Analysing the Cost-Effectiveness of Heritage Conservation Interventions: A Methodological Proposal within Project STORM

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ABSTRACT

Cost-Effectiveness Analysis (CEA) is a decision-support tool that allows strategy comparisons without the need for monetising expected outcomes. Since benefits to be gained in heritage contexts are inherently difficult to price, a CEA may provide valuable support to the allocation of cultural heritage preservation resources. Nevertheless, its application in the heritage sector is still limited, arguably due to difficulties in ‘effectiveness’ appraisals. STORM (Safeguarding Cultural Heritage through Technical and Organisational Resources Management) is an H2020-funded project for the development of Disaster Risk Management solutions for heritage sites facing natural hazards and climate change. Within its scope, a methodology for the CEA of conservation interventions was developed and applied to the Roman Ruins of Tróia (Portugal) pilot site. This paper describes the CEA methodology, including cost and effectiveness indicators and discount rate; and reports its application for the assessment of five strategies addressing the risks of a sand dune weighing upon a Roman well. Using expert opinion to tackle the effectiveness appraisals, the CEA showed that ordinary maintenance options are costlier but more effective than extraordinary maintenance ones. The most cost-effective option was the less intrusive strategy, matching current perspectives on archaeological conservation, and seemingly indicating that the procedure is robust.

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1. Introduction

Managing a heritage site entails daily decisions regarding its interpretation, access and conservation, including intervention planning. Many, if not most, of these decisions involve the allocation of scarce resources, such as time, money, and effort. On the other hand, and even if each heritage object is unique, conservation decisions should be anchored in an overall strategy that mirrors the concerns of communities when tending to their heritage.

In its ‘Conservation Principles’, Historic England (formerly English Heritage) proposes “setting out the framework within which we will make judgements on casework” (English Heritage 2008: foreword) as the means to achieve credibility, consistency and accountability in decision-making processes. Such frameworks would profit from less ambiguous decision-support tools in the heritage conservation sector, so that decision-making becomes more transparent and intelligible. Measuring the costs against the benefits of different resource allocation options is a common way of supporting transparency at all levels of decision-making.

Cost-effectiveness analysis (CEA) is “A tool based on constrained optimisation for comparing policies designed to meet a prespecified target” (Edenhofer et al. 2014, 1258), meaning a given policy/strategy is cost-effective if it represents the least cost solution to reach said target. Cost-benefit analysis (CBA), arguably more common in policy comparisons, differs from CEA in what it prices both costs and benefits; CEA resorts to monetary units solely for cost valuation, thus being preferable for projects yielding benefits that are difficult to monetise (EC 2008), such as those involving heritage contexts (Klamer and Zuidhof 1998).

STORM (Safeguarding Cultural Heritage through Technical and Organisational Resources Management) is an H2020-funded project for the development of Disaster Risk Management (DRM) solutions for heritage sites facing natural hazards and climate change. DRM approaches to heritage risk, and namely “preventive risk management planning”, have been hailed as “much more cost-effective” than post-emergency recovery (UNESCO-WHC et al. 2010, 8), but methods to clearly demonstrate it are still missing. Within STORM, a proposal towards this demonstration was put
forward, in the form of a CEA methodology to support decisions regarding the conservation of archaeological heritage facing natural or anthropogenic risks, including those amplified by climate change.

It should be noted that the CEA developed within STORM is specific to support decision-making regarding interventions affecting built heritage at site management level: it does not consider impacts outside the site, nor does it allow for region- or country-level analysis. In other words, it does provide support to decide the allocation of funding between different sites.

Below, after a brief review on the application of cost-effectiveness analyses in heritage contexts, the STORM CEA methodology proposal is described, followed by an application example to a case-study from one of the STORM pilot sites, the Roman Ruins of Tróia, in Portugal.

2. Cost-effectiveness analyses in DRM x heritage conservation

2.1. Economic evaluations in conservation planning

CBA and CEA are economic evaluation tools that are commonly used when comparing policy or strategy options. Essentially, both methods measure the costs against the outcomes of each option, and thus help determining the cost per unit of outcome, in the form of cost-benefit ratios, or cost-effectiveness ratios. As stated earlier, the difference between the two methods relies essentially on the measurement of the outcomes, which are monetised in CBAs and otherwise assessed in CEs.

For the measurement of costs, market prices are generally resorted to in both analyses and, for most cases, they are able to reflect the expenses associated with each option adequately and straightforwardly. However, decisions on which costs should be contemplated should be carefully pondered – for instance: Should opportunity costs be factored? Should environmental or social costs be included? How can maintenance costs be added?

Life Cycle Cost Analysis (LCCA) has been increasingly used as a planning tool in the civil construction sector, and notably retrofitting interventions (Pombo, Rivela, and Neila 2016). LCCA assists the computing of all costs associated to a building design for a given period, including, but not limited to, construction, operating and maintenance costs. Different design options can subsequently be cost-compared, and “LCCA can explore trade-offs between low initial costs and long-term cost savings [and] identify the most cost-effective system for a given use” (Davis et al. 2005, 3). While LCCA can be used for planning per se, it is more common as a supporting tool in CEs or multi-criteria analyses (Thiebat 2016), and, even if it has not been applied to heritage conservation interventions sensu stricto, it can still provide useful pointers for the computing of all the expenses of such interventions, promoting a more sustainable approach to planning.

