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Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial

A. Wain, G. Filipe, I. Tissot, L. Brambilla, M. Manso (Guest Editors | Editoras convidadas)

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The conservative restoration brings the 1907 Fiat 130 HP back on the track, pp. 225-237.

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CONSERVAR PATRIMÓNIO

EDITORIAL

Conservation of industrial and technological heritage

Conservação de património tecnológico e industrial

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The preservation of industrial and technological heritage appears as a subject in the field of cultural heritage and museology in the 1970s. However, its conservation practice is relatively recent compared to other expertise areas. Therefore, conservation assessment, intervention, and maintenance methodologies for this type of heritage are still open questions.

The conservation of industrial and technological heritage refers to the preservation, protection, and management of historic sites, structures, artefacts, and knowledge related to industrial and technological advancements. It encompasses the physical remnants of industrial processes, machinery, technological innovations, and associated cultural, social, and economic significance.

The successful preservation of tangible and intangible aspects of human achievements in the fields of industry and technology comprises several conservation challenges. Among others, we underline the development of conservation methodologies, the definition of management plans within a legal and regulatory framework and public awareness and engagement.

As mentioned, compared with other types of heritage, the conservation methodologies for industrial and technological heritage are still in the early stages of development. This situation is due to several reasons, including the specificity of this heritage which is often associated with technologies and processes that include machinery equipment related to the operating sites. To address these issues, specialised skills and technical expertise are required to ensure the continuing maintenance and, where appropriate, operation of the machinery.

Management plans for industrial and technological sites and artefacts must also have legal protection and regulatory frameworks to ensure their safeguard and guide their appropriate conservation and use.

To guarantee the proper conservation of industrial and technological heritage it is essential to raise public awareness and engagement. Moreover, it is fundamental to encourage young conservators in the field (of which there is still an insufficient number), and to that end, a reflection on the formation in academia is required.

Addressing these challenges requires a multidisciplinary approach involving collaboration between various management institutions and other stakeholders in industrial heritage, such as academia, industry, volunteer groups, private owners and visitors.

It was in this spirit and in this context that the LIBPhys-UNL and the Seixal Municipality through the Ecomuseum organised in Seixal (Portugal) in September 2022, the eighth edition of the Big Stuff conference, dedicated to the preservation of large-scale heritage.

The participation of 73 conservator-restorers, conservation scientists, museologists, historians, and students from around the world revealed the willingness of the scientific community to discuss, in an interdisciplinary way, the conservation of industrial and technological heritage.

The Big Stuff conference was an opportunity to share the work and research developed in recent years. Following the conference event, we considered our obligation to promote the dissemination of the papers presented, proposing to the Conservar Património journal directory board the edition of a special issue on industrial and technological heritage. The directory board members accepted the challenge, and we thank them for their confidence.

It is with great pleasure that we introduce this edition comprising 19 contributions (ten articles, five interventions and four notes). These contributions reflect aspects of the issues presented and discussed at the conference and speak eloquently of the current work and reflections being developed in the field of industrial and technological heritage conservation.

The contributions consider a variety of artefacts (*e.g.* aeroplanes, cars) and built structures, which illustrate the wide range of industrial and technological heritage. Topics include conservation concepts, methodologies for determining cultural heritage value, methods and techniques for diagnostic and conservation assessment, selection of materials, and reflections on training and skills required to intervene in industrial and technological heritage.

The diversity of approaches and research topics is evident in the articles section. Four of them consider the documentation of functional and functioning objects, hazardous collections and immovable heritage (Furtado, Riddle et al. and the two contributions by Ferreira-Lopes). The authors carry out a critical evaluation of the tools used in documentation and propose new methodologies that are integrative and more efficient.

The papers by Carrino et al. and Schröter et al. both deal with materials characterization, diagnostic and conservation assessment. The first one considers vibroacoustic techniques and machine learning to assess historical engines in operation. The second concerns the material characterisation of varnishes applied to technological heritage objects.

Two papers discuss methodologies for determining the cultural significance, important to identify appropriate intervention methodologies. Borges reflects on industrial and railway heritage, and Castanho Moraes presents two case studies of how to reuse immovable heritage to preserve its cultural value. One further paper discusses alternative conceptual lenses for approaching the conservation of technological and industrial heritage: Konstantinos proposes the application of the "caring thinking" of Lipman's philosophy to museological practice to provide new decision-making models for conservation.

The article by Wain et al. concerns the skills needed to ensure the conservation of industrial and technological heritage, and how the training of new generations in these areas can be adapted to fit the requirements of modern education systems.

In the interventions section, we present contributions that consider the conservation of large-scale objects, such as a WW II Supermarine Spitfire wing (Paillaux et al.), a dH Comet G-BIX plane, (Buergel), and a Fiat 130 car from 1907 (Lorenzone et al.). The conservation methodologies are illustrative of the specificities of the industrial and technological heritage objects, having opted in some cases for their re-functionalisation and others for their material conservation. The decisions depend on the context and conditions of the exhibition sites, the historical, technical, and industrial values of the objects, and budgetary and governmental constraints.

Two interventions are devoted to industrial immovable heritage conservation. Moreira Fontes describes the conservation of a wooden structure of a former blast furnace and Everett et al. of a nineteenth century iron truss bridge. These contributions discuss repair procedures that ensure structural stability but also preserve the industrial and cultural significance of these structures.

In the notes section are presented four projects illustrating the research that is being developed on the conservation of industrial and technological heritage and its challenges for the twentieth first century. Based on two projects, Chasqueira et al. introduce the concept of "creative conservation" to encourage reflective thinking on the preservation of collective memory.

The sustainability of keeping historic machinery in operation in the face of current environmental demands is approached by Rimmer.

The current research on materials to be used in technological heritage objects is highlighted by Smith et al., who present the preliminary results for the selection of protective coatings for artillery pieces on outdoor display.

Also, the importance of public engagement in the preservation and dissemination of heritage is represented by the contribution of Swinbank regarding the STICK network.

Finally, we would like to point out that three of these contributions result from works carried out by students, demonstrating that there is significant emerging talent working in this area.

The reflection and discussion provided in this volume demonstrate the imagination, solid research and consistent development that is ongoing in the conservation of industrial and technological heritage.

A preservação do património industrial e tecnológico surge como tema de discussão no domínio do património cultural e da museologia a partir de 1970. Por conseguinte, a conservação deste património é relativamente recente quando comparada com outras áreas de especialização, estando por definir as metodologias para o diagnóstico de conservação, intervenção e manutenção.

A conservação do património industrial e tecnológico considera a preservação, proteção e gestão de locais históricos, estruturas, artefactos e o conhecimento dos desenvolvimentos industriais e tecnológicos. Incluem-se vestígios materiais de processos industriais, maquinaria, inovações tecnológicas, bem como o significado cultural, social e económico associado.

O sucesso da preservação e salvaguarda dos aspetos tangíveis e intangíveis das realizações humanas nos domínios da indústria e da tecnologia compreende vários desafios de conservação. Entre outros, destacam-se o desenvolvimento de metodologias de conservação, a definição de planos de gestão no âmbito de um quadro legal e regulamentar e a sensibilização e o envolvimento do público.

Como mencionado, em comparação com outras áreas de especialização do património cultural, as metodologias de conservação do património industrial e tecnológico ainda estão em fase de desenvolvimento. Esta situação deve-se a vários fatores, nomeadamente à especificidade deste património, muitas vezes associado a tecnologias e processos industriais que incluem maquinaria e respetivos locais de operação. Para abordar estas questões, são necessárias habilitações especializadas e competências técnicas que garantam a manutenção contínua e, quando apropriado, a operação de maquinaria.

Os planos de gestão para sítios e objetos industriais e tecnológicos devem incluir proteção legal e enquadramento regulamentado de forma a garantir a sua salvaguarda e orientar para a sua conservação e utilização adequadas.

Para garantir a conservação adequada de património industrial e tecnológico, é essencial promover a sensibilização e o envolvimento da comunidade. Além disso, é fundamental incentivar jovens conservadores para esta área (dos quais ainda há um número insuficiente), sendo para isso necessário refletir sobre a formação académica.

A abordagem a estes desafios requer uma perspetiva multidisciplinar envolvendo a colaboração entre instituições de gestão e outras entidades com potencial interesse no património industrial, como a academia, a indústria, voluntários, privados e visitantes.

Foi com este espírito e neste contexto que o LIBPhys-UNL e a Câmara Municipal do Seixal, através do Ecomuseu, organizaram no Seixal (Portugal), em Setembro de 2022, a oitava edição da conferência *Big Stuff*, dedicada à preservação de património técnico de grande dimensão.

A participação de 73 conservadores-restauradores, cientistas da conservação, museólogos, historiadores e estudantes de todo o mundo revelou a vontade da comunidade científica em discutir, de forma interdisciplinar, a conservação do património industrial e tecnológico.

A conferência *Big Stuff* foi uma oportunidade para partilhar o trabalho e a investigação desenvolvidos nos últimos anos. Após a conferência, considerámos ser nossa obrigação a promoção e a divulgação mais abrangente dos trabalhos apresentados, e propusemos à direção da revista Conservar Património a edição de um número especial sobre o património industrial e tecnológico. Os membros da direção aceitaram o desafio, e por isso agradecemos-lhes a confiança que em nós depositaram.

É com grande satisfação que apresentamos esta edição, composta por 19 contribuições (dez artigos, cinco intervenções e quatro notas). Estas contribuições espelham parte dos assuntos apresentados e discutidos na conferência e são eloquentes do trabalho que está a ser desenvolvido em conservação de património industrial e tecnológico.

As contribuições consideram uma variedade de objetos (por exemplo, aviões, automóveis) e estruturas edificadas ilustrando a diversidade e abrangência do património industrial e tecnológico. Os tópicos incluem conceitos de conservação, metodologias para determinar o valor do património cultural, métodos e técnicas de diagnóstico e avaliação do estado de conservação, seleção de materiais e reflexões sobre a formação e competências necessárias para intervir no património industrial e tecnológico.

A diversidade das abordagens e tópicos de investigação estão patentes nos artigos. Quatro deles abordam a documentação de objetos funcionais e em funcionamento, coleções com materiais perigosos e património imóvel (Furtado, Riddle et al. e as duas contribuições de Ferreira-Lopes). Os autores realizam uma avaliação crítica das ferramentas usadas na documentação e propõem novas metodologias integradoras e mais eficientes.

Ambos os artigos de Carrino et al. e Schröter et al. tratam da caracterização de materiais, diagnóstico e avaliação da conservação. O primeiro utiliza técnicas de emissão acústica e de *machine learning* para avaliar motores de veículos históricos em funcionamento. O segundo diz respeito à caracterização de vernizes aplicados a objetos de património tecnológico.

Dois artigos discutem metodologias para atribuir os significados culturais que determinam posteriormente as metodologias de intervenção. Borges reflete sobre o património industrial e ferroviário, e Castanho Moraes apresenta dois casos de estudo sobre a reutilização do património imóvel de forma a preservar o seu valor cultural. Um outro artigo discute modos conceptuais alternativos para abordar a conservação do património tecnológico e industrial: Konstantinos propõe a implementação do "pensamento cuidadoso" da filosofia de Lipman na prática museológica para fornecer novos modelos de tomada de decisão para a conservação.

O artigo de Wain et al. trata das competências necessárias para garantir a conservação do património industrial e tecnológico, e como a formação das novas gerações nestas áreas pode ser adaptada às exigências dos sistemas de ensino modernos.

Na secção das intervenções, apresentamos contribuições que consideram a conservação de objetos de grande dimensão, como uma asa de um *Supermarine Spitfire* da Segunda Guerra Mundial (Paillaux et al.), um avião dH Comet G-BIX (Buergel) e um carro Fiat 130 de 1907 (Lorenzone et al.). As metodologias de conservação ilustram as especificidades dos objetos de património industrial e tecnológico, optando em alguns casos pela sua refuncionalização e noutros pela sua conservação material. As decisões consideraram o contexto e as condições dos locais de exposição, os valores históricos, técnicos e industriais dos objetos, bem como de restrições orçamentais e governamentais.

Duas intervenções são dedicadas à conservação do património industrial imóvel. Moreira Fontes descreve a conservação de uma estrutura de madeira de um antigo alto-forno e Everett et al. de uma ponte de ferro do século XIX. Estas contribuições abordam procedimentos de reparação que garantem a estabilidade estrutural, mas também preservam o significado industrial e cultural destas estruturas.

Na secção das notas são apresentados quatro projetos que ilustram a investigação que está a ser desenvolvida na conservação de património industrial e tecnológico e os seus desafios para o século XXI. Com base em dois projetos, Chasqueira et al. introduzem o conceito de "conservação criativa" para incentivar o pensamento reflexivo sobre a preservação da memória coletiva.

A sustentabilidade de planos de manutenção de máquinas históricas em funcionamento face às exigências ambientais atuais é abordada por Rimmer.

A investigação sobre materiais a serem usados atualmente em objetos de património tecnológico é destacada por Smith et al., que apresentam os resultados preliminares para a seleção de revestimentos protetores de peças de artilharia em exposição ao ar livre.

Além disso, a importância do envolvimento do público na preservação e divulgação do património é representada pela contribuição de Swinbank sobre a rede STICK.

Finalmente, gostaríamos de destacar que três destas contribuições resultam de trabalhos realizados por estudantes, demonstrando que existe um talento emergente significativo a trabalhar nesta área.

A reflexão e discussão proporcionadas neste volume demonstram a imaginação, a investigação sólida e o desenvolvimento consistente que estão em curso na conservação do património industrial e tecnológico.

CONSERVAR PATRIMÓNIO

Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
ARTICLE / ARTIGO

A tale of hazards: Ingenium's industrial collections move

Uma história dos perigos: o movimento das coleções industriais na Ingenium

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Abstract

In 2018, Ingenium began a large-scale collections move, consolidating artefacts from four rental warehouses into a new purpose built storage facility. Collection hazards were assessed, prioritised and treated according to Ingenium's comprehensive Collection Risk Management Program (CRMP), placing health and safety at the forefront of collections care. This paper will present hazard assessment and mitigation in one warehouse, the *Building 2421 Reserve Collection*, showing the challenges overcome to move a large industrial collection on a tight schedule and with limited staffing and resources. A selection of case studies will provide examples of hazard mitigation in artefacts containing asbestos, radioactivity, polychlorinated biphenyls (PCBs) and mercury. The case studies demonstrate how simple solutions and triage treatments were implemented by conservators and specialised contractors in order to mitigate collection hazards during the move project. The Building 2421 Reserve Collection move was completed in December 2021 and the full collections move was completed in August 2022.

KEYWORDS
Collections move
Asbestos
Polychlorinated biphenyls (PCBs)
Mercury
Radioactive
Hazardous collections

Resumo

Em 2018, a Ingenium iniciou uma mudança em grande escala de coleções, consolidando artefactos de quatro armazéns de aluguer para uma nova instalação de armazenamento construída para o efeito. Os perigos das coleções foram avaliados, priorizados e tratados de acordo com o abrangente Programa de Gestão de Riscos de Coleção (CRMP) da Ingenium, colocando a saúde e a segurança na vanguarda dos cuidados com as coleções. Este artigo apresentará a avaliação e mitigação dos riscos num armazém - *Building 2421 Reserve Collection* - mostrando os desafios superados para mover uma grande coleção industrial com tempo, pessoal e recursos limitados. Uma seleção de casos de estudo fornecerá exemplos de atenuação dos perigos em artefactos contendo amianto, radioatividade, bifenilos policlorados (PCBs) e mercúrio. Os casos de estudo demonstram como soluções simples e tratamentos de triagem foram implementados por conservadores e empreiteiros especializados, de modo a atenuar os riscos de recolha durante o projeto de mudança. A mudança para o *Building 2421 Reserve Collection* foi concluída em Dezembro de 2021 e a mudança completa das coleções foi concluída em Agosto de 2022.

PALAVRAS-CHAVE
Movimentação de coleções
Amianto
Policlorobifenilos (PCB)
Mercúrio
Radioatividade
Coleções perigosas

Introduction

We begin as all good tales begin: once upon a time… in land far, far away, where winters are cold and summers are hot, there was a museum corporation by the name of Ingenium. Nestled in the capital of Canada, the city of Ottawa, Ingenium runs three national museums located on three separate campuses: the Canada Aviation and Space Museum (CASM), Canada Science and Technology Museum (CSTM), and Canada Agriculture and Food Museum (CAFM). The three museums contain a variety of artefacts from scientific and technological history with special focus on Canada.

Previously, Ingenium's collections were stored in four rental warehouses. The Ingenium Centre, a new purpose-built storage facility, was recently constructed to house the 165,000 large and small artefacts. From 2018 to August 2022 the characters in our tale worked to prepare and move the artefacts into their new home, finding and fixing collections care issues along the way.

Amongst the four old and outdated rental buildings was the *Building 2421 Reserve Collection* comprising 5500 industrial artefacts. This industrial collections space included thousands of artefacts accessioned after the closure of the Ontario Hydro Museum of Electrical Progress in 1992 as well as two radioactive storage rooms. However, the collections storage space was overcrowded, leading to a host of issues due to lack of access. The collections move presented an opportunity to correct some collections care deficiencies and meet modern collections standards. Literature research and consultations on-site with other museums nationally and internationally assisted with the planning stages prior to moving the collection.

Three conservators worked full-time assessing and mitigating hazards in the *2421 Reserve Collection*. Conservation staff led the move project and led hazard assessment and mitigation, physical stabilisation and packing or palletising of each artefact. A team of artefact handlers, mount-makers, cataloguers and curators split their time between this collection and the other three buildings and contractors were called upon to complete specialised work. The 5500 artefacts were moved over 12 months between October 2020 and December 2021, with several COVID-19 lockdowns causing stoppage of work.

Project background: hazards in collections

Many of Ingenium's artefacts could not legally be moved without first mitigating their inherent hazards. Laws and regulations that govern labelling, storage, movement, and disposal of hazardous materials on an industrial scale often also apply in museum settings. Ingenium conservators are not certified health and safety professionals, but served as the defacto collections hazard management experts during the move.

Hazard management has always been part of Ingenium's collections practices. Assessments previously occurred as needed, but systematic hazard assessment was not possible in the overcrowded old collections spaces. In 2018, a comprehensive Collections Risk Management Program (CRMP) plan was implemented. The new CRMP put staff and visitor safety at the forefront of our conservation and collections practices, prioritising hazard management with the ultimate goal of making our collections spaces more physically accessible to the Canadian public. The beginning of the CRMP aligned with the beginning of the move, providing an opportunity to systematically assess each artefact in the collection.

As part of the CRMP, we underwent training in relevant areas, for example becoming certified Asbestos Type 1 and 2 workers (Ontario). However, external training courses were not available for most hazards we encountered. We also consulted external experts at the Canadian Nuclear Safety Commission during the project. We attempted to consult relevant experts at federal PCB Program, but these consultations showed a gap of awareness of the museum context. This led us to develop internal training protocols for each hazard. We produced written documents called *Artefact Hazard Risk Assessments and Safe Work Practices* (or RASPs) for each hazard type, which are mandatory reading material for all people working in the collections spaces. RASPs serve as a starting point to inform staff and volunteers of risks and safe work practices for each hazard, allowing them to develop safe move protocols. Labelling follows the Standard Global Harmonised System (GHS) for artefacts that contain a known chemical product. We also have labels for non-GHS hazards, for example: split rim tires, or stored mechanical energy. Labels are printed on cardstock paper and tied to an artefact when the hazard is identified. Hazards are flagged digitally in our museum management database with an icon appearing in the database file to indicate the presence of hazardous materials.

A tale of asbestos

Asbestos in museum collections

Asbestos containing materials (ACMs) are widely found in industrially-manufactured artefacts due to their resistance to heat and chemicals. A naturally occurring group of fibrous minerals, asbestos has been used by humans since prehistoric times. It was commercialised and became common in a variety of products in the late 1800s following the Industrial Revolution [1]. Canadian industrial history is deeply connected to the mining and manufacturing of asbestos, having once been a leading supplier of asbestos worldwide. Asbestos mining in Canada ceased in 2011, decades after being declared a human carcinogen by the World Health Organization's International Agency for Research on Cancer in 1987 [2]. The long term health effects of asbestos exposure are well known, including mesotheliomas, lung disease, and cancers [3].

ACMs are prevalent in museum collections worldwide. Asbestos can be found in artefacts with a heating element such as toasters, ovens and lamps, historic textiles, insulation, gaskets, fire hoses, natural history and mineralogical specimens, and many other artefacts common to scientific collections. Although asbestos is commonly listed on museum hazard websites, conservation literature has a relative dearth of papers that cover possible treatments for ACM artefacts [4].

Asbestos mitigation at Ingenium

At Ingenium, asbestos mitigation generally falls into three categories: disposal, isolation or encapsulation. Provincial laws dictate which treatment is appropriate for which type and quantity of asbestos, and whether the treatment can be conducted by Ingenium conservators, or by an external specialised asbestos contractor [5]. When appropriate, the ACM part may be removed from the artefact and disposed of as hazardous waste in consultation with the curator. Alternatively, small artefacts or parts of large artefacts may be isolated by sealing them in double-layered enclosures of 6 mil polyethylene sheeting. When removal or disposal of the part is not possible, or the historical significance of the ACM part outweighs its hazardous nature, encapsulation can be an appropriate hazard mitigation strategy.

There are various methods for encapsulation of asbestos. A detailed discussion of these processes is outside the scope of this paper. However, a method using two asbestos remediation products is commonly used at Ingenium: Childers CP-240 CHIL-LOCK (Clear), to wet the asbestos fibres and consolidate them for further treatment, and Childers CP-211 CHIL-BRIDGE, a white paste-like encapsulant [6-7]. These are products that can be safely and legally used in Canada for asbestos remediation.

Case study: two steam engines

This section's tale begins with two steam engines, both containing friable asbestos. These steam engines were selected from 436 asbestos treatments conducted during the move of the *Building 2421 collection*. The first steam engine in our story is a Corliss engine manufactured by

E. Leonard & Sons in London, Ontario in 1903 (Figure 1). This type of engine was mainly used in the textile and metallurgy industries.

When assessing the artefact prior to moving it to the new storage facility, we discovered a thick layer of asbestos insulation beneath the metal cladding. The asbestos was open to the air on the bottom (Figure 2a). Ingenium conservators have Ontario Type 1 and 2 asbestos certification, which allows us to remediate up to 1 m^2 of friable asbestos in our artefacts [8]. However, since we estimated that about 3 m^2 of asbestos was present, we were required by law to contract Type 3 asbestos specialists to work on this artefact.

The specialist contractors built an enclosure around the engine housing from a wooden frame and plastic tarp material (Figure 2c). The asbestos abatement was performed inside this enclosure, and only the specialised contractors could enter the enclosure during work. We discussed in detail the scope of work and the exact steps to be followed with the contractors, checking in at regular intervals during the two days of work. The contractors removed as much of the friable asbestos as possible, filling the void with Rockwool insulation and applying a canvas patch with encapsulant (Figure 2b). The materials used in their treatment have not been tested for long-term archival stability, but meet the legal requirements for asbestos mitigation. Treatments such as these increase the overall accessibility of our collections, as our new storage areas are safer for staff, visitors, and others who handle the collection.

The second steam engine in our tale is a uniflow steam engine dated circa 1920, manufactured by Fitchburg Steam Engine Co. and used in a University of Toronto engineering laboratory. During our pre-move condition assessment, we discovered some friable asbestos in the insulated housing (Figure 3a). In this case it was under 1 m^2, so it could be treated in-house. The asbestos insulation was located under a layer of painted green canvas, and was relatively well encapsulated by design. However, friable asbestos was present at the seams and at two damaged areas.

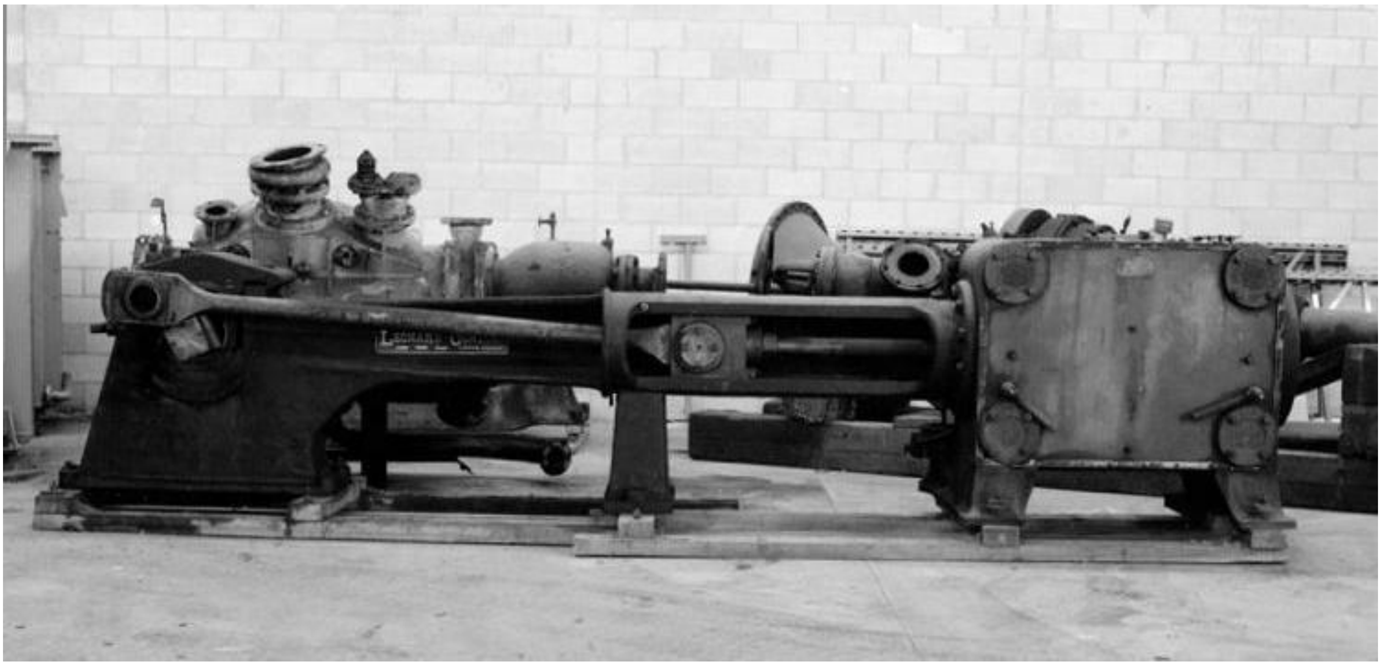

Figure 1. Corliss steam engine, ca. 1903, manufactured by E. Leonard and Sons in London, Ontario, Canada (Artefact number 1980.0526).

Figure 2. Treatment of asbestos in the Corliss steam engine (Artefact number 1980.0526) by specialised contractors: *a)* detailed view before treatment; *b)* detailed view after treatment; *c)* during treatment showing the custom-built enclosure.

Due to the size of the tears and extreme friability of the asbestos, we could not apply consolidants directly, as it was causing the asbestos to further detach from the artefact. Removal of the asbestos was also not practical, as it would both compromise the visual integrity of the artefact and expose more asbestos, worsening the hazard. We decided that a patch method would be best to encapsulate the torn areas. We worked on this artefact wearing a particulate P100 respirator, eye protection, a hooded Tyvek suit and nitrile gloves (Figure 3c). The surfaces were HEPA vacuumed before and after treatment. We soaked the area with an asbestos removal agent (CP-240) to wet the asbestos fibres and prepare them for encapsulation, as required by the asbestos regulations [5]. We then applied a canvas patch and a thick, white paste-like encapsulant (CP-211) to fully contain the damaged areas. This treatment protocol follows common industry practices and was implemented in consultation with asbestos specialist contractors according to applicable regulations.

The final triage treatment is visually discordant with the surrounding artefact, but does effectively mitigate the hazard (Figure 3b). Given the extremely tight timeline of the collections move project, our team was assessing, treating and moving dozens of artefacts per day and only 1.5 hours was dedicated to documentation, treatment and report writing of this large artefact. As conservation professionals, it is important to share a variety of treatments (not just the pretty ones), and we take comfort in the fact that the triage treatment made these artefacts safe to move and interact with. In the future, it would be possible to re-treat the encapsulated areas to make it more visually appealing, for example by in-painting to match the green colour of the surrounding steam engine housing.

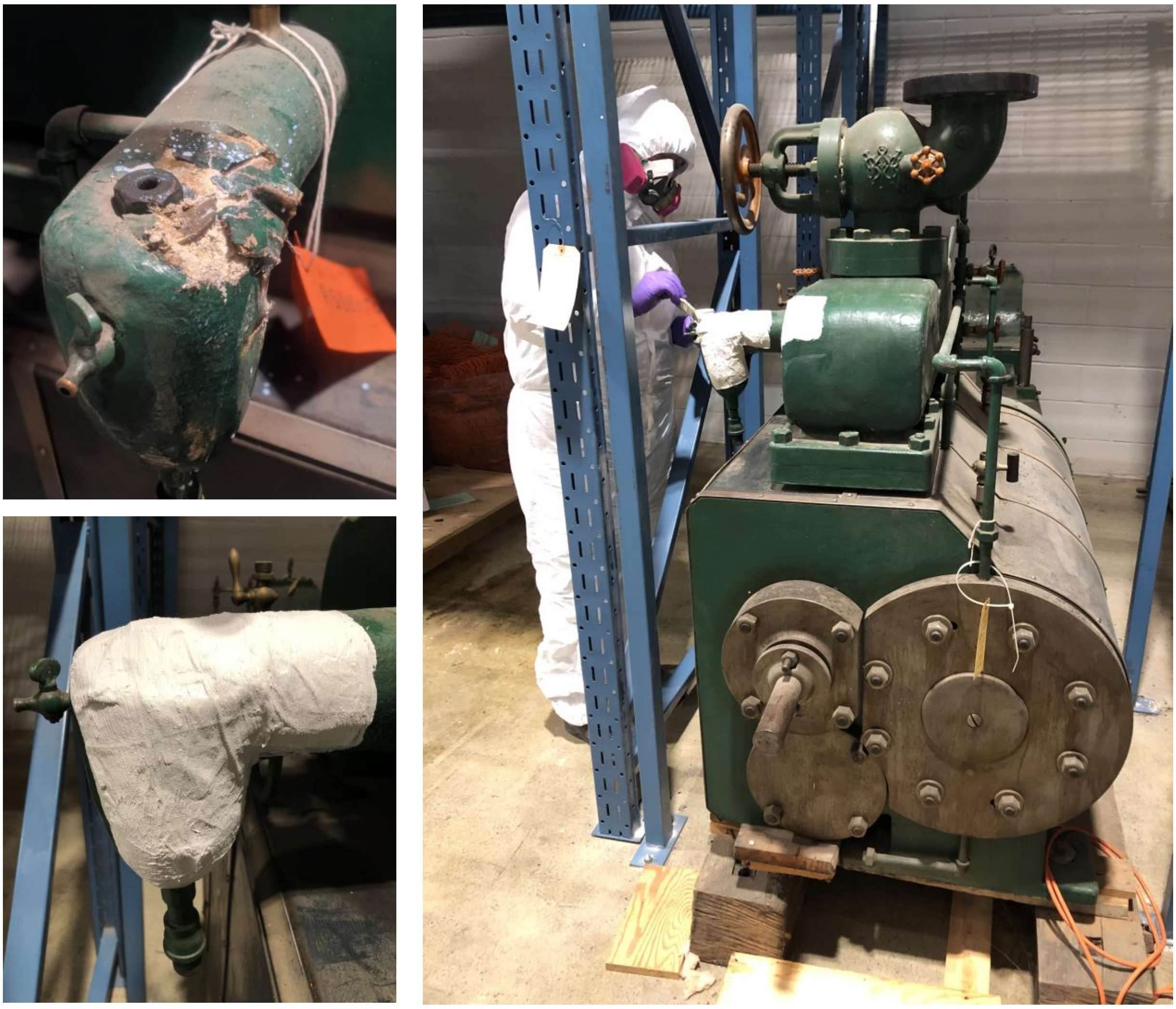

Figure 3. Encapsulation of friable asbestos by Ingenium conservators (Artefact number 1969.1317): *a)* detail of a friable area before treatment; *b)* detail of an area after treatment; *c)* during treatment showing a conservator wearing PPE.

Once the asbestos hazard was mitigated, the two steam engines were ready to be moved to the new purpose-built Ingenium Centre. However, both steam engines were too heavy to be moved by our in-house forklifts. As a result, we contracted specialist heavy machinery movers to move these and other overweight artefacts in the *2421 Reserve Collection*.

A tale of radioactivity

Radioactive hazards in museum collections

The radioactive collection at Ingenium includes a variety of artefacts and includes aircraft dials, ore samples, and historic wellness products (erroneously) thought to have positive health effects. The health effects of radiation are well known, including DNA changes, cancer, acute radiation syndrome (ARS), and cutaneous radiation injuries (CRI) [9]. High frequency or ionising radiation includes alpha (α), beta (β), and gamma (γ) rays. Alpha particles are unable to penetrate the skin but cause damage when inhaled or ingested into the body. Beta particles are able to penetrate the skin, but can be blocked by clothing or other thin barriers. The effects of β radiation are less harmful than that of αradiation, though once again the most harm is caused by ingestion or inhalation [10]. Gamma radiation causes the largest concern for health effects. Gamma radiation is able to penetrate and cause damage as it passes through the human body, and requires thick and dense shielding [10]. These three types of radiation make up the radiation hazards faced in a museum collection. While αand β are most concerning in the form of radioactive dust and flaking paints, γ radiation is a concern in all forms. A luminescent dial for example, would pose a risk of exposure to γ radiation based on proximity to the dial, but flaking paint or fine radium dust coming off the dial poses a risk of αand βdamage if ingested, inhaled, or if it were to enter the body through a cut.

