Chapter 23
Technological Change – Risk or Opportunity for UNESCO World Heritage?

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Abstract This chapter provides reflections on the consequences of technological change in relation to World Heritage properties. While technological change is a core means of human adaptation and survival, it becomes a risk if the pace is too fast. This has increasingly affected societies worldwide since the industrial revolution, resulting in many negative consequences for people and the environment. Technological change is also associated with positive developments, such as those brought about by digital technology. Insights into both risks and opportunities are given in this chapter, and they are illustrated with examples, such as mining and digital geomedia. Technological change appears as a double-edged sword, but there is currently no methodology for assessing its consequences for World Heritage properties. Therefore, the chapter turns to lessons learnt from the Historic Urban Landscape approach, the UNESCO Man and the Biosphere Programme, and from impact assessment methods. While these provide useful inspiration and a basis for further reflection, the chapter concludes by emphasizing the necessity of a methodology for assessing the impacts of technological change on World Heritage properties against the background of the Sustainable Development Goals.

Keywords Geotechnology · Sustainable development · Impact assessment · Technological innovation

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M.-T. Albert et al. (eds.), *50 Years World Heritage Convention: Shared Responsibility – Conflict & Reconciliation*, Heritage Studies,
https://doi.org/10.1007/978-3-031-05660-4_23

23.1 Introduction and Problem

Our time is characterized by technological change – there is hardly any area of personal or professional life, which has not been affected by increasing mechanization and digitization. This triggers profound changes in working and living conditions, and it has diverse ecological, economic, social, cultural and political consequences. The consumption of resources has increased significantly because of increasing industrialization and technologization. These are often associated with a wide range of negative impacts for the environment and people, resulting from the extraction, processing and use of energy raw materials such as coal and oil and metallic raw materials such as iron and copper or rare earths. These developments have been greatly influenced by rapid population growth, as the need for food, energy and urbanization have been increasing – over 50% of the world's population now live in cities, with the associated land consumption. As a result of these processes, humans, through activities involving technological change, leave behind a clear "human footprint".[1] We consume significantly more resources than the Earth can regenerate within 1 year, which makes the aims of sustainability impossible. The so-called "Earth Overshoot Day", which marks the day when the needs of people exceed the capacity of the Earth, was on July 29, 2021 (https://www.overshootday.org/).

These developments have extensive direct and indirect effects on those 1154 cultural and natural properties inscribed on the World Heritage List. Many properties are directly influenced by the expansion of cities and urban infrastructure and the associated increase in land and resource consumption. This includes deforestation to obtain raw materials and arable land, which leads to further changes in use. In addition, there are factors such as global tourism and climate change, indirectly associated with technological change, which threaten the survival of World Heritage properties. It is worth noting that the preamble of the World Heritage Convention opens with the acknowledgement that heritage is increasingly threatened "also by changing social and economic conditions" (UNESCO, 1972, Preamble). This threat has not diminished since the adoption of the Convention in 1972. If anything, it has increased, being partly facilitated by technological change. Some of the 52 properties currently inscribed on the "List of World Heritage in Danger"[2] (UNESCO, n.d.-d), such as the Historic Centre of Vienna or the delisted sites of the Dresden Elbe Valley and Liverpool, provide an illustration.

Despite potential negative consequences, technological change is also linked to a wide range of opportunities for the protection, preservation and sustainable development of World Heritage properties. For example, modern digital (geo)technologies such as satellite and drone data, digital applications for

[1] Human footprint is a quantitative analysis measuring the relationship between the consumption of resources by humans and the number of resources the Earth can produce.

[2] The List of World Heritage in Danger is defined in Article 11(4) of the World Heritage Convention, and it foresees the adoption of special financial and other support measures for highly endangered properties.

processing spatial data, geographic information systems (GIS) or GPS-supported surveying techniques can help to provide documentation about World Heritage properties, to record and analyse their state of conservation, thus contributing to their long-term preservation. In addition, in line with Article 5 of the World Heritage Convention, which names measures for States Parties to take, including for the presentation of World Heritage properties, digital media offer many opportunities. For example, they help create 3D animations and other forms of visualization for a larger audience and promote various uses, as exemplified further in this paper.

