservation and in addition to interventions of repair, stabilisation, rehabilitation and modernisation, which in some cases may be unsustainable, there are undoubtedly maintenance activities. Article 4 of the Venice Charter [25] places maintenance first for the purposes of conserving sites and monuments.

Following the GPP, which represented an exceptional intervention carried out with ad hoc funds, attention was paid towards how to manage maintenance activities by incorporating them into the context of an ordinary process with ordinary funds.

With the aim of preservation, a management model needs to take into account all possible risks that can impact the site, and in addition to ordinary risks, it is also necessary to consider those situations that can turn into catastrophes. For this purpose, the management model should be based on an approach that prevents and mitigates risks and, if necessary, must be integrated with a disaster risk management plan [10].

An integrated approach to manage the cultural heritage becomes fundamental and can be interpreted in three ways: as a philosophy; as a process; and as a product [5].

The philosophy defines the principles, according to a cooperative approach, requiring changes in the organisation, cultures, and attitudes of participants, as well as an integration between resources and information across disciplines and sectors, identification of the main issues, and the quality of documentation.

As a process, the approach should be designed to facilitate coordination and consultation between agencies and local governments in order to exchange ideas and foster relationships with other organisations and their approaches.

As a product, the strategy is to facilitate the development of complementary monitoring devices and legislative integration, through the definition of requirements and motivations for integration, explanation of the relationship with other legislation, and monitoring requirements.

In response to the unprecedented confluence of contemporary challenges – encompassing climate change, the imperatives of sustainable development, and the imperative to adapt and revitalise cultural and collective values – the sustainable management model for Pompeii presents significant innovations compared to previous approaches.

• **Transcending the limitations of a conventional 'project,'** this model envisions the implementation of a sustainable management program that endures beyond the constraints of initial funding. Its ultimate objective is to

foster progressive economic self-sufficiency and ultimately achieve seamless integration into the Park's routine operational framework.

- **Extending beyond the scope of a mere 'major intervention,'** the model prioritises a holistic approach, encompassing an interconnected network of actions, procedures, and interventions. This framework is anchored in a long-term vision, characterized by a dynamic management strategy capable of adapting to evolving demands and unforeseen contingencies, such as the escalating impacts of climate change, economic fluctuations, and societal shifts.

- **While originating in Pompeii and drawing upon the valuable experience of the [GPP - likely the Great Pompeii Project]**, this model extends its influence beyond the confines of the ancient city, encompassing the broader surrounding region, including all sites under the Park's jurisdiction. Its explicit ambition is to catalyse sustainable growth, including robust economic development, within a substantial geographical area extending well beyond the immediate vicinity of Pompeii.

The overarching management strategy for Pompeii is based on four primary objectives, each corresponding to a distinct area of risk. However, within each of these domains, significant opportunities for growth and enhancement can be identified. (figure 3):

1. Heritage protection and maintenance.
2. Sustainable use, teaching and training.
3. Participation and cultural and economic development of the territory.
4. Strengthening of the management structure.

Figure 3. Gears of the Sustainable Model for the Management of the Archaeological Park of Pompeii.

In this sustainable management model of cultural heritage, protection and maintenance assume essential roles. Maintenance is a significant factor to consider when managing complex structures or sites, like Pompeii. It allows for a balance between maximising performance and minimising costs, while ensuring the preservation of the heritage. Maintenance involves technical, managerial, and administrative activities and aims to preserve the heritage assets to benefit their users and society, both now and in the future. A maintenance strategy refers to the approach taken to address a specific risk or risks that could potentially affect the preservation of cultural heritage.

The main concern regarding complex archaeological sites is the natural decay of the archaeological materials and structures, but this concern is further compounded by the inherent risks associated with the site's natural environment, including seismic activity, volcanic phenomena, and the escalating impact of climate change. In this context, the Archaeological Park of Pompeii launched a monitoring project in partnership with several universities and research institutions. This project aims to establish a comprehensive program of scheduled maintenance and interventions with the overarching objective of safeguarding the site's integrity. This necessitates a profound understanding of the site's current condition and the evolving patterns of deterioration that necessitate targeted attention.