Personal protective equipment can help to protect from α and β radiation. Tyvek suits, along with nitrile gloves and full face respirators can ensure that radioactive dust does not enter the body. Gamma radiation must be managed differently, by reducing the proximity to a radioactive source, and reducing the length of exposure [11]. In the case of Ingenium's large-scale collections move, the decision was to limit time of exposure to radiation by working as quickly and efficiently as possible with these artefacts. Radiation doses from each artefact were measured using a RadEye G-10 metre (Geiger counter) for γ radiation. A dosimeter 3700 survey meter was used to measure α and β radiation, and conservators wore whole-body and ring-format dosimeters to measure individual exposures.

Transport, disposal and storage of radioactive material is federally regulated in Canada under the *Nuclear Safety and Control Act* (S.C. 1997, c. 9) [12]. In order to ensure our processes followed the applicable legislation, we consulted with the Canadian Nuclear Safety Commission. Ingenium has been managing radioactive materials in collections for decades. Sue Warren, former Manager, Conservation Services, at Ingenium, has published on this topic and the luminous dial project which took place in the early 2000s [13].

Case study: a radium balance

Our next tale involves a radium balance with particular significance to Canadian industrial and radioactive history. This analytical balance and associated weights, bowls and tools were used in Port Hope, Ontario at the Eldorado Mining and Refining Company (Figure 4). They were used to weigh some of the first radium produced in Canada. As a result, the balance was covered in a layer of radioactive dust. Radium dust is hazardous when ingested, inhaled, or in contact with skin, due to the presence of γ, α, and βrays. Our first step was to take radiation readings at the surface of different areas of the balance, which read between 2 and 12 microSieverts per hour (µSv/hr) of γ radiation. For context, a person would have to work with this artefact for 83 hours to reach the annual public dose limit (APDL) of 1 milliSievert per year, a number that is set by the Canadian Nuclear Safety Commission [14].

Figure 4. Analytical balance (Artefact number 1969.1002).

So, direct exposure to radiation was a relatively low risk for this artefact. However, radium dust still posed an inhalation hazard. As a result, we wore personal protective equipment including Tyvek suits, nitrile gloves and particulate respirators while working with this and other radioactive artefacts. Our solution to the issue of radioactive dust was quite simple. We draped and sealed the balance in plastic sheeting during the move, to ensure the dust would be contained, and placed it in a Coroplast box for ease of handling (Figure 5). Once the balance had been moved to the new collections storage, the plastic was removed and disposed of with our PPE and other radioactive waste. This very simple approach allowed us to complete the move while maintaining the historic radium left on the balance.

The radioactive artefacts are now in their new home in the Ingenium Centre, stored in a purpose built radioactive artefact storage room. Artefacts were placed so that the radiation levels at the walls of the hallways and adjacent rooms measured below 2.5 μSv/hr, as recommended by the Canadian Nuclear Safety Commission. We also installed a radon gas sensor with a visual light alarm outside the room. The sensor will automatically vent to the outdoors should radon gas levels become too high, and the building operator will be notified.

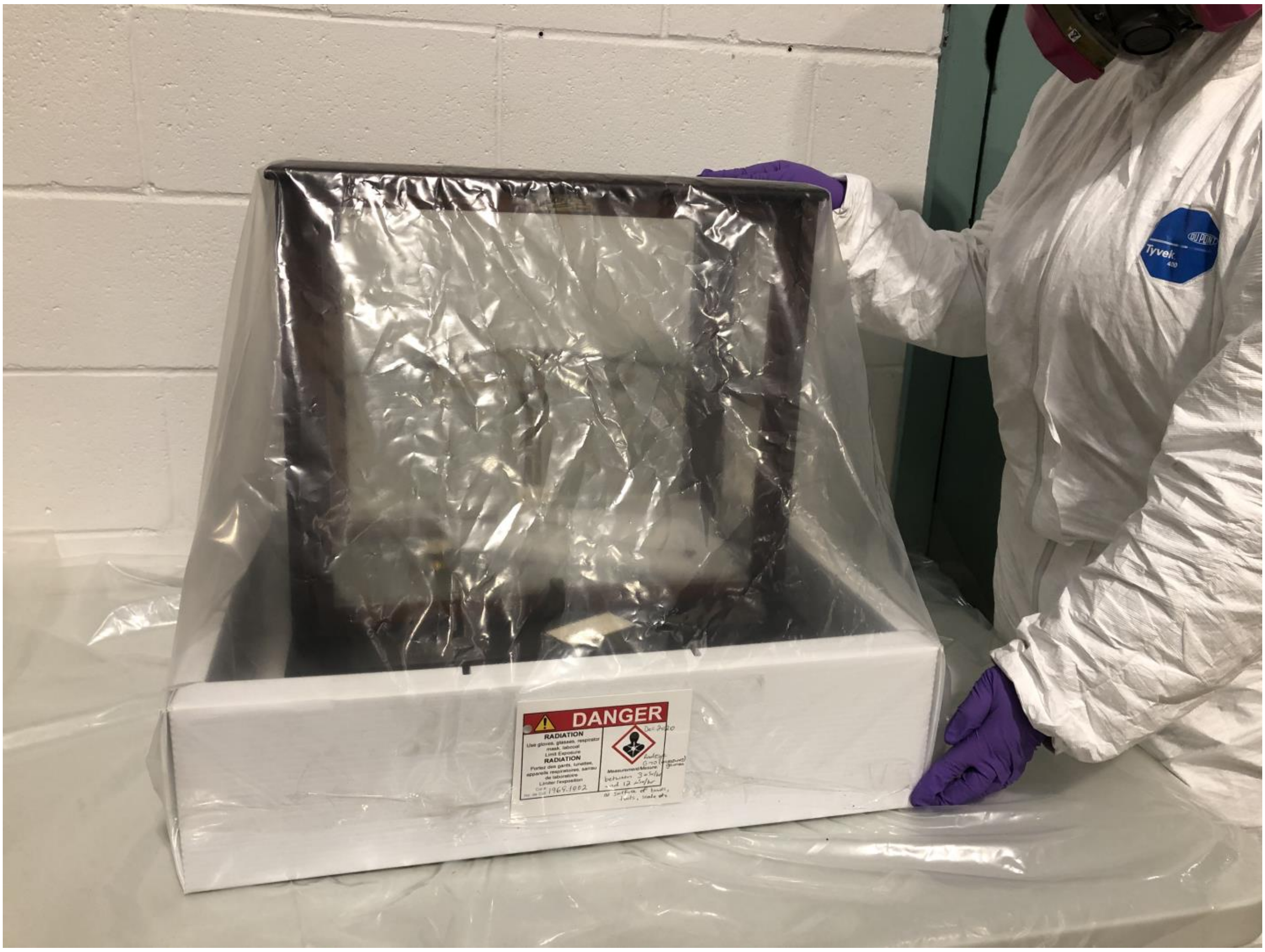

Figure 5. The radioactive analytical balance (Artefact number 1969.1002) contained in plastic during the collections move.

A tale of polychlorinated biphenyls (PCBs)

PCBs hazards in museum collections

Polychlorinated biphenyls, or PCBs, are a highly regulated class of compounds in Canada and internationally. They cause a wide variety of environmental and health concerns, including bioaccumulation, skin conditions, neurological damage, hormonal disruption, fertility damage, and cancer [15]. The first PCB was synthesised in the late nineteenth century but industrial production did not begin until 1929. Health concerns were first raised by the medical community as early as the 1930s, and in 1979 PCB manufacturing began to be regulated. In 2001, PCBs were included as Persistent Organic Pollutants in the United Nations Stockholm Convention [16].

PCBs are typically found in manufactured artefacts that need to withstand heat and provide fire resistance. They are most commonly found in capacitors, transformers, and electrical equipment. However, PCBs were also frequently used in hydraulic systems, brake fluids, plasticizers, paints, printing inks, fluorescent light ballasts, and carbonless copy paper. PCBs have also been used as pesticides and have been found applied to wooden artefacts in fine art museum collections [17]. Our research to date has focused on oils containing PCBs [18], and we have recently begun research into solid PCB materials.

In Canada, PCB legislation falls under the Environmental Protection Act (1999), *PCB Regulations* (SOR/2008-273) [19]. Museum collections are not currently considered an exception under the regulations, as a result, museums are not legally permitted to store any artefacts that contain materials with more than 50 ppm (or 50 µg/100 cm^2 surface contamination) of PCBs. Museums are also obligated to file an annual report detailing PCB-containing artefacts in their collection. Under current legislation, Canadian museums have until 2025 to be in full compliance and may be subject to inspections and fines for noncompliance.

Environmental contamination by PCBs, along with other persistent bioaccumulative toxic substances, have been shown to continually and disproportionately affect Indigenous peoples around the world [20]. As museums with colonial pasts, it is important to recognize that our collections hazards continue to contribute to this disproportionate impact, and that choosing to address PCBs and their history involves recognizing this impact and acknowledging our responsibility to dispose of PCBs safely going forward.

While Ingenium has long known that PCBs were present in our collection, testing and consequent documentation had been sporadic. In 2014, a major push was made to begin testing the large oil-filled transformers in the collection, and to conduct air quality testing. Since 2019, more comprehensive testing has been conducted as part of the collection move completed in August 2022. A significant portion of the testing and treatment of PCB materials in this period was conducted in the *2421 Reserve Collection*.

Case study: a tape-recorder player

This tape-recorder player was used between 1963 and 1996 as part of the Canadian Broadcasting Corporation (CBC) regional broadcast system inside the regional emergency headquarters in Nanaimo, British Columbia (Figure 6). The Nanaimo headquarters was one of seven underground bunkers across Canada designed to house military and government officials in case of a nuclear attack. Upon assessment of the artefact during the collections move, we found six black cylindrical capacitors in the interior which were stamped with Pyranol, a PCB trade name.

Figure 6. Tape-Recorder player (Artefact number 1996.0284).

This type of Pyranol capacitor is filled with a black potting material which has deteriorated, slowly melting onto lower surfaces (Figure 7a). We took a sample and sent it to an external environmental analytical laboratory for analysis via gas chromatography electron capture detection (GC-ECD) according to Environmental Protection Agency Method 8082A to determine its PCB levels [21-22]. The test result was 32100 µg/100 cm^2, indicating extremely high levels of PCB surface contamination, beyond the legal limit for museums in Canada.

The test results and the historical significance of the artefact created a dilemma. The capacitors could not be legally kept, but the artefact itself should remain in the national collection. Upon consultation with the curator, we determined that removal of the capacitors was the best option, allowing us to legally retain the rest of the unit. Due to the high level of PCBs, this work was done by specialised PCB mitigation contractors, who were brought in to work on a number of high level PCB artefacts. The contractors removed the capacitors, and decontaminated any surfaces that the potting material was in contact with using Varsol on cotton rags. We directly supervised the contractors, and assisted with disassembly of the artefact where needed. We also documented the work using digital photography and written treatment reports. Figure 7b shows an area after removal of a black cylindrical capacitor, and cleaning of PCB residues. Six capacitors were removed and documented photographically with written descriptions, and were disposed of as PCB waste.

This case study provides an example of one of our protocols for PCB mitigation in historic artefacts. For other artefact types, other methods of PCB mitigation such as draining PCB oil, or complete deaccession of the artefact were more appropriate [18]. Collectively, our PCB mitigation protocols ensure continued safe access to our collections.

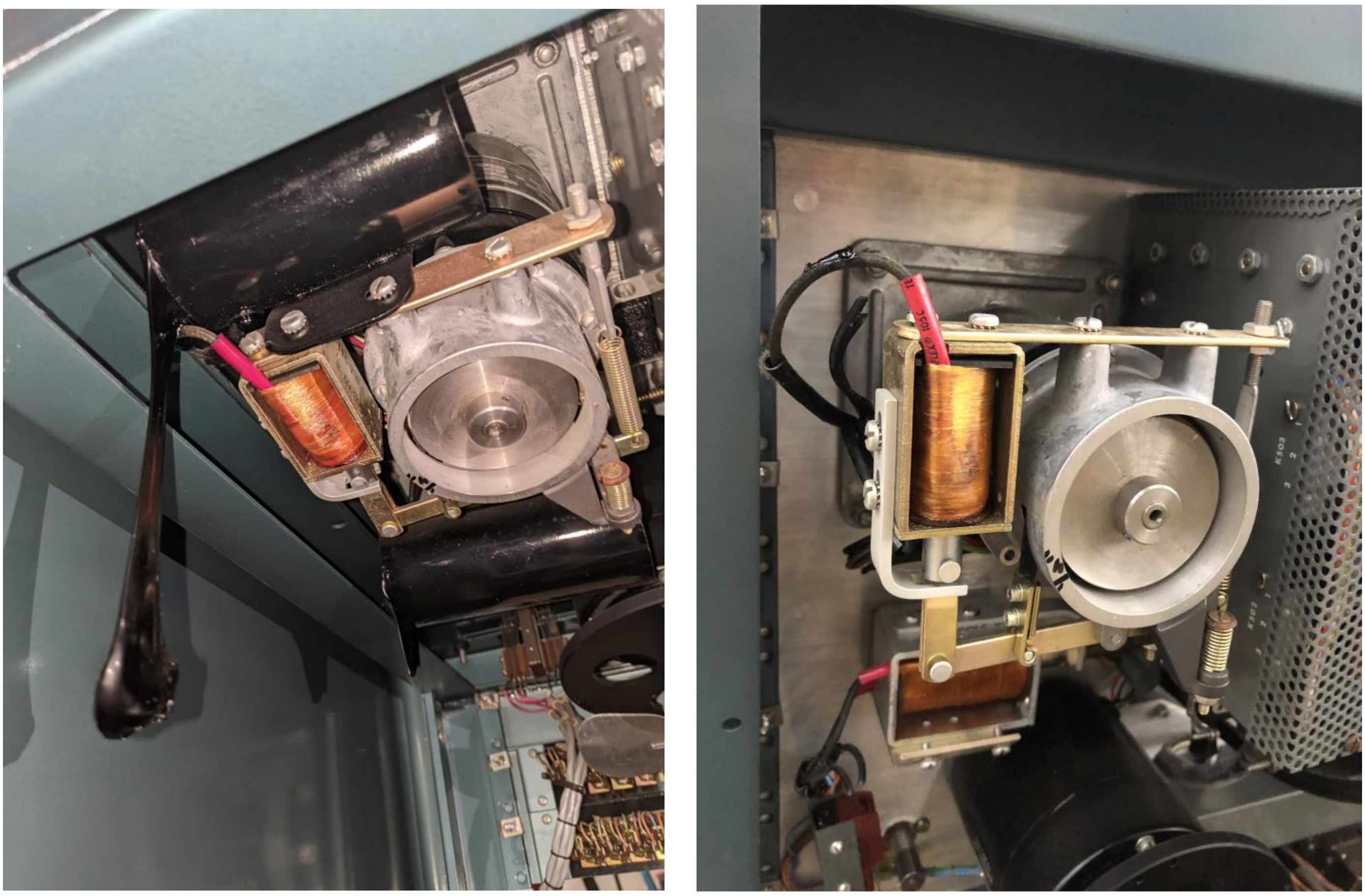

Figure 7. Remediation of PCB hazards in the tape recorder-player: *a)* before removal of PCB (Pyranol-branded) capacitor, showing black melting potting material; *b)* after removal of PCB capacitor.

A tale of mercury

Mercury hazards in museum collections

Mercury is an elemental metallic substance which is known for its liquid state at ambient temperature and its low viscosity. It causes a variety of neurological and other adverse health effects and is especially hazardous in its vaporous state [23]. The effects of mercury include neuromuscular changes, kidney damage, mood instability, and even death at high levels of exposure [24]. As mercury readily evaporates, any mercury spill is a cause for concern within a museum collection. A spill will quickly scatter into a dust-like coating on all surrounding surfaces, making it very difficult to clean, and increasing surface area from which to evaporate. In museum collections, mercury is found in a variety of artefacts, and several papers have been written regarding mercury pesticides and pigments in collections [25-26]. In Ingenium's collections, mercury is commonly found in thermometers, barometers, medications, rain gauges, pesticides on textiles, mineral collections and taxidermy, and electricity meters. This mercury is present in elemental forms, organic compounds such as methylmercury, and in inorganic compounds such as dental amalgamations.

Case study: crates of electrical meters

One of the challenges we faced during the collection move was large crates filled with unknown and uncatalogued artefacts from early electrical history. Many of these crates had not been opened since their arrival in 1992, following the closure of the Ontario Hydro Museum of Electrical Progress. Newspapers and magazines used as packing material indicated that the crates were likely last packed in the 1960s and 1970s. Upon arrival at Ingenium, each crate had been given an overall accession number for tracking purposes, but only a few crates had been assessed or repacked by Ingenium staff. There were approximately 30 crates, each with an average of 100 meters and other small electrical components. It became immediately apparent that unlabelled and unstable mercury-containing artefacts in these crates was of high concern.

During inspection of one of the first crates, we found a small mercury spill in the crate packing material. This incident prompted a thorough assessment of each crate to ensure we were not overlooking the risk of an additional mercury spill. Through this assessment we determined that the risk was highest in two situations. Firstly, some meters had a mercury switch present. These were sometimes in an additional wiring box on the meter, but other times were found only by opening the unit. Figure 8 shows two examples of mercury switches located inside two meters.

The second mercury risk in this collection was much easier to identify. Mercury type meters, such as those manufactured by Ferranti or Sangamo, contain a reservoir component (Figure 9). Many of the mercury meters in our collection had failed seals, which allowed mercury to leak into the meter case. Due to the expectation that all seals will eventually fail, causing future spills, we separated all mercury containing meters from the crates and stored them in plastic bins in our chemical artefact storage room. Any spills we encountered were cleaned using a Mercon mercury spill kit and a respirator with mercury vapour cartridges was worn in the presence of open mercury.

All mercury containing artefacts, including the meters, are now stored together in our chemical artefact storage room, including those found in the *2421 Reserve collection*. As an outcome of this project we acquired a mercury vapour monitor system for use in the chemical artefacts storage room. The VM 3000 Mercury Vapour Monitor sends notifications through audible and visual alarms, and email alerts when mercury vapour levels rise beyond a pre-set threshold, indicating the potential presence of a mercury spill and ensuring effective cleanup.

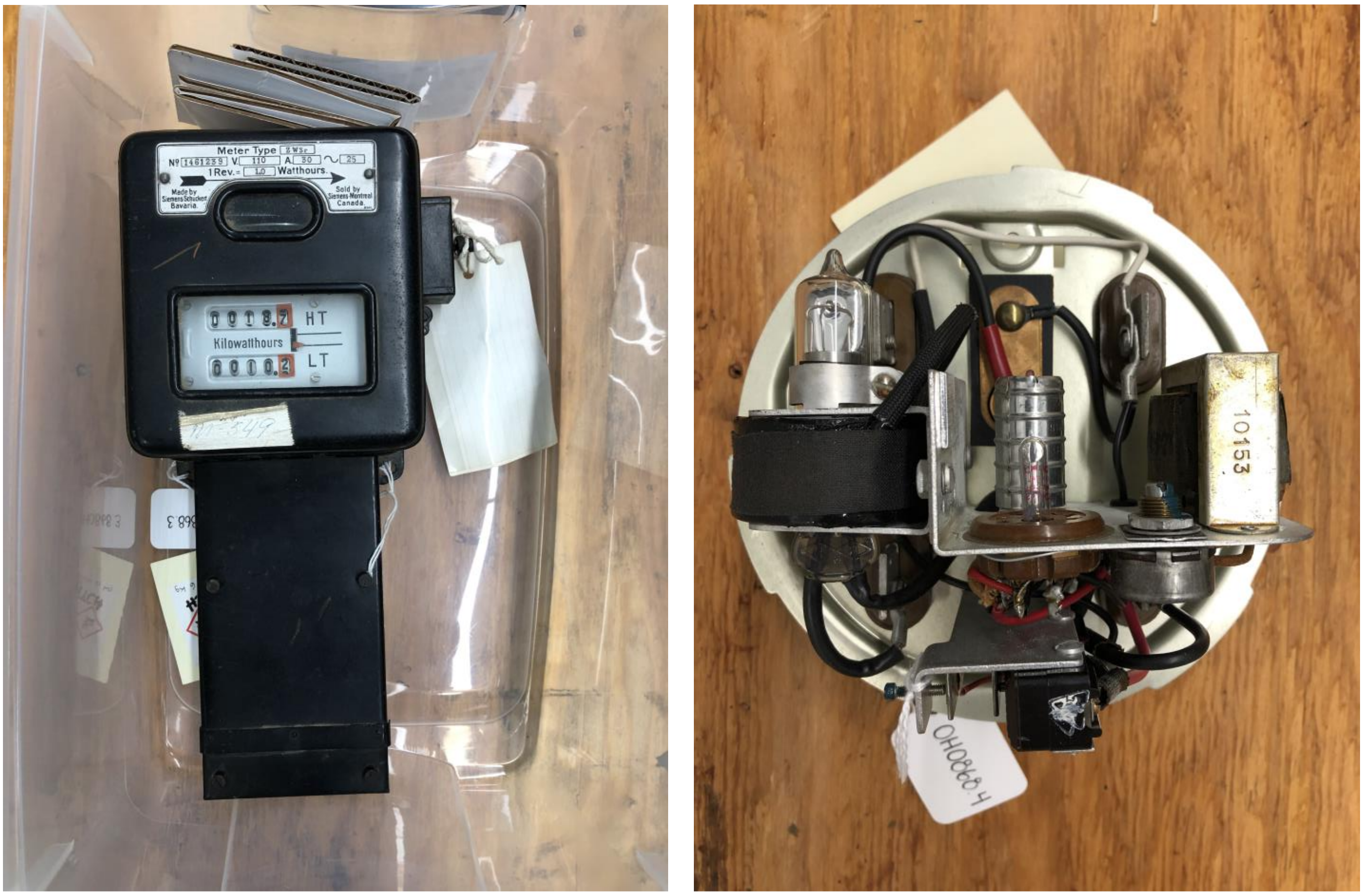

Figure 8. Examples of mercury switches in electrical meters: *a)* Siemens meter; *b)* Lumatrol meter.

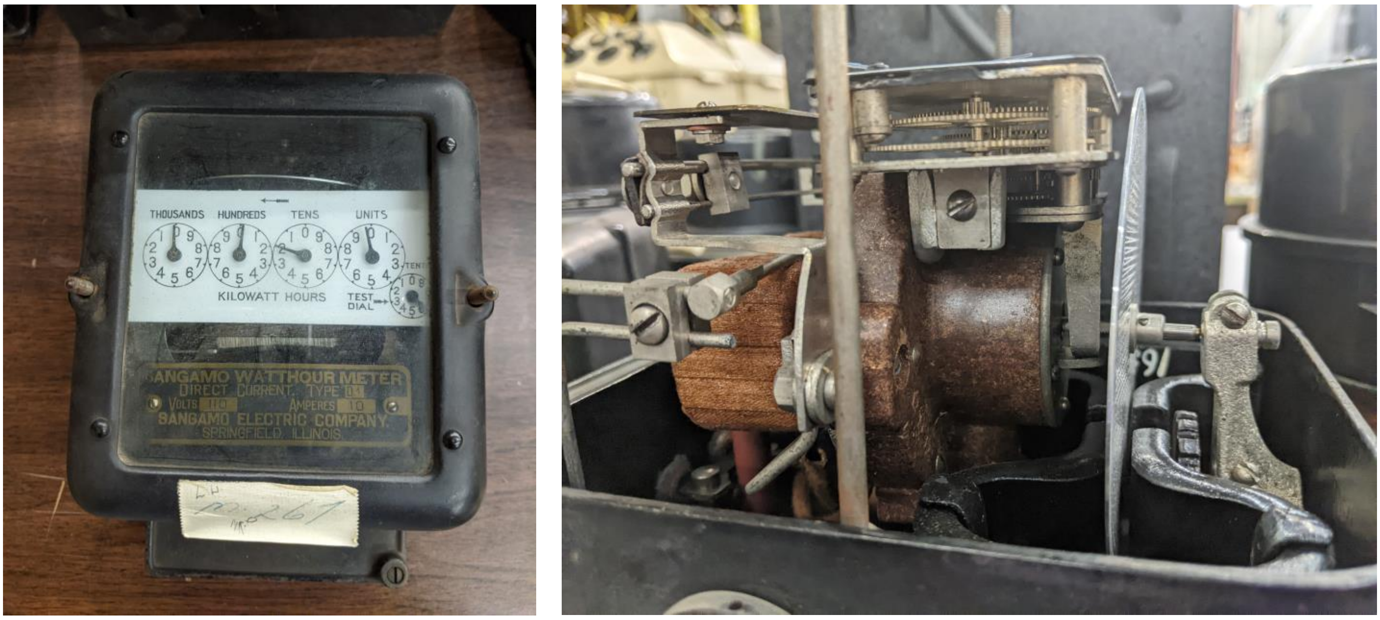

Figure 9. Example of a meter with a mercury reservoir, a Sangamo Type D meter: *a)* overall view; *b)* a mercury reservoir (brown component) in the interior of the meter.

Conclusions

The collections move provided an opportunity to assess and mitigate a variety of hazards in the collection. The move of the 5500 artefacts from *Building 2421* is a microcosm revealing that industrial collections such as these can be extremely hazard-rich, and showing the ability of Ingenium's CRMP process to effectively screen for hazards. Out of 5500 artefacts, we identified 1133 hazards, over 20 % of the total collection stored in *Building 2421*.

The case studies demonstrate how we dealt with typical hazards in the collection. Triage-type conservation treatments can be considered successful despite being visually incongruous, and are an essential tool in a large-scale collections move. Identifying hazards and understanding the regulations that allow a safe work environment are the first steps in ensuring that an industrial collection can be moved safely and legally. Laws dictate how certain hazardous artefacts can be treated, transported, labelled and stored. Knowing these laws lays out a framework, which gives us the knowledge and confidence to work with these materials, and sets limits which ensure the safety of all conservation staff. In these situations, outside contractors can provide the necessary knowledge, skills, and accreditations to effectively mitigate hazards. From simple solutions as demonstrated in the radioactive and mercury case studies, to mitigation treatments as with the asbestos and PCB case studies, we prioritise safety above all.

The new Ingenium Centre storage building has increased collection access and safety, with advanced hazard detection equipment like the radon sensor and the mercury vapour sensor. Better shelving, visual hazard tagging and updated hazard fields in the database mean the collection is not only in a much better environment, but that the researchers and public accessing the collection can take the appropriate precautions to do so. The move was completed on schedule, despite several COVID lockdowns. All of Ingenium's collections from our rental warehouses are now fully moved and incorporated into the new Ingenium Centre.

Acknowledgements

We would like to acknowledge the work of Erin Secord, Manager, Conservation Services at Ingenium for her instrumental work in developing the Collections Risk Management program. We would also like to acknowledge the work of Alyson Tang, Assistant Conservation Technician for her contribution to the Ontario Hydro move from 2020 to 2021.

REFERENCES

1. King, D., 'History of asbestos' (2022-12-20), in *Asbestos.com*, The Mesothelioma Center at Asbestos.com, https://www.asbestos.com/asbestos/history/ (accessed 2023-01-10).
2. 'The Government of Canada takes measures to ban asbestos and asbestos-containing products', in *Environment and Climate Change Canada*, Government of Canada, https://www.canada.ca/en/environment-climate-change/news/2018/10/the-government-of-canada-takes-measures-to-ban-asbestos-and-asbestoscontaining-products.html (accessed 2023-01-10).
3. 'Asbestos - health effects' (2021-04-07), in *OSH Answers Fact Sheets*, Canadian Centre for Occupational Health and Safety, Government of Canada, https://www.ccohs.ca/oshanswers/chemicals/asbestos/effects.html (accessed 2023-01-10).
4. Holzer, C., 'Asbestos containing objects in museum collections: the conservation of an asbestos suit in the Technical Museum Vienna, Austria', in *Student Posters Congress The Decorative, International Institute for Conservation of Historic and Artistic Works*,Vienna (2012), https://www.iiconservation.org/congress/sites/iiconservation.org.congress/files/IIC%202012%20Vienna%20Congress/student-posters/student-poster-518.pdf (accessed 2023-01-10).
5. 'O. Reg. 278/05: designated substance - asbestos on construction projects and in buildings and repair operations', in *Occupational Health and Safety Act, R.S.O. 1990, c. O.1*, https://www.ontario.ca/laws/regulation/050278 (accessed 2023-01-12).
6. 'Childers® CP-240 CHIL-LOCK Asbestos Removal Agent/Post Removal Sealer', in *Foster Childers*, https://fosterproducts.com/product/foster-cp-240/ (accessed 2023-01-10).
7. 'Childers® CP-211 CHIL-BRIDGE™ Bridging Encasement/Encapsulant Coating', in *Foster Childers*, https://fosterproducts.com/product/foster-cp-211/ (accessed 2023-01-10).
8. 'Asbestos - control strategies for workplaces' (2021-04-27), in *OSH Answers Fact Sheets*, Canadian Centre for Occupational Health and Safety, Government of Canada, https://www.ccohs.ca/oshanswers/chemicals/asbestos/control.html (accessed 2023-01-10).
9. 'Health effects of radiation' (2021-08-06), in *Radiation and Your Health*, Centers for Disease Control and Prevention, https://www.cdc.gov/nceh/radiation/health.html (accessed 2023-01-10).
10. 'Radiation basics' (2022-06-24), in *Radiation Protection*, United States Environmental Protection Agency, https://www.epa.gov/radiation/radiation-basics (accessed 2023-01-10).

11. 'Protecting Yourself from Radiation' (2022- 07-05), in *Radiation Protection*, United States Environmental Protection Agency, https://www.epa.gov/radiation/protecting-yourself-radiation (accessed 2023-01-11).
12. 'Nuclear Safety and Control Act (S.C. 1997, c. 9)' (2022-12-12), in *Justice Laws Website*, Government of Canada, https://laws-lois.justice.gc.ca/eng/acts/N-28.3/ (accessed 2023-01-12).
13. Warren, S., 'Dealing with radiation hazards: the luminous dial project at the Canada Science and Technology Museum', *Journal of the Canadian Association for Conservation* **35** (2010) 9-15, https://www.cac-accr.ca/wp-content/uploads/2018/12/Vol35_doc2.pdf (accessed 2023-01-10).
14. 'Radiation doses' (2020-12-22), in *Radiation*, Canadian Nuclear Safety Commission, Government of Canada, https://nuclearsafety.gc.ca/eng/resources/radiation/introduction-to-radiation/radiation-doses.cfm (accessed 2023-01-10).
15. 'Learn about polychlorinated biphenyls (PCBs)' (2022-06-05), in *Polychlorinated Biphenyls*, United States Environmental Protection Agency, https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs (accessed 2023-01-10).
16. 'The 12 initial POPs under the Stockholm Convention', in *Stockholm Convention*, United Nations Environment Programme, http://www.pops.int/TheConvention/ThePOPs/The12InitialPOPs/tabid/296/Default.aspx (accessed 2023-01-10).
17. Covaci, A.; Kawaki, P.; Indekeu, C.; Schepens, P.; Neels, H., 'Highly chlorinated toxic contaminants in pesticide-treated wooden art objects', *Archives of Environmental & Occupational Health* **61**(6) (2006) 245-248, https://doi.org/10.3200/AEOH.61.6.245-248.
18. Riddle, J.; Marshall, S., '"Don't you know that you're toxic?": Identification and hazard mitigation of Polychlorinated biphenyls (PCBs) during a large-scale collections move', oral presentation, Canadian Association for Conservation Annual Meeting, Hamilton, Ontario, 26-28 May 2022.
19. 'PCB Regulations (SOR 2008-273)' (2023-01-03), in *Justice Laws Website*, Government of Canada, https://laws-lois.justice.gc.ca/eng/regulations/sor-2008-273/index.html (accessed 2023-01-11).
20. Hoover, E.; Cook, K.; Plain, R.; Sanchez, K.;Waghiyi, V.; Miller, P.; Default, R.; Sislin, C.; Carpenter, D., 'Indigenous Peoples of North America: Environmental Exposures and Reproductive Justice', in *Environmental Health Perspectives* **120**(12) (2012) 1645-1649, https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.1205422 (accessed 2023-01-11).
21. *Protocol for Testing and Sampling at PCB Storage Sites in Ontario*, Ontario Ministry of the Environment, Queen's Printer for Ontario (2000), https://clu-in.org/download/contaminantfocus/pcb/protocol-for-sampling-ontario-4049e.pdf (accessed 2023-01-11).
22. 'Method 8082A: Polychlorinated Biphenyls (PCBs) by Gas Chromatography', *United States Environmental Protection Agency* (2007) https://www.epa.gov/sites/default/files/2015-12/documents/8082a.pdf (accessed 2023-01-11).
23. 'Mercury and health' (31-03-2017), in *Fact Sheets*, World Health Organisation, https://www.who.int/news-room/fact-sheets/detail/mercury-and-health (accessed 20-01-2023).
24. 'Health effects of exposure to Mercury' (2022-04-14), in *Mercury*, United States Environmental Protection Agency, www.epa.gov/mercury/health-effects-exposures-mercury (accessed 2023-01-11).
25. Goodall, R. A.; Measday, D. 'Measuring and mitigating mercury vapour in the collection cabinets at Museums Victoria', *AICCM Bulletin* **41**(2) (2020) 140-151, https://doi.org/10.1080/10344233.2020.1870301.
26. Strahan, D.; Tsukada, M., 'Measuring mercury emissions from cinnabar lacquer objects', *Studies in Conservation* **61**(3) (2016) 166-172, https://doi.org/10.1080/00393630.2016.1227048.