Processes that are linked directly or indirectly to technological change affect World Heritage properties for better or worse. If we consider the negative consequences, the question may arise whether the rapid pace of technological change and the associated consequences such as resource consumption and urbanization are compatible with the protection principles of the World Heritage Convention. If we consider the positive aspects, we cannot but notice the opportunities brought about by digital technology to present and experience World Heritage properties in new ways. However, there has been no comprehensive analysis of the impacts associated with technological change for World Heritage properties. Against this background, the aim of this article is to reflect on the risks and opportunities of technological change for World Heritage protection and on ways to mitigate the risks. The reflection is based primarily on insights from geography and examples of World Heritage properties, and it includes both positive and negative developments.

23.2 Signs of Technological Change and Their Consequences

Technological change has always accompanied human development. At the beginning of human history, the dynamics of these processes were still low. Nonetheless, even in earlier times, technological change sometimes led to extensive ecological, social and environmental upheavals. This began with the settling down of people during the Neolithic Cultural Revolution about 10,000 years ago, and the associated transition from hunters and gatherers to agriculture and animal husbandry, as well as the emergence of permanent settlements. (Haviland et al., 2016, 226). In particular, industrialization, starting in the second half of the eighteenth century, was accompanied by profound changes in economic and social conditions, which have since led to a worldwide increase in population, (over)consumption of resources and associated environmental pollution.

The manifold impacts of technology and technological innovations have been studied in a variety of fields, and they have become an important aspect of Science and Technology Studies (Hackett et al., 2008). For the purpose of this article, it is worth highlighting that the dynamics of technological change have continued to accelerate since the beginning of industrialization (Haviland et al., 2016, 607). This is evident in the number and spread of innovations, such as the invention of the steam engine, the railroad, electrical engineering, the automobile and, more recently, renewable energies and digital technology, the latter having increased the pace of change even more. The broader consequences, also resulting from global population growth, which has multiplied over the past 200 years, with more than half now living in urban areas, is evident in many statistics. They show socio-economic trends since 1750 of various indicators on the relationship between population growth and other variables such as land use, transportation or global tourism (Steffen et al., 2016). The deeper impacts may not be readily obvious in statistics, but technological change often goes along with environmental damage and the disruption of human settlements. Mining offers a good example.

In order to extract raw materials, large amounts of land are destroyed by the associated opencast mines and their production and transport facilities. These areas of land are not only lost for other uses, but the associated changes in ecological cycles between soil, plants and atmosphere also affect the immediate vicinity of these mining areas, with effects reaching even beyond. Technological change is also associated with new means of transportation and working conditions and with increased mobility, which makes people use their time differently, including their leisure time, as reflected in the increased numbers in global tourism. Due to the great influence of humans on the environment, it is now often spoken of as the era of the Anthropocene (Crutzen, 2006). From this, we can also infer that humans have not only an impact but also a special responsibility for the future of the planet in terms of sustainable development and the sustainability of the Earth.

The insights provided may create the impression that technological change is always negative, but technology has been crucial to human adaptation and survival. The adoption of technological innovations can lead to either disruption and abandonment of existing practices and tools or to adaptation, depending on how they are used (Haviland et al., 2016). In the next section, we give selected examples of both aspects as they relate to World Heritage.

23.3 Risks for UNESCO World Heritage Through Technological Change

Some world cultural and natural heritage properties reflect changes caused by natural processes or cultural-historical developments, including technological ones. For example, the Ancient Ferrous Metallurgy Sites of Burkina Faso illustrate the first phase of iron production development in Africa along with traditional iron ore smelting techniques (UNESCO, n.d.-a). Another example is the major mining sites of Wallonia in Belgium, considered to represent a testimony to the early dissemination of the technical, social and urban innovations of the industrial revolution (UNESCO, n.d.-c). Ironically, while World Heritage properties are valued for reflecting technological change, they do not remain unaffected by its consequences, like those described in the previous section. Plenty of cases can be found in reports on the state of conservation of World Heritage properties.