It is clear that an integrated approach requires the participation of the cultural and economic development of the territory through the implementation of a sustainable and innovative model of access and understanding by the public, aimed at increasing the number of tourists and extending the opening hours, as well as improving the ability to be self-sustaining through revenue growth, while respecting the preservation of the site. Different projects are being developed, such as: the creation of new permanent exhibitions to display new finds and enhance some areas of the sites; the creation of new illuminated routes to extend the opening hours of the site; the introduction of new evening tickets; and the reduction of the pressure generated by seasonal

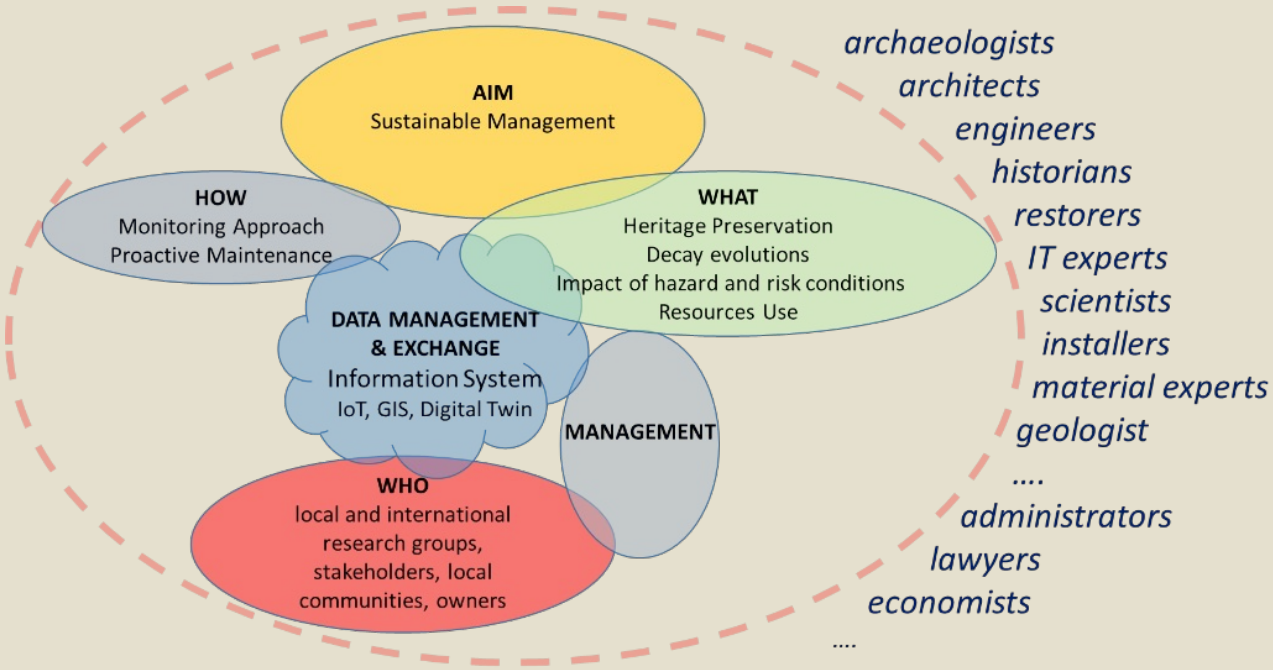


Figure 3. Elements of the Sustainable Management Model of the Archaeological Park of Pompeii.

mass tourism. Excavations in new areas of the sites of the Archaeological Park of Pompeii are being undertaken and the redevelopment of others is being embarked upon.

Since its discovery, the ancient city of Pompeii has served as an invaluable laboratory for experts in the fields of archaeology, restoration, and cultural heritage. Building upon this concept, the development of a novel utilisation for the ancient site, namely a dedicated "Campus," is currently underway. The renovated buildings called "Campus" will include several services for researchers, experts and students, such as an exhibition area, a storage-laboratory for scholars, a library/study centre, and a guest house. These spaces can serve as centres for training and the exchange of ideas, facilitating the development of research projects and can host exhibitions and conferences, consolidating Pompeii's role as a school for archaeology. These new assets will also have the potential to generate extra income through the introduction of a cafeteria and guest house. The Sustainable Management Model of Pompeii can be summarised in the following figure, which highlights the relevance of multi- and transdisciplinary approaches that require a common language to manage and integrate different skills and competences within a common vision.