Outcomes are generally more difficult to appraise when cultural heritage is involved. In economic terms, heritage assets may be described as having use and non-use values, i.e. market and nonmarket values, respectively (Mason 2002). The latter are not traded in the market, and, consequently, cannot be directly expressed in monetary units. The former are traded and can therefore be assigned a price; nevertheless, the public good character of cultural heritage objects, as well as the occurrence of externalities and/or normative market failures, will often prevent the obtaining of reliable use values for cultural goods (Klamer and Zuidhof 1998).

In economic evaluations in heritage contexts, the methods available for outcome estimates are either revealed preference methods (for use-value estimates: Travel Cost; Hedonic Pricing) or stated preference methods (for use and non-use value estimates: Contingent Valuation, Choice Modelling/Conjoint Analysis.)

Typically, these estimates are used in decision-support systems (DSS) for the evaluation of strategy options with impacts at site, city, region, or country level. Table 1 presents a few application examples of these methods for the valuing of costs and outcomes in heritage contexts.

As shown in the table, CBAs are often used in cultural heritage policy appraisals, but they will generally entail large research efforts/resources, due to the complexity of benefit valuations (Murzyn-Kupisz 2015; Riganti and Nijkamp 2005; Throsby 2016).

On the other hand, benefit (monetary) estimates – needed in CBAs – are generally based on the (revealed or stated) preferences of non-specialist stakeholders of the heritage asset, e.g. site visitors or agents benefitting from site tourism. These non-specialist stakeholders can value global conservation efforts, but they are not necessarily able to evaluate the technical differences between different conservation-restoration strategies, or their respective contributions to the preservation of a site’s significance, authenticity and/or integrity.

In the few applications of cost-benefit analyses to interventions planning at technical level, outcomes assessment was conceptualised differently. Nevertheless, and in spite of the wide acknowledgement of their usefulness, CBA/CEA applications have been scarce at this level, and mostly aimed at museum objects and/or collections care. Table 2 collects information on the few application examples found in specialist literature.
| Scope/ goal | Level | DSS | Costs assessment methods | Outcomes assessment methods | Reference |
|-------------|-------|-----|--------------------------|-----------------------------|-----------|
| Assessment of costs and benefits of heritage conservation in the Netherlands | City/ region | Costs vs. benefits | Estimated costs of a 20-year Cultural Heritage Protection Plan for the study area | • Hedonic Pricing (incl. regression analysis):<br>  □ housing comfort value<br>  □ sample size: 591 houses<br>  • Contingent Valuation (CV):<br>  □ recreation and bequest values<br>  □ sample size: 380 respondents | Ruigrok 2006 |
| Assessment of the impact of cultural tourism in Syracuse, Italy | City | Economic impact study | • Conjoint analysis (CA):<br>  - surveys cost-benefit trade-offs;<br>  - assessed congestion and carrying capacity of sites and its impacts on quality of life/visit experience;<br>  - sample: 4 focus groups of host community members (250 respondents) + tourists/visitors (250 respondents)<br>  • Input-output methodology (for use/market values):<br>  - tourist expenditure;<br>  - sample: 250 tourists/visitors (same as CA) | Riganti 2006 |
| Assessment of the economic viability of a conservation project at the My Son UNESCO WHS, Vietnam | City/ region | CBA | Estimated (total) costs of conservation project | Contingent valuation (CV):<br>  □ assessed the Willingness-To-Pay (WTP) for the conservation of the site;<br>  □ WTP assessed via face-to-face interviews;<br>  □ sample size: 967 respondents from (4) main stakeholder groups | Tuan and Navrud 2008 |
| Assessment of the benefits of heritage to the city of Valdivia, Chile and evaluation of a conservation funding scheme | City | CBA | □ Costs estimated for a non-profit to manage: site conservation, tourism products and heritage dissemination;<br>  □ costs: all non-profit expenses for 10 years. | Contingent valuation (CV):<br>  □ Stakeholder Group 1: tourists: WTP for access to the sites assessed via face-to-face questionnaires; sample size: 485 site visitors (national and foreign tourists);<br>  □ Stakeholder Group 2: residents: WTP for the conservation of the sites via donation; assessed via telephone survey; sample size: 389 residents. | Báez and Herrero 2012 |
| Assessment of the economic interest of seeking a UNESCO WHS designation in Nova Scotia, Canada | City/ region | Costs vs. Benefits | - Actual costs of preparing WH applications;<br>  - Estimates on management costs increase due to WH designation. | □ Regression analysis to estimate the impact of a UNESCO designation on visitor numbers;<br>  □ combined with site visitor survey to estimate average expenditure;<br>  □ allowed obtaining estimate on direct economic impact of WH designation;<br>  □ use (market) values only | Kayahan and Vanblarcom 2012 |
| Measuring benefits of heritage interiors conservation from climate change damage (Climate for Culture project) | Site | CV Benefit transfer | – | Contingent valuation:<br>  - assessed WTP for climate change-related conservation in 5 European countries;<br>  - online survey – sample size: ~4000 respondents across the 5 project countries.<br>  - interviews to visitors of ten project sites – sample size: ~2000 respondents.<br>  Benefit transfer:<br>  - WTP values were checked for cross-site and cross-country transferability. | Mourato et al. 2014 |