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Exploring Andalusian industrial heritage through data science: breaking down the gaps and concerns to visualise opportunities

Estudo do património industrial andaluz através da ciência de dados: diminuindo as lacunas e dificuldades para visualizar oportunidades

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Abstract

Industrial heritage, understood as the group of elements related to the work culture and production activities that emerged during the industrial revolution, has been surveyed and documented extensively in Spain in recent decades. This is particularly the case of recent years thanks to the advent of digital tools and systems. In the case of Andalusia, the efforts to document, disseminate and protect industrial heritage have been the subject of a variety of actions and projects. This paper describes the methodology used and the results obtained from a review of the existing 1,443 records of immovable assets of industrial heritage. The results point to deficiencies in the updating and incorporation of information in the Digital Guide, and to the need to carry out actions geared more towards understanding the elements as an integral whole made up of the landscape in which they appear.

KEYWORDS
Industrial heritage documentation
Heritage data science
Heritage database
GIS analysis
Assessment of heritage data records

Resumo

O património industrial, entendido como um conjunto de elementos ligados à cultura de trabalho e atividades de produção que surgiram durante o processo da revolução industrial, tem sido objeto de estudo e documentação em Espanha, nas últimas décadas e, em particular, com maior impulso nos últimos anos, graças à utilização de ferramentas e sistemas digitais. No caso da Andaluzia, os esforços para a sua documentação, divulgação e proteção têm sido objeto de várias ações e projetos. Este artigo descreve a metodologia utilizada e os resultados obtidos a partir de uma revisão dos 1443 registos existentes de elementos imóveis do património industrial. Os resultados mostram deficiências na atualização e incorporação de informação na Guia Digital, e a necessidade de executar ações orientadas para compreender e documentar os elementos de maneira mais integral, considerando os aspetos da paisagem em que aparecem.

PALAVRAS-CHAVE
Documentação do património industrial
Ciência de dados do património
Base de dados do património
Análises SIG
Avaliação dos registros de dados do património

Introduction

Industrial heritage, understood as the "remains consisting of buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transport and all its infrastructure, as well as places used for social activities related to industry such as housing, religious worship or education" [1] has close ties with the production, technology, culture, economy, ecology and knowledge produced during the industrial revolution. Furthermore, it has enormous value as a testament of the past and as an asset that can be reused today. Industrial heritage encompasses a wide range of elements and relations, both tangible and intangible, which demand a series of actions: from the identification, documentation and analysis of the assets to their treatment and intervention. Documenting, analysing and managing such a large volume of assets and information is extremely difficult with traditional tools and methods, and becomes even more challenging when we consider the different disciplines involved. It is of the utmost importance to ensure that this information is visible and to recognise its tangibility because both (information and tangibility) are sources of knowledge and play a vital role in preserving and promoting the memory of industrial heritage [2].

In Spain, industrial heritage has a different chronology from other countries, stretching from the mid-eighteenth century, with the advent of mechanisation, until the introduction of automated systems in the 1960s. Likewise, the industrial phenomenon did not occur homogeneously or at the same time across Spain. In the regions themselves, the difference is significant, with periods of greater impact in Catalonia and the Basque Country than in other regions. In the case of Andalusia, the pioneering experience occurred in the province of Malaga, in the steel and textile sectors. Until the early decades of the twentieth century, the contribution of Andalusian industry to the national industry largely reflected its population weight (between 17 % and 18 %) [3].

In recent decades, different national and regional bodies have gradually compiled an inventory of these assets. In the case of Andalusia, between 1993 and 1997 the Directorate General for Cultural Assets (the DGBC, after the Spanish acronym) compiled the "Inventory of Popular Architecture", and following the enactment of Law 14/2007 [4], three assets have been designated "sites of cultural interest" as assets of ethnological heritage: 1) the Alquife Mines; 2) the pier and village of Puerto de la Laja, the old mining railway and the village of Cañada del Sardón; and 3) La Tortilla Mine-Foundation, plus other assets in the Rio Tinto heritage area. In 1996 the DOCOMOMO (*Comite Internacional para Documentação e Conservação de Edificios, Sítios e Bairros do Movimento Moderno*) carried out a survey on industrial architecture in Spain, leading to the publication in 2004 of *La arquitectura de la industria, 1925–1965. Registro Docomomo Ibérico* [5]. Of the 160 buildings documented, 12 are located in Andalusia: *Presa del Jándula* (Jándula dam); *Hilaturas y Tejidos Andaluces* (textile plant); *Instalaciones mineras de producción de oro* (gold mines); *Presa de Anchuricas* (Anchuricas dam); *Central Térmica Cristóbal Colón* (thermal power plant, water control centre); *Industrias Lácteas Colecor* (dairy plant); *Industrias Textiles del Guadalhorce* (textile plant); *Gran Bodega del Tío Pepe* (winery); *Fábrica de cervezas El Águila* (brewery); *Compañía Internacional de Telecomunicaciones y Electrónica* (telecoms and electronics company); *Cydeplas* (plastic container plant); and *Fábrica Tecosa* (electronics factory). In 2006, aimed at disseminating a wider public knowledge, the Regional Housing and Land Management Ministry published *Patrimonio Industrial de Andalucía. Portfolio Fotográfico* with photographs of 28 industrial assets and spaces in the region [6]. Between 2005 and 2008, the Andalusian Institute of Historical Heritage (the IAPH, after the Spanish acronym), in collaboration with the DGBC and the University of Seville, compiled the Andalusian Register of Contemporary Architecture, which includes 67 industrial heritage assets. In 2011, the IAPH Documentation and Research Centre carried out a Research, Development and Innovation (R&D&I) project to analyse and diagnose the existing information about Andalusian industrial heritage [7-8]. In this document, Santofimia sets out guidelines for improving the systematisation of information in the Regional Ministry of Culture's information system. The project diagnosed the information on 203 Andalusian industrial heritage assets. That same year, the IAPH embarked on a collaboration with the Institute of Spanish Cultural Heritage (ICE, after the Spanish acronym) to draw up and monitor the National Industrial Heritage Plan [9]. Since then, the IAPH has been carrying out different actions and initiatives to document disseminate and raise public awareness about industrial heritage, especially in schools.

On a pan-Spain level, the first National Industrial Heritage Plan listed 49 assets [9]. Ten years later, the list had reached 100 and today it stands at 177 assets, all with basic information including the name and area occupied by the asset (or assets in the case of ensembles and landscapes), land registry details, situation with respect to the immediate vicinity, photographs, description, industrial sector, ownership and protection regime, state of repair, uses, etc. Of these 177 assets, 17 are located in Andalusia [10]. The actions and efforts for the inventory of industrial heritage at the national and local levels were carried out in a complementary manner. Currently, the National Industrial Heritage Plan is under review in collaboration with the IAPH for the Andalusian region.

The identification and documentation of built heritage is the preliminary step to deal with any work, research, management or problem related to it and forms part of the initial phases in the heritage value chain [11]. The procedure for identifying and documenting a specific immovable asset consists in gathering and processing different types of data, from the name, location and historical context to the physical description. This same heterogeneity is also found in the types of documentary sources and data formats, which range from texts and photographs to maps, site plans and other media. Digitalisation and the development of computational methods have speeded up the generation, editing, analysis, management and dissemination of the data gathered to document heritage. At the same time, they have facilitated the cross-disciplinary creation of information. In the field of industrial heritage, computational data provide specific solutions for a range of problems while offering different actions for saving, representing and understanding the elements involved. However, this complex system of digital processes and objects requires the definition of criteria and methods for differentiating between the nature of data, their analysis, processing and interpretation, and the results obtained: in other words, data, information and, knowledge [12].

Another point to bear in mind is that the maintenance, updating and dissemination of heritage information require constant and meticulous management by the competent public bodies, something which is often underestimated. In this respect, and in addition to actions to improve the dissemination and quality of heritage information, the primary objective of this survey is to offer a diagnosis about the records of immovable industrial heritage assets in Andalusia. The research was prompted by the need to revise and update the Andalusian Digital Guide Platform [13] to improve the quality of the open data, ensure greater access and reuse of the data, and develop a documentation plan for Andalusian industrial heritage in line with current needs. The following objectives were established:

- Gather and select records of assets belonging to the ten sectors of industrial heritage [7]: agri-food; railway; energy; chemical and cement; construction, ceramics and glass; cork, wood and furniture; textile; steel, metallurgy and metal construction; naval; and mining.
- Carry out a quantitative and qualitative analysis of the data.
- Generate visualisations of the data analyses to provide a clearer picture of the gaps and deficiencies detected.
- Develop a guideline for the documentation of the Andalusian industrial heritage.

Methodology

Main source: Digital Guide of Andalusian Cultural Heritage

It is important to point out that the Digital Guide Platform [13] is an open resource containing a large structured database of heritage records created with a controlled and systematised vocabulary. For example, it uses a specific terminology to classify and describe types, activities, events and historical periods based on the IAPH Heritage Thesaurus.

This digital resource was chosen as the main source of information for the survey because of the large and easily accessible volume of heritage data, which we were able to download as tables organised by fields, as shown below. The Digital Guide is also linked to the MOSAICO, an information system for the management of cultural heritage in Andalusia, ensuring the reliability of the data we proposed to analyse.

In the Guide users can search and explore the collections classified by heritage type: movable, immovable, intangible and, cultural landscapes. Most of the records are georeferenced and users can therefore view a base map to locate them and identify the spatial relationships between the heritage assets and the physical and human geographical aspects. Each asset is clearly identified and the descriptions also include the people involved in their construction, remodel or restoration. Lastly, the records contain details of the level of protection, bibliographic references, and links to other records in the guide as well to the institutional repository [14].

Information and data surveyed

Since the primary objective of this survey was to diagnose the state of the quantitative and qualitative information and data about the industrial heritage in Andalusia, we began by defining a set of general criteria to select the records. Accordingly, we only analysed records from the late modern period (the period from the mid-eighteenth century to the present, also referred to as the "contemporary period" by heritage professionals in Spain) and that belonged to the immovable heritage type. The scope of our diagnosis did not include records from earlier historical periods, although there are currently over 300 such records in the Digital Guide.

For the analysis, we surveyed the records that are open to public access from the Digital Guide Platform. Having established the preliminary criteria – historical period, heritage type and source – we then defined specific search criteria for each sector of industrial heritage. For this purpose, we selected a list of sectors, types and activities from the IAPH thesaurus that had been previously defined by Santofimia [7]. It covers 10 sectors, 76 types and 11 activities (Table 1).

The survey methodology consisted of six phases:

1) Identification of previous actions carried out to document industrial heritage.
2) Definition of the search criteria and sample selection.
3) Definition of the criteria and parameters for the quantitative and qualitative analyses.
4) Data gathering, downloading and processing.
5) Analysis and visualisation.
6) Interpretation of the results and proposed action plan.

The first phase consisted in gathering and summarising the actions carried out at the regional and national level to determine how the documentation process has evolved over time and to identify the gaps. This search was largely concentrated around the sources in situ (reports) and easily accessible online sources (DOCOMOMO, IAPH and Spanish Ministry of Culture and Sport).

Table 1. Potential examples of a conservator's caring thinking theory

Sector	Types	Activities
1. Agri-food	1. Sugar cane factories 2. Distilleries 3. Sugar cane mills 4. Olive presses 5. Water mills (flour) 6. Flour mills 7. Oil mills 8. Windmills 9. Tide mills 10. Oil factories 11. Olive pomace oil factories 12. Salting factories 13. Flour factories 14. Breweries 15. Tobacco factories 16. Soap factories 17. Soap plants 18. Semolina factories 19. Salt pans 20. Silos 21. Wineries 22. Tuna fisheries 23. Crushing plants 24. Canning factories 25. Bakeries 26. Wine presses 27. Granaries 28. Essence factories	1. Wine production 2. Vine growing 3. Olive oil production 4. Olive growing 5. Oil production 6. Flour production 7. Milling
2. Railway	1. Railway buildings 2. Railway stations (transport) 3. Transport infrastructures 4. Railway networks 5. Bridges* 6. Loading bays	
3. Energy	1. Electric energy factories 2. Electric infrastructures 3. Electric power plants 4. Hydraulic infrastructures 5. Energy plants	1. Energy production
4. Chemical and cement	1. Cement factories 2. Lime plants 3. Quarries 4. Gunpowder factories	
5. Construction, ceramics and glass	1. Pottery yards 2. Pottery workshops 3. Brick yards 4. Ceramic factories 5. Glass factories 6. Tableware factories 7. Brick factories	
6. Cork, wood and furniture	1. Carpentry workshops 2. Sawmills 3. Barrel and cask factories 4. Cork factories	
7. Textile	1. Weaving sheds 2. Fulling mills 3. Cotton plants 4. Spinning mills 5. Tailor's shops 6. Leather workshops 7. Paper factories	1. Dressmaking
8. Steel, metallurgy and metal construction	1. Forges 2. Smithies 3. Steel plants 4. Aircraft factories 5. Iron oxide factories 6. Artillery factories 7. Pellet factories 8. Car factories	
9. Naval	1. Shipyards 2. Docks 3. Ship repair yards	1. Ship construction
10. Mining	1. Extractive plants 2. Settling basins 3. Foundries 4. Mineral washing plants	1. Mining

*Since "railway bridges" does not exist as a type, we searched by "bridge" and then checked each record to verify whether it belonged to the railway sector or not.

Table 2. Attributes and respective descriptions. The first eight attributes are borrowed from the Digital Guide of Andalusian Industrial Heritage. The last two, "Information quality" and "Graphic resource", were added to supplement our analysis of the record contents.

Attribute	Description
Code	Record code that appears in the asset identification in the Digital Guide
Province	Province to which the record belongs
Town	Town to which the record belongs
Name	Name of the asset
Type(s)_Activity(ies)	Asset type(s) and/or activity(ies)
Historical period(s)	Historical period(s) to which the asset belongs
Protection regime	Legal entity responsible for the asset
Legal type	Classification of the asset according to the Andalusian Historical Heritage Act
Information quality	Classification of the information found in the "Description" and "Historical description" fields in the asset record, according to three categories: 1) Good, ii) Historical information missing, and iii) Incomplete
Graphic resource	Existence or not of a graphic resource of the asset in the Digital Guide

In the second phase consisting of the definition of the search criteria, we determined that the searches would focus exclusively on records from the contemporary period belonging to the ten sectors of immovable industrial heritage, with their respective types and activities.

In the next phase we defined the criteria and parameters for the quantitative and qualitative analyses (attributes) that we wanted to analyse. The first step in this process was to conduct a graphic analysis of a sample of 100 assets to test the data visualisation and the type of information gathered. After conducting the tests and verifying the results, we defined ten attributes to gather data from each record (Table 2).

Having selected the assets according to the above criteria, we proceeded to download the data from the Digital Guide as CSV files for processing as XLSL files. For this survey, the data processing phase consisted in "cleaning the data", i.e. correcting characters not recognised when importing the data to XLSL and removing data repeated in certain fields (for example, in many records the "Type" field repeats the name, i.e. the same field might contain "sugar cane factory, sugar cane factory").

Having completed the fourth phase of gathering, downloading and processing data, we proceeded to perform the different qualitative analyses. As the first step, we checked each record to analyse the "Documentation" and "Graphic resource" fields and insert the attributes in these fields into the analysis table. Having completed this analysis, we then performed the quantitative and qualitative analyses using data visualisations, statistics, graphs and maps. As the final step, we proposed a plan for documenting immovable industrial heritage in Andalusia.

Results and discussion

During our survey we identified 1,443 records, including four records (three in the railway sector and one in the mining sector) that straddle two provinces rather than a single province. Figure 1 shows the provinces with the largest number of records are Huelva (280), followed by Jaén (237) and Almería (225).

In relation to records by sector, the largest number of records corresponds to agri-food (542), mining (317), energy (226) and railway (227). Naval (9) and cork, wood and furniture (11) are the sectors with the fewest records. As for the distribution of sectors per province, certain sectors predominate, as shown in Figure 2. Based on the large number of records analysed, this is indicative to a certain extent of each province's history in terms of its production and economy. At the beginning of the contemporary period, agriculture was one of the pillars of the Andalusian economy, when compared both with Spain as a whole and Europe [15]. Agriculture retained its importance in Andalusia until the end of the twentieth century, at which point its relative weight in the region's economic structure began to decline [3]. This process impacted the development of the region in two ways: in aspects related to its physical morphology and structure, and in the gradual introduction of mechanisation and technology that ultimately changed the business model, labour relations and the new logistical dynamics created.

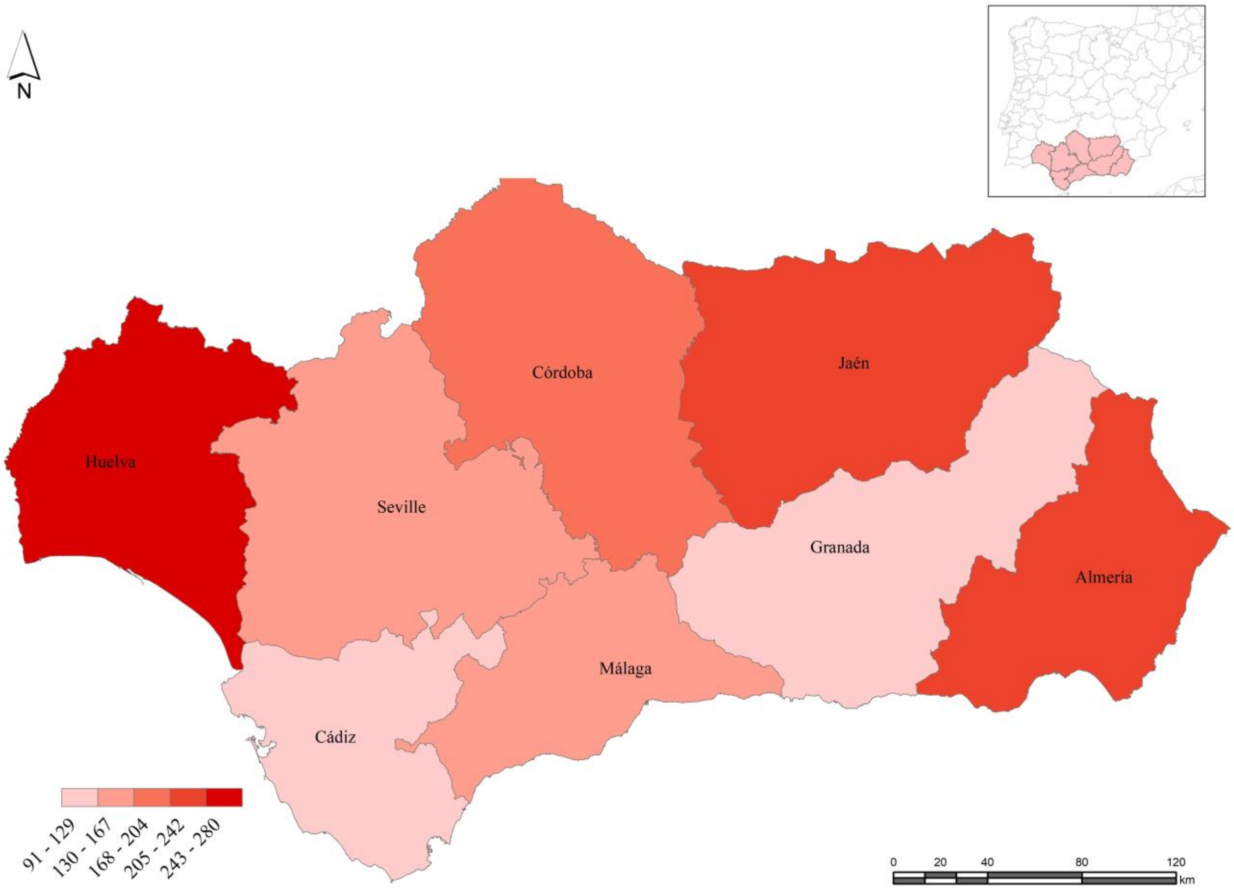

Figure 1. Map showing the number of immovable industrial heritage records per province in Andalusia.

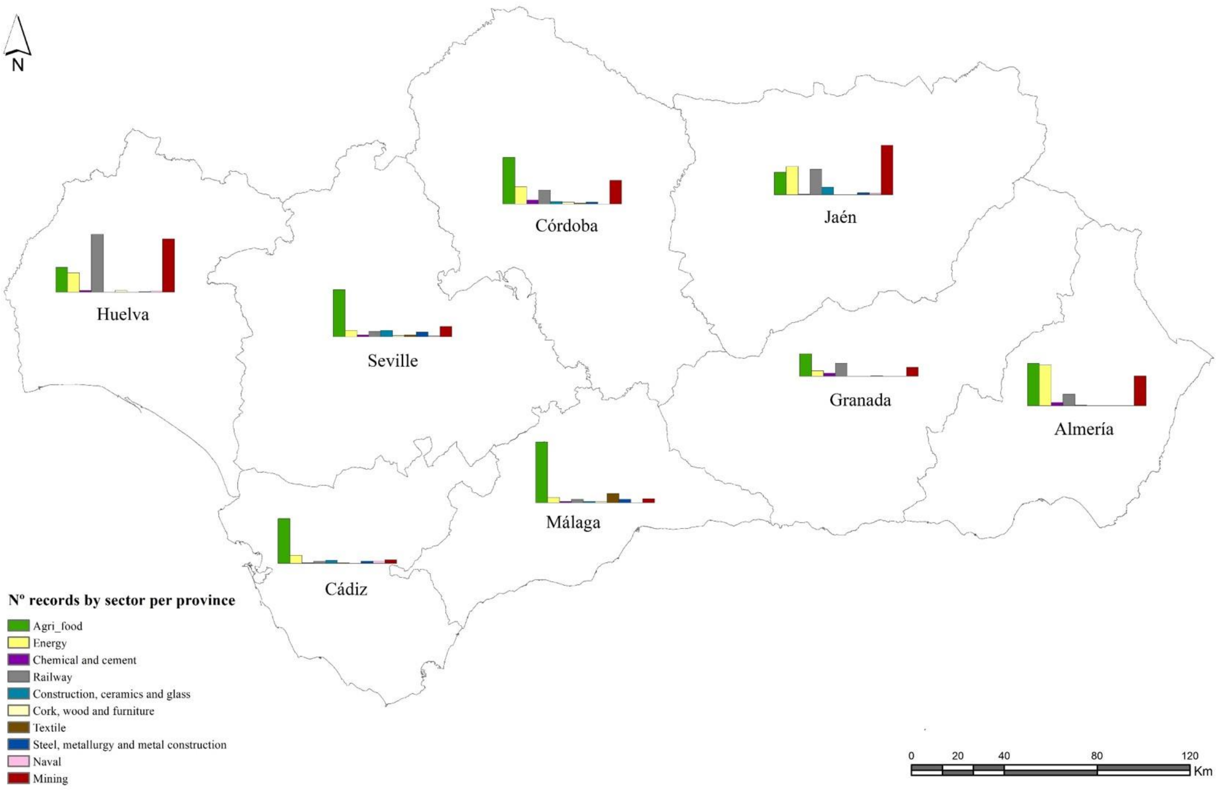

Figure 2. Map showing the sector breakdown of records for each province in Andalusia.

Detailed sector analysis of each province

To obtain more information about the quantity and quality of the records, we created detailed visualisations of each province aimed at gathering more specific data with which to devise a documentation plan more in keeping with the real situation. The data visualisation reveals a greater number of records in the agri-food, railway and mining sectors. Furthermore, these sectors present a greater diversity in relation to the distribution of records per province; this is especially the case of the railway sector, where Huelva is by far the province with the greatest number of records (Figure 3).

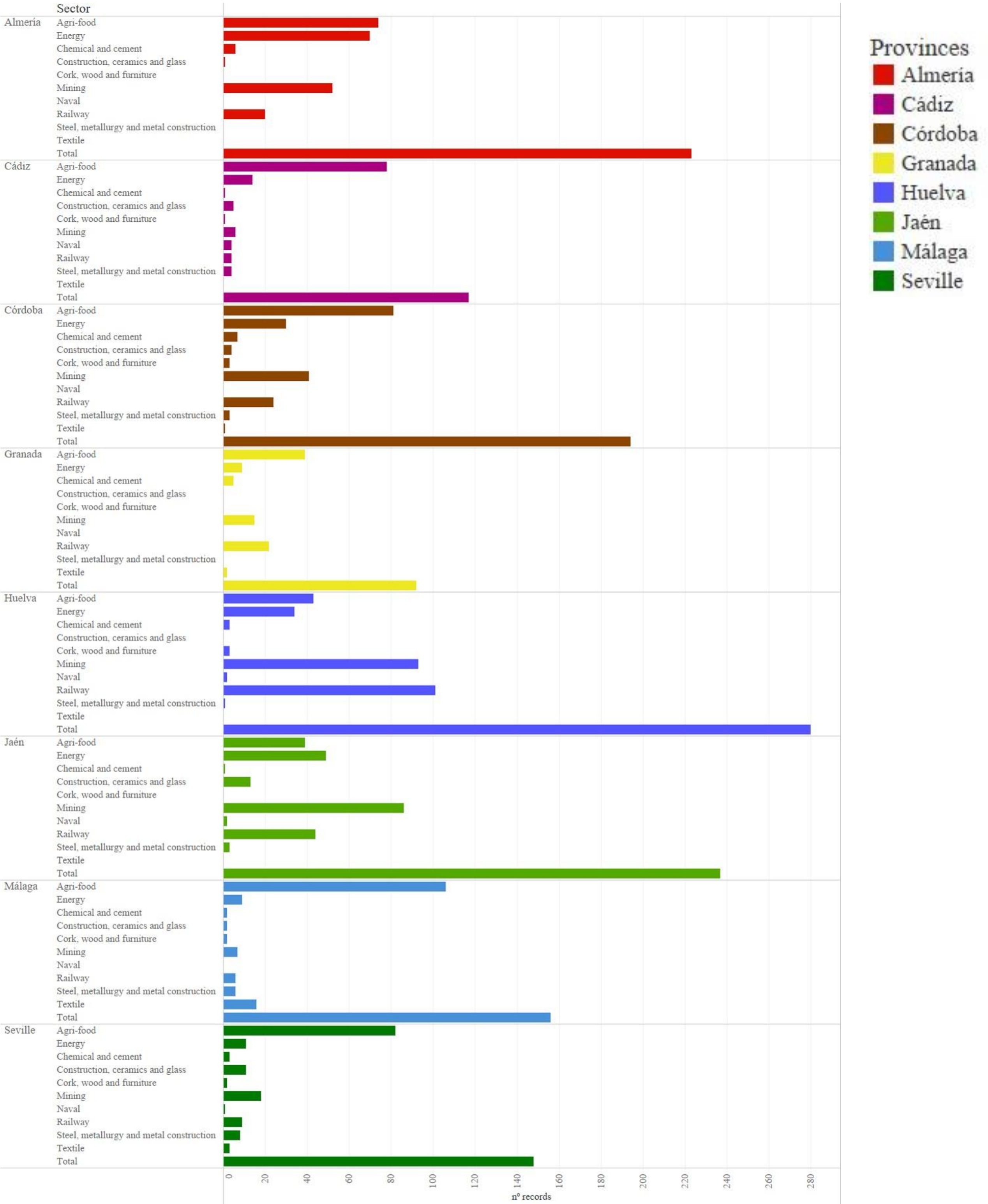

Figure 3. Detailed data visualisation by province and sector.

Typological analysis

We also analysed the records by type, 1) to ascertain whether any sector types were missing from the Thesaurus, and 2) to identify the types with the fewest records in order to determine whether there are any surveys and/or assets in Andalusia that have yet to be documented. The main cases detected are analysed below.

The agri-food sector is characterised by a fairly diverse distribution of records by type: of the 28 types in this sector, eight have more than 20 records. We observed a very small number of records for certain types. For example, there are only five records of the "Silos" type, whereas other surveys corroborate the existence of 148 silos in Andalusia [16]. Likewise, there are only five records of the "Canning factories" type, whereas other surveys point to as many as 45 and around of 4,300 workers [17-18] in the town of Ayamonte alone (Figure 4).

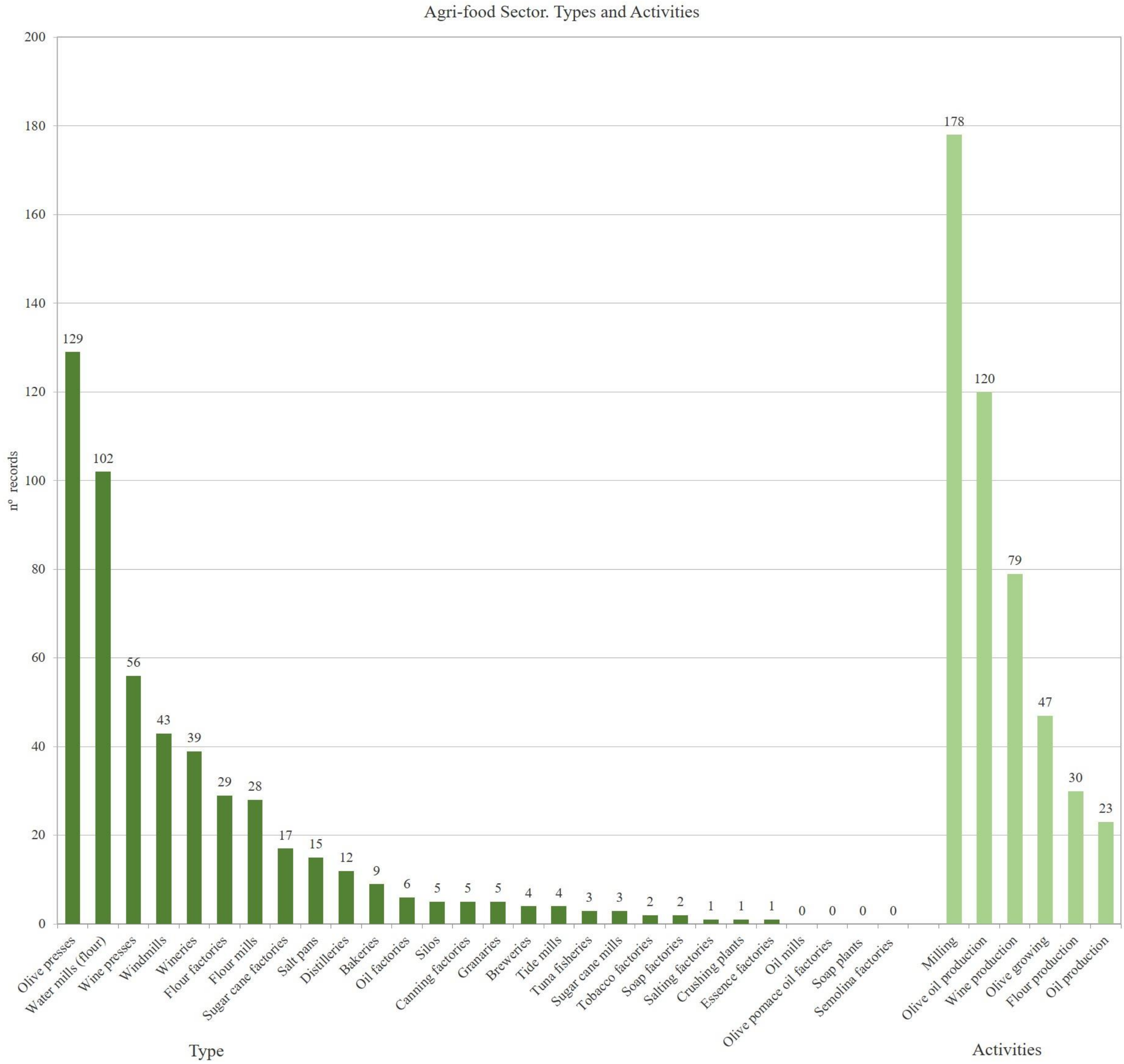

Figure 4. The number of records per type and activity in the agri-food sector.