4. The Maintenance Approach

The neglect of routine maintenance activities [24, 26, 27] exacerbates the necessity for more costly and extensive repair interventions. This phenomenon poses a significant risk to the integrity and authenticity of cultural heritage sites. The deferred maintenance not only increases the financial burden but also jeopardises the very fabric of these invaluable assets [28]. In order to prevent and mitigate damage, to control deterioration processes, and to maintain the standards achieved through the activities of the GPP, a proactive approach to maintenance has been considered in Pompeii. The main goal is to avoid and/or control the damage caused by the processes of decay through regular and ordinary maintenance thanks to the development of intervention strategies based on an existing knowledge of the factors that affect the site.

The maintenance model follows an approach engineered according to the International Organisation of Standardisation (ISO) [29], which in the case of archaeological park is outlined in the following flow-chart.

Proactive maintenance strategies aim to anticipate and address potential risk conditions, controlling the circumstances that can lead to

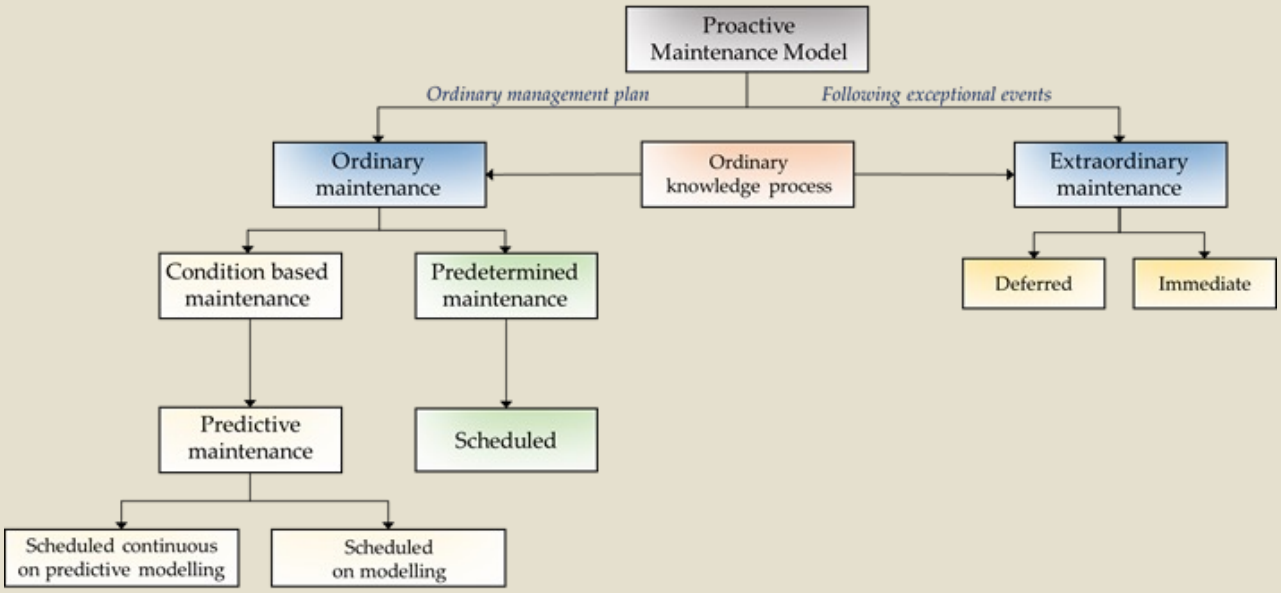


Figure 5. Flow-chart Proactive Maintenance Model.

damage. Within the context of archaeological remains, the implementation of such strategies is advantageous as it allows early identification of at-risk areas that can affect the safety of the site. The applied approach consists of ordinary maintenance activities to avoid or reduce the impact of damage due to natural decay and/or specific actions for exceptional natural or manmade catastrophes. In addition, maintenance can be carried out with minimum intervention according to Venice Chart and Nara principles [25, 30].

The strategy to preserve complex sites needs to define performance targets and accepted levels of damage as well as outline and forecast the decay processes that affect the site in order to predetermine ordinary maintenance within the general management plan. For this purpose, it is necessary to improve the accuracy of predicting the occurrence of damage or unacceptable conditions.