(Continued)
| Scope/ goal | Level | DSS | Costs assessment methods | Outcomes assessment methods | Reference |
|------------|-------|-----|--------------------------|----------------------------|-----------|
| Estimating consumer surpluses and total values attributed to the Poseidon temple, Sounio, Greece | Site | Travel cost | – | Travel cost: - estimates recreational use value from a revealed WTP (travel costs) to visit the site; - travel costs assessed via survey to temple visitors; - sample size: 150 respondents. | Tourkolas et al. 2015 |
| Evaluation of investments on projects aimed at adaptive re-use of urban heritage assets in developing countries | City | (ex post) | CBA | – | □ Ex-post benefit quantification using a set of context-defined economic impact indicators; □ indicators assessed through surveys; □ projects’ impact inferred from comparison with control city/site; □ “appropriate econometric metrics” were used in one of the sites to analyse tourism trends. | Throsby 2016 |
| Analysing social choices for allocation of conservation resources in Scotland | Country | Contingent valuation | – | CV method: - assessed the WTP for a 10-year protection of historic sites; - public opinion on resource allocation between sites; Sample size: 946 Scottish residents | Kuhfuss, Hanley, and Whyte 2016 |
| Ex-post assessment of building requalification options in terms of sustainability | Building | Life cycle analysis | Life Cycle Cost, as defined in ISO 15686–5; for computing construction, use, replacement, and maintenance costs. | – | Thiebat 2016 |
Literature review thus seems to indicate that the evaluation of the outcomes of different technical options cannot be adequately expressed by monetary units, i.e., cost-outcome assessments of such options are better served by CEAs than CBAs; and that expert assessment is required to carry out these evaluations.

2.2. Economic evaluations in DRM

As stated earlier, the STORM project focused on devising tools that would support the implementation of DRM in heritage contexts. In such contexts, risk control measures will, to a large extent, take the form of conservation interventions.

In other sectors, economic evaluations of risk control methods are recurrent, and CBA is a commonly employed tool in DRM decision-making. Nevertheless, in many instances, an analysis of cost-effectiveness will suffice: “CBA seems to be an appropriate tool for a relative evaluation of different mitigation alternatives rather than for an absolute evaluation of one individual mitigation measure. CBA is simplified considerably when different alternatives attaining the same utility are evaluated against each other. This approach would apply in the situation where a level of risk acceptance has been set by the relevant community and the question is how to most effectively meet this standard. In order to determine the most competitive alternative,

| Table 2. CEAs in conservation planning at technical level. |
|----------------------------------------------------------|
| **Scope/ goal** | **Level** | **DSS** | **Costs assessment** | **Outcomes assessment** | **Reference** |
| Assisting decision making related to projects at museum level (e.g. conservation actions, collection use, accession decisions, etc.) | Museum environments | CEA, since outcomes are not monetised | ‘whole life’ costs: including “capital costs and a financial projection over the life of the facility” (Cassar 1998, 8) | Benefits defined as effectiveness; Effectiveness assessed via expert discussion: a variable number of experts is gathered who decide (1) on the weighting given to (predefined) decision criteria and (2) on the ranking of each project in each criterion; Both scoring phases begin as individual tasks and are followed by expert discussion until a consensus is reached; Expert team selection depends on the case at hand, aimed at “representing not only curatorial and conservation interests but also the wider constituency of regional and central users” (Cassar 1998, 17); A number of 6 to 7 experts was considered pertinent in the reported examples. | Cassar 1998 |
| Assist decisions on the allocation of resources to risk control options | Museum collections | CBA | Purchase prices and salaries needed to implement each option in the given timespan. | Semi-qualitative (expert) evaluations of the different risk control options “In many cases it is possible to have a clear idea that we feel that this damage is much worse than that damage, or that this enjoyment is more intense than that enjoyment. This relative ranking of feelings is often a sufficient degree of quantification to help make a sensible decision. After all, our goal is not to quantify but to distinguish between options.” (Ashley-Smith 2000, 71) | Ashley-Smith 2000 |
| Economic evaluation of three different conservation strategies for the Fontana dell’Acqua Felice, Rome, Italy | Architectural object | Multi-criteria analysis (MCA) | Market costs | Based on the evaluation of the following criteria: Vulnerability of the object after the treatment, to be assessed by experts on a scale of 1–9; Employment generated by each option: number of workers. | Sestini, Sammartino, and Laurenzi Tabasso 2013 |
| Decision-making support tool for choosing between different risk treatment options | Museum environments | CEA | – | Effectiveness: “amount of risk reduced” (Michalski and Pedersoli 2016, 145) Effectiveness quantification based on planner judgement: the step-by-step application of the ABC method should endow the planner with the knowledge necessary to ascertain the percentage of risk that is reduced by each risk treatment option. | Michalski and Pedersoli 2016; Pedersoli, Antomarchi, and Michalski 2016 |
only relative comparisons of cost-effectiveness are necessary.” (Fuchs 2013, 124, emphasis added)

In fact, and still under a DRM framework, the CEA usefulness may extend beyond the appraisal of mitigation measures: “Cost-effectiveness analysis is less comprehensive than benefit-cost analysis, but can be appropriate when the benefits from competing alternatives are the same or where a policy decision has been made that the benefits must be provided” (MMC/NIBS 2005, 363).