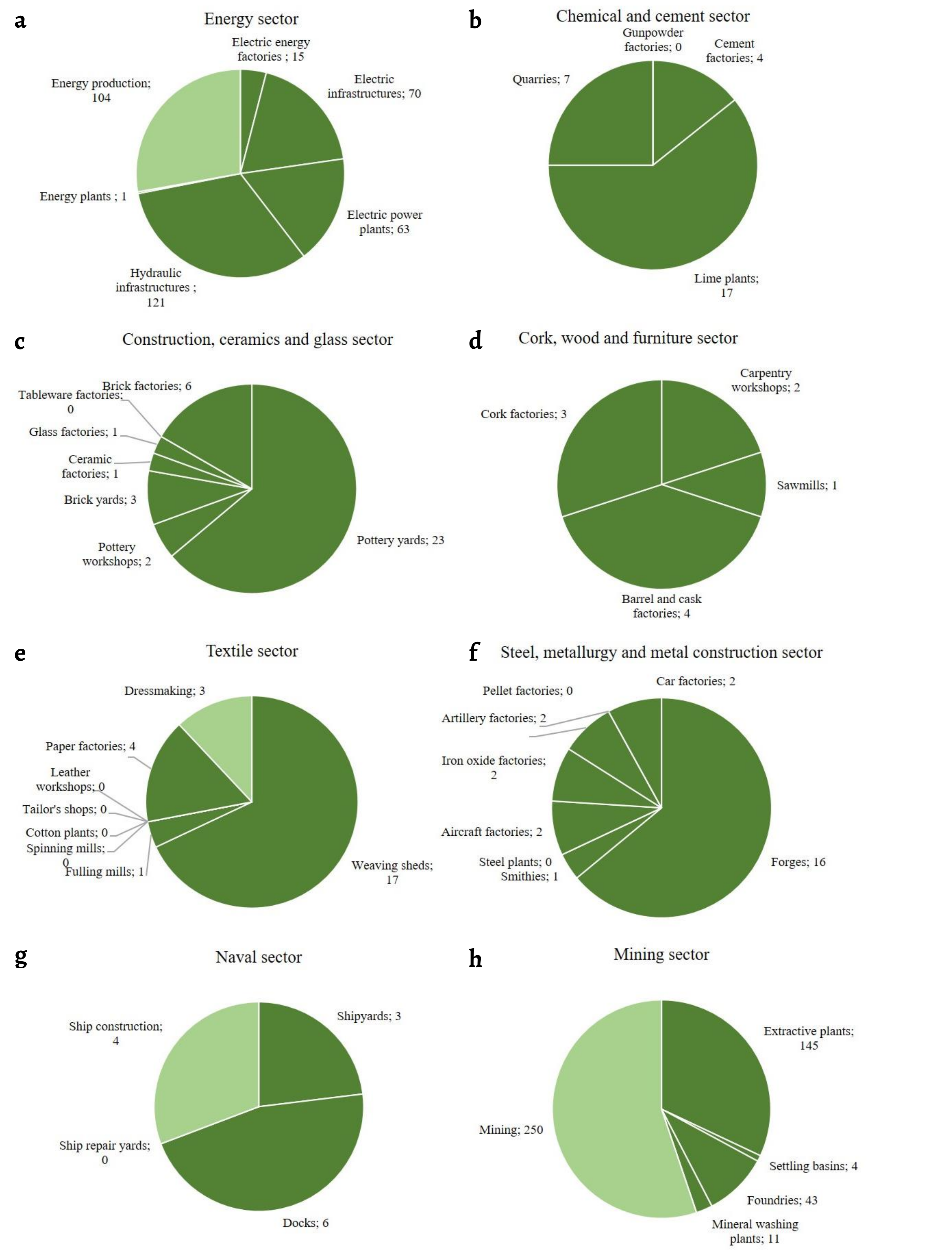

Figure 5. The number of records per type and activity in the eight remaining sectors: *a)* energy; *b)* chemical and cement; *c)* construction, ceramic and glass; *d)* cork, wood and furniture; *e)* textile; *f)* steel, metallurgy and metal construction; *g)* naval; *h)* mining.

In relation to the railway sector, we find a predominance of the "Bridge" type (144 records), the absence of "Railway housing" in the Thesaurus, and very few records for the other types in this sector - "Stations" (41), "Transport infrastructures" (23), "Loading bays" (eight) and "Railway networks" (four) since their combined total is lower than the total number of "Bridge" records. The data analyses and visualisations for the eight remaining sectors point to gaps in certain types where other surveys and projects corroborate a greater number of immovable assets, as shown in Figure 5. For example, this affects "Ship construction" in the naval sector [19]; "Spinning mills" and "Cotton plants" in the textile sector [20].

Analysis of the protection regime

An analysis of the protection regime for the different records reveals the sectors and provinces with the most and least information about the legal entity responsible for the assets. In this case, the records were classified according to three categories: "PCA" (Protected Cultural Asset); "GC" (for assets included in the General Catalogue); and "N/R" (No known protection regime).

The sector analysis revealed a higher percentage of records with a legal entity in the mining sector, followed by the energy and naval sectors. By contrast, the sectors with the highest percentage of records without a protection regime are cork, wood and furniture, followed by construction, ceramics and glass, and then steel, metallurgy and metal construction. Furthermore, although the agri-food and railway sectors account for a high share of records of industrial heritage assets in Andalusia, they also have a high percentage of assets without a protection regime. Figure 6 shows a high number of records without a protection regime, either because the Digital Guide has not been updated properly or because these assets have not yet been surveyed for possible inclusion in a protection regime.

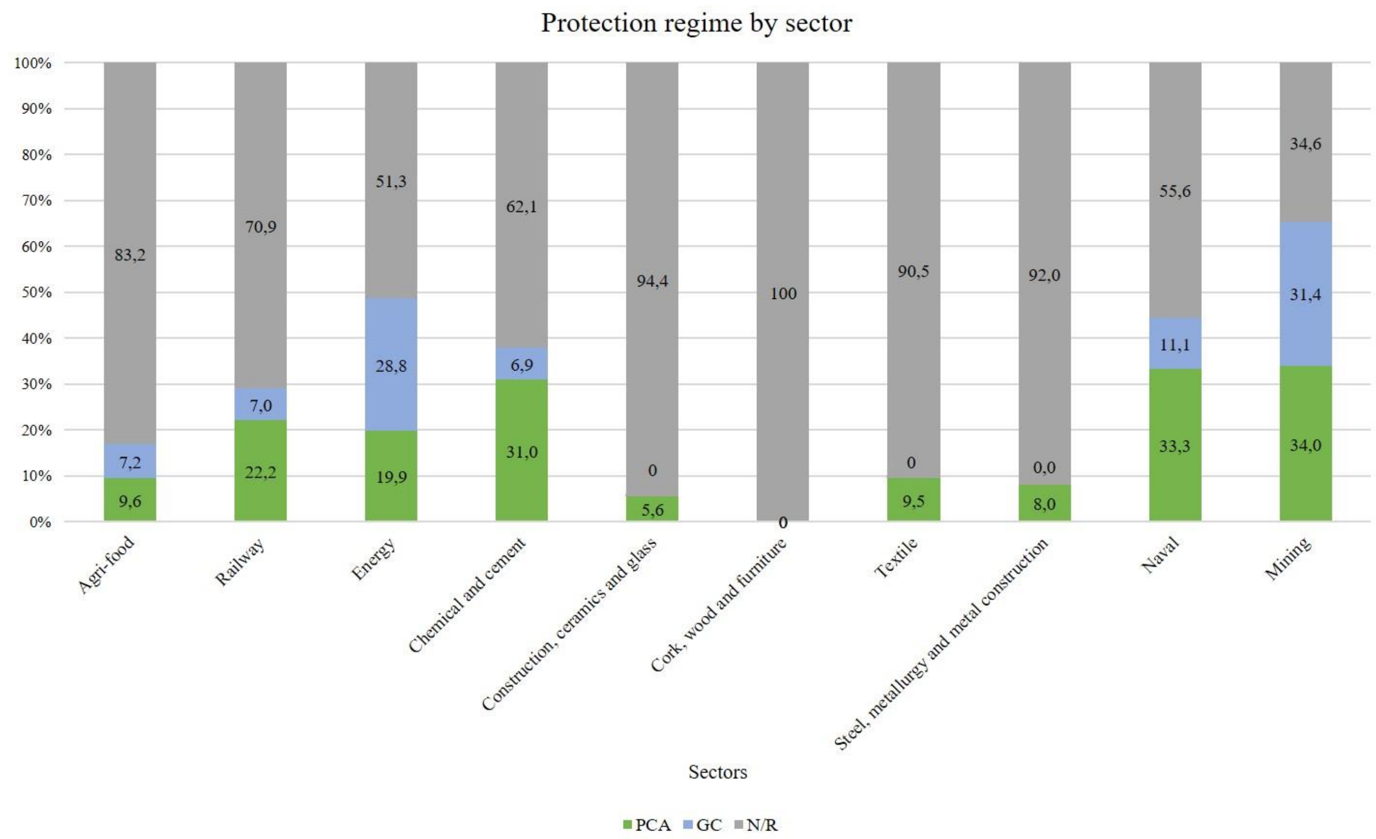

Figure 6. Percentage per sector of the assets analysed in this sample with a protection regime.

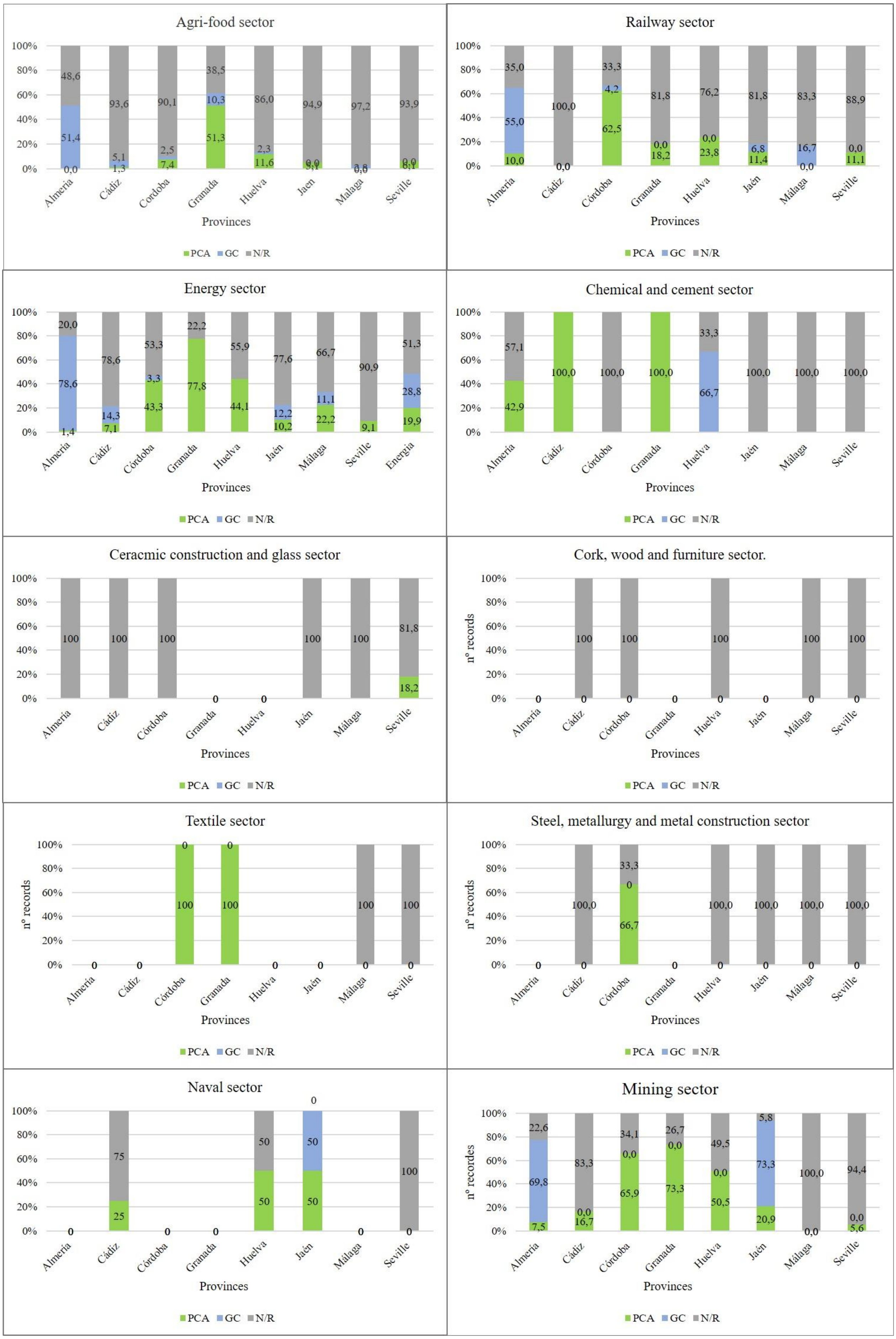

Figure 7. Detailed analysis by sector and province of the protection regime for the immovable assets of industrial heritage.

To gain a clearer picture of the status of the protection regime of immovable industrial heritage assets, we conducted a more detailed analysis of each sector and province, as shown in Figure 7. In relation to the agri-food sector, the highest percentage of assets with a legal protection entity corresponds to the provinces of Granada (61.6 %) and Almería (51.4 %), and GC is only the category of protection regime observed in Almería. With regard to the railway sector, the provinces of Córdoba and Almería have the highest percentages: 66.7 % and 65 %, respectively. In the energy sector, the percentage of assets with a protection regime is distributed more evenly between the provinces. Seville, Cádiz and Jaén are the provinces with the lowest percentages: 9.1 %, 21.4 % and 22.4 %, respectively. We find the same phenomenon in the mining sector, where at least five provinces have a higher average percentage of assets belonging to the PCA and GC protection regimes, while the provinces of Málaga, Seville and Cádiz have the highest number of assets without a protection regime: 100 %, 94.4 % and 83.3 %, respectively.

In the chemical and cement sector, there are greater provincial differences but it is important to put this into context: there are only 29 records in total in this sector, far fewer than in the above sectors analysed. In the provinces of Cádiz (one record) and Granada (five records), all the assets belong to the PCA category, while in Almería (seven records) and Huelva (three records), 42.9 % have PCA status and 66.7 % are included in the General Catalogue, respectively. None of the records in the remaining provinces belong to a protection regime.

In the other sectors, some provinces do not have any records. In the case of cork, wood and furniture, none of the records in the provinces that have them belong to a protection regime. In the construction, ceramics and glass sector, only the province of Seville has records with a protection regime: 18.2 % with PCA status. In the textile sector, only the provinces of Granada and Córdoba have records with legal protection, in this case representing 100 %. In the steel, metallurgy and metal construction sector, the only province with records belonging to a protection regime is Córdoba: 66.7 % with PCA status. Lastly, in the naval sector, the province of Jaén has one PCA record and one GC record, the province of Huelva has one PCA record (50 % of its records), and of the four records in the province of Cádiz, one has PCA status.

Information quality analysis

By analysing the “Description” (specific description of the property, such as building characteristics) and “Historical description” (the historical context of the property and its changes over time) fields we were able to verify the quality of the current information in the Digital Guide. Of the 1,443 assets, 551 records have complete information in both fields, while 665 records (approximately 46 % of the total) only have complete “Description” fields, with no information in the “Historical description” field. Furthermore, 227 records – approximately 15 % of the total – have incomplete information, with no data in either the “Description” or “Historical description” fields.

To provide more detailed base information for the future action plan, we also conducted a sector analysis. Figure 8 shows the sector percentages according to the following categories: “Good”, “Missing historical description” and “Incomplete”. The sectors with the highest percentage of information classified as “Incomplete” are construction, ceramics and glass and steel, metallurgy and metal construction. Likewise, if we analyse the number of records, we see that the agri-food sector has the highest number with gaps in these fields.

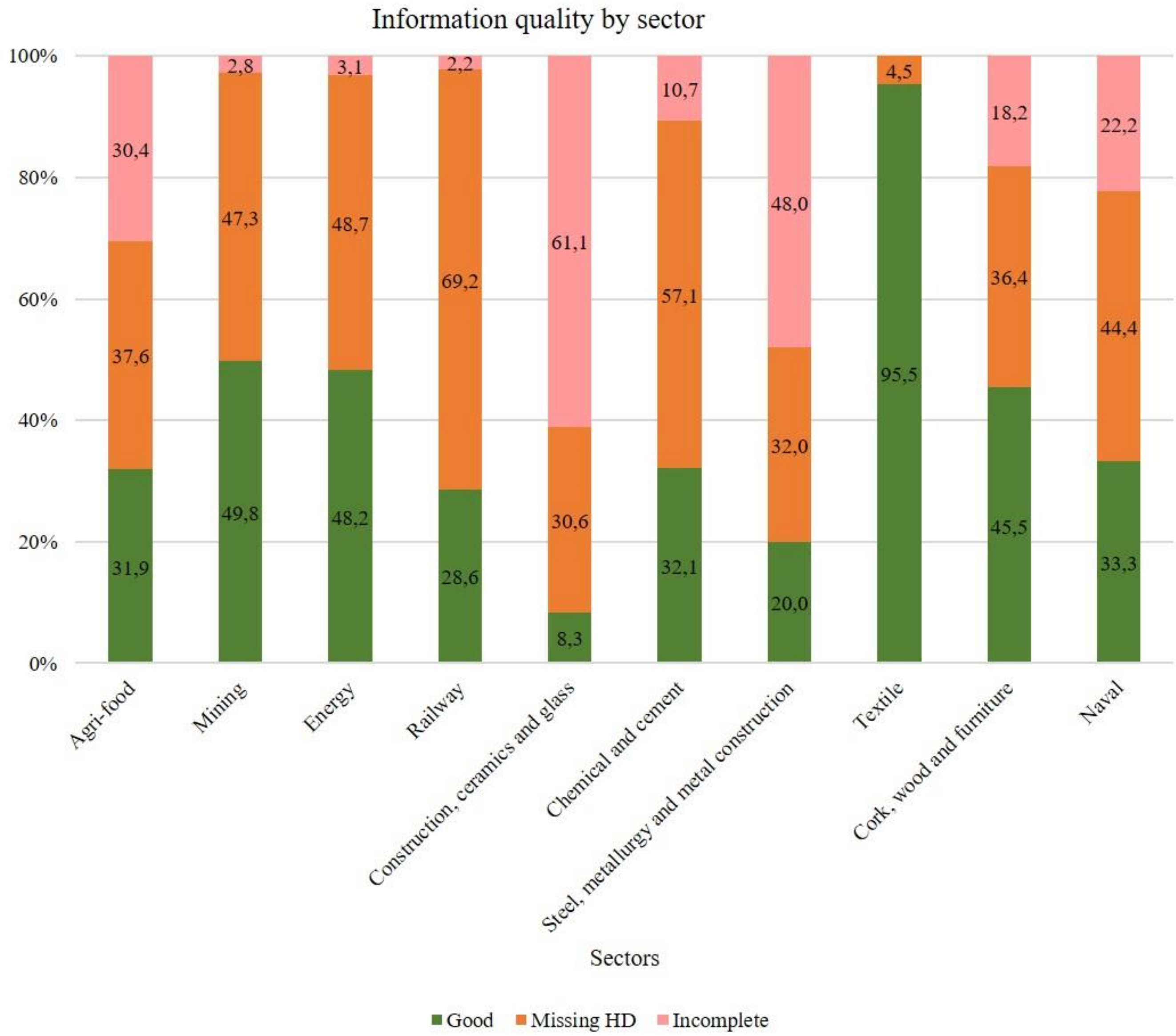

Figure 8. Information quality by sector. The graph shows the percentage corresponding to "Good", "Missing historical description" and "Incomplete".

Analysis of graphic resources

One of the resources used in the Digital Guide to provide visual information about the records is a photograph of the asset in question. Our diagnosis revealed that approximately 46 % of the records do not have photographs (660 records).

Conclusions

Considering their urban and even territorial scale, we may conclude that the origin and formation of immovable industrial heritage assets was neither definitive nor static, and that remains true today. On the contrary, these assets adopt the form of small systems immersed in larger and more complex systems with a dynamic organisation. This dynamism is an intrinsic characteristic of heritage, in which the passage of time and the relationships between the assets and "actors", whether natural or not, are the determining factors of their transformation. This survey analysed a large sample of immovable assets of Andalusia industrial heritage by sector, type and province to verify the status of the documentation in the records in the Digital Guide. We understand that this is a necessary and important preliminary step for establishing guidelines in the medium and long term.

Firstly, the diagnosis points to the need to complete and update the existing records in the Digital Guide. This updating process affects aspects of the protection regime and the information in the "Description" and "Historical description" fields. As observed from our analysis, approximately 65 % of the assets in the Digital Guide do not belong to a protection regime; this high percentage may be owing to the fact that the guide has not been properly updated over the years. Furthermore, nearly 46 % of the records are missing information in the "Historical description" field, which highlights the need to carry out more thorough research and documentation regarding this aspect with a view to generating and disseminating more complete information about those assets.

Secondly, we also detected a lack of records for certain types and activities, despite the existence of considerable information and surveys already undertaken that can be used to add new records and/or complete and update existing records. For example, this affects silos, canning factories, ship construction, spinning mills and cotton plants. Furthermore, the lack of a specific "railway bridge" type in the IAPH Thesaurus greatly slowed down the sample gathering process and will undoubtedly be a key point for researchers and the network of agents who want to contribute information, as well as providing greater visibility and connecting such assets to other types of railway heritage. The same is true of "railway housing": the absence of this type meant that we were unable to map and search for these records. We also detected the lack of other types and activities and the need to improve the terminology of some of the existing ones in the Thesaurus. For example, the agri-food sector needs to include "slaughterhouse", "storage building", "fish farm", "ice factory", "snow pit" and "cheese factory"; the chemical and cement sector should include "resin factory", "medicinal products factory", "plastering", "lime kiln" and "plaster kiln"; and the naval sector needs to include "port" and "lighthouse" [21]. The same is true of "activities", especially as regards conducting analyses that include intangible heritage in the future. The Thesaurus needs to be improved to include activities in all industrial sectors, such as "chemical and cement", "construction, ceramics and glass", "cork, wood and furniture" and "steel, metallurgy and metal construction".

Thirdly, the analyses show that 46 % of the records in the sample do not have a graphic resource, even though such resources offer key information for improving the dissemination, knowledge and recognition of these assets.

Having completed our survey, we were able to establish the following preliminary guidelines for future actions:

- Update the Digital Guide to include records already identified in municipal plans or catalogues.
- For assets where robust surveys and research already exists, gather the information to include in the records and/or create new records. Human resources in public management are still limited and the information validation processes often require fieldwork, which slows down the input of new data.
- Attract and bring new "informers" to the IAPH network of stakeholders [22] to improve citizen participation in the construction of industrial heritage documentation.
- Identify the towns that have no records but for which there is historical evidence of a secondary activity related to a specific sector, even if it is not the primary sector.
- Apply for grants and subsidies to carry out data gathering activities and fieldwork. In relation to this action, the IAPH recently obtained a grant from the Ministry of Universities for the documentation of the industrial heritage of the Guadiana Eurocity, which will enhance the value of heritage values in cross-border landscapes.
- Review and propose a new categorisation of industrial heritage in order to create a detailed list and improve data systematisation.

The IAPH network of stakeholders could play a key role in improving industrial heritage identification and documentation. This network is an agile way of involving social groups and heritage agents in the generation of knowledge available in the Digital Guide, in line with international recommendations and the Andalusian Innovation Strategy 2020 RIS3. Different actors can participate in this network, such as institutions (museums, town councils, provincial councils, etc.); the academic world (universities, research groups and centres, etc.); entrepreneurs (production, crafts, culture, design, etc.) and civil society (associations, fraternities, social movements, etc.). To collaborate, the actors initially fill out a form available on the "IAPH network of stakeholders" website [22] or contact by mail. In May 2022, this network of cultural heritage reporting agents comprised 130 members. They belong to all the categories and types of agents contemplated in the network, providing the Digital Guide with information about different territorial and heritage aspects [23].

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REFERENCES

1. TICCIH, International Committee for the Conservation of Industrial Heritage, Moscow (2003), https://ticcih.org/wp-content/uploads/2013/04/NTagilCharter.pdf (accessed 2023-06-08).
2. Ferreira-Lopes, P., 'Modelos digitales de información SIG y Grafos aplicados en patrimonio: la fábrica edilícia en el antiguo Reino de Sevilla en el tránsito de la edad moderna', PhD Dissertation, Department of Graphic Expression, Universidad de Sevilla, Sevilla (2018), http://idus.us.es/handle/11441/81525 (accessed 2022-03-14).
3. Olmedo Granados, F.; Díaz Quidiello, J.; Calvero Salvador, M., *Atlas de historia económica de Andalucía, siglos XIX y XX*, Instituto de Estadística y Cartografía de Andalucía. Consejería de Economía y Conocimiento, Junta de Andalucía (2016), https://www.juntadeandalucia.es/institutodeestadisticaycartografia/atlasterritorio/at/atlas_presenta.html (accessed 2023-06-08).
4. Consejería de Cultura, *Ley 14/2007 de 26 de noviembre de Patrimonio histórico Andaluz*, Consejería de Cultura de la Junta de Andalucía, Sevilla (2007).
5. García Braña, C.; Landrove, S.; Tostões, A. (eds.), *La arquitectura de la industria, 1925 - 1965. Registro Docomomo Ibérico*, Fundación Docomomo Ibérico, Barcelona (2004).
6. Consejería de Obras Públicas y Transportes, *Patrimonio industrial de Andalucía: portfolio fotográfico*, Consejería de obras públicas y transportes, Sevilla (2006).
7. Santofimia Albiñana, M., *Patrimonio industrial de Andalucía. Análisis, diagnóstico y propuesta de sistematización de la información*, Consejería de Cultura de la Junta de Andalucía, Sevilla (2011), https://repositorio.iaph.es/bitstream/11532/300671/1/Parimonio%20Industrial%20Andalucia.pdf (accessed 2022-02-14).
8. Santofimia Albiñana, M., 'El proyecto I+D Patrimonio industrial de Andalucía', in *Actas del II Jornadas andaluzas de patrimonio industrial y obra pública*, Fundación del Patrimonio Industrial de Andalucía, Cádiz (2012).
9. Ministerio de Cultura y Deporte, *Plan nacional de patrimonio industrial*, Ministerio de Cultura y Deporte del Gobierno de España (2011), http://www.ticcih.es/wp-content/uploads/2011/06/PLAN-NACIONAL-DE-PATRIMONIO-INDUSTRIAL.pdf (accessed 2023-06-08).
10. 'Mapa interactivo y fichas documentales del listado de elementos industriales', *Ministerio de Cultura y Deporte del Gobierno de España* (2020), https://www.culturaydeporte.gob.es/planes-nacionales/planes-nacionales/patrimonio-industrial/actuaciones/mapa-interactivo.html (accessed 2022-02-14).
11. Azkarate, A.; Barreiro, D.; Criado, F.; García Camino, I., Gutiérrez Lloret, S.; Quirós, J. A.; Salvatierra, V., 'La Arqueología hoy', in *Medio siglo de arqueología en el cantábrico oriental y su entorno*, ed. A. L. Ortiz de Landaluze, Instituto Alavés de Arqueología y Diputación foral de Álava, Vitoria-Gasteiz (2009) 599-615.
12. Pinto-Puerto, P., 'Introducción', in *Modelos digitales de información en la tutela sostenible del patrimonio cultura. Contribución al conocimiento e innovación social*, Universidad de Sevilla, Sevilla (2020) 23-45.
13. Instituto Andaluz de Patrimonio Histórico, *Guía Digital del patrimonio cultural de Andalucía*, Consejería de Cultura y Patrimonio Histórico de la Junta de Andalucía, Sevilla, http://guiadigital.iaph.es/inicio (accessed 2022-04-19).
14. Korro Bañuelos, J.; Rodríguez Miranda, Á.; Valle-Melón, J. M.; Zornoza-Indart, A.; Castellano-Román, M.; Angulo-Fornos, R.; Pinto-Puerto, F.; Acosta Ibáñez, P.; Ferreira-Lopes, P., 'The role of information management for the sustainable conservation of cultural heritage', *Sustainability* **13** (2021) 4325, https://doi.org/10.3390/su13084325.
15. Ferreira-Lopes, P.; Mateo Caballos, C., 'El patrimonio industrial agroalimentario en Andalucía: diagnóstico y directrices para su identificación y documentación', in *Actas del III Congreso internacional de patrimonio industrial y obra pública*, ed. Fundación del Patrimonio Industrial de Andalucía, Motril (2021) 1-7.
16. *Red Nacional de Silos y Graneros*, https://web.archive.org/web/20230406180212/https://silosygraneros.es/ (accessed 20223-05-18).

17. Cáceres Feria, R., *Mujeres, fábricas y charangas: el trabajo femenino en el sector conservero de Ayamonte (Huelva)*, Junta de Andalucía, Sevilla (2002).
18. Ríos Jiménez, S., 'Origen y desarrollo de la industria conservera de pescado en Andalucía (1879-1936)', *Revista de historia industrial* **29** (2005) 55-86.
19. Silveira García, P., *Guía del patrimonio cultural de la pesca en Andalucía, Consejería de Agricultura y Pesca*. Agencia de Gestión Agraria y Pesquera de Andalucía, Junta de Andalucía, Sevilla (2011), https://juntadeandalucia.es/export/drupaljda/1337159654Guia_patrimonio_cultural_de_la_pesca.pdf (accessed 2022-08-01).
20. Asociación de Mujeres Rosa Chacel, *En busca de la Hilandera. Una morada a la historia de las trabajadoras de Hytasa*. Ayuntamiento de Sevilla, Sevilla (2021), http://enbuscadelahilandera.es/wp-content/uploads/2021/02/HILANDERAS-PARA-WEB.pdf (accessed 2022-12-14).
21. Sánchez Beitia, S.; Grzeszcyk, M., *Catálogo de Faros con valor patrimonial en España*, Ministerio de Educación, Cultura y Deporte, Instituto del Patrimonio Cultural de España, Madrid (2017), https://www.culturaydeporte.gob.es/planes-nacionales/dam/jcr:d252961c-9f75-42fe-8264-d28ab0d63b01/catalogofaros.pdf (accessed 2022-02-14).
22. 'Red de Agentes Informantes del patrimonio cultural', *Instituto Andaluz de Patrimonio Histórico.– Consejería de Cultura y Patrimonio Histórico de la Junta de Andalucía*, https://juntadeandalucia.es/organismos/iaph/areas/documentacion-patrimonio/red-agentes-informantes.html (accessed 2022-04-20).
23. 'Red de Agentes Informantes del Patrimonio Cultural de Andalucía. Colaboraciones', *Instituto Andaluz de Patrimonio Histórico – Consejería de Cultura y Patrimonio Histórico de la Junta de Andalucía*, https://www.juntadeandalucia.es/export/drupaljda/red_agentes_informantes_patrimonio_cultural_colaboraciones_iaphMayo2022.pdf (accessed 2022-07-30).

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CONSERVAR PATRIMÓNIO

Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
ARTIGO / ARTICLE

O património ferroviário no contexto da UNESCO: aspetos ferroviários para sua interpretação e salvaguarda

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The railway heritage in the context of UNESCO: railway aspects for its interpretation and safeguard

Resumo

O protagonismo industrial e ferroviário na promoção do desenvolvimento económico, social e regional nos últimos séculos não é refletido nas políticas de preservação internacional. O universo industrial e especificamente o ferroviário possui características particulares que demandam uma interpretação diferente dos demais bens culturais e pouco se avançou nesse sentido ao longo dos 50 anos da Convenção para a Proteção do Património Cultural e Natural Mundial. Dessa forma o artigo contextualiza a criação do património internacional e a presença dos bens industriais como Património da Humanidade para justificar a necessidade de um novo olhar para esses bens. Dentro desse problema é apresentado especificidades do património ferroviário e a proposição de oito aspetos que proporcionam a leitura e interpretação das suas principais características, responsáveis pela atribuição dos seus valores patrimoniais e consequentemente do seu significado cultural.

PALAVRAS-CHAVE
Património industrial
Aspetos
Significado cultural
Preservação

Abstract

The industrial and railway protagonism in promoting economic, social and regional development in recent centuries is not reflected in international preservation policies. The industrial universe, and specifically the railway sector, has characteristics that demand a different interpretation from other cultural assets and little progress has been made in this regard over the 50 years of the Convention for the Protection of the World Cultural and Natural Heritage. In this way, the article contextualizes the creation of international heritage and the presence of industrial goods as World Heritage to justify the need for a new look at these goods. Within this problem, specificities of the railway heritage are presented and the proposition of eight aspects that provide the reading and interpretation of its main characteristics, responsible for the attribution of its heritage values and, consequently, its cultural significance.

KEYWORDS
Industrial heritage
Aspects
Cultural significance
Preservation

A idealização de um património internacional

A institucionalização internacional do património que traz a ideia de uma herança comum para toda a humanidade completou 50 anos em 2022. Não é só oportuno a reflexão desse momento como também olhar para uma tipologia que comumente não tem a sua devida importância atribuída para ser salvaguardada para as futuras gerações como a herança industrial e especificamente a ferroviária.

O artigo contextualiza a ideia de património internacional e os critérios adotados para sua classificação, além de associar o papel do património industrial e ferroviário. Por meio dessa problematização, a ampliação da noção de património estende-se do contexto histórico e estético ao significado cultural. A sua concretização trará alguns autores do património industrial e ferroviário que apontam o real significado desta tipologia. Assim, os aspetos a interpretar e avaliar devem ser diferentes do "património comum" e com base no quadro teórico abordado propõe-se uma série de aspetos que permitem a interpretação do significado cultural do património ferroviário como as suas características específicas.

A noção de património comum da humanidade tem sua origem na Carta de Veneza (1964) quando é citado que a humanidade tem a consciência de preservar e transmitir os valores e o património comum para as futuras gerações. Conceitos importantes são abordados na Carta que vão ser adotados como critério para a classificação do bem cultural como património da humanidade. Entretanto, a ideia de património da humanidade é efetivada em 1972, na 17ª Conferência Geral da UNESCO.

> *Constatando que o património cultural e o natural estão cada vez mais ameaçados de destruição, não apenas pelas causas tradicionais de degradação, mas também pela evolução da vida social e económica que as agrava através de fenómenos de alteração ou de destruição ainda mais importantes; (…) Considerando que, perante a extensão e a gravidade dos novos perigos que os ameaçam, incumbe à coletividade internacional, no seu todo, participar na proteção do património cultural e natural, de valor universal excecional, mediante uma assistência coletiva.* [1]

Ao considerar que determinados bens do património cultural e natural se revestem de excecional interesse que necessita a sua preservação como elementos do património da humanidade e perante a gravidade dos novos perigos que os ameaçam, cabe à coletividade internacional participar da proteção desse património de valor universal excecional.

Ainda que bastante polémico é necessário apontar um património cultural que seja comum para a espécie humana, garantir o direito das futuras gerações a usufruir dos recursos culturais que favoreçam seu desenvolvimento, fruição e quiçá sobrevivência nos mais variados aspetos, sendo a Convenção de 1972 um marco – juntamente com as Convenções de Haia – na salvaguarda dos bens culturais comuns à humanidade.

Para cumprir este objetivo é efetivado o Comité do Património Mundial, o Centro do Património Mundial e a Lista do Património Mundial (LPM), onde são inscritos os bens de valor universal "excecional", que passaram a representar toda a humanidade [1].