Predetermined maintenance needs to be scheduled by considering objective criteria and suitable time windows according to accepted risk levels. Ordinary maintenance also involves condition-based activities, which depends on the ongoing monitoring data. In practice, the monitoring approach compares the evolution of physical parameters with a set of criteria, thresholds, or limits. If the observed conditions are acceptable, no specific maintenance will be carried out. However, if the conditions do not meet acceptable standards, maintenance will be necessary and should be planned accordingly. This type of maintenance could be defined as non-proactive condition-based maintenance, as it does not involve making predictions related to a specific case. Proactive condition-based maintenance, on the other hand, uses data collected throughout the system's lifespan to generate or update a forecast about its future condition.

Following extreme or exceptional events, a specific maintenance plan can be required. However, for a sustainable management, the expected emergency situations also need a well-defined plan integrated and compatible with the ordinary maintenance. After such situations, even if the overall conditions could manifest into a critical situation, the overall response to the event will certainly be better if integrated into an ordinary process.

5. The Monitoring Strategy

The effective implementation of a maintenance approach necessitates a profound and continually evolving understanding of the site's safety and decay dynamics. The preservation of cultural heritage demands the adoption of rigorous strategies and methodologies for the continuous acquisition and monitoring of the site's overall condition. This monitoring process is meticulously designed to provide real-time updates on the evolving state of decay and the prevailing safety conditions.

Analogous applications have been successfully implemented in other complex environments, such as the management of critical road infrastructure [31, 32, 33], as well as in the assessment of structural suitability [34, 35].

In the case of Pompeii, considering the complexity of the site, the many and varied assets, the countless hazards and risks that could have an impact on the heritage, and their inestimable value, a suitable multi-level and multi-scale monitoring approach has been developed. The monitoring system is based on different methodologies and techniques, which consider more data/time resolution (multi-scale) and more accuracy concerning the assessment (multi-level), within three assessment levels:

1. Local Assessment (LA)
2. General Assessment (GA)
3. Detailed Assessment (DA)

LA provides an extensive understanding of the condition of the site by means of expeditious onsite surveys carried out annually by expert teams.

GA leads to a broad understanding about the overall condition of the site and it is carried out monthly by means of drones and artificial intelligence (AI) applications. GA can be considered as a method to quickly manage

emergency situations. LA and GA can be used to both identify and resolve critical issues through ordinary maintenance and to recognise the circumstances that require the in-depth assessment of DA.

DA is carried out promptly in response to the results of the LA and/or GA and provides in-depth assessments as well as resolving critical at-risk issues with the support of monitoring devices.

The monitoring approach developed (Figure 6) makes use of WebGIS, IoT and Digital Twins

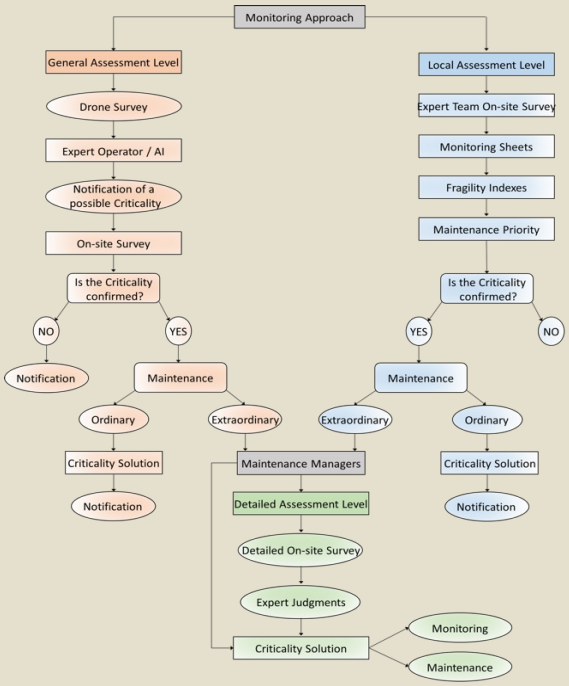


Figure 6. Flow-chart Monitoring approach.