Mining and other extractive industries – to continue the example given previously – are often mentioned as factors affecting World Heritage properties. The City of Potosí in Bolivia is one such example, which has been inscribed on the List of World Heritage in Danger since 2014; one threat is mining, which leads to the degradation of the historic site (UNESCO World Heritage Centre, 2020). Mining was also the factor that led to the first removal of a property from the World Heritage List, Oman's Arabian Oryx Sanctuary, in 2007 (UNESCO, n.d.-b). The goal of the World Heritage Convention is to protect the properties, for which it has dedicated mechanisms, such as the "List of World Heritage in Danger". However, Oman wished to reduce the property to 90% in order to proceed with hydrocarbon prospection (UNESCO, 2007). In fact, if one looks at the 14 primary factors listed by the World Heritage Centre as affecting World Heritage properties, 4 of them are directly related to technological change: buildings and development (47%), transportation infrastructure (33%), service infrastructure (17%) and physical resource extraction (17%). Other factors, such as pollution (16%), are often indirectly related to technological change (UNESCO, n.d.-e; UNESCO World Heritage Centre, 2014) (See Fig. 23.1).

Technological innovation and change, as well as the social and ecological transformation processes that are associated with them (Veuve, 2020), often result from human striving for (economic) prosperity, greater efficiency in work processes and the production of goods and services to ensure subsistence or increase capital and

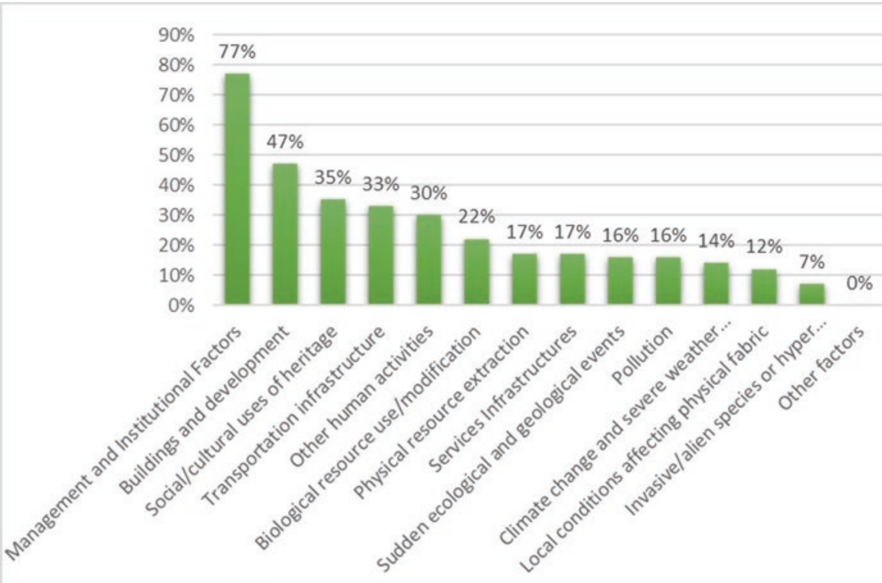

Fig. 23.1 The main threats affecting World Heritage properties. (*Note.* The statistical analysis covers the period 1979–2013 and includes 13 factors. The threats have not changed since then, but a new category entitled "other factors" has been added. However, to date, there is no statistical information for this threat. [Graph A. Siegmund 2021])

productivity (Jischa, 2007). Technological change has always been part of human life and is often a necessary component of human adaptation and survival. Thus, technological change per se is not the problem, but, as already indicated in Sect. 23.2, the scale and pace of change certainly are. World Heritage historic cities or other properties in areas experiencing rapid growth and infrastructure development illustrate this problem (UNESCO World Heritage Centre, 2010). Sometimes World Heritage properties are virtually "enveloped" by settlements and economic land, as the example of the Pyramid of Cheops in Egypt shows (see Fig. 23.2) (Hemeda & Sonbol, 2020).

While technological change may affect all properties directly or indirectly, through influences on climate, carbon dioxide emissions and other forms of environmental pollution, the extent of the threat depends on the local conditions and characteristics of the property. Nevertheless, it seems to have a greater impact on properties located in urban growth regions, in opencast mining areas or areas rich in natural resources. We presented illustrations regarding mining and urbanization. An example concerning impacts on natural areas is the tropical forests of Sumatra in Indonesia. The property has been on the List of World Heritage in Danger since 2011, and it is highly affected by deforestation, illegal logging and agricultural encroachment (Fig. 23.3) (UNESCO, 2011a).