Em 1977, foi anunciado o primeiro Guia Operacional para a implementação da Convenção, que apontava critérios para os elementos culturais ou naturais que expressassem valor universal excecional fossem reconhecidos como património da humanidade. Logo, os candidatos a património cultural da humanidade deveriam:

> *1) Representar um acontecimento artístico ou estético único, uma obra de arte do génio criativo humano;*
> *2) Ter exercido considerável influência por um longo período – ou dentro de uma área cultural no mundo – nos desenvolvimentos subsequentes da arquitetura, da escultura monumental, do design dos jardins e das paisagens, das artes ou dos assentamentos humanos;*
> *3) Ser único, extremamente raro ou de grande antiguidade;*

> *4) Estar entre os mais característicos exemplos de tipos de estrutura, sendo esse tipo representante de um importante desenvolvimento cultural, social, artístico, científico, tecnológico ou industrial;*
> *5) Ser exemplo característico de um significante ou tradicional estilo de arquitetura, método de construção ou de assentamento humano, que é frágil por natureza ou que se tornou vulnerável sob o impacto de mudanças socioculturais irreversíveis;*
> *6) Ser importantemente associado a ideias ou crenças, com eventos ou pessoas de excecional importância histórica ou significância.* [2]

O critério 4 dava grande possibilidade de reconhecimento e inclusão de bens industriais e ferroviários como património mundial. Porém, em 1978, apenas um bem industrial foi inscrito na Lista, a Mina de Sal Wiliczka, na Polónia.

Com base em Orientações Técnicas, o Comité, em 1980 propõe algumas alterações nos critérios e exigência de um teste de autenticidade para a inscrição na LPM. O critério 4 teve a expressão “desenvolvimento tecnológico e industrial” subtraída, e redefinida como “um excecional exemplo de um tipo de estrutura que ilustra um estágio significativo na história” [3]. “A retirada da expressão «desenvolvimento tecnológico e industrial» repercutiu em menos reconhecimento dos bens industriais, privilegiando uma maior inclusão do património europeu e religioso na LPM, expressando, dessa forma, a supremacia da atribuição dos valores artísticos e arquitetónicos em relação aos valores sociais” [4].

O património industrial ganha maior evidência com a instituição do TICCIH - *The International Committee for the Conservation of the Industrial Heritage*, em 1978 e os debates e manifestações são concomitantes com a dimensão internacional do património. A ausência de bens industriais e ferroviários tornava claro que o sistema de identificação e avaliação preteria os bens dessa natureza. De acordo com Bitencourt [4] com apoio de instituições e órgãos consultivos como o Icomos e o Ticcih, foram realizados estudos temáticos para instrumentalizar a avaliação das ferrovias.

Em 1992, foi realizado um estudo que constatou um desequilíbrio regional e temático na LPM, que predominava bens situados na Europa e relacionados com a arquitetura religiosa. Com a ideia de tornar a Lista mais representativa, foi ressaltado a importância de inclusão da arquitetura moderna, sítios industriais, paisagens rurais e canais [4]. Assim, a expressão tecnologia foi incorporada no critério 2 (exibem um importante intercâmbio de valores humanos, ao longo de um período dentro de uma área cultural do mundo, em desenvolvimentos em arquitetura ou tecnologia, artes monumentais, planeamento urbano ou paisagismo) e reincorporada no critério 4 (ser um exemplo notável de um tipo de edifício ou conjunto arquitetónico ou tecnológico ou paisagem que ilustra um estágio significativo da história humana), no Guia Operacional de 1996 e permanece até o último em 2021.

Relacionado a inscrição dos bens industriais e ferroviários, dos 1154 bens inscritos na lista do património mundial até 2021 apenas 54 são de origens industriais e cinco ferroviários.

A nomeação de sítios industriais como Património da Humanidade pela UNESCO - entre outras, a Siderurgia de Völklingen (Alemanha), a Vila Mineira de Sewell (Chile), a Siderúrgica Engelsberg (Suécia), o Centro Histórico do Porto (Portugal), New Lanark (Escócia) e a Cidade de Ouro Preto (Brasil) -, de acordo com Dezen-Kempter [5] reflete o reconhecimento do significado simbólico e social que assinalam esses monumentos industriais como património cultural. Kempter afirma que é consenso nas justificativas de inclusão desses monumentos industriais o reconhecimento da excecionalidade, tanto do desenvolvimento técnico associado ao bem, quanto da atividade desenvolvida num período significativo da história humana, sem esquecer a excecionalidade arquitetónica.

A Ferrovia Semmering, na Áustria, foi a primeira inscrição de um sítio ferroviário na LPM. Deu-se apenas em 1998, vinte anos depois de publicada a primeira Lista. O reconhecimento de bens industriais ferroviários como património da humanidade deveria ser algo natural, devido o impacto que causou na sociedade do século XIX e XX, entretanto, até o ano de 2021 apenas cinco bens de natureza ferroviária estão presentes na Lista. Em relação à Lista Indicativa, de 1720 sítios inscritos, apenas sete ferrovias apresentam-se candidatas ao Património Mundial.

Bitencourt [4] afirma que o indeferimento da inscrição da Ferrovia Semmering em 1996, levantou a necessidade de estudos temáticos para instrumentalizar a avaliação como bem mundial. O mais famoso deles é de 1999, intitulado *Railway as World Heritage Sites*, de autoria de Anthony Coulls. Neste artigo, é avaliado a inscrição da Ferrovia Semmering como primeiro bem ferroviário inscrito, conclui que há lacunas no reconhecimento do património industrial e levantar particularidades das ferrovias que deveriam atender critérios específicos.

> *Qualquer sítio deve estar dentro dos critérios especificados na Convenção. No entanto, as características particulares e peculiares dos sítios industriais significam que os critérios necessitam ser desenvolvidos e refinados antes de serem utilizados na prática pelo Comité do Património Mundial no exercício de seus poderes.* [6]

Coulls [6], apresenta uma proposta pioneira e inovadora ao levar para o contexto internacional uma abordagem específica para os bens de natureza ferroviária. Uma das suas premissas é a compreensão da linha férrea como uma unidade sistémica, conectada e que não poderia ser compreendida por vários elementos isolados. No contexto geral sugere quatro critérios de identificação com base em aspetos universais para o diverso desenvolvimento dos caminhos de ferro pelo mundo. São eles o trabalho indicativo de um génio, que está diretamente associado ao design técnico e à engenharia; a influência de uma tecnologia inovadora, que é uma particularidade e influência diretamente relacionada com a proposta primária das ferrovias, o deslocamento de materiais e passageiros; um excelente ou típico exemplo que vai estar relacionado com sua sobrevivência, eventos históricos e originalidade vão conferir uma exclusividade ferroviária; e o quarto critério é a ilustração do desenvolvimento social ou económico, já que ao cumprir com sua função de transporte, serviu questões políticas, sociais, económicas e culturais que transformaram profundamente regiões. Coulls [6] compreende as ferrovias como um complexo técnico-social dotado de atributos materiais e imateriais, que interrelacionados expressam o saber fazer tecnológico, o intercâmbio de ideias e conhecimento, assim como a tipologia construtiva e os impactos sociais e económicos nos locais que estão presentes [4].

No ano de 2022, completou 50 anos da Convenção do Património Mundial e pouco se avançou na interpretação e na especificidade do património industrial e ferroviário de modo que este seja abordado e compreendido na sua essência. Ao buscar contribuir com essa lacuna é apresentado uma reflexão contemporânea do património e como interpretar a tipologia industrial e ferroviária.

A especificidade do património industrial e ferroviário

Segundo Carsalade [7] é fundamental para o entendimento contemporâneo de património cultural os conceitos de cultura e memória, já que ao mudar a cultura, transformam-se os valores e as atitudes quanto ao património. Logo, a preservação não é a capacidade do bem permanecer como está, mas de acompanhar as mudanças socioculturais.

O património foi por muito tempo guiado pelas dimensões históricas e estéticas [8], entretanto, como elemento de interação reflexiva e construtor de consciência, extrapolam essas dimensões que devem considerar as transformações e permanências na construção social tanto no tempo como no espaço [9]. A perceção atual do património cultural precisa estar associada à vida contemporânea, fruto da dinâmica industrial que alterou irreversivelmente os modos de vida tradicionais [10].

Casanelles-Rahola [11] atribui duas características importantes ao conceito de património para compreender o património industrial. Uma é o "objeto testemunho de uma época", que abrange os objetos não artísticos das sociedades e a outra é dada ao bem histórico como "objeto de estudo" cuja finalidade é compreender as sociedades do passado. Casanelles-Rahola afirma que as mudanças se sucedem de maneira aceleradas desde o final da segunda guerra mundial, levando a uma sociedade denominada como "pós-industrial" e nos faz a repensar o conceito de património, que deve estar ligado ao novo conceito de "antiguidade". Portanto, "devemos incluir objetos da era industrial como bens patrimoniais, uma vez que podemos considerá-los conceitualmente antigos, já que são de outra época da história" [11].

Assim, são tanto "objetos testemunhos" como "objetos de estudo" que servem para compreender a sociedade industrial, que já não é mais atual e torna-se campo de estudo da arqueologia industrial. A reflexão conceitual do património faz-se necessário porque está associado a um tempo recente e com características diferentes dos bens históricos e estéticos que a sociedade tinha sob o conceito de património [12] e é nesse novo marco conceitual que está o "caráter" do património industrial, no qual são formados por bens relacionados com a produção, não só objetos de estudo, mas também testemunhos de uma época passada. Ainda agregam o valor do protagonismo da revolução social e económica que mudaram a sociedade para a atual sociedade pós-industrial [12, p. 59].

As dimensões histórica e estética são restritivas quando aplicadas ao património industrial. Enquanto património era sinônimo de obras arquitetonicamente monumentais, os bens industriais estão estreitamente relacionados com a técnica, organização do trabalho, da produção e circulação dos bens materiais, assim, Bergeron [13] afirma que esses bens exigem uma mudança de olhar e que a avaliação seja de ordem técnica e secundariamente de ordem estética. Segundo Bergeron, o patrimônio industrial, requer uma apreciação distinta em relação à arquitetura, que exige uma nova perspetiva. Esses artefactos não devem ser avaliados apenas com base nos cânones tradicionais da arquitetura, como um ramo das belas artes. Em vez disso, eles devem ser considerados levando em conta as referências e critérios específicos do processo de produção e técnica utilizados [13].

Com o mesmo raciocínio, Soto e Ganges [10] defendem que o património industrial seja abordado como um sistema complexo de organização do espaço de trabalho, sem renunciar o arquitetónico, apenas colocados em hierarquias diferentes, pois sobressaltam-se os aspetos técnicos, científicos e históricos.

Casanelles [12] argumenta que a preservação do património industrial tem a função de reforçar a memória coletiva da história e ser um elemento de estudo da vida cotidiana e do trabalho. Em conformidade com Bergeron [13], Casanelles [12] defende que em princípios do século XXI, ao repensar o conceito de património, os bens industriais são mais que rememorativos e sua conservação não deve ser realizada para que seja apenas contemplado, mas sim compreendido. Assim, para Casanelles [12], o bem cultural industrial tem uma função didática para compreensão da história social e económica. Divide o valor didático em três eixos: o "tecnológico", associado à engenhosidade humana para executar as tarefas com mais eficiência. O "social", referido às relações sociais, à dinâmica da vida industrial e condições de vida e de trabalho. E o terceiro é o "ambiental", que está associado ao impacto das ações humanas no meio ambiente. Casanelles [12] afirma que os três eixos podem ser vistos tanto através da dimensão temporal como espacial e conferem ao património industrial uma interdisciplinaridade essencial que extrapola a dimensão histórica e estética para as relações sociais.

Ainda sobre a reflexão para compreensão do entendimento de património industrial, Casanelles [11] aponta noções como antiguidade, testemunho e documento. O novo conceito de antiguidade, deve-se ao fato que somos a primeira geração que vamos classificar como bens patrimoniais os objetos que nós mesmos utilizamos. No bojo da industrialização, objetos móveis e estruturas que representavam um avanço tecnológico, tornam-se obsoletos em poucos anos e assim exigem uma nova compreensão do conceito de antiguidade, que até então estavam associados a objetos que pertenceram a outras gerações.

A segunda é a noção de testemunho, já que os bens provenientes da industrialização testemunham uma época que foram protagonistas de uma revolução social e económica que modificou a sociedade e o seu conhecimento é fundamental para a compreensão da sociedade atual.

O terceiro é o bem industrial como documento por ser um objeto de estudo para compreender a sociedade industrial. Sua análise fornece informações qualitativas com base científica que não se podem obter através de documentos escritos.

Para Bergeron [13] o bem industrial requer uma mudança de olhar, já que seu valor cultural exige uma apreciação maior de ordem técnica e menor de ordem estética. Meneguello [14] corrobora com essa ideia ao afirmar que a arquitetura industrial é dotada de inteligência e técnica específicas, em busca da máxima eficiência da produção e da menor perda de tempo nos deslocamentos.

Um consenso entre autores e documentos internacionais é a identificação e documentação dos bens industriais. A inventariação, ainda que seja um levantamento preliminar, ajuda a selecionar o que preservar e estabelecer critérios para uma política coerente de preservação [15]. A Carta de Nizhny Tagil [16] afirma a "importância da identificação, do inventário e da investigação para proteger os vestígios industriais que pretendem preservar para as gerações futuras". Enquanto o Princípio de Dublin [17] defende a pesquisa e documentação das estruturas industriais, sítios e paisagens como essenciais na identificação, conservação e apreciação do seu significado e valores.

Casanelles-Rahóla ainda afirma que a importância do património industrial construído reside em sua implantação e impacto em um determinado local. O número de elementos da mesma tipologia existentes nos lugares de tradição industrial, determinam que a salvaguarda de seus elementos é seletiva, pois não se pode justificar que tudo seja preservado para a posteridade. Para fazer uma seleção, é essencial realizar um inventário, determinar as tipologias implantadas e os elementos singulares que existem com base em vários parâmetros entre os quais se destaca: a escolha como representante de uma tipologia, a singularidade dentro das tipologias, o ônus histórico que esse material repousa para sua comunidade e, naturalmente, seu valor estético. A importância dos diferentes parâmetros dependerá do fato de o bem ser considerado de importância local, regional ou nacional [11, p. 60].

Para Kühl [15] a identificação do processo produtivo, as etapas de implantação, a linguagem arquitetónica e as relações sociais e urbanas estabelecidas são aspetos que constroem a identidade do bem e fundamentais para a interpretação dos atributos e seus valores.

Freire [18] na sua tese, aborda as ferrovias sob uma perspetiva sistêmica pelas redes estabelecidas entre toda a estrutura na sua complexidade funcional, cujas transformações fazem-se necessárias para o dinamismo da atividade. A modernização tecnológica não só é esperada como necessária. Na sua construção teórica, identifica características essenciais da rede ferroviária, que se manifestam na: formação do seu "traçado linear, na diversidade de bens; na interdependência, conectividade e adaptabilidade dos bens" [18] que compõem a operação dos trens. Faz referência aos elementos, estruturas, ferramentas e equipamentos construídos para funções específicas que dentro da lógica sistêmica e funcional são interdependentes. Com um olhar aprofundado sob a ótica do funcionamento ferroviário, Freire afirma que os "elementos constitutivos de uma rede ferroviária foram organizados no espaço não de maneira aleatória, mas orientados por uma lógica que estabelecia sua distribuição" [18]. A lógica era transportar mercadorias e passageiros, por consequência, informação e ordem.

Comumente vistos como protagonistas, as estações e trens promoviam o embarque e desembarque, entretanto, sem a superestrutura e equipamentos como os trilhos, dormentes, armazéns, caixas d'água e oficinas, não haveria qualquer atividade ferroviária. Há ainda os ferroviários e estrutura social (vilas, espaços sociais). Anjos [9] que aborda a supracitada autora, completa que para atender à demanda do transporte e sua manutenção, a lógica funcional ferroviária, bem como sua organização espacial, apresentam-se como aspetos de suma importância, já que são interdependentes [9, p. 53].

A ideia dos pátios como núcleo das funções centrais de Freire converge com Soto [19] que afirma que as instalações técnicas ferroviárias desenvolvem um trabalho indispensável para o funcionamento do sistema.

Para Anjos [9], ter clareza sobre o quê, porquê e de que maneira se preservar os bens procedentes da industrialização, demanda um amplo conhecimento sobre suas especificidades e sua compreensão como monumentos que interessam à coletividade.

De acordo com Freire [18], o não raro avançado estado de abandono de estruturas ferroviárias, leva a perda não só da leitura funcional e espacial como dos processos de produção, trabalho e logística que estavam inseridos. Deixa-se assim de preservar importantes atributos físicos capazes de transmitir o conhecimento ampliado sobre funções e utilidade. Rufinoni afirma que

> *a composição espacial do conjunto industrial – considerando as especificidades de implantação e projeto condicionadas pela atividade produtiva e as relações desses conjuntos com as áreas urbanas envoltórias, elementos que compõem uma paisagem particular – em geral não é respeitada. Em muitos casos, a preservação do património industrial resume-se à manutenção de edifícios ou estruturas ("excecionais"?) isoladas: um edifício de arquitetura interessante, uma chaminé ou um equipamento "curioso"; estruturas preservadas para serem mergulhadas em uma ambiência nova na qual o passado industrial é identificável somente pela presença de resíduos descontextualizados.* [20, p. 222]

Meneguello [14] já abordava, inclusive com relação à dimensão, que os bens industriais deveriam ser compreendidos pela complexidade de atividades e não apenas em edifícios isolados, "a dimensão dos bens ou conjuntos industriais construídos nos obrigam a pensar sobre como incluir o património industrial dentro de políticas de requalificação urbana. Estes bens relacionam-se entre si em complexas redes e a sua salvaguarda isolada é insuficiente para a compreensão da sua a atividade. Pensar nos edifícios industriais implica em pensar sobre como realizar as escolhas dos exemplares a serem protegidos para a memória e para a cidade." [14, pp. 1820-1821].

Para Soto [19, p. 14] é imprescindível abordar o património ferroviário a partir de uma sólida formação patrimonial, superando a visão monumental clássica, e considerar os elementos constitutivos do sistema ferroviário a partir das categorias patrimoniais que sublinhem a relação entre esses elementos – e os aspetos intangíveis, já que a ferrovia é um sistema sócio-técnico, a partir da noção de conjunto.

Para Canelles-Rahóla, a preservação isolada de bens industriais apenas "informa sobre a existência de uma atividade produtiva, mas não sobre seu funcionamento e nem a complexidade das relações em um espaço" [11]. Soto [19] corrobora com a ideia de Freire [18] quando afirma o quão limitador é no caso do património ferroviário a seleção apenas das estações como alvo de conservação. Essa visão tem eclipsado a necessária interpretação técnica e funcional da ferrovia através dos seus conjuntos e as relações funcionais e espaciais do complexo industrial e ferroviário que extrapolam o entendimento de um edifício [19, p. 4].

Assim, sob a perspetiva dos caminhos de ferro como um objeto complexo e sistêmico, Freire [18] aponta os atributos físicos como: conectividade, sistematicidade e funcionalidade. Essas características peculiares à ferrovia para exercerem suas atividades de maneira utilitária, estão sujeitas às transformações demandadas pelos avanços tecnológicos e à dinâmica dos processos de produção e do trabalho. Esta é uma característica dos bens da ciência e da tecnologia, sua complexidade e também a sua mudança.

Anjos [9] também referenciada em Freire, afirma que os atributos se manifestam no traçado ferroviário, na estrutura e forma espacial, na organização do espaço ferroviário, na diversidade tipológica e, fundamentalmente, na capacidade dos elementos remanescentes de transmitir sua lógica funcional, o que não ocorre apenas por meio dos elementos mais antigos. Soma-se ainda a relação que estabelece com o contexto urbano em que se inseriu ou colaborou para definir. Estes aspetos configuram atributos físicos da rede ferroviária passíveis de ser identificados no presente com o auxílio da história e da memória, sem esquecer a lógica funcional ferroviária que articula esses elementos [9, pp. 59-60].

Pode-se então, baseado nesse aporte teórico afirmar que as características dos bens de origem ferroviária são sua conectividade, sistematicidade, função, técnica, relações de trabalho e sociabilidade, além de histórica, arquitetónica, ambiental, memorial, científica e tecnológica.

Anjos [9] analisa pedidos de classificação de bens ferroviários ao Instituto do Património Histórico e Artístico no Brasil que foram tanto deferidos como indeferidos para identificar através da narrativa dos documentos os atributos ferroviários e seus significados.

Vinculados ao valor histórico da ferrovia está a representação da modernidade económica, integração territorial de caráter nacional e formação urbana. Como alvo de modernização também é ressaltado as transformações realizada. Anjos [9] afirma que nenhum dos documentos analisados fazem referência à relação entre os componentes do pátio ferroviário e a sua funcionalidade.

Para a qualidade estética estão as questões arquitetónicas e paisagísticas transformadas pela ferrovia. Neste aspeto podemos identificar exemplos de materiais, como o uso do ferro em variadas formas (que também entra na dimensão tecnológica), as obras d'arte e a tipologia construtiva dos imoveis que caracteriza a ferrovia. A dinâmica (função) e organização do trabalho estão relacionados aos aspetos culturais e sociais do universo ferroviário. A relação entre a matéria e os que viveram a atividade ferroviária representam os laços que são expressos pela memória, pelo sentimento e simbolismo. Também é atribuída a dinâmica do ir e vir proporcionada pelo complexo ferroviário.

Além desses aspetos observados também há apontamentos relacionados ao simbolismo e memória, a autora afirma que estão fortemente associados ao significado e representam uma estreita relação com o bem ferroviário.

De acordo com Freire [18], os bens imóveis são compreendidos por pátios e edificações que compõem a infraestrutura e superestrutura de maneira articulada entre si e o espaço em que estão inseridos. Também pode ser todo espaço geográfico gerado pela ferrovia onde se desenvolveram atividades relacionadas com as rotinas de trabalho do cotidiano dos trabalhadores e sociedade. A dimensão imaterial dos bens, vinculam-se a sua matéria e através deles compreende-se o know-how, a técnica, organização do trabalho, aspetos que remetem à memória social e cultural das ferrovias.

Em relação aos bens móveis e integrados, a autora compreende como fontes que possa evidenciá-las como testemunhos históricos dos caminhos de ferro.

Bitencourt [4], ao avaliar ferrovias como património cultural mundial e o seu Valor Universal Excecional (VUE) faz uma pesquisa dos bens ferroviários já classificados pela UNESCO e a partir dos Dossiers de Nomeação faz uma análise de conteúdo para identificar os principais atributos das Ferrovias Mundiais que vão remeter ao VUE.

De acordo com a UNESCO, os atributos vigentes são forma e projeto, materiais e substância, uso e função, tradições e técnicas, localização e espaço, linguagem e outras formas de património intangível, espírito e sentimento, bem como a outros fatores internos e externos. Entretanto, nos documentos analisados, ao apontar os atributos em categorias, Bitencourt identificou onze e apenas cinco (dos sete) correspondiam aos estabelecidos pela UNESCO. As novas categorias de atributos identificadas correspondem ao: Período construtivo; Conceção, mão de obra e gestão; Intercâmbio tecnológico; Composição do conjunto; Relação com o entorno natural e construído; e Relação sócio territorial.

Ao refletir sobre a compreensão contemporânea do património para além da suas dimensões históricas e estéticas que permitem apreciar bens de tipologia industrial sob o viés da sua complexidade e especificidades apontadas por autores e pelos dossiers da UNESCO realizados por Bitencourt, faço uma reflexão e proponho oito Aspetos que permitem interpretar e identificar as principais características dos bens ferroviários que vão facilitar a atribuição dos valores patrimoniais e consequentemente do seu significado cultural.

Tabela 1. Aspetos e seus respetivos significados

Aspeto	Significado
Proveniência	Associada aos registos que compõem a história do bem ferroviário. Faz-se relevância o contexto de sua conceção até os dias atuais com os registos históricos de pertinência, inclusive os sinais e efeitos físicos da sua passagem no tempo. Também está incluído objetos obsoletos.
Localização	Está associada às características geográficas de implantação dos caminhos de ferro, como edifícios e obras d'arte.
Composição dos equipamentos e sua relação com o entorno	A leitura da composição espacial e funcional dos equipamentos permite compreender a organização ferroviária e as consequências no território, assim como sua paisagem, já que os conjuntos ferroviários definiram um novo núcleo e uma nova ordem urbana.
Conceção construtiva, técnica e tecnológica	Relacionada com as características do saber fazer ferroviário, o desenvolvimento de novas técnicas e tecnologias, manipulação de novos materiais e novas tipologias construtivas que proporcionaram construções antes impossíveis para a engenharia.
Material circulante e bens móveis	Peça-chave para a compreensão da atividade ferroviária são as locomotivas e carruagens. Com grande poder didático estão os demais objetos móveis como o relógio da estação, o apito do guarda do comboio, sinos, os uniformes dos funcionários, entre vários outros. Também compõe este aspeto o acervo documental.
Funcionalidade	A lógica funcional do sistema ferroviário é proporcionar o deslocamento, que vai desde transportar pessoas e mercadorias à ideia e cultura.
Relação socioeconómica e territorial	As ferrovias transformaram a vida das pessoas ao possibilitar o acesso a localidades antes distantes ou de difícil acesso. Esse deslocamento proporciona novas relações sociais, territoriais e económicas.
Espírito, sentimento e outras características imateriais	Está relacionado com a imaterialidade, ou seja, com sensações como o afeto, emoção e paixão. Ligado à memória, que de maneira simbólica remete às tradições, rituais, rotinas, às técnicas e à operacionalização ferroviária.

Estes aspetos foram submetidos para apreciação e sugestão de especialistas internacionais que fizeram importantes considerações não só a nomenclatura adotada como seu significado. Dessa forma os aspetos passaram de uma proposição individual para um balizamento coletivo internacional (Tabela 1).

Considerações

Este artigo propôs-se contextualizar o património industrial e ferroviário no contexto internacional, tendo como base a política da UNESCO que no ano de 2022 completou 50 anos da criação da Convenção do Património Mundial. É claro a discrepância dos bens de outra natureza e tipologia que integram a LPM, já que os critérios de avaliação não são compatíveis entre todos os bens. Dessa forma, procurou expor através do alargamento da compreensão contemporânea do património que através da significância é possível contemplar bens de tipologia industrial e ferroviária, visto que a admiração estética dá o lugar a compreensão da herança e a verdade material passa para a transmissão dos seus significados. De tal forma, com objetivo de esclarecer as especificidades ferroviárias de modo que sua interpretação seja mais próxima da sua natureza, é criado com base em um conjunto de autores especializados uma série de aspetos. Estes aspetos permitem a leitura das principais características ferroviárias que vão justificar a atribuição dos seus valores e consequentemente do seu significado cultural, que justifica sua classificação como património, de acordo com a ideia contemporânea de património cultural. Ainda que não exposto, este sistema já foi aplicado de modo satisfatório no Complexo Ferroviário do Barreiro.

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REFERÊNCIAS

1. Unesco, *Convenção para a proteção do património mundial, cultural e natural*, Paris (1972), https://whc.unesco.org/archive/convention-pt.pdf (acesso em 2020-05-13).
2. Unesco, *Guia operacional*, Paris (1977), CC-77/CONF.001/8 (unesco.org) (acesso em 2023-07-22).
3. Unesco, *Operational guidelines for the implementation of the world heritage convention* (1980), https://whc.unesco.org/archive/opguide80.pdf (acesso em 2023-07-22).
4. Bitencourt, A. P., *As Ferrovias como património cultural mundial: os estados-parte, a UNESCO e o valor universal excepcional*, Dissertação de doutoramento, Departamento de Desenvolvimento Urbano, UFPE, Recife (2015).
5. Dezen-Kempter, E., *O lugar do património industrial*, Dissertação de doutoramento. Instituto de Filosofia e Ciências Humanas, Universidade Estadual de Campinas, Campinas, São Paulo (2011), https://hdl.handle.net/20.500.12733/1614661 (acesso em 2018-06-05).
6. Coulls, A.; Divall, C. M., 'Railways as world heritage sites', *Locality* **10** (1999) 7-11.
7. Carsalade, F. de L., 'A preservação do património como construção cultural', *Arquitextos* **12**(139.03) (2011), http://www.vitruvius.com.br/revistas/read/arquitextos/12.139/4166 (acesso em 2023-07-22).
8. Viñas, S. M., *Contemporary Theory of Conservation*, Elsevier, Oxford (2005).
9. Anjos, C. C. dos., *A proteção do património cultural ferroviário no Brasil entre 2000 e 2015: do tombamento à inscrição, um caminho de distanciamento das especificidades do objeto a preservar*, Dissertação de mestrado, Departamento de Desenvolvimento Urbano, UFPE, Recife (2018), https://repositorio.ufpe.br/handle/123456789/32343 (acesso em 2018-12-07).
10. Soto, J. L. L.; Ganges, L. S., 'Las fronteras del patrimonio industrial', *Llámpara: patrimônio industrial* **2** (2009) 7-20, https://uvadoc.uva.es/handle/10324/1682 (acesso em 2023-07-22).
11. Casanelles-Rahóla, E., 'Recuperacion y uso del patrimônio industrial', *Cadernos do Centro Latinoamericano de Economia Humana* **88** (2004) 57-64.
12. Casanelles-Rahóla, E., 'Nuevo concepto de patrimonio industrial, evolución de su valoración, significado y rentabilidade nel contexto internacional', *Revista Bienes Culturales* **7** (2007) 59-70, http://www.mcu.es/patrimonio/docs/MC/IPHE/BienesCulturales/N7/11 (acesso em 2023-07-22).
13. Bergeron, L., 'L'impact de la modernization économique et le patrimoine industriel', in *Identification and documentation of modern heritage - World Heritage papers 5*, UNESCO World Heritage Centre, Paris (2003) 18-22.
14. Meneguello, C., 'Patrimônio industrial como tema de pesquisa', in *Anais do I Seminário Internacional História do Tempo Presente*, Universidade Estadual de Santa Catarina, Florianópolis (2011) 1819-1834.
15. Kühl, B. M., *Arquitetura do ferro e arquitetura ferroviária em São Paulo: reflexões sobre a sua preservação*, FAPESP, São Paulo (1998).
16. The International Committee for the Conservation of the Industrial Heritage, *Carta de Nizhny Tagil para o património industrial*, s.n., Nizhny Tagil (2003), https://ticcih.org/wp-content/uploads/2013/04/NTagilPortuguese.pdf (acesso em 2013-02-13).
17. The International Committee for the Conservation of the Industrial Heritage, , *Princípios de Dublin: Conservation of industrial heritage sites, structures, areas and landscapes*, Icomos (2011), Microsoft Word - GA2011_ICOMOS_TICCIH_joint_principles_EN_FR_final_20120110.doc (acesso em 2023-07-22).
18. Freire, M. E. L., *Patrimônio ferroviário: a preservação para além das estações*, Dissertação de doutoramento, Departamento de Desenvolvimento Urbano, UFPE, Recife (2017).
19. Soto, J. L. L., 'Los ferrocarriles y el patrimonio mundial. Del monumento al paisaje cultural', in *VI Congresso de História Ferroviária*, s.n., Vitoria (2012), https://www.docutren.com/historiaferroviaria/Vitoria2012/pdf/6046.pdf (acesso em 2018-12-10).
20. Rufinoni, M. R., *Preservação e restauro urbano: Intervenções em sítios históricos industriais*, Editora Fap-Unifesp, São Paulo (2013).

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CONSERVAR PATRIMÓNIO

Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
ARTICLE / ARTIGO

How Lipman's "caring thinking" theory for human thought may encourage the safeguarding of industrial and technological heritage

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Como a teoria *caring thinking* de Lipman para o pensamento humano pode incentivar a preservação do património industrial e tecnológico

Abstract

This paper describes the potential for "caring thinking" of Matthew Lipman's philosophy to be applied from education to museological practice to enhance new decision-making models for conservation. "Caring thinking" is crucial when applied from education to heritage conservation, as it does not only concern the treatment of the deteriorated parts of any industrial object but the truth, the museological content that lies beyond the aesthetic or historical values that have to be thoroughly examined. The Lipman theory articulates complex modes of thought that include: a) valuational, b) affective, c) active, d) normative and e) the empathy of man for human ingenuity, effort and expectations. This effort, reflects the need for the industrial and technological heritage conservator not only to extend the life-span of the collections but to strive to retain their intangible value and enhance the viewer's museological engagement with them.

KEYWORDS
Lipman
Caring thinking
Decision making
Empathy
Ethics

Resumo

Este artigo descreve o potencial da filosofia *caring thinking* de Matthew Lipman quando aplicado desde a educação até à prática museológica, para melhorar os novos modelos de tomada de decisão para a conservação. O *caring thinking* é crucial quando usado desde a educação à conservação do património, uma vez que não diz respeito apenas ao tratamento das partes deterioradas de qualquer objeto industrial, mas também à verdade, ao conteúdo museológico que se encontra para além dos valores estéticos ou históricos que têm de ser cuidadosamente examinados. A teoria de Lipman articula modos complexos de pensamento que incluem: a) o valorativo, b) o afetivo, c) o ativo, d) o normativo e e) a empatia pelo engenho, esforço e expectativas humanas. Este empenho reflete a necessidade do conservador do património industrial e tecnológico em prolongar o tempo de vida das coleções, em manter os seus valores intangíveis, e melhorar o envolvimento museológico do espectador com elas.

PALAVRAS-CHAVE
Lipman
Caring thinking
Tomada de decisões
Empatia
Ética

Introduction

Matthew Lipman was an American educationalist and philosopher who became the founding father of the worldwide educational movement "Philosophy to school children" all over the world. Cam called him a "meliorist by temperament" as his philosophy was inspired by the writings of John Dewey which he read during the World War II. The shift from a conventional academic career to his work for children started in the social and political ferment in the late 60s, grounded in his beginning to think about the need for educational change in teaching the Vietnam war generation of undergraduates, caring for his own children or seeking ways to improve the growing need for social change through education [1].