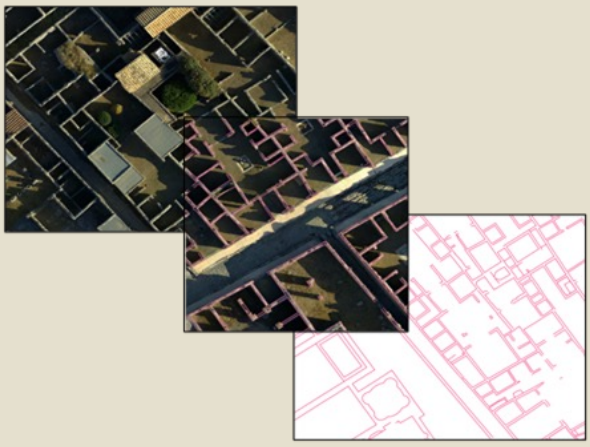
to describe the site's condition with the aim of developing predictive models to support proactive maintenance policies.

The GA level involves the analysis of high-resolution images, obtained by a drone survey (figure 7a), with the aim of evaluating the evolution of the site, by comparing images taken in two time periods. The images are georeferenced using a specific procedure (figure 7b) and catalogued in the GIS database of the Park.

The LA level involves the use of a methodology based on compiling standardised monitoring forms, which permits the identification and description of the most prevalent conditions of decay for each type of element, subdivided into: wall structures; decorations; architraves; horizontal elements. Figure 8 shows the screenshots of the web app platform that was developed to support the visual inspection.

In the case of exceptional conditions of decay or following exceptional events, the monitoring approach can help evaluate the need for a DA level. The DA level is undertaken by multidisciplinary teams comprising experts in archaeology, architecture, engineering, restoration, and related fields. This process incorporates the use of sensor-based monitoring systems to enhance the comprehension of specific critical points within the site. Figure 9 show an example of proposed network to monitor a test site of the Archaeological Park of Pompeii.

(a)



(b)

Figure 7. Survey plan for the acquisition of orthophotos of the Park via drone.

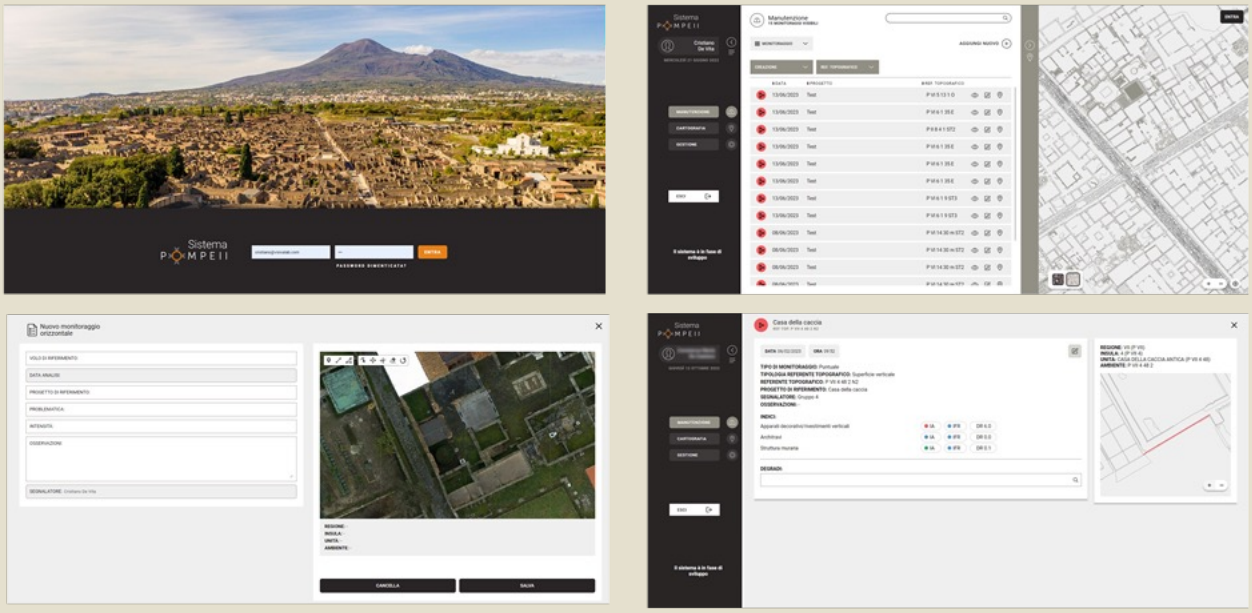


Figure 8. Web-based software for Local Assessment Level.