Within STORM, CEA was preferred to CBA for the appraisal of conservation interventions precisely to avoid pricing the societal gains of such efforts. In effect, the estimation of benefits is a costly endeavour; but, more than that, the impacts of conservation interventions are largely technical in nature, and cannot, therefore, be assessed by non-specialists such as visitors and local residents.

It should nevertheless be noted that there is not yet, neither for CEAs nor for CBAs, a “consensus on the minimum criteria necessary for conducting a comprehensive CBA [and, by extension, a CEA] for DRM” (Shreve and Kelman 2014, 231). This namely translates into an absence of a “standard or systematic approach detailing what variables need to be assessed to represent vulnerability, disaster consequences, or even the appropriate spatial and temporal scales for determining CBA, vulnerability, or disaster consequences” (Shreve and Kelman 2014, 231). The proposals developed herein thus stem from the consultation of several specialised literature sources – from risk management, to economic analysis to heritage conservation – and different heritage experts.

3. CEA methodology proposal

3.1. Background

The foremost objective behind the STORM CEA is to support decision-making on the conservation of cultural assets. In its widest sense, heritage Conservation may be defined as “All actions designed to understand a heritage property or element, know, reflect upon and communicate its history and meaning, facilitate its safeguard, and manage change in ways that will best sustain its heritage values for present and future generations” (Nara+20 2016, 147).

Archaeological assets, such as the STORM pilot sites – the Roman Ruins of Tróia, in Portugal; the Baths of Diocletian, in Italy; the Fortezza of Rethymno, in Greece; the Mellor Archaeological Site, in the United Kingdom; and the Grand Theatre of Ephesus, in Turkey – mainly embody scientific/evidential, historical, and educational values. In such contexts, conservation actions are typically undertaken to safeguard the fabric as main value repository, whilst minding “present and future” interpretation and fruition. When approached from a DRM perspective, the objective is the same, with conservation actions framed as the control of risks threatening the values of the heritage element, their fruition and/or interpretation/communication.

To implement a CEA for the assessment of conservation options, these must be comparable, i.e., yield comparable outcomes. These outcomes may be defined as the conservation of a heritage asset; or, from a DRM perspective, as the reduction of risks impending on a heritage asset.

Even if, as underlined earlier, minimum criteria for the development of a CEA within a DRM framework are not yet consensual among experts (Shreve and Kelman 2014), there are, nevertheless, four critical elements to any CEA: objectives; costs; effectiveness (outcomes); and comparisons. These elements, along with underlying assumptions (e.g. scope, time horizons), should be formulated clearly and carefully, to prevent misinformed and/or misleading analyses (Canoy et al. 2013).

3.2. Objectives and scope

In a CEA, the definition of objectives is critical, since it is against those objectives that the different alternatives will be appraised. These objectives must be defined clearly, including scope of application and considered time horizon. Either part of a DRM strategy or framed under a conservation perspective, site-specific objectives for the interventions should be clearly stated.

Examples of objectives may be phrased as: ‘to control landslide risks on a given structure for 30 years’; or ‘to prevent all risks on a given structure for 5 years’; or ‘to prevent material loss on a given structure for 50 years’. Only from a clear definition of objectives, it is possible to define the strategy alternatives that will be then analysed for cost-effectiveness: All defined strategies/conservation actions must allow reaching the defined objective.

3.3. Costs and discounting

The information required for the full cost characterisation of conservation actions is described in Table 3. Costs are divided into ‘Initial investment costs’ and ‘Future costs’, since conservation interventions may imply further actions, e.g. regular maintenance; future costs must be discounted to present values, to respect the common metric needed for the analysis (Svensson 2010). At the time of conducting this analytical work,
the social discount rate recommended by the European Commission was 4% (EC 2015).

### 3.4. Effectiveness

In a CEA, effectiveness should be represented by simple indicators (EC 2008); which will depend on the expected outcomes. Following the conservation definition above, effectiveness may be characterised as the degree to which heritage values are preserved and/or enhanced by the implementation of a given project/action.

In material conservation research, ‘effectiveness’ is often decomposed into two different analytical categories: efficacy and compatibility. Efficacy is undoubtedly important, as there is no point in applying underperforming actions; but the ultimately decisive factor will (or should) always be the compatibility of the solution towards the object (Delgado Rodrigues and Grossi 2007). In this proposal, efficacy is therefore presupposed for the considered treatment alternatives. In turn, compatibility is defined as the extent to which an action may be performed upon a heritage object without threatening its present or future significance (Revez and Delgado Rodrigues 2016), thus incorporating the notion of non-harmfulness towards cultural significance in the short and long runs.