Lipman's applied epistemology utilizes the terms of critical thinking, creative thinking and moral reasoning in order to articulate discourse about human thought at the level of human consciousness. He argued that, while critical thinking is important and extremely valuable, it is not enough to make decisions or solve problems. He pointed out the need for young children to also develop their creative and loving side of thinking [1]. In 1995, in the context of human coexistence and contribution, he articulated the "caring thinking" philosophy, a condition of higher level of thinking [2].

Caring thinking is analyzed in this paper with an emphasis on a thought, a process that safeguards collections and especially curates and restores the industrial heritage. As Lipman's theory is encouraging the development of children's thinking for problem solving, its extension to adults will help to analyze caring thinking practices in the field of human care and culture. Translating this to the profession of the conservator, however, is a challenge for two reasons. Firstly, because in contrast to ethnographic, religious or archaeological collections, industrial heritage is mainly treated as "a big stuff collection" that is difficult to care for, conserve, handle, restore or display (indoors or outdoors) by following ethical approaches or established conservation theories for works of art. Secondly, because in 1800 with the advent of industrialization, due to experimentation by artists and the development of unconventional materials, machines progressively integrated themselves from human activity into artistic creation. Therefore, preventing deterioration, making assessments, and restoring the immaterial aspects behind the industrial revolution object or contemporary artwork seems difficult to approach.

Lipman's theory for caring-thinking

According to Lipman, "caring thinking" is governed by feeling and inner meditation and consists of the following types:

1) Valuational thinking: this type of thinking refers to meaning that is structured by the facts (or objects) themselves. According to Lipman, it is a mode of thought he admires because it makes people feel important, shows interest, and prioritizes and values people and objects (with different criteria or taste).
2) Affective thinking: this compassionate way of thinking is an affective response to the need to do justice by establishing what is right and just, what is wrong, what is judged immoral or unethical and what should last.
3) Active thinking: this is a type of care giving ability. It tackles a problem with passion, examining its cause. It utilizes language and communicating codes , initiates a proposal, constructs a proposed plan of care and relates to sustainability, conservation and development (environmental, cultural, etc.).
4) Normative thinking: this refers to structuring meanings, thinking through of rules for actions that can be applied into local or global contexts and frameworks. Students or sort of persons usually defend their values by mentioning laws "for the common good" which Lipman describes as a caring conduct, expressing what has or ought to be done:

it is expressed through solidarity, moral treatment of events and by avoiding personal self-centeredness.

5) Empathic thinking: according to Lipman, the concept of "feeling, experiencing, thinking and behaving" as if you have experienced the problem yourself feeds leads the thought to immediate action. In this way, care is provided through empathy by substituting for the 'weak', speaking for someone who is not able to take care of him or herself. This last issue does not only concern teachers who take care of their students in education but also doctors and nurses, and even conservators, who preserve the lives of patients (or industrial collections through caring thinking theories and practices.

Bornstein, referring to Lipman's philosophy claimed that it is consistent with Heidegger's twentieth century phenomenological contributions to hermeneutics and existentialism [3].Heidegger expressed his belief by using the term of "Dasein" being-in-the-world existence [4].This is a "pre-ontological" understanding that shapes our lives through actions and ontology. For example we care for things or people, foresee and prevent ourselves from doing bad things, always trying to prove who we are, and how our actions define our identity. Caring thinking can only be explained by analyzing the partnership of man with his environment through time in terms of the present, the past and the future. As Petrou comments, in Heidegger's and Lipman's philosophy the terms of "caring with" or "caring for" (things and people) contain multiple forms of human relations such as prevention, help, defense, upbringing, counseling, co-existing [5]. Conversely, thinking that care for people instead of museum collections (as in the case of humane nursing) concerns patients who have a self-care deficit as they need to become independent in order to recover their health. In terms of treatment, it aims to help them "acquire and adopt their cognitive and cultural attitudes, techniques and procedures that will empower them to promote and even maintain a healthy lifestyle". In this way, the issue particularly pointed out by Held concerns not only a thought that cares as a virtue but as an act that presupposes motivations of offering or self-disposition [6]. In fact, we do see that caring relationships between a teacher and a student require a response to the student's need, partial intimacy between the two, sensitivity, empathy and trust. For Caruana et al. sustainability principles help those engaged in art education to promote ethics of care and awareness of broad social needs and goals [7].

Taking all the aforementioned into consideration, caring can be understood as "our behavior towards people or things which are judged or evaluated to be important and useful, as long as it helps us to obtain something, to achieve our goals relatively to world, environment and people" [5, pp. 159-160, 165]. I believe that conservators appear to confirm Lipman's theory that caring-thinking is valuational when they classify data and value information (deterioration history, pathology and conditions of the preservation state of the work of art, technological assessment of past restoration interventions, etc.) with an emphasis on the safeguarding, prevention of damage and planning of actions in order to prevent further deterioration of the objects. Furthermore, caring for the intangible heritage means valuation of artifacts, traditional crafts, customs, narrations and cultural spaces associated therewith (Figure 1).

In the field of contemporary art in particular, Dominguez-Rubio says that all works of art are subject to processes of biological-physicochemical decay phenomena, but some are more "manageable or docile" since they respond more directly to the actions of the conservator at the moment when the objects fail to heal themselves [8].

Figure 1. View of equipment from the 1850's olive-oil soap making "Patounis" company in Corfu, whose technique was inscribed in 2017 on the National Inventory of the Intangible Cultural Heritage of Greece (2022).

Caring and social commitment in the aftermath of modernity

The contribution of conservation (in the context of collection care, safeguarding and cultural management) seems to be consistent with the social mission of museum professionals who make decisions, collect, investigate and also preserve ethically in a sustainable way, the evidence of human culture. Muñoz Viñas in the "new theory for conservation" by using the term "oxymoron" characterizes the nature of conservation as working against the biological process of aging in museums. Today, there is a modern art challenge where the "performativity" or the "intangibility" of the material objects convey meanings or messages, that are considered, thought or viewed differently to the classical notion of art conservation [9].

In nursing, Willis et al. similarly consider "an oxymoron" action to be the practice of the "art of caring" through a work intensification schedule which is missed care in a constantly controlled environment in hospitals due to lack of time [10]. Such negative or positive incentives prompted Lipman to explain that caring "with" or "for" is not due to an emotional incentive but is a "genuine cognitive value". He relates caring thinking for people to caring thinking for culture in order to examine the conditions of circumstances. The concept of caring for patients or for culture deals with the institutional framework within which curators of galleries care for works of art, doctors care for health and curates care for souls [2, p. 9]. In other words, only when we see things in specific contexts, do we experience them logically and value them. This declaration of estimating and valuating things, bodies or personalities explains our tendency to set priorities, discover differences or similarities and provide patients with medical treatment (through nursing) or objects (through conservation).

However, it seems that caring thinking in the cases of cultural or nursing theories lies in the roots of schooling, in terms of the teaching of ethical issues. Caruana et al. argue that caring relies on the development of a cooperative existence based on the principles of social justice and an awareness of the consequences of present actions and decisions. This means that students should not be encouraged to care about future impacts of present actions, but "learn how to care, respect for diversity, compassion and the wellbeing of a community" [7, p.240]. Instead, Lipman's theory seems to be primarily concerned with the development of students' critical thinking and awareness by encouraging them to go further than an established, imprecise and uncreative way of thinking as he suggests that "thinking be considered an experiential connecting". In the case of healing art, the etymology of the word "curatorship" (from the Latin *curare*: *cura* = treatment), suggests the "treatment of the disease" entails feeling that promotes actions carried out from a humanitarian motive. For Hölling, Bewer and Ammann critical thinking treats the work of art as a "battery of time" [11]. More specifically, the authors adopt the statement of the art historian D. Joselit that the objects are "carriers of time" which hold an infinite potential for staging meanings or actions, while their valuation depends on the complex system of material relations or constructs in which they exist. On the one hand our attitude and thinking towards objects is expressed through the actions of collecting, exhibiting, and caring for them due to their transience or alterations over time. On the other hand, objects become batteries-witnesses of past interventions of man (creatively or destructively) which proves their impact on humans and vice-versa. This interaction is expressed through restoration, signifying a means of "healing or restoring health or renewing something old or lost", while conservation was meant "to keep intact, preserve and guard". However, when conservation problems arise in "this day and age" in contemporary objects, restoration looks like an oxymoron because the restored objects lack timeliness [11, p.5].

Even the reasoning of the postmodern conservator (about the conservation of matter, material or the symbolic meaning of the artwork or of a mechanical gadget or used tool) seems to be consistent with Lipman's philosophy: the active thinking of care assesses and initiates the effectiveness of conservation before it is even implemented, as conservation is a response to the question "what world would we like to live in?". In the modern period in the epistemology of conservation, conservators face the historical and technical primary question of how do we as conservators assess the "patina", a term that may be perceived "not as an indication of physical or chemical aging of the object but as a criterion of historicity, which conservation must preserve" [12, p. 373]. After all, the huge dimensions of an industrial or contemporary collection, with its deterioration process that encourages fruitful thinking, is an outstanding stimulus for decision-making, caring and exhibiting (Figure 2).

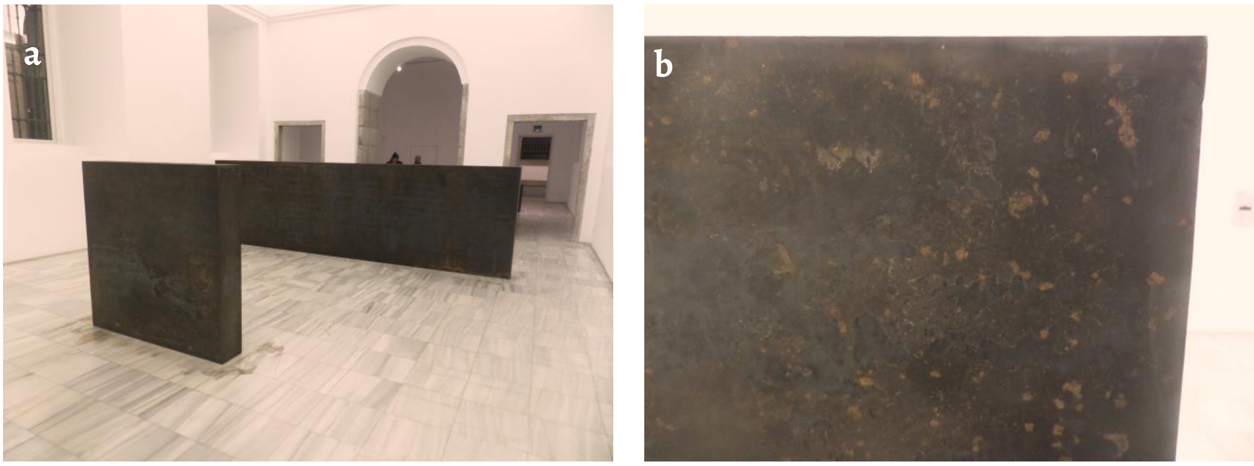

Figure 2. The "Equal-Parallel: Guernica-Bengasi" sculpture by Richard Serra made of metal blocks in Reina Sofia Museum: *a)* general view; *b)* detail from the patina of the hot-rolled Corten steel (2018).

In the postmodern era, caring thinking philosophers and stakeholders expressed their opinion that ephemeral collections, site specific monuments and art installations require alternative conservation treatments [13]. The effort to provide care, and struggle with active thinking dilemmas, has prompted conservators to consider how realistic their expectations are, and how they will negotiate with living artists so as to fulfill their expectations without compromising the values and art stories that need to emerge after conservation [14-16].

Ethical dilemmas that emerge during the evaluation of the state of preservation of industrial-contemporary collections

In relation to Lipman's caring-thinking in education, it may be tentatively considered that conservation-caring presupposes the “evaluation of a problem” by the conservator and the finding of a solution by opening up to human emotion. This trial of safeguarding culture, preventing damage and restoring is part of a creative way of thinking.

Hiiop states that the care of classical forms of art is based on a conduct of ethics that focuses on theoretical, philosophical and technical judgments, but that for contemporary art revisions are required [17].She declares that the "oxymoron of caring thinking" for objects is the moment when museum professionals find it difficult to accept biological aging. According to her, conservation in the postmodern era is an "anachronistic concept, the care of static collections" that are treated as sacred relics at a time when visual creativity is indifferent to time and its impact (wear and tear, decay).

Regarding the institution of museums, Goodman [18] asks when an object is a work of art, and answers that it becomes one when it functions as a symbol; a stone becomes a work of art not when it is on the street but in the museum, where it performs a symbolic function, with its texture, color, and form representing a sample of a certain period of origin or composition. A useful object can function as art and a work of art can function as a utilitarian object [19, p. 27]. Thus, one problem in contemporary art is due to the use of recycled tools and re-used materials in artworks, where the poor state of preservation symbolizes conceptual deconstruction of man’s attitude, and therefore the re-used items should not be restored (Figure 3).

A typical example of caring used for the safeguarding of industrial heritage is the case study of the Industrial Gas Museum in Athens. In order to highlight the industrial heritage in parallel with the preparation and implementation of the museological study, the caring-thinking framework of the working group considered the restoration of the old factory buildings as urban venues and the conservation of the associated mechanical equipment that was in need of special protection. The conservation interventions were discreet and concerned specific machines such as chillers, steam engines or locomotives that were cleaned or put into operation via generators or manually, so that the visitor has an experience of their operation. This is a museological proposal, which regardless of conservation, will safeguard the collection so that the visitor may obtain a complete view of the lighting process produced by the gas [20].

Lipman's philosophy of caring thinking can be matched to conservation approaches as shown in Table 1.

My personal opinion is that the deep relationship that the conservator develops with the objects-collections is similar to the loving dimension of the nurture-child caring (or care of the educator for his students, or parental caring for children according to Lipman). For the conservator’s way of nurturing through art caring seems to bring emotions of satisfaction. Furthermore, it provides happiness, optimism and achievement through the success of the completion of the conservator’s conservation/restoration tasks, dexterities and skills (Figure 4).

Figure 3. An old scratched and corroded press used in the *Compressed Cotton* (1961) sculpture of N. Kessanlis. The deterioration and patina of its metals, the stains on the cloth and the wood are parts of its degradation meaning (2020).

Table 1. Potential examples of a conservator's caring thinking theory

Modes of thought according to Lipman´s model	Examples of ethical dilemmas faced by a conservator of industrial collections
Valuative thinking	"What are the weaknesses of this conservation project and how may I face them?" "This battery is in poor condition". "How will I preserve the industrial collection or its meaning in the 'best possible' way?" "How will I be evaluated morally by my colleagues and society?" "By what kinds of conservation standards and opportunities?" "I think that this object is attributed to this company…"
Affective thinking	"I have to respond to…" Defending the inventor´s intentions before/after conservation. Justifying the collection when it is exposed in public in an exhibition.
Active thinking	Preliminary examination of the object, physic-chemical analysis, technical studies of its construction method, causes of deterioration. Proposed conservation working plan and risk-assessment. "This enamel needs varnishing…."
Normative thinking	"How will I apply basic ethical principles in their validity and legal status?"(e.g. the Greek Law 3028/2000 based on the protection of Antiquities and cultural heritage in general or the Professional Code of Conduct for Conservators, 2000) [21-22].
Empathy	a) Care for the (functional) object at the moment when its industrial inventor/factory worker/user "fails": initial expectations, conditions, challenges. b)Empathy for the industrial object's inventor in relation to the museological interpretation and meaning-making that may enhance the experience of the visitor. "How can I make people discover the value of a machine, it´s use or technological impact."

Figure 4. A detached paper sketch: *a)* before and *b)* after conservation; the conservator's way of caring thinking revolved around the problem of restoring the health of this "fragile" artwork-being sensitive like a child (2018).

Even though Lipman does not consider the factor of emotion exclusively in the activation of caring thinking, Tomkins and Bristow argue that the theory of caring is based on indications of the effectiveness of emotion. They also consider that the foundations of care are the administration of justice, the assurance of moral laws and peace in the world [23, pp.3, 5, 12]. The safeguarding of any civilization or (industrial/technological) heritage is important because it is fair for people to have the right to discover their own roots, identity, and traditions (Figure 5). Clavir [24] mentions that in contrast to established Western museum conservation practice, First Nations people present alternative viewpoints (not only intellectually but also emotionally).The question concerns thinking of the deep connections either between people and objects or for the impact of museums in society due to their nature. For example, indigenous people such as the Maori in New Zealand have used objects in their traditions and rituals as an intrinsic element of maintaining their lifeways, language, art, narrations and cultural identity [25]. For this reason, many museums' preservation policies have changed from being focused purely on the preservation of material culture, keepers to embrace people-based approaches that permit interactive museological or educational use of objects and conservation of their intangible values. As Wijesuriya and Court explain, in the case of Asian cultures, the key issue for sustainability is dialogue through the development of global programmes on people-centered approaches to conservation, embracing the importance of Traditional Knowledge Systems (TKS) of local communities in safeguarding heritage [26]. These systems may be seen today as the outcome of a community connection with living heritage, as community members are respected as "knowledge holders" who gain access, rediscover cultural or agricultural landscapes, architectural and engineering solutions or practice their skills. In the context of built heritage conservation, Wijesuriya [27] suggests that "de-secularisation" – the removal of the Western sense of separation between materiality and spirituality of urban and rural sites – is vital to promote more holistic approach to caring for heritage.

Figure 5. View of a historical lithographic press at the engraving studios of the Athens School of Fine Arts. Such industrial objects are important to new artists allowing them to use and even restore them (2022).

Conclusions

Regardless of the scientific background of the conservation profession, or the theoretical or practical specialization of the conservator in a specific category of collections, care is a cognitive act based on philosophical, ethical issues [28, p. 17]. In Lipman's philosophy care is a conscious act which entails several modes of thinking [29].The rationale of care in culture can be related to "curation", "collection management", or "preservation or conservation" – loving or emotional actions demonstrating the moral commitment of museum professionals (as they oppose the decay caused by nature itself). A caring thinking philosophy that comes from the creation-genesis of the tangible object, which is otherwise doomed to oblivion if it is not, conserved [14]. Caring thinking examines and evaluates events, conditions and facts. It preserves the intangible – what is behind the "icon" and "aesthetics" of the objects, reaching the intent or aim of creation, the transmission of memories, functions, human disciplines, lifestyles, artistic or scientific techniques, creating dexterities, etc. This is important not only to the museums of today but in the long-term in the context of extending the life-span of (industrial) objects, and their role in society.

REFERENCES

1. Cam, P., 'Matthew Lipman (1923-2010)', *Diogenes* **58**(4) (2011) 116-118, https://journals.sagepub.com/doi/10.1177/0392192112462202.
2. Lipman, M., 'Caring as thinking', *Inquiry: critical thinking across the disciplines* **15**(1) (1995) 1-13, https://doi.org/10.5840/inquiryctnews199515128.
3. Bornstein, J. C. L., 'Towards an understanding of Matthew Lipman's concept of caring thinking', *The Journal of Philosophy for Children* **16**(3) (2003) 17-24, https://doi.org/10.5840/thinking20031634.
4. Heidegger, M., *Being and time*, Blackwell publishers, Oxford (1962), http://pdf-objects.com/files/Heidegger-Martin-Being-and-Time-trans.-Macquarrie-Robinson-Blackwell-1962.pdf (accessed 2023-2-01).
5. Petrou, A.; Chatzivasili, G., *Η σκέψη στη φιλοσοφία για παιδιά: διάλογος και προοπτικές* [*Thinking in Philosophy for children: dialogue and perspectives*], Diadrasi Editions, Athens (2022).

6. Held, V., *The ethics of care: personal, political, and global*, Oxford University Press, Oxford (2007).
7. Caruana, C.; Gatt, I.; Vella, R.; Zammit, C., 'A politics of care and responsibility: art and education for sustainable development research', *Arts and Education* **4** (2021) 236-258, https://doi.org/10.54916/rae.119523.
8. Dominguez Rubio, F., 'Preserving the unpreservable: docile and unruly objects at MoMA', *Theory and* Society **43** (2014) 617–645, https://doi.org/10.1007/s11186-014-9233-4.
9. Muñoz-Viñas, S., 'The artwork that became a symbol of itself', in *Theory and practice in the conservation of modern and contemporary art*, eds. A. Weyer and U. Schaedler-Saub, Archetype, London (2010), 11–22, https://www.academia.edu/44683434/The_artwork_that_became_a_symbol_of_itself (accessed 2022-12-12).
10. Willis, E.; Henderson, J.; Hamilton, P.; Toffoli, L.; Blackman, I.; Couzner, L.; Verrall, C., 'Work intensification as missed care', *Labour and industry* ***25***(2) (2015) 118-133, https://doi.org/10.1080/10301763.2015.1060811.
11. Hölling, H. B.; Bewer, F.; Ammann, K., 'Material encounters', in *The explicit material: inquiries on the intersection of curatorial and conservation cultures*, eds. H. B. Hölling, F. Bewer and K. Ammann, Koninklijke Brill, Leiden (2019) 1-14.
12. Philippot, P., 'Restoration from the perspective of the humanities', in *Historiacal and philosophical issues in the conservation of cultural heritage*, eds. N. Stanley-Price, K. M. Talley and A. M. Vaccaro, Getty Conservation Institute, Los Angeles (1995) 216-229.
13. Ferianni, B., 'How to pass on an idea', in *Ephemeral monuments, History and conservation of installation art*, eds. B. Ferriani and M. Pugliese, Getty Conservation Institute, Los Angeles (2013) 93-129.
14. Saaze,V.,*Installation Art & the Museum*, Amsterdam University Press, Amsterdam (2003).
15. Wielocha, A., 'The artist interview as a platform or negotiating an artworks possible futures', in *Sztuka I Dokumentacja* **17** (2018) 31-45, https://incca.org/artist-interview-platform-negotiating-artworks-possible-futures-2018 (accessed 2022-12-12).
16. Wielocha, A., 'Art objects as documents and the distributed identity of contemporary artworks', *Art Matters International journal for Art History*, **Special Issue 1** (2021) 106-113, https://www.academia.edu/52700050/Art_Objects_As_Documents_and_the_Distributed_Identity_of_Contemporary_Artworks (accessed 2022-3-3).
17. Hiiop, H., 'The Possibility of patina in contemporary art or, does the "New Art" have a right to get old?', in *Koht ja Paik. Place and location. Studies in environmental aesthetics and semioticsVI*, eds. E. Näripea, V. Sarapik, and J. Tomberg, Eesti Kunstiakadeemia Kirjastus, Tallinn (2008) 153–166, http://www.eki.ee/km/place/pdf/kp6_10_hiiop.pdf (accessed 2023-05-17).
18. Cohnitz, D.; Rossberg, N., *Nelson Goodman, Philosophy now*, vol.2, McGill Queen's University Press, Ontario (2006) 378-379.
19. Kertemlidou, P., Η διαλεκτική της καλλιτεχνικής δημιουργίας με το βιομηχανικό χρηστικό αντικείμενο, Epikentro Editions, Athens (2021).
20. Koutsoudaki-Gerolymbou, E.; Florou, M., 'The industrial gas museum in Technopolis', in *Τετράδια Μουσειολογίας* 9, eds. A. Gazi and A. Bounia, Kaleidoscope Editions, Athens (2014) 31-36.
21. Greek Law for the Protection of Antiquities and Cultural Heritage, https://opi.gr/images/library/nomothesia/ethniki/nomoi/3028_2002.pdf (accessed 2022-3-05).
22. Professional Code of Ethics of Conservator, http://www.onemagazino.com/2021/11/blog-post.html (accessed 2023-4-19).
23. Tomkins, L.; Bristow, A., 'Evidence based practice and the ethics of care: "what works" or "what matters?"', *Human Relations* **76**(1) (2023) 118-143, https://doi.org/10.1177/00187267211044143.
24. Clavir, M., *Preserving what is valued – Museums, conservation, and first nations*, UBC Press, Vancouver (2002).
25. Court, S.; Wijesuriya, G., *People-centred approaches to the conservation of cultural heritage: living heritage*, ICCROM, Rome (2015) https://www.iccrom.org/sites/default/files/publications/2020-10/traditional-knowledge-systems.pdf (accessed 2023-04-19).
26. Wijesuriya, G. and Court, S. (Eds.), *Traditional knowledge systems and the conservation and management of Asia's heritage*, ICCROM, Rome (2020) https://www.iccrom.org/publication/traditional-knowledge-systems-conservation-and-management-asia%E2%80%99s-heritage%C2%A0 (accessed 2023-04-19).
27. Wijesuriya, G., 'Towards the de-secularisation of heritage', *Built Heritage* **1**(2) (2017) 1-15, https://openarchive.icomos.org/1811/1/Towards_the_De-secularisation_of_Heritag.pdf.
28. Tronto, J., 'An ethic of care', *Generations: Journal of the American Society on Aging* **22**(3) (1998) 15-20, https://www.jstor.org/stable/44875693 (accessed 2020-11-05).
29. Lipman, M., *Thinking in education*, 2nd ed., Cambridge University Press, Cambridge (2003).

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An in-depth look at the application of GIS for industrial heritage documentation

Uma análise detalhada da aplicação dos SIG para a documentação do património industrial

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Abstract

The use of geospatial technologies to identify and document architectural heritage, with the associated benefits for managing information, is already relatively widespread. However, there has been little discussion about the difficulties, decision-making process and problems encountered when using GIS to digitize data, identify and document this heritage. This study sets out to propose a conceptual work to explore the relationship between immovable industrial heritage documentation and GIS application on the basis of case studies, in particular: the identification and documentation of the industrial heritage in the Eurocity of Guadiana and the olive mills in Écija. After discussing the workflow developed, the difficulties and problems encountered, and how these determine the structure of the GIS model, the decision-making process and the results, this paper concludes that further progress is still necessary to acquire a more pragmatic vision of the use of GIS in the field of industrial archaeology.

KEYWORDS
Immovable industrial heritage
Industrial archaeology
GIS applied in heritage documentation
Information management
Decision-making process
Safeguarding of industrial heritage

Resumo

A utilização de tecnologias geoespaciais para identificar e documentar o património arquitectónico, com os benefícios associados à gestão da informação, está já relativamente difundida. No entanto, tem havido pouca discussão sobre as dificuldades, o processo de tomada de decisão e os problemas encontrados na utilização dos SIG para digitalizar dados, identificar e documentar este património. Este estudo pretende propor um trabalho conceptual para explorar a relação entre a documentação do património industrial imóvel e a aplicação dos SIG com base em estudos de caso, em particular: a identificação e documentação do património industrial na Eurocidade do Guadiana e dos moínhos de azeite (Écija). Após discutir o trabalho desenvolvido, as dificuldades e problemas encontrados, e como estes determinam a estrutura do modelo SIG, o processo de tomada de decisão e os resultados, conclui-se que são necessários mais progressos para adquirir uma visão mais pragmática da utilização do SIG no domínio da arqueologia industrial.

PALAVRAS-CHAVE
Património industrial imóvel
Arqueologia industrial
SIG aplicado na documentação do património
Gestão da informação
Processo de tomada de decisões
Salvaguarda do património industrial

Introduction

Industrial archaeology is defined as the multidisciplinary study of the tangible evidence of social, economic, technological and scientific development of the period since industrialisation [1-2], usually considered to stretch from the mid-eighteenth century until the 1960s. The timeline for the process of industrialisation may vary according to the country or even a particular region. In the case of Portugal and Spain, the differences are regional. For example, in Spain industrialisation had a greater impact in Catalonia and the Basque Country, while the same is true of the north-west Lisbon-Porto region in Portugal. In this context, industrial heritage may be defined as the movable, immovable and intangible assets that bear witness to past and ongoing industrial processes related to production, the extraction of raw materials, their transformation into goods and the associated energy and transport [3]. However, some authors consider that the timeline defined by the Industrial Revolution merely "facilitates" the study of evidence but does not reflect the historical reality, and they therefore believe that the definition should include assets from periods before the eighteenth century (proto-industrial heritage) [4]. Despite the lack of a general consensus on the timeline, there is broad agreement that industrial archaeology implies the use of methods derived from the discipline of archaeology as well as from anthropology, geography, architecture, history, economics, engineering, etc. [5-6]. This interdisciplinary nature is also accompanied by approaches based on collaborative projects and, more recently, by the use of digital methods. The field of digital humanities is a core component of the case studies presented here, insofar as they are exploratory projects that generate empirical hypothesis models and testing models aimed at finding alternatives to the methods traditionally used to record and study industrial heritage.

Spatial information science, and GIS (Geographical Information Systems) in particular, currently offer several applications for the field of cultural heritage [7-8]. GIS permits the analysis of cultural heritages in continuous spatial scales considering historical buildings, courtyards, historical towns, archaeological sites, and landscapes [9-10]. Also, they have been used for heritage management to achieve better planning and preservation [11]. The GIS "model" used is defined according to the characteristics and objectives of the study or project in question [12]. The purpose of these models is to simplify the reality by incorporating the necessary data to observe a particular phenomenon. This ranges from a simple visualisation of specific attributes, to more complex spatial analyses that include diachronic and synchronic studies, the interaction with pre-existing elements, the transformation of the landscape or asset, etc.

This work examines two case studies focused on immovable industrial heritage: the Guadiana Eurocity and the olive mills in Écija. The main objectives of this paper are:

- present the methods and materials used in the workflow to identify and document the industrial heritage;
- highlight the difficulties and problems encountered in the development of both cases;
- identify the impact of the difficulties and problems on the decision-making process and the product generated.

It is important to reiterate the complexity of managing an industrial heritage asset and the impact of the physical environment in which it is located, which is essential for carrying out the industrial activity. Analyses related to these two case studies conducted from different disciplines (anthropology, architecture, history, etc.) confirm that the industries and their associated activities did not only play a role in the anthropisation of the built landscape. They were also instrumental in transforming the lifestyles and characteristics of their communities and their identity. In the case of Eurocity, among others, we could cite the relevance of: studies about woman workers in Ayamonte [13], the canning industry in Algarve [14-15], the industrial urbanization of Vila Real de Santo Antonio [16-17] and historical and territorial approach [18]. In the case of Écija, the studies carried out previously include, among others: in the field of pre-industrial archaeology [19-21], territorial planning [22] and industrial landscape [23].

The Guadiana Eurocity

The aim of this case study was to generate a preliminary inventory of the immovable industrial heritage in the Guadiana Eurocity, recognised as a European Grouping of Territorial Cooperation in 2018, as the basis for the construction of guidelines for developing sustainable cross-border cultural tourism. The territorial scale adopted for this case study is regional–inter-municipal. Specifically, the Guadiana Eurocity has a cross-border, trans-national inter-municipal scale encompassing the Portuguese municipalities of Castro Marim and Vila Real de Santo Antonio and the Spanish municipality of Ayamonte (Figure 1). Together, they form an area of approximately 500 Km^2.

The three municipalities are mainly connected by an industrial past centred around fishing and salt production, while the river Guadiana is the physical link that has enabled them to share knowledge, techniques, people and goods since time immemorial. The industrial elements were largely associated with these two productive activities that were carried out in what is now the Eurocity from the mid-nineteenth century to the beginning of the twentieth-first century. Despite the inter-connections in the development of these industries, such as the resulting landscape, few studies have treated the Eurocity as a single entity. The predominant tendency has been to carry out isolated studies related to a particular discipline, topic or place. We were able to identify 138 elements: 57 in Vila Real de Santo Antonio, 9 in Castro Marim and 72 in Ayamonte (Figure 2).

Figure 1. Map showing the location of the Guadiana Eurocity.

Figure 2. Examples of assets in the Guadiana Eurocity: *a)* and *b)* canning factories (Ayamonte); *c)* canning factory (Vila Real de Santo Antonio); *d)* salt marsh (Castro Marim).

Olive mills in Écija

The second case study takes place on the historical olive mills in Écija, a rural town in the Sevilla province with an olive oil tradition dating back hundreds of years. These buildings, which had beam and weight presses, were the main oil production units for centuries. Their presence was documented as early as the seventeenth century when a population census in 1640 identified 240 mills [24]. Bundles 358 and 908 at the Écija Archive of Notarial Records contain the plans of two olive presses at sixteenth-century mills whose spatial and functional structures are the same as those found in the other mills identified in the field visits. This figure remained practically unchanged until the mid-twentieth century [25], when many units fell into disuse and began to disappear.

The mills formed part of a complex process associated with the agro-industrial activity, from picking the fruit to shipping the end product to national and international markets. In our view, the mills should therefore be considered in a holistic manner with all the elements of the olive groves: the type of cultivation; the road transport and communication system; the water collection, transfer and storage system; and the facilities associated with the agricultural and domestic activity of the mills. However, in this paper we focus solely on the mills. The scale considered for this case study was determined by the jurisdictional boundaries of the municipality, approximately 980 Km^2 (Figure 3 and Figure 4).