As already mentioned in passing, and as illustrated by examples such as Venice, the Great Wall of China, or Machu Picchu (UNESCO World Heritage Centre, 2021), World Heritage properties can also be endangered by mass tourism. This is accompanied by environmental damage associated with visitor transport, accommodation and supply, and a lack of appropriate infrastructure such as waste disposal. Even the causes associated with armed conflicts could go hand in hand with technological

Fig. 23.2 Endangerment through urbanization Cheops-Pyramid/Egypt. (*Note.* Sentinel-2 (ESA) image courtesy of the U.S. Geological Survey)

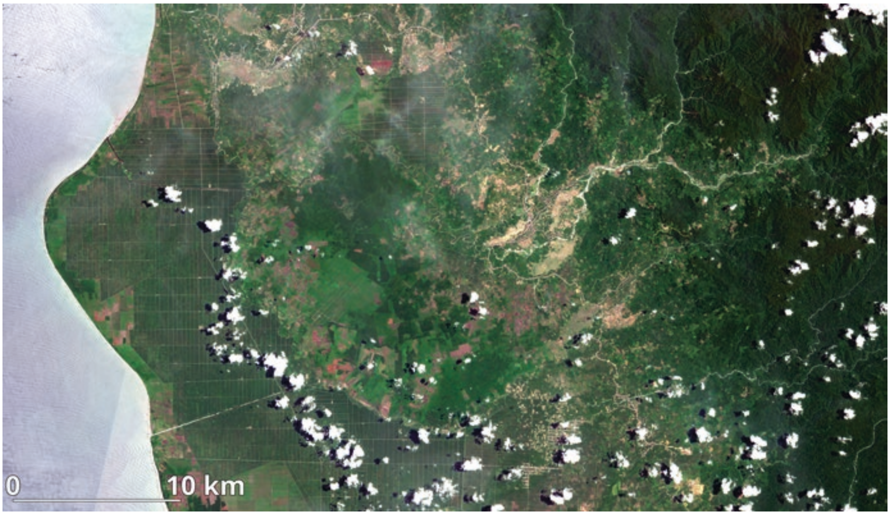

Fig. 23.3 Endangerment through deforestation, Kerinci-Seblat National Park, Indonesia. (*Note.* Sentinel-2 (ESA) image courtesy of the U.S. Geological Survey)

change, for example, by fostering disputes over resources (Ferguson, 2001). Many other examples could be added, but those already given illustrate the risks of technological change to World Heritage properties. They also reveal that most of the risks stem from one fundamental problem, namely the need to strike a balance between conservation on the one hand and use, development and change on the other. In other words, there is a need to approach conservation as sustainable change.

23.4 Potentials of (Geo-) Technologies for the Sustainable Development of World Heritage Properties

Technological change does not have to lead to disruptions. It may also lead to adaptation and bring about opportunities for World Heritage properties. Digital technologies are perhaps the best example in this regard, and many believe these technologies greatly contribute to the sustainable development of World Heritage properties. This is not to say that digital technology may not have unwanted consequences. Each technology can be a curse or a blessing. Research shows that there are direct environmental effects from the production, use and disposal of digital technology, such as global warming and e-waste, and indirect effects from changes in patterns of consumption and production (Bieser & Hilty, 2018; Bedford et al., 2021). Yet, in many regards, digital information and communication technologies can present numerous opportunities (Xiao et al., 2018).

The rapidly growing range of digital technologies is just as extensive as the diverse potential uses in the context of World Heritage – a comprehensive overview is hardly possible. Yet, the potential can be illustrated with the example of modern geotechnology, although even the spectrum of such digital geotechnologies is extremely large. It ranges from the use of remote sensing methods based on satellite and aerial image data and the digital processing of spatial data using geographic information systems (GIS) to laser and GPS-supported surveying methods. On this basis, geotechnologies can make an important contribution to the recording, analysis and monitoring, reconstruction, restoration and conservation and sustainable planning and management of World Heritage properties (Xiao et al., 2018). This has been well illustrated by several authors in the Technological Change section of this book, who present applications ranging from digital maps to interactive tools. However, in order to present their potential compactly, we can use a principle known to geoinformatics, namely the IMAP principle (abbreviated from Input, Management, Analysis and Presentation) associated with the use of digital geomedia. This is presented briefly below.