Following its definition, the compatibility of the alternatives must be evaluated in terms of expected material and immaterial impacts: heritage materials are cultural significance vehicles, and therefore damage to or loss of these materials decreases their significance; additionally, significance is an immaterial concept, and may be impaired even if materials are safeguarded, e.g., when fruition becomes compromised. Therefore, it is suggested that effectiveness be assessed semi-quantitatively, from 1 (lowest) to 10 (highest) (Table 4):

It should be noted that the proposed effectiveness assessment scale is an even Likert-scale, where the midpoint, i.e., the point which is equidistant from both ends of the scale, is a decimal value (5.5). While using intermediate unit values is admitted in this proposal, and thus choosing a mid-point is possible, the rating guidelines do not clearly suggest it. This choice of an even Likert intended to discourage the choosing of the neutral option (represented by the mid-point), instead inducing the evaluator to take a clearer stand on their assessment (Croasmun and Ostrom 2011). This apparent restriction to the freedom of the analysts is compensated by a relatively large (10-point) scale, which provides a wider set of ranking options to choose from, granting the responder more independence (Joshi et al. 2015). On the other hand, 10-point scales allow finer differences to be highlighted and seem to yield results that are reliable and comparable with the ones obtained using the more common five- or seven-point scales (Dawes 2008).

It is furthermore recommended that a minimum level of effectiveness is put forth, below which no option should be chosen. It is difficult to set a rule for this tolerability level, but an application of this

| Table 3. Cost characterisation of built heritage conservation actions. |
|------------------------|-----------------|-----------------|-----------------|-----------------|
| INITIAL INVESTMENT COSTS | Costs | Costs | Yeardly repetitions |
| Cost categories/procedures | Unit | Quantity | Unit price | Total |
| Conservation planning and Documentation | | | | |
| Documentation, significance assessment, etc. | | | | |
| Monitoring | | | | |
| Regular inspections, environmental monitoring, etc. | | | | |
| Conservation-restoration | | | | |
| Cleaning, consolidation, etc. | | | | |
| Structural (conservation) interventions | | | | |
| Retrofitting, structural stabilisation, etc. | | | | |
| Expected loss in revenue due to restrictions to visitor access/spending | | | | |
| Total initial investment costs | | | | |
| FUTURE COSTS | Costs | Costs | Yeardly repetitions |
| Cost categories/procedures | Unit | Quantity | Unit price | Total |
| Monitoring | | | | |
| Regular inspections, environmental monitoring, etc. | | | | |
| Maintenance and Preventive conservation | | | | |
| Water access control, biological control, etc. | | | | |
| Expected loss in revenue due to restrictions to visitor access/spending | | | | |
| Yearly future costs | | | | |
| Discounted future costs* | | | | |
| Total costs (initial ± discounted) | | | | |

*Social discount rate = 4% (EC 2015).

N.B.: Not all cost categories will be necessarily required, and some categories may require further division into more specific procedures: rows should be added as necessary to adequately compute costs.
Table 4. Parameters and rating guidelines for conservation effectiveness assessments.

| Analytical parameter | Rating guidelines [1–10] |
|----------------------|--------------------------|
| M: Material non-harmfulness (short and long run) | 10: similar and/or low-aggressiveness products/methods |
| Physical-chemical aggressiveness | 5–6: moderately aggressive products/methods |
| I: Immaterial non-harmfulness (short and long run) | 1: aggressive/very dissimilar products/methods |
| Significance level: maintained/enhanced – reduced | 10: actions do not harm or interfere with cultural fruition/ do not reduce the site’s values/ do not imply the removal of any original material/ are fully reversible; |
| Perceptiveness of shape or function: maintained/enhanced – reduced | 5–6: actions partially prevent the fruition and/or research of the site/ require/cause the loss of some values, original material or information/ are partially reversible/removable; |
| Type of approach: preventive; curative; reconstruction | 1: actions strongly interfere with the significance, integrity or fruition of the site/ require/cause the loss of original material/ are fully irreversible |
| Compliance with conservation guidelines | |
| Visibility of interferences or disturbances to fruition | |
| Percentage of original material remaining | |
| O: Operator skills | 10: Team members with specific training and experience |
| Training of involved operators/professionals in the concerned specialities | 5–6: Some team members without specific training or experience |
| 1: No team members with specific training and experience | Estimated uncertainty of the rating, calculated as the standard deviation to the average rating values. |

methodology (see Section 4) suggests that a minimum value of five (5) could be set for each effectiveness parameter, below which the option should be excluded.

3.5. Uncertainty

In this methodology, there are two possible sources of uncertainty: the choice of the discount rate and the subjectivity in effectiveness appraisals. The discount rate will not be discussed here, since no reliable alternatives were found to the one recommended by the EC.

The subjectivity in the appraisals of effectiveness is tackled here via expert discussion. Many proposals rely on expert discussion for the assessment of conservation actions, methods, products (e.g. Delegou et al. 2012; Revez and Delgado Rodrigues 2016; Sanna, Atzeni, and Spanu 2008; Sasse and Snethlage 1997) and strategies (Nesticò, Morano, and Sica 2018; Rudokas et al. 2019). What is more, it could be argued that subjectivity is inescapable, even in ‘compatibility’ or ‘effectiveness’ assessments relying solely on measuring equipment: choosing which parameters to measure and/or how much these measurements impact final decisions can be regarded as sources of subjectivity, which often remain unacknowledged.

In this sense, expert discussion is viewed as a tool that not only recognises but also handles the inevitability of subjectivism by promoting its rational debate until consensus are reached. From the theoretical standpoint, intersubjectivity is increasingly viewed as desirable in heritage conservation-related decisions, provided it includes the stakeholders affected by such decisions (Muñoz Viñas 2005).