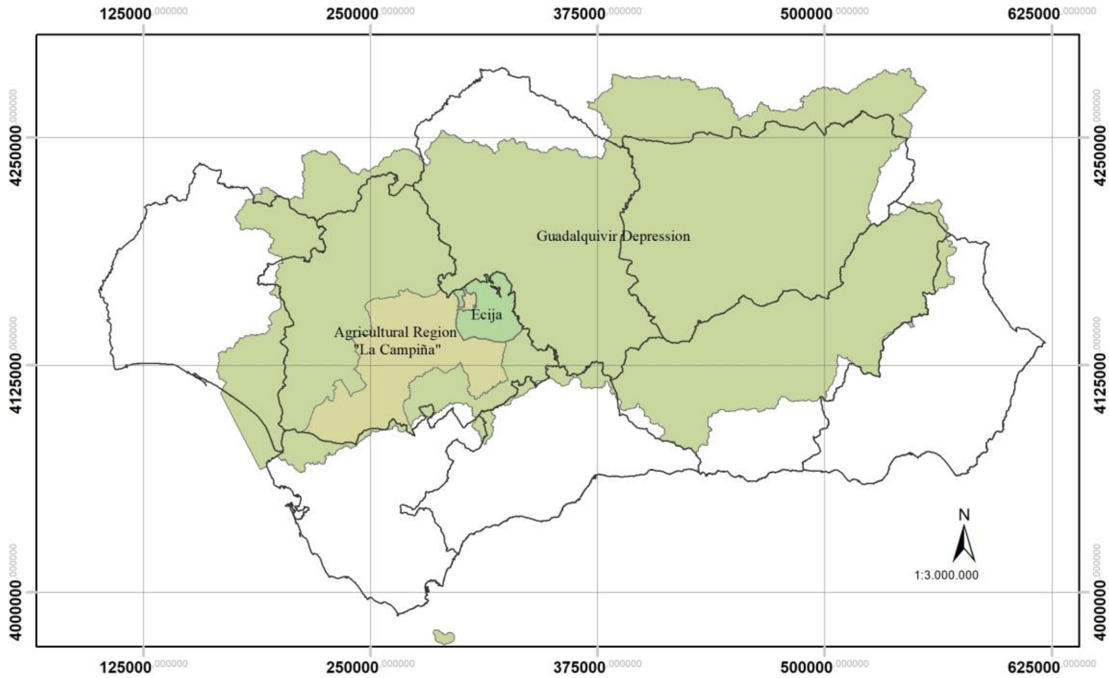

Figure 3. Situation of Écija in the Agricultural Region of the Guadalquivir Depression in Andalucía, Spain.

Figure 4. Charcón mill in Écija. It still contains the robust counterweight tower characteristic of beam and weight presses.

Materials and methods

Intrinsic to industrial archaeology, the chain of processes involved in heritage work includes conservation, with view to preserving the heritage, as well as actions designed to enhance its value: identification, research, dissemination and protection. Heritage "value" emerges when we can identify cultural assets, so it is therefore crucial to understand the value of these assets and how to enrich it [26]. Since research and management are lengthy processes, for the two case studies we have adopted as our basis the "value chain", defined as a sequence of interrelated phases that provide a holistic view of the heritage. These are: 1) identification; 2) documentation and recording; 3) assessment and implications; 4) intervention; 5) dissemination and socialisation; 6) economic impact and reflection [27-28]. In this paper we focus primarily on the aspects and issues related to the first two phases of the "value chain", which according to the Nizhny Tagil Charter play an important role in the assessment and knowledge of heritage [2, 29].

The Faro Convention on the Value of Cultural Heritage for Society [30] changed the path of legislation by focusing on the elements that give value to cultural heritage through a people-centred approach. It defined the European cultural heritage as elements connected to a context of common remembrance, identity and healthy cultural diversity. In consequence, knowledge and use of heritage form part of the citizen's right to participate in cultural life. Heritage is seen as a resource for human development, the enhancement of cultural diversity and the promotion of intercultural dialogue, and as part of an economic development based on the principles of sustainable resource use.

Having embarked on the study of the social and cultural aspects connected to the local industry, we focused on immovable industrial heritage as the first phase of our research of the built past. The two case studies share the main objective of documenting and recording the immovable industrial heritage through the same methodology and the application of the GIS.

Method for identifying and documenting the immovable industrial heritage

As the method for identifying and documenting the immovable industrial heritage assets in the two case studies mentioned above, we defined the same workflow comprising six phases that impact the architecture of the GIS model: 1) identification of the heritage type and time frame; 2) selection of sources and data collection; 3) design of the geodatabase; 4) data processing and digitalisation; 5) data visualisation; 6) output package (Figure 5).

Regarding the GIS's tools used in the institutions, we find a similar scenario. In Portugal, the Directorate-General for Cultural Heritage (DGPC) is the organization in charge of the protection and care of the national heritage. For the inventory of architectural heritage, the DGPC uses a relational database linked to a spatial data infrastructures (SDI) called SIPA [31]. The DGPC uses *ArcGIS* software as a base tool, and its public visualization uses *ArcGIS online* [32].

In Andalusia, the Andalusian Institute of Historic Heritage (IAPH) is the organization in charge of the protection and care of the regional heritage [11]. The information system called *Guía Digital del Patrimonio Cultural de Andalucía* [33] provides structured semantically enriched data and a map viewer of the assets. The Guide is an open and public platform and its linkage with the IAPH's internal relational database management system [34], and an internal SDI. For the updating and management of the SDI, *ArcGIS* is also used. However, unlike in Portugal, the public geographic viewer provided is through *Mapea* [35]. Both case studies used *ArcGIS* software during phases 3 to 6. The Eurocity case also used *QGIS* and *Tableau* software for phase 5.

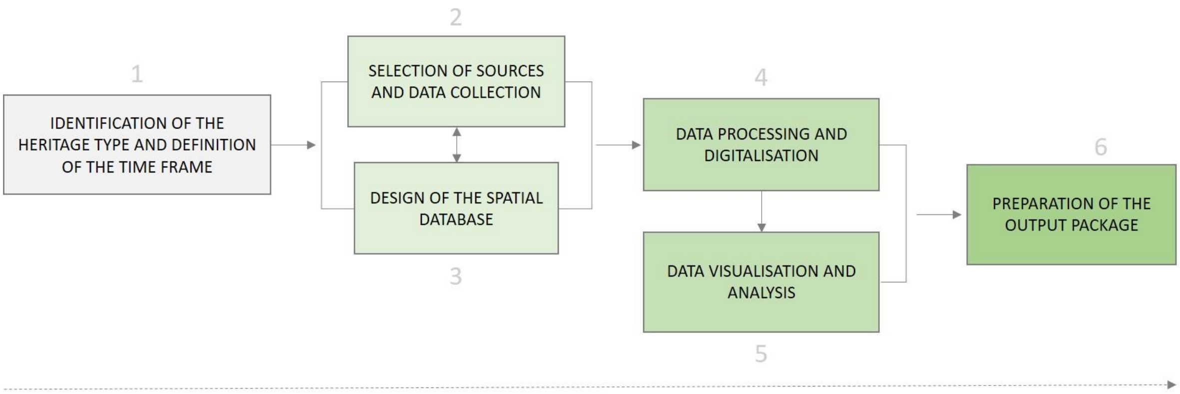

Figure 5. Workflow for the identification and documentation.

Definition of the heritage type and time frame

For the Guadiana Eurocity case study, the project focused on the industrial assets that were mainly used between 1840 and 1960 (mid-nineteenth to mid-twentieth century). The fishing and salt production activities carried out in this geographical area translated into numerous canning and salting factories as well as salt marshes. The initial inventory work identified 21 different types of industrial heritage in eight sectors.

In the case of the Écija olive mills project, the research identified seven different types in three sectors, including the elements from the proto-industrial period, with a temporal arc stretching from the sixteenth century to the mid-twentieth century. The olive oil production boomed in the sixteenth century due to the demand for oil from the Americas [19]. This historical aspect, coupled with the existence of a plan in the Écija Archive of Notarial Records (APNE) of a sixteenth-century mill with the same functional layout as the mills studied, suggests that constructions of this type proliferated in that century (Table 1).

Table 1. Industrial heritage types.

Sector	Type	
	Guadiana Eurocity	**Écija**
Agri-food	Flour factories Salting factories Canning factories Ice factory Jam factory Warehouses Windmills Tide mills	Oil mills Warehouses Olive oil production waste pond (*bejinero*)
Transport	Railway buildings Railway stations Transport infrastructures	Railway buildings Railway stations Transport infrastructures*
Energy	Hydraulic infrastructures: Dams	
Mining and quarrying activities	Salt marshes - Salt pans	
Construction, ceramics and glass	Earthenware factory	
Cork, wood and furniture, paper and graphic arts industry, leather and footwear industries	Printing: Lithographic workshops	
Industrial urban planning, housing and social facilities	Housing for large landowners, workers' housing Refectories	Housing for seasonal workers
Other elements	Market buildings Fresh-fish market (*Lonja*)	

* Roads from the olive grove to the mill and from the mill to a main.

Selection of sources and data collection

Both cases studies required the consultation and selection of primary sources, mainly historical documents with unstructured information (comprising historical, economic, architectural and other data), plans and old photographs. The main secondary sources were published articles, books and/or institutional documents about the object of study or its historical context.

In both cases, fieldwork played an important role for gathering data about the assets. The territory itself is a living and dynamic source of documentation in which it is still possible to identify and visualise material witnesses and remains of the industrial past. In this case, we are not only talking about built material witnesses but also the cultural landscape of each area of study. In the case of the memory of the production culture, these industrial landscapes have left a still visible trace on the territory and, in the case of the Eurocity, there is still the living memory of those who worked in the old factories and salt marshes. The contact and collaboration with various local stakeholders in Spain and Portugal were crucial in this respect.

As regards the use of existing layers, in both cases we employed feature layers and raster layers (aerial photographs) from public institutions and international servers. This facilitated both the fieldwork and the generation of new records (Phase 4 – Data processing and digitalisation) (Table 2).

Table 2. Sources for data collection.

Case study sources	Guadiana Eurocity	Ecija
Primary sources	Documents, photographs, maps and plans from the following archives, libraries and institutions: Vila Real de Santo Antonio Municipal Archive; District Cuncil of Vila Real de Santo Antonio; Vila Real de Santo Antonio Muncipal Library; Andalusian Virtual Library; Ayamonte Municipal Archive; Faro District Archive; Huelva Provincial Archive; Map Catalogue of the National Geographical Institute (IGN), the Andalusian Institute of Statistics and Cartography (IECA); Catalonian Cartographical Institute and Simancas General Archive (AGS); Digital Periodical and Newspaper Library of the National Spanish Library.	Documents, photographs, maps and plans from the following archives, libraries and institutions: Cartographic Archive of Geographical Surveys of the Geographical Centre of the Army; Seville Cathedral Archive; APNE; AGS; Nobility Historical Archive; Écija Municipal Archive (AME); Murcia Municipal Archive; Santa María de Écija Parish Archive; Hispanic Digital Library; Spanish Digital Library; Royal History Academy Digital Library; Spanish National Library; Andalusian Virtual Library; Bibliographic Heritage Virtual Library; French National Library; Strasbourg National and University Library; Map Catalogue of IGN; IECA; Seville University Ancient Collection; Catalonian Cartographical Institute; Écija Institute of Secondary and Vocational Education.
Secondary sources	Papers, books, monographs, etc.	Papers, books, monographs, etc.
Fieldwork	We visited on several occasions to the assets.	18 routes subdivided into 43 sections [25] where we identified the mills as well their service infrastructure.
Layers sources (raster, vectorial and servers)	For the layers of the physical environment of Andalucía we used the feature layers of DERA100 of REDIAM. For the context layers in the Algarve, we used OSM. Aerial photographs of the US Army flight (Series B 1956-57) of the IGN, the inter-ministerial flight (1977-1983) of REDIAM, of the IGN; World Imagery from Esri, Maxar, Earthstar Geographics, and the GIS User Community.	Écija Municipal Council supplied a *shapefile* of the mills, but it was incomplete. The transport layers were obtained from the IGN while the ones related to the physical environment were obtained from REDIAM. Aerial photographs of the US Army flight (Series B 1956-57) of the IGN, the inter-ministerial flight (1977-1983) of REDIAM, the SIGPAC flight (1998-2003) of the IGN and the latest PNOA orthophotos (2019) of the IGN.
Stakeholders	Governance Laboratory of the Guadiana Eurocity, Vila Real de Santo Antonio Municipal Council, researchers of Algarve University, researchers of Huelva University, technicians of the Vila Real de Santo Antonio Archive, technicians of the Ayamonte Archive, residents of Ayamonte, residents of Vila Real de Santo Antonio, residents of Castro Marim.	Researchers of Seville University, researchers of the TUTSOMOD Project, technicians of the Écija Notarial Records Archive, technicians of the Écija Municipal Archive, Écija Municipal Council.

Design of the geodatabase

The use of GIS enables us to present many different layers of information. This means that we can have different thematic layers for a given area which enhance our understanding of it. The first step to creating a model was to define the geographical feature type (a feature associated with a real location on Earth) for both case studies to generate a feature vector (point, line and/or polygon). The aim of generating feature vectors is to represent real-world phenomena, in our case the immovable industrial heritage. The data structure designed for each case study corresponds to the objectives pursued.

In the case of the Guadiana Eurocity, the objective was to create a preliminary inventory of the immovable industrial heritage in the three municipalities, including both demolished and existing assets, to generate an information model of the industrial memory of the Eurocity and record its current state of conservation. This model would subsequently form the basis for the heritage classification and management and for the development of cross-border industrial tourism guidelines. We used the IAPH Thesaurus to ensure a controlled vocabulary in the table of attributes and facilitate subsequent interoperability with public administrations.

For the Écija olive mills, the principal aim was to identify all the olive oil mills that had ever existed in the municipality, including those now lost, and then to drill down to a more detailed level in order to provide two outputs: a source of knowledge for the classification of the mills contemplated in the Écija general land use plan; and a heritage management tool (Table 3).

Table 3. List of data structure fields.

Field/Attribute	Case study	
	Eurocity	**Écija**
Shape (point/line/polygon)	×	×
Province	×	×
Municipality	×	×
Municipal code	×	×
Name	×	×
Other name	×	×
State of conservation	×	×
Level of protection	×	×
Historical period	×	×
General type	×	×
Specific type	×	×
Activity	×	×
Historical description	×	×
Architectural description	×	×
Geographical coordinates	×	×
Sources	×	×
Owner	×	×
Date founded	×	-
Date closed	×	-
Address	×	×
Old Address	×	×
Registration	-	×
Village/Zone/Plot	-	×
Year disappeared	-	×

Data processing and digitalisation: creation of the feature layers

In both case studies the spatial database was constructed by vectorising the immovable assets. This process consisted in creating point, line or polygon feature layers for the geographical location of each asset. Viewing and comparing aerial photographs and maps from different periods of the areas of study played a vital role in this phase.

In the Guadiana Eurocity, we used point and line layers as well as polygon layers. The points were used to represent certain longitudinal infrastructures and assets, specifically the dams and salt marshes found in the municipality of Castro Marim. We also had to generate line layers to represent the railway tracks that had been vital for the entire industrial production system in the area. The polygon layers contain the most records since these were used to represent industrial and infrastructure buildings as well as the houses of the workers' and large landowners.

We also worked with the three types of feature vector in the case of Écija. We treated the asset as a polygon due to the scale of both the architectural asset and the mill habitat, while for larger territorial scales we worked exclusively with points. This circumstance was repeated in the case of the infrastructure associated with the mill, whereas the elements of the water storage, collection and transfer system were represented according to their geometry. Lastly, the communication and transport system were represented with lines and the olive grove with polygons.

Data visualisation

Once we had created the feature layers and organised them in the GIS table of contents, we were able to visualise the vector files using any of the pre-existing maps as the base layer. The graphical representation of the vector files can also be used to visualise one or more of the assigned attributes, such as the state of conservation, timeline, building type or level of protection (Figure 6 and Figure 7).

Figure 6. Maps shows the polygon records and some of the photographs of the buildings linked to them: *a)* the Vila Real de Santo António assets; and buildings: *b)* 1; *c)* 17 to 20; *d)* 19; *e)* 36; *f)* Ayamonte–Guadiana Eurocity assets; and buildings: *g)* 0; *h)* 8; *i)* 10; *j)* 31-33.

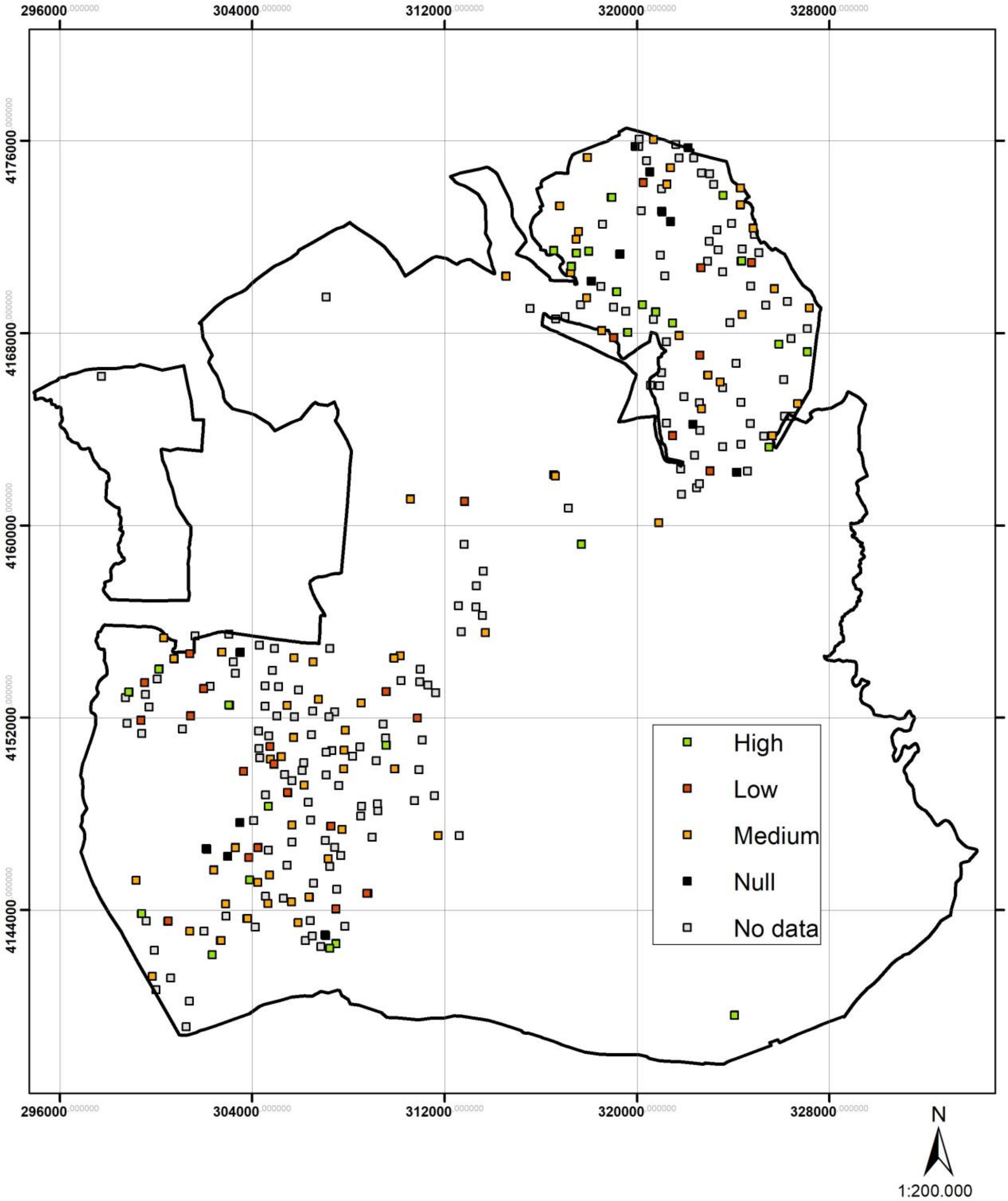

Figure 7. Level of architectural merits according to the 2009 land use plan: high (green); medium (orange); low (red); none (black). Grey represents the mills not included in the land use plan.

Creation of the output package

The last phase of the process was the creation of "output package", consisting of the feature layers in *shapefile* with their respective metadata, such as the record tables, in *.xml* format. The publication of these files in the institutional repositories will facilitate greater accessibility as well as the reuse and sustainability of the data. In both cases the University of Seville repository [36] will be used, and in the case of the Guadiana Eurocity the output package will also be published in the digital repository of the Andalusian Institute of Historical Heritage [37]. In the case of the Écija mills, the elements of the spatial database will be added to the existing spatial data infrastructure currently used by Écija Municipal Council.

Challenges in the development of the case studies

The first challenge related to the data collection was to determine which data to consider and which to ignore. Although at the outset of both projects we had every intention of collecting as many data as possible, in practice the particularities of each case determined the data to include. For the Eurocity, it became clear while we were compiling the documents that the initial approach was not viable because of the resources, time frame and characteristics of the project. The Guadiana Eurocity research project lasted six months and was carried out with a single STIP grant. In the case of the Écija mills, it was possible to acquire more data because of a longer time frame and exclusive dedication to the project (part of a four-year pre-doctoral project with funding to match).

The second challenge affected the Eurocity case study only and concerned the need to work with documentary sources in two countries (namely, Portugal and Spain), which revealed different ways of recording industries in the nineteenth and twentieth centuries. This aspect involved critical analysis of the volume of documents and the type and characteristics of the data contained in them. In this case, after analysing the sources we made the decision to simplify the data that would be included in the geodatabase to prioritise data quality over data quantity. We therefore selected a restricted number of attributes that would allow us to create a preliminary inventory without losing sight of important elements of the Eurocity.

The third challenge was to identify the exact location of the assets. In the case of the Eurocity, many of the documents do not include the full address of the asset; most of the time only the street is mentioned, without the number. Besides, the names of streets have changed over the years, which further complicated the matter. In the case of the municipality of Vila Real de Santo Antonio, there was a rigorous work done previously on the changes of the toponymy of the streets [38] which has helped us to identify the locations. On the other hand, in the case of Ayamonte, we have had to make comparisons by juxtaposing old plans with the current plan. To prevent the loss of the identified records, we decided that the feature layers would only include assets for which we had discovered the exact location and that we would simply record the others in the output package tables. In the case of Écija, the continuity of olive oil production until the mid-twentieth century, the isolated location of the mills and the existence of a sizeable number of maps and orthophotographs made it easier to identify the olive mills with graphical resources, although it was more difficult when we encountered inaccuracies in the nineteenth-century maps and name changes. We backed up this identification of the location of the mills by cross-checking the initial information with bibliographical references and the data obtained from our field visits. However, with regard to mill infrastructures located outside the mill proper, only the topographical map (1951–58) contained accurate information.

The fourth problem was to deal with the lack of certain historical data. There are several reasons for the omission of certain data. In the first place this is because the information about the asset found in historical documents tends to be vague. In the case of the mills, since these are buildings that emerged over the course of several centuries (some mills disappeared and others were only built in the nineteenth century) the exact date of construction is not always known (it was not recorded in any document). This is also true of the documents we consulted about the Eurocity, which only contain a brief reference to the construction of the asset and the date it opened. Another difficulty encountered in the Écija case study was the fact that important documentary sources such as the Ensenada Land Registry and the Accounting Ledger have yet to be transcribed.

The omission of certain data is also explained by the difficulty of collecting them in situ, mainly due to the impossibility of accessing the asset or parts of it. In both case studies, certain field data could not be collected. The reasons for this varied:

- lack of structural safety of the asset;
- access refused by the owner;
- no access roads;
- overgrown vegetation in certain areas or rubbish accumulation;
- closed due to rehabilitation works (Eurocity);
- intense cultivation around the asset (Écija).

Based on the experience of both case studies, it is clear that working with data from earlier centuries presents a great challenge and that the database should therefore allow certain fields to be left blank. In this case, the decision to use the GIS and the spatial database provided the necessary flexibility to correct, add and update information. This means that the process can be an ongoing one, which is extremely useful for heritage management.

Conclusions

Knowledge of industrial heritage contributes to cultural identity and its systematic spatial identification can contribute to the preservation of industrial and architectural heritage, raising cultural sustainability. This paper discusses two case studies concerning the identification and documentation of immovable industrial heritage that share the same workflow and use of the GIS. Knowledge of built industrial heritage provides valuable information about the history intrinsic to production processes and the environments in which they are carried out. The paper also highlights the need for greater knowledge and dissemination of a type of heritage that has yet to be fully appreciated – namely, immovable industrial heritage in Portugal and Spain.

The comparative approach adopted for the two case studies and the discussion of the problems encountered and decisions made demonstrate the role played by the solutions adopted in the identification and documentation of the assets. In other words, although the methods and tools used to create the models are very similar, the end product is the result of a series of decisions, often personal and/or agreed with the stakeholders.

It is clear that the GIS information model is a significant tool for carrying out Phases 1 and 2 of the "value chain" because it permits the systematisation of information, interconnected field and desktop work, greater interoperability and the opportunity to reuse the generated model. However, as demonstrated [9, 39], the complexity of the heritage means that it is not always compatible with the simplification required by digital information modelling. One of the significant results obtained was that, despite the difficulty and/or impossibility of acquiring certain data, the flexibility of the tool allows the omission of these data, while supporting a continuous process and the possibility of adding data in the future. This is a key issue for public administrations, as it allows the possibility to improve the quality of information.

Although we observe many benefits in the use of GIS, three issues related the sustainability and reuse of the data have yet to be resolved: 1) the credits for the data generated, since the models are created by researchers and then implemented in public administration systems, often without preserving any reference to the authors; 2) the institutions have to bear the cost of maintaining and updating the information; 3) the institutions often lack upgraded tools and the technical knowledge to use them. These issues are particularly significant in the case of the Eurocity because although the model was initially created jointly, the "output package" will be managed and used differently in each country.

The team hope that these initiatives will enable institutions and communities to develop decision-making skills and manage their development processes in a way that ensures that industrial architecture heritage contributes to the social, cultural and economic dynamics of the communities of the Guadiana Eurocity and Écija. Faro Convention Action, through its heritage-led work, creates field-based platforms where transversal issues and the Council of Europe institutional knowledge and experience are brought together around concrete actions, setting examples for the type of society we aspire to build.

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REFERENCES

1. Neaverson, P.; Palmer, M., *Industrial Archaeology: Principles and Practice*, Routledge, London (2012).
2. TICCIH, *The Nizhny Tagil Charter for the Industrial Heritage,* International Committee for the Conservation of Industrial Heritage, Moscow (2003), http://international.icomos.org/18thapril/2006/nizhny-tagil-charter-e.pdf (accessed 2022-09-01).
3. ICOMOS-TICCIH, *The Dublin Principles* (2016), https://ticcih.org/wp-content/uploads/2013/10/GA2011_ICOMOS_TICCIH_joint_principles_EN_FR_final_20120110.pdf (accessed 2022-09-01).
4. Hernandéz, R.; Ortuñez, P. P.; Zaparaín, F., 'La puesta en valor del patrimonio industrial: inventariarlo. Una muestra del caso palentino', in *VI Congreso International restaurar la memoria: La gestión del patrimonio: hacia un planteamiento sostenible*, vol. 2, ed. J. Rivera Blanco, Junta de Castilla y León-Consejeria de Cultura y Turismo, Valladolid (2010) 227-232.
5. Aracil, R.; Cerda, M.; García Bonafé, M., *Arqueología industrial en Alcoi*, Ayuntamiento de Alcoi, Alcoi (1980).
6. Casado Galván, I., 'La arqueología industrial: una investigación multidisciplinar', in *Contribuciones a las Ciencias Sociales* (2009), http://www.eumed.net/rev/cccss/06/icg18.htm (accessed 2021-04-15).
7. Ferreira Lopes, P., 'Achieving the state of research pertaining to GIS applications for cultural heritage by a systematic literature review', *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* **42**(4) (2018) 169-175, https://doi.org/10.5194/isprs-archives-XLII-4-169-2018.
8. Rodríguez Miranda, Á.; Ferreira Lopes, P.; Martín Etxebarria, G.; Korro Bañuelos, J., 'Linear programming for the analysis and virtual recreation of historical events: the allocation of the artillery during the Siege of Bilbao in 1874', *Virtual Archaeology Review* **12**(25) (2021), https://doi.org/10.4995/var.2021.15278.
9. Ferreira Lopes, P., Modelos digitales de información – SIG y grafos – aplicados en el patrimonio: la fábrica edilicia en el antiguo reino de Sevilla en el tránsito a la edad moderna, PhD Dissertation, Department of Architectural Graphic Expression, Universidad de Sevilla, Sevilla (2018), https://idus.us.es/handle/11441/81525 (accessed 2021-03-13).
10. He, J.; Liu, J.; Xu, S.; Wu, C.; Zhang, J., 'A GIS-Based Cultural Heritage Study Framework on Continuous Scales: A Case Study on 19th Century Military Industrial Heritage', *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, **XL-5/W7** (2015) 215-222, http://doi.org/10.5194/isprsarchives-XL-5-W7-215-2015.
11. Korro Bañuelos, J.; Rodríguez Miranda, Á.; Valle Melón, J. M.; Zornoza Indart, A.; Castellano Román, M.; Angulo Fornos, R.; Ferreira Lopes, P., 'The role of information management for the sustainable conservation of cultural heritage', *Sustainability* **13**(8) (2021) 4325, https://doi.org/10.3390/su13084325.
12. Ferreira-Lopes, P.; Moya Muñoz, J.; Fondevilla Aparicio, J. J., 'Prospección de la producción científica sobre los modelos SIG aplicados al patrimonio', in *Modelos digitales de información en la tutela sostenible del Patrimonio Cultural. Contribución al conocimiento e innovación social*, ed. F. Pinto Puerto, Universidad de Sevilla, Sevilla (2020) 122-128.
13. Cáceres Feria, R., *Mujeres, fábricas y charangas: el trabajo femenino en el sector conservero de Ayamonte (Huelva)*, Consejería de Cultura, Junta de Andalucía, Sevilla (2002).
14. Da Costa Amaro, A., *A indústria Conservera na construção da malha urbana no Algarve: das estruturas produtivas à habitação operária (1900-1960)*, Master Dissertation, Department of Architecture, Universidade de Évora (2015), http://hdl.handle.net/10174/28687 (accessed 2021-03-13).
15. Rodrigues, J. M. V., 'A indústria de conservas de peixe no Algarve: 1865-1945', Master Dissertation, Department of History, Universidade Nova de Lisboa (1997), http://hdl.handle.net/10362/21335 (accessed 2021-09-01).
16. Custódio, J., 'A indústria conserveira vila-realense. Um caso peculiar de urbanização industrial e de património', *Monumentos: Revista semestral de edifícios e monumentos* **30** (2009) 106-121.
17. Figueras, R., *Vila Pombalina*, Camara Municipal de Vila Real de Santo Antonio, Vila Real de Santo Antonio (1999).
18. Domínguez, J. A. M., *La Eurociudad del Guadiana: Perfil e identidad en la frontera ibérica*, vol. 8, Servicio de Publicaciones de la Universidad de Huelva, Huelva (2021).

19. García-Dils de la Vega, S.; Ordoñez Agulla, S.; Sáez Fernández, P.; Venegas Moreno, C.; Rodríguez, J., 'A preindustrial landscape in 18th-century Écija (Seville-Spain): The olive-oil production facilities as territorial markers', in *Landmarks and socio-economic systems: proceedings of Le Mans COST conference*, vol. 1, PU Rennes, Rennes (2006) 75-88.
20. Sancho Corbacho, A., 'Haciendas y cortijos sevillanos', *Archivo hispalense: Revista histórica, literaria y artística* **17**(54-56) (1952) 9-27.
21. Tejido Jiménez, F., *Cortijos, haciendas y lagares: arquitectura de las grandes explotaciones agrarias de Andalucía. Provincia de Sevilla*, Dirección General de Vivienda y Arquitectura, Sevilla (2009).
22. Martín Ojeda, M., *Ordenanzas del Concejo de Écija (1465-1600)*, Ayuntamiento de Écija, Diputación de Sevilla, Sevilla (1990).
23. Moya Muñoz, J., 'El olivar en Écija: un paisaje olvidado', in *Análisis y comunicación contemporánea de la arquitectura*, n 17, Universidad de Sevilla, Sevilla (2019) 138-153, https://dialnet.unirioja.es/servlet/articulo?codigo=7033018 (accessed 2021-03-13).
24. Gil-Bermejo García, J., 'Écija en la primera mitad del siglo XVII: notas demográficas y económicas', in *Actas del I Congreso de Historia de Andalucía, Andalucía Moderna (siglos XVI-XVII)*, tomo II, Monte de Piedad, Publicaciones del Monte de Piedad y Caja de Ahorros de Córdoba, Córdoba (1978) 127-144.
25. Moya Muñoz, J.; Pinto-Puerto, F., 'Digital models applied to the typological analysis of the olive oil mills with beam and weight presses in Écija', *Virtual Archaeology Review* **13**(26) (2022) 116–134, https://doi.org/10.4995/var.2022.15077.
26. Sierra Delgado, J. R., 'Arquitectura, programa y plusvalía: el Proyecto patrimonial', *Neutra* **11** (2004) 14-21.
27. Azkarate, A.; Barreiro, D.; Criado, F.; García Camino, I.; Gutiérrez Lloret, S.; Quirós, J.A.; Salvatierra, V., 'La Arqueología hoy', in *Medio siglo de arqueología en el cantábrico oriental y su entorno,* eds. Ortiz de Landaluze and A. L., Vitoria-Gasteiz, Instituto Alavés de Arqueología y Diputación foral de Álava, Álava (2009) 599-615.
28. Solaun Bustinza, J.; Onaindia, U. G.; Ortega, L. A.; García, J. R.; Navarrete, A. M.; Aberasturi, A. A. J., 'Group of monuments of Portilla (Basque Country, Spain). A project about comprehensive management of heritage', in *REHAB 2014, Proceedings of the International Conference on Preservation, Maintenance and Rehabilitation of Historical Buildings and Structures*, eds. R. Amoêda, S. Lira and C. Pinheiro, Green Lines Institute for Sustainable Development, Barcelos (2015).
29. ICOMOS, *Principles for the recording of monuments, Groups of Buildings and Sites* (1996), https://www.icomos.org/en/charters-and-texts/179-articles-en-francais/ressources/charters-and-standards/387-principles-for-the-recording-of-monuments-groups-of-buildings-and-sites-1996 (accessed 2022-09-01).
30. 'Faro Convention Action Plan Handbook 2018-2019', in *Council of Europe – Culture and cultural heritage* (2018), https://www.coe.int/en/web/culture-and-heritage/faro-action-plan (accessed 2022-04-23).
31. *SIPA. Sistema de Informação para o Patrimonio Arquitectónico*. http://www.monumentos.gov.pt/site/APP_PagesUser/SitePageContents.aspx?id=a9663831-7fd2-48b4-a692-ebb6046b68a4.
32. *Atlas do Patrimonio classificado e em vias de classificação,* https://patrimoniodgpc.maps.arcgis.com/apps/webappviewer/index.html?id=7f7d5674280f41849c0a0869ced22d91 (accessed 2023-01-30).
33. 'Guía Digital de Patrimonio Cultural de Andalucía', in *Instituto Andaluz del Patrimonio Histórico – Consejería de Turismo, Cultura y Deporte*, https://guiadigital.iaph.es/inicio (accessed 2023-04-10).
34. 'Mosaico', in *Junta de Andalucía – Consejería de Turismo, Cultura y Deporte*, https://juntadeandalucia.es/organismos/turismoculturaydeporte/areas/cultura/bienes-culturales/recursos-difusion-patrimonio/paginas/mosaico.html (accessed 2023-04-10).
35. 'Mapea', in *Junta de Andalucía – ideAndalucía*, https://www.ideandalucia.es/portal/mapea (accessed 2023-04-10).
36. 'Depósito de Investigación de la Universidad de Sevilla', in *idUS*, https://idus.us.es/?locale-attribute=en (accessed 2022-10-30).
37. 'Repositorio de Activos Digitales del IAPH', in *Instituto Andaluz del PatrimonioHistórico*, https://repositorio.iaph.es/ (accessed 2022-10-30).
38. Cavaco, H., *Toponímia de Vila Real de Santo António*, Câmara Municipal de Vila Real de Santo Antonio, Vila Real de Santo Antonio (2001).
39. Lerario, A., 'The role of built heritage for sustainable development goals: from statement to action', *Heritage* **5** (2022) 2444–2463, https://doi.org/10.3390/heritage5030127.