Input data can be generated through remote sensing methods using satellite and aerial image data. This can serve to record the state of a property without any physical contact. Through the additional use of drones and the associated high spatial resolution of the aerial image data, this is possible even with small-scale structures down to the size of a centimetre. With the help of aircraft and drone-assisted laser scanning, the structures of World Heritage properties can be recorded in a higher resolution and even in three dimensions, without the sites themselves being accessed and damaged. It is often only through the use of remote sensing data that the extent of a World Heritage property becomes visible (Xiao et al., 2018). Furthermore, the use of satellite, aerial photo or drone data can be used to map and explore, at different scales, areas that are otherwise inaccessible or difficult to access due to a lack of transport infrastructure or for security reasons. Such methods are becoming increasingly important as non-contact and thus "non-destructive" methods in the context of World Heritage, and they have been applied to properties such as the Old Town of Ávila, Spain, Kathmandu Valley, Nepal, or My Son Sanctuary, Vietnam (Xiao et al., 2018, 397–402).

Beginning with the satellite Landsat in the 1970s, a variety of Earth observation satellites are now available, with data of varying characteristics (e.g. spatial, temporal, spectral resolution) available free of charge, such as the satellite data and derived data products under the European Union's Copernicus program. They offer a wide range of possibilities to promote the protection, preservation, management and sustainable planning as well as communication of the universal values of World Heritage properties. This is evident in the increasing number of specialist conferences and calls for tenders and special issues in journals such as "Earth Observation for Heritage Documentation", in preparation under the "International Journal of Applied Earth Observation and Geoinformation".

Following the IMAP principle, with the help of GIS, spatial data of World Heritage properties not only can be generated but also managed and analysed. Datasets with different scales, underlying coordinate systems and properties (vector and pixel-based data) from different sources can be integrated into a kind of digital spatial database. The resulting different data layers can be further analysed with GIS by combining or blending different datasets to generate new information. Finally, GIS serves to visualize and thus present the corresponding data in the form of (interactive) maps, animations or three-dimensional representations. Thus, modern geotechnologies are of particular importance for the documentation, management and presentation of complex structures, as is the case with many World Heritage properties. In combination with historical data and maps, which in turn can be digitized, the comprehensive development of the properties can be traced (Nicu, 2017).

In addition to facilitating more efficient management, geotechnologies may contribute to research, knowledge and appreciation of the universal values of these properties by enabling accessibility for a broader audience as well as participation. According to a study, 71% of the population in the USA in 2015 already used digital media to access UNESCO cultural and artistic assets instead of visiting them on site (Nicu, 2017). Thus, digital technology may reduce the environmental impact of World Heritage tourism, such as carbon dioxide emissions and resource consumption associated with the transport, accommodation and supply of visitors. (Xiao et al., 2018). The data obtained with geotechnologies can also be combined with Augmented Reality (AR) and Virtual Reality (VR) technology, providing novel means of knowledge transfer and interaction with World Heritage (Kenderdine et al., 2008, 275). Geotechnology presents opportunities not simply for World Heritage but for its use in a way that responds to the Sustainable Development Goals related to the protection and safeguarding of cultural heritage (SDG 11.4) and the promotion of sustainable tourism (SDG 8.9) (Xiao et al., 2018).

23.5 The Way Forward – Reflections on Risks and Opportunities

As we have seen above, technological change may be a risk or an opportunity. However, the question of whether technological change in the balance sheet tends to favour or hinder World Heritage conservation cannot be answered conclusively. Not only is "technological change" too broad a concept, including as many technologies as humans have created, but its impacts also depend too much on the particular conditions of individual World Heritage properties. Thus, the question is whether and how it is possible to ensure that the properties can be protected and used sustainably despite or precisely because of technological change.

To tackle this question, inspiration can be taken from related activities regarding World Heritage and other programmes relevant for heritage conservation, such as the Historic Urban Landscape approach (HUL) or the UNESCO Man and the Biosphere Programme (MAB). HUL is an approach to the management of heritage properties promoted through the Recommendation on the Historic Urban Landscape (UNESCO, 2011b). It was developed because the previous conservation paradigm, based on a separation of the property, with its core components expressing the Outstanding Universal Value (OUV), from the surrounding area, was no longer appropriate. Today, sustainable conservation requires perceiving the site in context as part of a region in which people live and work (Kloos, 2014). The HUL initiative was specifically launched for World Heritage properties in urban areas, hoping to achieve a stronger integration of urban World Heritage protection within the respective socio-economic context (Kloos, 2014). In a similar vein, a shift in perspective is needed for a broader view of the impacts of technological change on World Heritage properties, not limited to the boundaries of a property and its buffer zones but in relation to its use and consequences locally and regionally.