In this proposal, each effectiveness assessment should be rated by the site manager plus a sufficient number of relevant experts and/or stakeholders. Since heritage sites are strongly context-contingent, no rigid definitions of ‘sufficient’ or ‘relevant’ can be offered here. Nevertheless, it is recommended that (1) a minimum of three heritage experts (with no vested interest in any of the proposed strategies) are invited; and that (2) the choice of assessors is duly justified and reported.

The guidelines put forth to rate each conservation strategy are considered encompassing enough to avoid the definition of case-specific evaluation criteria. This option should allow the revisiting of decisions and the future learning of lessons by comparing the ratings of different decisions in the same site or, even, in different sites.

Following the expert evaluation, the ratings may be simply averaged into a final value, using standard deviation as an uncertainty measure, as exemplified below. Alternatively, a weighted average may be used, for instance, if a specific expert, e.g. the site manager, should be granted a higher say in the final rating.

The expert team should, nevertheless, agree on the weights given to different opinions; and the scoring should be individual, thus providing an idea of the confidence level via standard deviation. If a consensus is found necessary, then the Delphi method (IEC 2009) is recommended instead of a live discussion. Expert judgment elicitation methods such as Delft’s Classical Method (Cooke and Goossens 2004) have been suggested as potentially useful in reducing bias, and thus uncertainty.
4. Application: CEA of an intervention at the Roman Ruins of Tróia

To test the robustness of the CEA methodology, and towards its validation, this proposal was applied to a case study in one of STORM’s pilot sites, the Roman Ruins of Tróia (Portugal). The Roman Ruins of Tróia correspond to the remains of the largest known fish-salting production centre of the Roman Empire, with 27 fish-salting workshops identified and a production capacity surpassing that of all other sites of its kind; it was built in the first half of the 1st century CE, remaining active until the first half of the 5th century.

The archaeological site is located in a Natura 2000 protected area (Sado estuary) and, since 1910, is listed as a National Monument (highest Portuguese heritage protection grade) due to its exceptional historical and scientific values, considerable educational values, and the aesthetics of its setting.

4.1. Objectives and scope

An intervention undertaken at the Tróia site in 2010, the conservation of the well in Workshop 1, for which two different options were contemplated and budgeted, was chosen for applying the CEA with a time horizon of 30 years.

The well is located in the main archaeological area of the Tróia site, Workshop 1. Recent excavations date its construction to the 2nd century CE, meaning it post-dates the remaining workshop structures; nevertheless, the well still belongs to the first Roman fish-salting industry occupation phase (Vaz Pinto, Magalhães, and Brum 2010). The cultural significance of the well within the site is high, as it helps illustrating the structure of a functional Roman fish-salting workshop and the importance of water access within it; this significance is thus composed of exceptional scientific/research/evidential values and relevant educational values.

The goal of the intervention was the conservation of these values, including:

- to stabilise the structure, thereby reducing its vulnerability;
- to reduce hazard impact;
- to preserve cultural values/fruition.

The well is formed by two elements: the well proper and its access staircase, both built in stone masonry, using local/regional stones and ceramic materials. The staircase stretches for ~7 m in a straight line, in a ~ NE-SW direction, where 15 stairs allow reaching an arched opening, at a ~ 2.9 m depth.

When the current site manager was charged with the preservation of the Ruins, this well was facing imminent collapse due to the pressure of a neighbouring dune (Figure 1). The southeast wall of the staircase was at the greatest peril of failing, already showing significant deformation above a fracture across most of its length, and loss of a few stone elements.

In terms of conservation condition, it was more or less evident that the weight of the dune adjacent to the southeast staircase wall was the main deterioration agent affecting the well, and therefore any conservation intervention had to contemplate a solution for dune pressure containment. The first step towards the implementation of such a solution, carried out in 2008, was the removal of the upper part of the dune, effectively pushing it back a few metres away from the well. Nevertheless, the solution proved insufficient and the weight of dune still affected the archaeological structure a few years later (Vaz Pinto, Magalhães, and Brum 2010). The most reliable option, eventually undertaken, was to build a gabion wall, buried adjacent to the southeast wall, to divert the dune pressure (Figure 2).

The gabion wall system may be considered a hazard and/or exposure reduction action but managing the vulnerability of the archaeological structure, i.e. stabilising it using appropriate conservation procedures, was additionally required. In 2010, two options were contemplated for this stabilisation:

- to dismount the southeast wall areas exhibiting deformation, subsequently remounting them with a corrected profile; and stabilising the remaining structures using conservation-restoration methods;
- to stabilise the whole well resorting solely to conservation-restoration methods.

Figure 1. Well in workshop 1 of the Roman Ruins of Tróia in 2007.
Both interventions were designed and budgeted, with the site manager eventually choosing the second option, to keep fabric disturbance to a minimum and due to its lower price.

These two options were analysed for a 30-year period, coupled with the ordinary and/or extraordinary maintenance actions needed to ensure durability for the whole period under analysis. In heritage contexts, periodic maintenance may be ordinary, i.e., occurring more frequently (e.g. yearly) and thus requiring less invasive conservation procedures; or extraordinary, i.e. occurring seldom and therefore demanding more profound conservation measures. These options are in line with other proposals for the assessment of conservation interventions (Sestini, Sammartino, and Laurenzi Tabasso 2013).