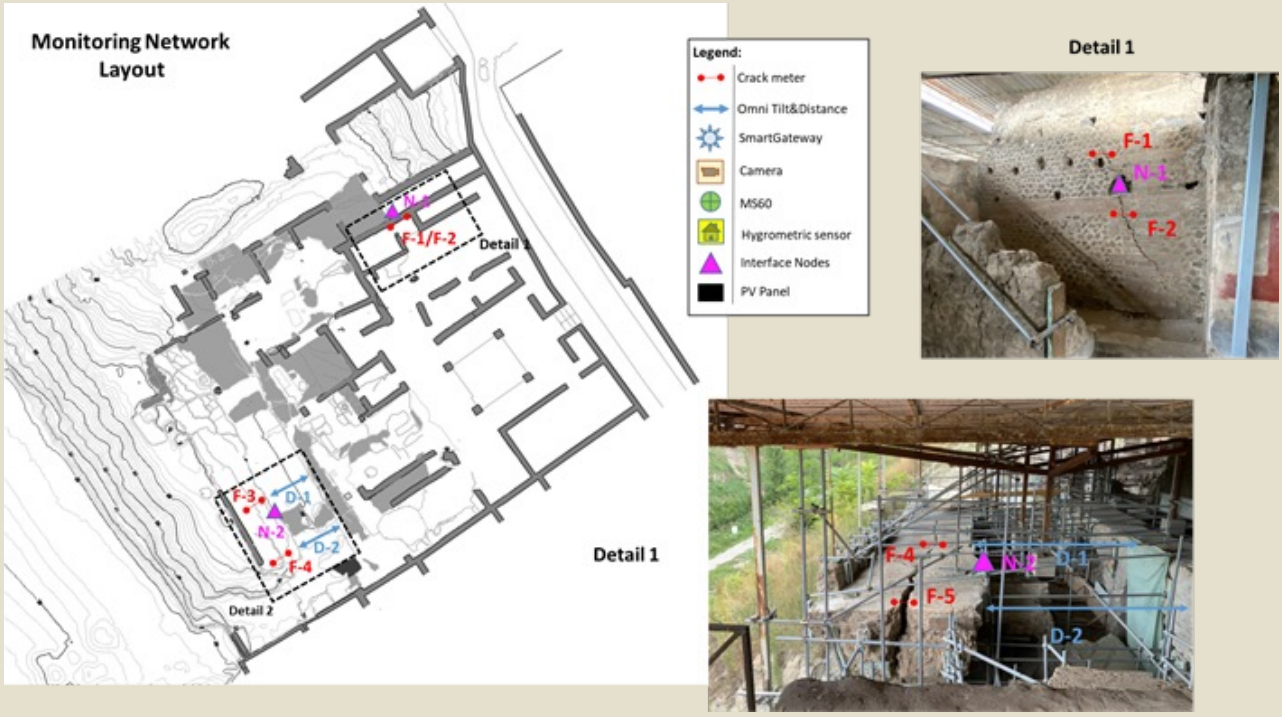


Figure 9. Example of monitoring networks into the Archaeological Park of Pompeii.

6. Conclusions

The conservation of Pompeii represents a major challenge for the management of the site. Based on the experience of the Great Pompeii Project, a new model has been developed over the last three years. The model transcends a mere project as it constitutes a paradigmatic approach, inherently receptive to ongoing refinement and expansion.

Furthermore, as a model, it can be seamlessly integrated into the routine operation of the Park, whereas a project, by its very nature, remains circumscribed and consequently exceptional.

The maintenance program is inextricably linked to and responsive to the data derived from the systematic monitoring of the entire site, facilitated by a web application and the deployment of Artificial Intelligence. In essence the model aspires to reach a sustainable transition from an exceptional state to a routine one, to be applied on daily base.

The model consists of integrated series of approaches and strategies that consider the site condition, and evaluate its potential risks and hazards to which it could be subjected. Moreover the proposed model aims to use human and economic resources responsibly, implementing innovative technologies to preserve the site, and improving accessibility and public outreach of the site.