The MAB Programme may also offer some insights. MAB was launched by UNESCO in 1971 with a focus on the sustainable use and conservation of the resources of the biosphere, and it aims to establish a scientific basis for the relationship between people and their environment. This programme's strategy is specifically adapted to support the 2030 Agenda for Sustainable Development, the Sustainable Development Goals (SDGs) and the Paris Climate Agreement (UNESCO, 2017). Such measures have also been taken in the context of World Heritage, in particular since the adoption of the *Policy Document for the Integration of a Sustainable Development Perspective into the Processes of the World Heritage Convention* by the General Assembly of States Parties to the World Heritage Convention in 2015 (UNESCO World Heritage Centre, 2015). However, the biosphere reserves protected under MAB serve as models for national or regional demonstration of sustainable development (UNESCO, 2017, 22). While a similar idea exists as a modest suggestion in the *Policy Document* (paragraph 5), the emphasis is much stronger in the Lima Declaration on the UNESCO Man and the Biosphere (MAB) Programme and its World Network of Biosphere Reserves (WNBR) as well as in its action plan adopted in 2016 (UNESCO, 2017). World Heritage properties reflect technological change, as exemplified above, but they could more strongly serve as models to illustrate sustainable adaptation strategies to technological change.

Furthermore, it is worth considering the potential of impact assessment methods. They are available and have been used in the context of World Heritage for about a decade (ICOMOS, 2010; Pereira Roders & van Oers, 2012). Environmental Impact Assessment (EIA) and Heritage Impact Assessment (HIA) are cases in point. As authors who have assessed these methods explain, EIA focuses on "major development projects such as roads, industrial plants or airports" and their potential impacts on cultural heritage, including larger areas, while HIA focuses on proposals for change and "the analysis is confined to the impacts on cultural significance" (Pereira Roders & van Oers, 2012, 105). Both EIA and HIA incorporate the impacts of technological change, but it would be worth considering the potential of an assessment tool with technological change at its core. Such methods have been used since the 1970s. They are known as Technology Assessment (TA) and continue to be used in adapted forms, based on the lessons learnt over time (Grunwald, 2018). It would be worth considering how such methods can be tailored to World Heritage. They can be enhanced by the potential of digital technology in building future scenarios to capture and evaluate the risks associated with technological change and its potential for World Heritage (Weyer, 2017; Xiao et al., 2018). To align fully with the Sustainable Development Goals, they could even include the negative impacts associated with the use of digital technology, not only environmental, as noted above, but also those resulting from digital obsolescence and the need to consider the preservation of World Heritage-related digital data.

23.6 Conclusion & Outlook

Technological change is a key characteristic of our time. While it has always accompanied human development as a necessary means of adaptation and survival, the pace and scale of change have intensified greatly, making technology one of the main factors influencing the dynamics of human societies today. As the examples provided show, technological change has resulted in a series of negative consequences for people and the environment. World Heritage properties, with all their typological diversity, have not remained unaffected. The tensions between development needs and conservation requirements appeared to be one of the main factors negatively affecting many properties, whether cultural or natural. At the same time, not all forms of technological change are negative. There are positive examples, and one of them, chosen for purposes of illustration in this chapter, was digital geomedia. It has not only proven beneficial for World Heritage properties but also contributes to achieving the Sustainable Development Goals (Xiao et al., 2018).

Many other examples of risks and opportunities could have extended our presentation; in fact, so many so that a comprehensive overview is hardly possible. Technological change is a very broad concept. Furthermore, its impacts depend heavily on local and regional contexts, and they are manifold. Yet, how can we foresee the impacts of change in the absence of a methodology for assessing the consequences of our actions today? How can we proceed efficiently in the absence of guidelines, which capture the complexities of the problems we are facing? How can we use the opportunities of technological change while avoiding or at least minimizing the risks it brings? No answers can be given today, but answers must be given in the future if our aim is the sustainable conservation of World Heritage properties. Thus, when envisioning the way forward, a methodology for assessing the impacts of technological change on World Heritage properties, developed against the background of the Sustainable Development Goals, as well as a policy instrument with technological change at its core, emerge as indispensable tools.

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