Albeit they do not fully respond to the pre-defined goal (conservation of cultural values), hypothetical strategies – (i) post-collapse recovery and (ii) structure reburial – were

Figure 2. Building of a gabion wall next to the well in workshop 1: archaeological survey of the dig (top), gabion wall building and burying (bottom).

Figure 3. Cost-effectiveness of the analysed strategies.
additionally considered, for comparison purposes and, particularly, to ascertain how the methodology would process them. All strategies are summarised in Table 5.

### 4.2. Cost-effectiveness analysis

In terms of cost analysis, most values, and namely those associated to strategies A, B, and C, correspond either to the values that the site manager effectively payed; or were obtained from budget plans originally requested by the site manager to conservation firms; values for maintenance – ordinary and extraordinary – and other actions in strategies D and E were priced based on the experience of the conservation professionals at Nova Conservação, also considering the 2010 budget plans available for the well intervention.

Attention is drawn to the fact that the shifts in costs expected from a variation of visitors due to the different interventions are not factored, since there is no data available for this calculation. It should be additionally mentioned that the pushing back of the dune, having been carried out 2 years prior to the point where the decision analysed in the current chapter had to be made, is considered here as a sunk cost, and is thus not factored in any of the strategies either; all strategies assume that this step has already taken place.

Table 6 provides an example of a cost breakdown for one of the analysed strategies.

Table 7 compares the costs of the different strategies for the 30-year conservation of the well.

From the table, the following conclusions may be withdrawn:

1. Strategy A is the most expensive one, not only because it implies a partial wall reconstruction, raising the initial investment needed; but also because it was factored here together with the most comprehensive maintenance strategy (yearly ordinary maintenance), raising the future costs;
2. Strategies A and B have the same future (maintenance) costs, which are the highest among the different strategies, a result which might help explaining why regular maintenance action plans are so seldom implemented;
3. Strategy E looks like the obvious choice – and it would be, if the main strategy objective was limited to (i) the safeguarding of the material integrity of the structure, or (ii) the mitigation of dune pressure risks upon the well. However, the impairment of (present) fruition must also be factored in the final decision, cf. the aforementioned objective to preserve cultural values/fruition.

The effectiveness of the different strategies was appraised considering the previously defined objectives. Assessment ratings were requested from the site manager (an archaeologist) plus three heritage conservation experts. The selection of these experts was discussed with the site manager, who would, in principle, be the responsible for this selection in a non-experimental application of the methodology. For this selection, the following aspects were considered:

- (i) the type of heritage asset: archaeological;
- (ii) the goals of the intervention: conservation of very high scientific and educational values;
- (iii) the nature of the strategy options: largely material-related;
- (iv) the impacted stakeholders: mainly site visitors and archaeological researchers.

The site manager represented the impacted stakeholders and provided the necessary archaeology expertise and, therefore, it was decided that the remainder expert panel should integrate material conservation professionals, preferably experienced in working with archaeological assets. The chosen experts included: (1) a conservation scientist, specialising in stone conservation; (2) an architect, specialising in heritage preservation impact studies; and (3) a conservator-restorer, specialising in archaeological assets.

The strategies were explained to the experts, who were then invited to give their assessments using the rating table. These values are presented in Table 8, with the exception of the parameter ‘operator skills’, which was assumed as having a maximum value for all strategies – i.e., it was assumed that, whatever the strategy, the site manager would prefer to have the work carried out by duly trained professionals (as indeed happened).
In Table 9, averaged ratings are presented together with a brief summary of the comments offered by the experts as grounds for the assessments. Total effectiveness is shown as the average of the assessments together with the standard deviations of the ratings, used here as a measure of the uncertainty associated with the ratings.

The average values were then combined with the costs estimated for each strategy, so as to obtain cost-effectiveness ratios (Table 10).

According to the C/E ratios, strategy E is the most cost-effective for the conservation of the well; it is not, however, an acceptable strategy when educational values are considered, since it implies the reburial of the well. As highlighted earlier, the position and importance of the well within the main visiting area make its visual access critical. Of course, strategy E would not in fact be a feasible option, given the objective defined for the intervention, and therefore it should have not integrated the CEA in the first place.

Nevertheless, its inadequacy is reflected in the effectiveness values of strategy E, which fall in the lower end of the scale, averaging 3 (±1.41). Imposing a minimum value of 5 for each individual effectiveness parameter (M, I, O) would be a relatively simple way of excluding incompatible strategies.

An analysis of the cost-effectiveness diagram (Figure 3) clearly shows that strategy D, lying in the lower right quadrant, is entirely unacceptable. Strategy A, nevertheless, is the least cost-effective.

Due to its much lower costs, strategy E is the only one lying to the left of the average cost line. What is more, because of its compatibility with the archaeological materials, the overall effectiveness of strategy E is average, despite its very low immaterial effectiveness. The imposing of a tolerability threshold would be a pertinent solution to deal with any strategy achieving their purposes by compatibility trade-offs across the different effectiveness dimensions (M, I, O), e.g. a well-planned conservation intervention executed by professionals that are not adequately trained.