The Archaeological Park of Pompeii is presently undertaking a series of initiatives designed to facilitate the attainment of several key objectives relating to suitable development, of lesser-known archaeological sites close to the ancient city of Pompeii. This action will mitigate the detrimental effects of overtourism and anthropogenic pressure on the ancient city that is currently experiencing excessive numbers of visitors. The active engagement of local communities within the tourism sector will be paramount to the success of this sustainable approach, fostering collaborative partnership that drive economic growth through increased visitor numbers.

The model we propose here aims to safeguard and preserve cultural heritage through the implementation of proactive maintenance methodologies founded upon systematic and periodic monitoring.

Sustainability is posited as a paramount objective, attainable through the strategic utilisation of digital technologies and Artificial Intelligence leading to a sustainable decision making process.

Author Contributions

Management Model Conception, G.Z., L.P., V.C.; Development Support, L.P., V.C.; Supervision G.Z.; Scientific Analysis to Support Monitoring L.P., C.L., C.M.D.G.; Technical Management and Implementation V.C., A.S., A.Z.; all authors have read and agreed to the published version of the manuscript.

Funding

The Archaeological Park of Pompeii (PAP) and the Ministry of Culture (MiC) funded this research.

Data Availability Statement

All the data and Model are property of the Archaeological Park of Pompeii (PAP).

Acknowledgments

The research was conducted thanks to the willingness to develop an innovative model to allow a sustainable and resilient management of a complex archaeological site by the Archaeological Park of Pompeii with the support of a team of the Department of Civil Engineering of the University of Salerno. The model has been developed thanking also to a team composed by experts of the Archaeological Park of Pompeii, Ales S.p.a (Arte Lavoro E Servizi S.p.a.) and VISIVALAB.

References

Osanna M., 2020, Il grande progetto Pompei per l'insula Occidentalis, Pompeii Insula Occidentalis Conoscenza, Scavo, Restauro e Valorizzazione, L'Erma di Bretschneider, Roma, p. 13-14, ISBN: 9788891316103 (in Italian).

Picone R. and Osanna M., 2018, RESTAURANDO POMPEI. Riflessioni a margine del Grande Progetto, L'Erma di Bretschneider, Roma, ISBN: 978-88-913-1727-8 (in Italian).

Mauro A., 2019, From the extraordinary nature of the great Pompeii project to planned conservation, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2nd International Conference of Geomatics and Restoration, Milan, vol. XLII-2/W11.

Hosagrahar, J., Soule, J., Fusco Girard, L., Potts, A. (2016). "Cultural heritage, the un sustainable development goals, and the new urban agenda. BDC.", Bollettino Del Centro Calza Bini, 16(1), 37-54. https://doi.org/10.6092/2284-4732/4113

UNESCO, 2013, Managing cultural world heritage, ISBN: 978-92-3-001223-6.

Decision (EU) 2017/864 of the European Parliament and of the Council of 17 may 2017 on a European Year of Cultural Heritage (2018);

European Framework for Action on Cultural Heritage COMMISSION STAFF WORKING DOCUMENT, ISBN 978-92-76-03453-7, doi:10.2766/949707.

Romao X., Bertolin C., "Risk protection for cultural heritage and historic centres: Current knowledge and further research needs." International Journal of Disaster Risk Reduction 67 (2022): 102652.

Sesana E., Gagnon A., Ciantelli C., Cassar J., Hughes J., Climate change impacts on cultural heritage: A literature review. WIREs Climate Change. 2021;12. DOI: 10.1002/wcc.710

UNESCO, 2010, Managing Disaster Risks for World Heritage, ISBN: 978-92-3-104165-5.

UNI 10144:2006, 2006, Classificazione dei servizi di manutenzione - Classification of Maintenance Services (in Italian)

UNI 10224:2007, 2007, Manutenzione – Processo, sottoprocessi e attività principali – Principi Fondamentali -Maintenance – Process, sub-processes and main activities – Fundamental Principles – (in Italian).

Decreto legge 91 del 08/08/2013, Disposizioni urgenti per la tutela , la valorizzazione e il rilancio dei beni e delle attività culturali e del turismo.(in Italian)

Legge n.112 del 7/10/2023 (GU 08/10/2013 n. 236) (in Italian)

Decreto 12/01/2017 Ministero dei beni e delle attività culturali e del turismo Adeguament delle soprintendenze speciali gli standard internazionali in material dei musei e luoghi della cultra (GU Serie generale n 58 del 10/03/2017) (in Italian)

References

Bevilacqua A,, Macedonio G., Neri A., Orsi G. and Petrosino P., 2022, Volcanic Hazard Assessment at the Campi Flegrei Caldera, Italy, Campi Flegrei. Active Volcanoes of the World. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-37060-1_12.

Latorre D., Di Stefano R., Castello B., Michele M. and Chiaraluce L., 2023, An updated view of the Italian seismicity from probabilistic location in 3D velocity models: The 1981–2018 Italian catalog of absolute earthquake locations (CLASS), Tectonophysics, Elsevier, Amsterdam, vol. 846, ISSN: 0040-1951.

Amato V., Covolan M., Dessales H. and Santoriello A., 2022, Seismic Microzonation of the Pompeii Archaeological Park (Southern Italy): Local Seismic Amplification Factors, Geosciences, vol.12 p 275, https://doi.org/10.3390/geosciences12070275.

Osanna M., Rinaldi E., 2018, Planned conservation in Pompeii: complexity and methodological choices, Journal of Cultural Heritage Management and Sustainable Development, Emerald Group Publishing, Bingley, vol. 8 n.2 p. 111-129, https://doi.org/10.1108/JCHMSD-05-2017-0025

GPP Projects, Progetti G.P.P. - Pompeii Sites.

Open Pompeii, The public digital archive of the heritage data of the Archaeological Park of Pompeii, POMPEII (pompeiisites.org)

Miele F., 2011, La conservazione della memoria materiale e immateriale. Sistemi informativi di catalogo e territoriali in Campania, Archeologia e Calcolatori, vol. 22 p. 7-34, ISSN 1120-6861.

Smart@Pompei, Smart Pompei - Pompeii Sites.

Petzet M., 2009, International principles of preservation, International Council on Monuments and Sites, Hendrik Bäßler Verlag, .Berlin, vol. 20, ISBN 978-3-930388-54-7.

The International Charter for the Conservation and Restoration of Monuments and Sites, 1964, Venice.

UNI 10146:2007, 2007, Criteri per la formulazione di un contratto per la fornitura di servizi finalizzati - Criteria for the formulation of a contract for the provision of maintenance services- (in Italian).

UNI 10992:2002, 2002, Previsione tecnica ed economica delle ttività di manutenzione (budget manutenzione) di aziende produttrici di beni e servizi – Criteri per la deinizione, approvazione, gestione e controllo- Technical and economic forecast of maintenance activities (maintenance budget) of companies producing goods and services - Criteria for the definition, approval, management and control.

Jokilehto J., 2006, Considerations on authenticity and integrity in world heritage context, City & time 2.1 (2006): 1, URL: http://www.ct.ceci-br.org

SO_13822, 2010, Bases for design of structures — Assessment of existing structures, https://www.iso.org/standard/46556.html

References

ICOMOS, 1994, The NARA document on authenticity, The Nara Conference on Authenticity in Relation to the World Heritage Convention, Japan.

Ministry of Infrastructure and Transport, 2020 Ministerial Decree 578/2020, Adoption of Guidelines for Risk Management of Existing Bridges and for the Definition of Requirements and Indications relating to the Dynamic Monitoring System, Rome, Italy.

Pregnolato M., 2019, Bridge safety is not for granted–A novel approach to bridge management, Engineering Structures, Elsevier, Amsterdam, vol. 196, DOI: https://doi.org/10.1016/j.engstruct.2019.05.035.

IM-SAFE, 2020, Horizon 2020 research and innovation programme under grant agreement No 958171, https://im-safe-project.eu.

Frangopol D. M., and Liu M., 2007, Maintenance and management of civil infrastructure based on condition, safety, optimization, and life-cycle cost, Structures and Infrastructure Systems, Taylor & Francis, Milton Park, vol. 3 pp. 29-41, DOI: 10.1080/15732470500253164.

Petti L., Lupo C. and De Gaetano C.M., 2023, A Methodological Framework for Bridge Surveillance, Applied Sciences, 13.8, 4975, https://doi.org/10.3390/app13084975.