If strategy E is excluded, strategies B and C fall below average costs and into the upper left quadrant, where the most cost-effective solutions will be found. In this quadrant, strategy B is more cost-effective than strategy C and would thus be the advised one.

5. Conclusions

The planning of conservation interventions is very often hindered by unclear outcome definitions and, consequently, a general lack of evaluation criteria. It is believed that the proposed methodology can assist in this definition and ensuing evaluation, supporting a current and ethical approach to the conservation of the values, authenticity and material integrity of archaeological sites; as well as clearer and more consistent
Table 7. Costs of the different strategies for the conservation of the well in workshop 1.

| Costs                              | Strategy A | Strategy B | Strategy C | Strategy D | Strategy E |
|------------------------------------|------------|------------|------------|------------|------------|
| Initial investment costs           | 22,559.25 € | 17,188.00 € | 17,188.00 € | 26,688.00 € | 7,500.00 € |
| Future costs                       |            |            |            |            |            |
| Total (discounted)                 | 18,398.72 € | 18,398.72 € | 15,345.00 € | 10,230.00 € | –          |
| Totals (initial + future discounted)| 40,957.97 € | 35,586.72 € | 32,533.00 € | 36,918.00 € | 7,500.00 € |

Table 8. Expert assessments on the effectiveness of the different strategies.

| Strategies | Effectiveness parameters* | Experts |
|------------|--------------------------|---------|
| A          | M                        | I 5     |
|            | I                        | II 6    |
|            | I                        | III 7   |
|            | I                        | IV 6    |
| B          | M                        | I 9     |
|            | I                        | II 8    |
|            | I                        | III 9   |
|            | I                        | IV 10   |
| C          | M                        | I 7     |
|            | I                        | II 8    |
|            | I                        | III 8   |
| D          | M                        | I 1     |
|            | I                        | II 1    |
|            | I                        | III 2   |
| E          | M                        | I 9     |
|            | I                        | II 8    |
|            | I                        | III 9   |
| *Operator skills were fixed at 10 for all strategies, assuming the site manager would necessarily contact adequately trained professionals to carry out the chosen strategy. |

The CEA methodology was applied to a conservation intervention carried out in the Roman Ruins of Tróia not only to illustrate the process, but also to highlight the type of information needed. It is worth noting that the recommended option, albeit not the less costly, was the less intrusive and most maintenance-relying one; this agrees with current perspectives on the conservation of archaeological assets, seemingly indicating that the procedure is robust. It is also entirely in accordance with the type of approaches promoted by the Sendai Framework for Disaster Risk Reduction 2015–2030: “Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment. These can be drivers of innovation, growth and job creation. Such measures are cost-effective and instrumental to save lives, prevent and decision-making. It is furthermore held that the procedure is relatively easy to implement and may provide helpful directives towards more integrated, DRM-oriented, conservation approaches.

Table 9. Average assessments with synopses of expert comments.

| Strategy | Material non-harmfulness (M) | Immaterial non-harmfulness (I) | Operator skills (O) | Effectiveness (E)* |
|----------|------------------------------|-------------------------------|---------------------|--------------------|
| A        | wall dismount                |                              |                     |                    |
|          | $I = 6$                      |                               | $O = 10$            | $E_A = 7.17 \pm 0.61$ |
| B        | compatible procedures and mostly compatible materials from a physical-chemical point of view | $I = 9.25$ | $O = 10$ | $E_B = 9.42 \pm 0.57$ |
| C        | similar to strategy B, but imposes more stress upon the structure due to the repetition of more intrusive interventions. | $I = 7$ | $O = 10$ | $E_C = 8.42 \pm 0.45$ |
| D        | wall collapse                |                              |                     |                    |
|          | $I = 1$                      |                               | $O = 10$            | $E_D = 4.08 \pm 0.21$ |
| E        | reburial of the well is a compatible and effective way of preventing material stress upon the well. | $I = 3$ | $O = 10$ | $E_E = 7.17 \pm 0.95$ |

*Total effectiveness calculated as: $E = \frac{M + I + O}{3} \pm \sigma$. 
reduce losses and ensure effective recovery and rehabilitation.” (UN 2015, 18)

Applications to other conservation/DRM actions, e.g., emergency interventions, in the remainder STORM pilot sites, will allow further validation of the methodology. On the other hand, and although the current CEA proposal was initially developed for material conservation, i.e. conservation actions interfering with the heritage fabric, it would arguably be useful to test its extension to non-structural DRM measures, e.g. monitoring or training actions.

Yet another application of the methodology that would be interesting to pursue once a sufficient body of data is gathered is to understand its potential usefulness as a knowledge transfer tool for sharing of good practices and/or lessons learnt.

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**Table 10. Summary of the cost-effectiveness parameters for the five analysed strategies.**

| Strategies | Costs (£) | Effectiveness (Avg ± Std dev.) | C/E ratios (£) |
|------------|-----------|-------------------------------|---------------|
| A          | 40,957.97 | 7.17 (±0.61)                  | 9041.14       |
| B          | 35,586.72 | 9.42 (±0.57)                  | 3779.12       |
| C          | 32,533.00 | 8.42 (±0.45)                  | 3865.31       |
| D          | 36,918.00 | 4.08 (±0.21)                  | 5715.07       |
| E          | 7500.00   | 7.17 (±0.95)                  | 1046.51       |
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