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CONSERVAR PATRIMÓNIO

Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
ARTIGO / ARTICLE

Desafios na preservação de objetos funcionais em contexto museológico: o papel da documentação na salvaguarda de coleções de instrumentos musicais

Challenges in preservation of functional objects in museological context: the role of documentation in safeguarding of musical instruments collections

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Resumo

Os instrumentos musicais são objetos que, à semelhança dos objetos científicos e industriais, não foram construídos para serem observados. O seu propósito de criação assenta numa função cultural específica: serem tocados. Este propósito pode ser momentaneamente recuperado dentro dos museus, quando os instrumentos incorporados nas coleções são tocados em eventos performativos como concertos, recitais, entre outros. A documentação museológica assume um papel particularmente relevante neste contexto, não só na preservação do suporte material dos instrumentos musicais, como também na salvaguarda de informações relativas aos registos dos eventos performativos enquanto parte do historial destes objetos. Este artigo tem como objetivo apresentar algumas considerações sobre o papel da documentação enquanto parte do processo de salvaguarda dos objetos museológicos, com particular enfoque nas coleções de instrumentos musicais.

PALAVRAS-CHAVE
Documentação
Instrumentos musicais
Objetos funcionais
Uso performativo
Museus

Abstract

Musical instruments are objects that, like scientific and industrial objects, were not built to be observed. Their creation purpose is based on a specific cultural function: to be played. This purpose can be momentarily recovered within museums, when the instruments incorporated in the collections are played in performative events such as concerts, recital, among others. Museological documentation assumes a particularly relevant role in this context, not only in the preservation of the material support of musical instruments, but also in safeguarding information about the records of performative events as part of the history of these objects. This article aims to raise some considerations about the role of documentation as part of the conservation of museological objects, with a particular focus on musical instruments collections.

KEYWORDS
Documentation
Musical instruments
Functional objects
Performative use
Museums

Enquadramento conceptual: a funcionalidade dos instrumentos musicais enquanto objetos integrados em instituições museológicas

A funcionalidade em contexto museológico é um tema frequentemente relacionado com o património científico e industrial. No entanto, existem outras áreas intrinsecamente implicadas nesta discussão, que incluem o património musical – mais concretamente, coleções que integram instrumentos musicais. No âmbito deste artigo, considera-se como "objeto funcional" aquele cujo propósito de criação assenta numa função prática que não é totalmente compreendida apenas pela observação destes objetos, devido à dimensão performativa particularmente forte associada [1].

Em 2016, Panagiotis Poulopoulos [2] defendeu que existem duas fases no período em que o instrumento musical cumpre o seu papel como meio de produção de som. A primeira está associada ao momento da sua construção, na qual são os aspetos materiais – o tipo de material utilizado, a técnica de construção, as dimensões – que importam aos intervenientes. A segunda fase é referente ao seu uso original. A estas duas fases acrescentaria uma terceira, aplicável aos casos em que o objeto é incorporado numa instituição museológica: a recontextualização do objeto. A recontextualização pode ser relacionada com o conceito de "musealização", que é definido como um processo em que os objetos são retirados do seu contexto de origem para serem estudados como testemunhos de uma determinada realidade [3]. No geral, é o que acontece à grande maioria dos bens culturais que são incorporados numa instituição museológica. Quando se opta por expor objetos que, na sua génese, não foram criados para serem observados num contexto museológico, tal como acontece com os instrumentos musicais, estamos a tomar uma decisão que vai alterar o propósito original de um determinado bem cultural. No entanto, no caso dos instrumentos musicais a sua função original pode ser momentaneamente recuperada, quando estes são tocados em iniciativas performativas promovidas pelas instituições museológicas.

Enquanto objetos integrados em coleções museológicas, os instrumentos musicais têm características que ultrapassam os seus atributos materiais e as suas propriedades acústicas. Podem, igualmente, ser interpretados como testemunhos de um determinado período temporal e área geográfica específica, que refletem estilos artísticos presentes noutras artes decorativas, ou até mesmo como artefactos de carácter arqueológico, histórico e/ou antropológico [4]. Em suma, são objetos que contribuem fortemente para a compreensão, não só da parte musical, como também de aspetos da vida social, política, cultural e até mesmo tecnológica do mundo onde vivemos [1, 4-5]. Isto significa que, enquanto "documento histórico", um instrumento musical pode ser categorizado, simultaneamente, como um objeto artístico e como um objeto técnico.

O desejo de prolongar a durabilidade destes objetos advém de uma civilização que almeja salvaguardar o património dos seus antepassados e transmiti-lo às gerações futuras, a partir da preservação (material e imaterial) de diferentes tipos de artefactos e da tentativa de recriação de tradições performativas, das quais a música faz parte [6]. A música, enquanto forma de expressão artística, é considerada como uma parte fundamental da vida das sociedades e é uma das temáticas recorrentes nas coleções museológicas europeias.

Os museus com coleções de instrumentos musicais são, entre outros aspetos, instituições compostas por objetos que podem ser considerados como testemunhos materiais que atuam como pontes entre o tangível e o intangível [5]. O uso de instrumentos históricos em eventos performativos fomenta a relação entre a "materialidade" (o que é tangível) e a "imaterialidade" (o que é intangível). Isto é, reforça a ideia do instrumento enquanto meio/suporte material de produção de som e enfatiza o carácter único, irrepetível e efémero dos eventos performativos [7-8].

Dilemas éticos e desafios na conservação de coleções de instrumentos musicais

Eticamente, as instituições museológicas devem assegurar que todos os objetos e coleções (permanentes ou temporárias) são geridos de forma rigorosa, para que estes possam ser transmitidos nas melhores condições às gerações futuras [9].

Neste sentido, faz parte das responsabilidades do museu assumir a decisão do uso performativo dos instrumentos musicais com base numa avaliação de vantagens e desvantagens, tendo em conta que apenas os instrumentos descritos como aptos a serem tocados é que devem ser considerados nesta decisão [6]. Segundo a *Association of British Transport & Engineering Museums* (ABTEM) o conceito de "uso" está associado à recuperação da função original de um objeto, através do desenvolvimento de atividades que promovam o propósito da sua criação [10]. Para além do uso performativo, as atividades educativas, expositivas ou de investigação são outros exemplos de uso dos instrumentos musicais em instituições museológicas [8].

Esta problemática não é recente. Durante décadas, as abordagens dos museus estiveram divididas entre a capacidade de um objeto funcionar e a preservação do seu suporte material original. As práticas de conservação museológica tinham como objetivo compreender a química dos materiais, com vista ao desenvolvimento de medidas de prevenção que evitassem a deterioração dos instrumentos. Contudo, no início do século XXI, observa-se que o estudo do objeto como um todo começa a ser privilegiado. É neste âmbito que surgem uma série de conferências organizadas pelo Comité Internacional de Museus e Coleções de Instrumentos e Música (CIMCIM) centradas na temática da preservação da função dos instrumentos musicais. Durante os últimos encontros, entre 2017 e 2020, a funcionalidade foi discutida, não como um agente de deterioração, mas sim como uma opção válida para a comunicação e interpretação de um instrumento musical [11]. Atualmente, o uso performativo dos instrumentos musicais continua a ser um tema que divide as opiniões dos profissionais, uma vez que, a preservação dos atributos físicos dos instrumentos musicais, nomeadamente do som, é, na maior parte das vezes, contraditória: por exemplo, a preservação do registo áudio de um instrumento musical implica que este seja tocado.

Genericamente, pode-se compilar duas abordagens polarizadas sobre este assunto. A favor do uso performativo, os argumentos recorrentes centram-se no valor da experiência musical, educativa e de investigação. Numa das perspetivas apresentadas por Andrew Lamb [1], se não nos for permitido ouvir a música que produz, a nossa experiência fica limitada aos atributos físicos – materiais e de construção – dos instrumentos. Por sua vez, Arnold Myers [8] sublinha a importância que os concertos e outros tipos de eventos performativos podem exercer na transmissão do "valor intangível" dos instrumentos musicais, ao permitirem uma experiência única, quer para quem os toca quer para a audiência. Ou seja, se não for permitido ouvir o som que os instrumentos produzem, a experiência dos intervenientes é limitada e o papel do instrumento enquanto documento histórico só é parcialmente cumprido.

Numa perspetiva oposta, é defendida a ideia da preservação da integridade histórica dos instrumentos, contrária ao uso e à sua manutenção contínua, que têm como consequência o desgaste irreversível das peças originais e, como tal, a sua substituição. Ora, se por um lado, é aceitável permitir que um determinado instrumento musical seja tocado sem comprometer seriamente a sua conservação, por outro, nunca se deve perder a noção de que estes objetos são bens culturais que não podem ser substituídos. Se esta ideia se tornar secundária demasiadas vezes em benefício do desejo da experiência musical, então o instrumento pode sofrer alterações ou danos irrecuperáveis [1].

Um dos princípios basilares dos museus assenta precisamente na salvaguarda das suas coleções [9], e como tal, as instituições museológicas tendem a preservar os instrumentos musicais através da não utilização destes objetos. Para alguns profissionais, isto pode significar limitar ou até mesmo reduzir estes objetos às suas características físicas visíveis. Não sendo o objetivo deste artigo validar as abordagens apresentadas, consideremos o uso performativo como uma forma excecional de comunicar e interpretar um instrumento musical. Neste sentido, como é que a documentação dos instrumentos musicais pode contribuir para a sua preservação?

A documentação do uso performativo como parte do processo de salvaguarda: desafios e oportunidades

O termo "documentação" aplicado ao contexto museológico pode adquirir, em síntese, dois sentidos: o mais comum, enquanto registo, em qualquer que seja o suporte, de uma determinada informação que pode adquirir a forma de ficha de inventário ou de entrada de catálogo; e como o resultado de todas as informações sobre um determinado objeto resultantes das demais funções museológicas [13].

Enquanto processo de conservação preventiva, a documentação é indispensável para o conhecimento quantitativo e qualitativo de uma coleção – através dos inventários, é expectável que as instituições museológicas tenham conhecimento do número de bens culturais incorporados nas suas coleções e do seu estado de conservação [14]. A documentação enquanto função museológica assume um papel fundamental na gestão das coleções ao permitir a produção de conhecimento sobre os objetos incorporados, seja através da "contextualização interna" das informações que advêm dos processos como a incorporação, os empréstimos e a conservação, seja a partir do próprio objeto e dos estudos realizados. Seja de origem, ou posterior à sua incorporação, a documentação relativa a um objeto deve ser tratada e gerida como uma parte essencial do seu historial. As informações registadas vão contribuir significativamente para a criação de atividades no âmbito da programação cultural – como é o caso das iniciativas de uso performativo dos instrumentos musicais – e na promoção do estudo e da investigação do acervo museológico [10, 15-16].

Independentemente da posição do museu relativamente ao uso dos instrumentos musicais da sua coleção, toda a documentação que resulta da avaliação do estado de conservação do(s) instrumento(s) deve ser associada à(s) ficha(s) de inventário do(s) instrumento(s), pois estas são informações que não só justificam e validam em que circunstâncias é que a decisão foi tomada, como também contribuem para o historial do(s) instrumento(s) tocado(s). O registo dos materiais e dos processos adotados garantem que, no futuro, as ações de conservação são baseadas na compreensão do estado do objeto no momento, e na opinião profissional que influenciou as escolhas de conservação [17]. A documentação assume particular relevância aquando da movimentação de um instrumento musical, dado que é uma fase de grande vulnerabilidade para estes bens culturais, em particular: sem a gestão apropriada da documentação, a dissociação das informações e a deterioração física do instrumento são duas consequências possíveis. Segundo Ana Panisset [18], os sistemas de informação são meios que permitem gerir estes problemas. Apesar da autora se referir às questões da arte contemporânea, estas questões são transversais e podem ser relacionadas com as coleções de instrumentos musicais.

Linhas orientadoras para a documentação do uso performativo de instrumentos musicais

A maioria das informações básicas recolhidas para os inventários e catálogos é recuperável, como por exemplo as dimensões ou a transcrição de uma inscrição, o nome do construtor ou do local onde o instrumento foi construído. Contrariamente, existem informações que são passíveis de serem perdidas com facilidade se não forem registadas convenientemente, como dados sobre a anterior proveniência do instrumento ou informações sobre quem o tocou, quem o ouviu e em que contexto (antes e/ou depois da sua integração no museu) [8] – o que justifica a necessidade de desenvolvimento de normas de documentação específicas.

A definição de procedimentos de documentação de instrumentos musicais integrados em coleções museológicas deve ter em consideração a quantidade e a diversidade de informação que é passível de ser obtida através deles, o que os torna autênticos "documentos" tridimensionais [4].

Com base em dois documentos orientadores – *Standards in the museum curation of musical instruments* [6] e *Guidelines for the care of larger and working historic objects* [10] – é possível definir um conjunto de dados considerados imprescindíveis para o registo das informações relacionadas com o uso performativo dos instrumentos musicais em iniciativas museológicas. Importa salientar que, apesar de existir um conjunto de normas de inventário portuguesas relativas aos instrumentos musicais [19], estas não incluem nenhuma referência ao uso performativo destes objetos e, como tal, não foram consideradas nesta síntese. Embora de forma genérica e muito sintetizada, a documentação deve incluir:

- uma declaração de significado ou *significance statement* – definir o significado, ou seja, a razão pela qual um objeto é mantido numa coleção, é de importância extrema na definição de um plano de conservação preventiva. Sem esta reflexão, questões como o potencial uso do(s) instrumento(s) não podem ser respondidas [16];
- um plano de conservação preventiva (que pode ser individual ou coletivo, se os instrumentos da coleção forem semelhantes) – deve referir em que circunstâncias, por quanto tempo e por quem é que o instrumento pode ser tocado. Este plano deve ainda incluir a informação sobre as condições de limpeza e manuseamento, assim como os materiais a serem utilizados em ambas as situações;
- os registos de intervenções de conservação curativa e de restauro – estes registos descrevem todas as intervenções realizadas num determinado instrumento, incluindo os materiais utilizados, os métodos adotados e todas as informações que justifiquem estas escolhas;
- um plano de manutenção – deve incluir as rotinas de manutenção (se aplicável) do instrumento, assim como ações de limpeza ou de conservação curativa;
- um registo de operações ou *operating log* – consiste num ficheiro que compila todos os detalhes das diversas ocasiões em que um objeto é utilizado em atividades museológicas. No caso dos instrumentos musicais, o registo de operações deve incluir todas as informações referentes ao uso performativo do instrumento.

No caso dos instrumentos que podem ser tocados em concertos, por exemplo, a documentação permite reunir informações relacionadas, não só com a preservação do suporte material destes objetos (que se materializa nos documentos referidos anteriormente), mas também com o evento em questão. Estes eventos são fontes de informações tendencialmente irrecuperáveis se não forem devidamente registadas e que geram conhecimento sobre os instrumentos musicais e as iniciativas performativas da instituição. Por isso, quando o museu opta por permitir que um instrumento seja tocado, deve assegurar o registo das informações relacionadas com o evento, isto é:

- a identificação do(s) interveniente(s) – quem é que vai tocar o instrumento;
- o repertório – se forem obras incluídas no acervo da instituição, a informação deve estabelecer essa relação;
- a regularidade com que o(s) instrumento(s) será(ão) tocado(s);
- a duração do(s) concerto(s);
- o local onde o evento se realizará;
- registos audiovisuais, quando possível – segundo as recomendações do Comité Internacional de Museus e Coleções de Instrumentos Musicais (CIMCIM), qualquer evento que inclua a interpretação de instrumentos musicais históricos deve ser realizado para o máximo de audiência possível e deverá ser privilegiada a gravação dos concertos.

A documentação é um processo basilar das práticas de conservação preventiva e impõe um diálogo entre as diferentes áreas museológicas: desde a conservação, à programação cultural, mas também a parte administrativa-financeira e a investigação. É incontornável a necessidade de adoção de um sistema de informação que permita a inter-relação de todos estes dados.

Em suma, e considerando o estado da arte, é possível definir-se, sinteticamente, alguns dos atuais desafios e linhas de trabalho no âmbito da documentação de coleções de instrumentos musicais, que incluem: 1) desenvolver ferramentas para a tomada de decisão no sentido da gestão das coleções; 2) desenvolver normas de procedimentos para a recolha de informações relacionadas com os eventos de uso performativo de instrumentos das coleções museológicas; 3) definir o tipo de informação essencial para a construção dos registos de eventos e como é que estas informações se irão cruzar com a documentação associada dos instrumentos tocados.

Considerações finais

O valor e o significado dos objetos culturais incorporados em instituições museológicas residem tanto nos seus suportes físicos, cuja salvaguarda é da responsabilidade destas instituições, como na representação das épocas históricas e culturais de que fizeram parte. Para alguns objetos, isso inclui um elemento performativo particular, no qual o suporte material é um meio para completar uma ação – os instrumentos musicais são exemplo disso. Uma das suas características fundamentais é o som que produzem.

O uso performativo dos instrumentos musicais levanta uma série de argumentos – a favor e contra – devido à dimensão ética implícita neste assunto. Este é um dos desafios que os museus enfrentam e reflete a constante pressão que estas instituições sofrem por parte das comunidades interessadas, cujas expectativas assentam, frequentemente, em ver e ouvir os instrumentos expostos. O recurso a eventos performativos como forma de exposição dos instrumentos musicais é uma das abordagens adotadas pelas instituições museológicas a favor da recuperação da função original destes bens culturais. A informação que advém destes eventos é essencial para o historial do instrumento tocado e deve ser preservada como parte da sua documentação associada.

Enquanto função museológica central, a documentação é um meio indispensável para a preservação dos objetos integrados em instituições museológicas, enquanto meio de conhecimento e de valorização dos bens culturais. Enquanto parte do processo de salvaguarda dos objetos museológicos, a documentação museológica assume uma particular importância: potencializa a conservação preventiva dos objetos – através do conhecimento prévio dos seus materiais, as ações de conservação são baseadas na compreensão do estado do instrumento na altura e no pensamento que influenciou as escolhas de conservação; e permite validar a tomada de decisões – a partir de um conjunto de procedimentos, o uso performativo de um determinado instrumento musical é justificado e a preservação de informações relacionadas com este evento, incluindo o registo áudio do instrumento tocado, é assegurada. Em suma, é evidente a relação entre as práticas de documentação e as práticas de preservação e de conservação preventiva, basilares para as atividades desenvolvidas nos museus.

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REFERÊNCIAS

1. Lamb, A., 'To play or not to play: the ethics of musical instrument conservation', *Conservation Journal* **15** (1995), http://www.vam.ac.uk/content/journals/conservation-journal/issue-15/to-play-or-not-to-play-the-ethics-of-musical-instrument-conservation/ (acesso em 2023-06-14).
2. Poulopoulos, P., 'New voices in old bodies: a study of "recycled" musical instruments with a focus on the Hahn Collection in the Deutsches Museum', in *Deutsches Museum Studies* **2**, vol. 2, W. Füßl, U. Hashagen, U. Kernbach & H.Trischler, Monsenstein und Vannerdat, Münster (2016), https://www.deutsches-museum.de/assets/Verlag/Download/Studies/studies-2-download.pdf (acesso em 2023-06-14).
3. Desvallées, A.; Mairesse, F. (Eds.), 'Musealização', in *Conceitos-chave de Museologia*, trad. B. Soares e M. X. Cury, Comité Brasileiro do Conselho Internacional de Museus, Pinacoteca do Estado de São Paulo, Secretaria de Estado da Cultura, São Paulo (2013) 56-58, https://www.icom.org.br/wp-content/uploads/2014/03/PDF_Conceitos-Chave-de-Museologia.pdf (acesso em 2023-06-14).
4. Bouquet, J., *The objects of research: the documentation of musical instruments at the NMM*, National Music Museum, South Dakota (2010), http://collections.nmmusd.org/News/Newsletter/December2010/DocumentationArticle.html (acesso em 2023-06-14).
5. Gün, B., *Collection management policy for a musical instruments museum*, Dissertação de Mestrado, Departamento de Civilizações Anatolianas e Gestão de Património Cultural, Universidade de Koç, Istambul (2008), https://acikbilim.yok.gov.tr/bitstream/handle/20.500.12812/170439/yokAcikBilim_312100.pdf?sequence=-1&isAllowed=y (acesso em 2023-06-14).
6. Andrew, P. (Ed.), *Standards in the museum curation of musical instruments*, Museums, Libraries and Archives, Londres (2005), https://collectionstrust.org.uk/wp-content/uploads/2017/02/Museums-Libraries-Archives-Council-Standards-in-the-Museum-Curation-of-Musical-Instruments-2005.pdf (acesso em 2023-06-14).
7. Salazar, D., *A performance e o espaço museológico – Os museus de artes performativas*, Dissertação de Mestrado, Departamento de Museologia, Universidade Nova de Lisboa, Lisboa (2013), https://run.unl.pt/handle/10362/10602 (acesso em 2023-06-14).
8. Myers, A., 'Information preservation for musical instruments – keynote from the annual conference', in *CIMCIM Bulletin* **September** (2017) 4-8, https://cimcim.mini.icom.museum/wp-content/uploads/sites/7/2019/01/Bulletin_September_2017_small__version.pdf (acesso em 2023-06-14).
9. International Council of Museums, *ICOM code of ethics for museums*, ICOM, Paris (2017), https://icom.museum/wp-content/uploads/2018/07/ICOM-code-En-web.pdf (acesso em 2023-06-14).
10. Association of British Transport & Engineering Museums, *Guidelines for the care of larger and working historic objects*, Collections Trust, Leicester (2018), https://abtemguidelinesorg.files.wordpress.com/2018/02/124317-abtem-guidelines-booklet.pdf (acesso em 2023-01-03).
11. Bär, F. P., 'CIMCIM and CIMUSET joint project and conference "Playing and operating: Functionality in museum objects and instruments', in *CIMCIM Bulletin* **December** (2020) 12–13, https://cimcim.mini.icom.museum/wp-content/uploads/sites/7/2020/12/2020_December_CimcimBullettin.pdf (acesso em 2023-06-14).
12. Bruyn-Ouboter, V. de, 'Material or immaterial? A questionnaire to help decisions about the preservation of musical instrument', in *Wooden musical instruments different forms of knowledge – Book of end of WoodMusICK COST Action FP1302*, eds. M. A. Pérez e E. Marconi, Cité de la Musique, Paris (2018) 35–47, https://www.researchgate.net/publication/332104247_Wooden_Musical_Instruments_Different_Forms_of_Knowledge_Book_of_End_of_WoodMusICK_COST_Action_FP1302 (acesso em 2023-01-03).
13. Alves, J., *Avaliação para gestão de coleções em museus: uma proposta de indicadores de desempenho com base na norma SPECTRUM*, Dissertação de Doutoramento, Departamento de Estudos do Património - Museologia, Universidade do Porto, Porto (2020), https://hdl.handle.net/10216/131189 (acesso em 2023-06-14).
14. Panisset, A., *A documentação como ferramenta de preservação: protocolos para documentação e gestão do Arquivo Artístico da UFMG*, Dissertação de Doutoramento, Departamento de Arte e Tecnologia da Imagem – Preservação do Património Cultural, Universidade Federal de Minas Gerais, Minas Gerais (2017), http://hdl.handle.net/1843/LOMC-BC2GCX (acesso em 2023-06-14).
15. Furtado, C., *Documentação e inventariação da coleção de instrumentos musicais do Museu Nacional da Música: diagnóstico e contributo para a elaboração de um guia de utilizador sob a perspetiva de sistema integrado de informação*, Dissertação de Mestrado, Departamento de Museologia, Universidade Nova de Lisboa, Lisboa (2021), https://run.unl.pt/handle/10362/118996 (acesso em 2023-06-14).
16. Pye, E., 'Challenges of conservation: working objects', in *Science Museum Group Journal* **6** (2016), http://dx.doi.org/10.15180/160608 (acesso em 2023-06-14).
17. Hallam, D., 'Ethical and philosophical issues of operating functional objects: a developing approach', in *Proceedings of the International Conference BigStuff 2007: Beyond Conservation - Industrial Heritage Management*, online (2007) 38-43, https://doi.org/10.5281/zenodo.4086263 (acesso em 2023-06-14).
18. Panisset, A. M.; Bevilacqua, G. M. F.; Froner, Y-A., 'Documentation as a tool for preventive conservation: results of a project', in *Documenting diversity – Collections, catalogues & context*, CIDOC, Nova Delhi (2015), https://cidoc.mini.icom.museum/wp-content/uploads/sites/6/2018/12/CIDOC_2015_Full_paper_Panisset_Bevilacqua_Froner.pdf (acesso em 2023-01-03).
19. Trindade, M. H. (Ed.), *Normas de inventário - Instrumentos musicais*, Instituto dos Museus e da Conservação, Lisboa (2011), http://www.ibermuseos.org/pt/recursos/documentos/normas-de-inventario-instrumentos-musicais/ (acesso em 2023-01-03).

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Investigating five totalizing counters manufactured by the Alphonse Darras company of the CNAM collections in Paris

Investigação de cinco contadores totalizadores fabricados pela empresa Alphonse Darras das coleções do CNAM em Paris

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Abstract

The paper reports the study of five totalizing counters preserved in the collections of the CNAM (museum of the *Conservatoire National des Arts et Métiers*) in Paris. These artefacts are part of a *corpus* of over forty counters attributed to the Darras company founded by the engineer Alphonse Darras (1860-1936). In the framework of the LacCA project at *Haute Ecole Arc*, Neuchâtel (Switzerland), dedicated to the characterization of lacquered copper-alloys, the focus of the study were the different aspects of the object's coatings. Lacquers were frequently applied on technical objects with the double aim of protecting them from corrosion and to provide a specific esthetical appearance. Five totalizing counters showing various shapes and surface colors were chosen from the lot and examined with a non-invasive multi analytical approach. The comparative study – investigating lacquering processes and materials – contributes to the historical study of these artefacts.

KEYWORDS
Transparent lacquers
Copper alloys
19th-20th century
Non-invasive methods
UV fluorescence
FTIR

Resumo

Este artigo descreve o estudo de cinco contadores totalizadores conservados nas coleções do CNAM (museu do *Conservatoire National des Arts et Métiers*) em Paris. Estes artefactos fazem parte de um *corpus* de mais de 40 contadores atribuídos à empresa Darras, fundada pelo engenheiro Alphonse Darras (1860-1936). O estudo desenvolvido no âmbito do projecto LacCA da *Haute Ecole Arc*, Neuchâtel (Suíça) sobre caracterização de ligas de cobre lacadas, incidiu sobre as diferentes características dos revestimentos dos objetos. As lacas eram frequentemente aplicadas em objetos técnicos com o duplo intuito de proteção contra a corrosão e decoração. Cinco contadores totalizadores com diferentes formas e cores, foram selecionados e examinados através de diferentes técnicas analíticas não invasivas. O estudo comparativo – investigando os processos e os materiais de lacagem – contribui para o estudo histórico destes artefactos.

PALAVRAS-CHAVE
Lacas transparentes
Ligas de cobre
Séculos XIX-XX
Métodos não invasivos
Fluorescência UV
FTIR

Introduction

The CNAM museum in Paris is part of the *Conservatoire National des Arts et Métiers* (CNAM) and one of the oldest scientific and technological museums in the world. Founded in 1794, its collections of scientific instruments and technical objects were expanded throughout the nineteenth century, especially thanks to donations from industrialists or with items from industrial, national or universal exhibitions. The present case study was carried out in the context of a project dedicated to objects made of lacquered copper alloys (LacCA) at *Haute Ecole Arc* (Neuchâtel). This coating technology can be found frequently in both decorative arts and technical heritage collections. In the latter case, the main purpose of these coatings is to provide protection against corrosion, guaranteeing both reliability of the object's function and providing a specific esthetical appearance [1]. These finishes are an integral part of the manufacturing process of the objects. If well preserved, they are evidence of the history of the materials and processes used, as well as of the know-how of the people involved in the specific production of these technical objects. Their characteristics can also potentially provide indications about age and provenance of the artefacts when studied systematically [1-2].

It is known from literature that copper alloys on technical objects were usually coated with shellac-based lacquers during the nineteenth century. These coatings, prepared by dissolving the resin in alcohol, were applied with a brush whereas small pieces could also be dip-coated [3]. Cylindrical parts were often lacquered with the help of a lathe [4-5]. The same type of lacquer recipes were still referenced in the practical guides of the twentieth century [6], even though the first synthetic polymers based on cellulose nitrate were developed in parallel for metal coatings [7]. Shellac-based recipes were also later used for the relacquering of ancient objects both by private collectors and museum conservators [1, 8-11]. However, it must be pointed out that shellac-based recipes for both copper-based decorative objects and technical instruments were often more complex. Additional binding media or plasticizers could be used to improve the coating properties as well as organic dyes to enhance the surface appearance of the metal [12-14]. Moreover, shellac – a natural animal-produced resin and wax mixture – comes in different grades and shades (seedlac, buttonlac, shellac in flakes…) and different processing and bleaching methods of shellac were developed and improved during the nineteenth century in France [15-17]. Nevertheless, only few studies dedicated to ancient lacquers on technical objects have been reported in the literature to date [13] and morphological aspects of the lacquers as well as coating thickness are rarely mentioned. A small selection of a huge but still unexplored *corpus* of counters from the Darras Company was investigated. The transparent coatings and metal substrates of five totalizing counters were characterized using non-invasive and portable techniques on site in the conservation center of the museum.

Studied pieces and their historical context

The five counters that are studied in this paper were donated to the museum in 1987, twenty-five years after the closure of the company that had manufactured them. They were probably part of a small heritage collection of the company itself. Founded by Eugène Deschiens (1826-1889) in 1866 at 123 boulevard Saint-Michel in Paris, the workshops (*Ateliers Eug. Deschiens*) were bought in 1894 by Alphonse Darras (1860-1936), a construction engineer, who developed and directed the business until his death. From 1936, his widow and his children continued the business under the name *Etablissements Alph. Darras*.

Unlike other French scientific instrument or precision mechanics manufacturers of the nineteenth century (for example. Chevalier, Lerebours et Secretan, Soleil-Duboscq-Pellin, Ruhmkorff, Carpentier, Froment Ducretet, Deleuil, Richard, Brunner, Breguet, Soleil-Duboscq, or Golaz) and in spite of its longevity, the history of the Deschiens-Darras firm has not been traced and written up to now. For the historical introduction of this paper, various sources coming from archival holdings of the museum were explored, among which are trade catalogues of the manufacturer [18]. Documents from the Archives of the Commercial Court of

Paris and specific issues of the Journal of Commercial Archives of France (which published company formations, modifications, dissolutions, bankruptcy declarations as well as commercial property sales) were studied in particular [19-21].

It is known that the Paris workshops of the Alphonse Darras Company were at a later time transferred to 2 and 4 rue de Seine in Viry-Châtillon, to the location of the Stempert factory, specialized in bolt production machines. This factory had been acquired by Alphonse Darras in 1924. In 1958, Darras' widow created a new company to continue the business, and this factory remained her property until its closure in 1963.

The Alphonse Darras company, successor of *Maison E. Deschiens*, was specialized in the manufacture of telegraphic and telephone equipment as well as precision mechanics. In a context of a strong industrial expansion, the business focused on industrial control systems by means of different types of counters: totalizing counters and lap counters. These were used for measuring fluid flow, the speed (revolutions per minute) or power of the rotating machinery to which they were connected, or as odometers or tachymeters.

Due to its success, the company could invest and acquire in 1915 the *Ateliers Vve Payen*, property of the widow of Louis Payen, who, in turn, was the successor of Thomas de Colmar, a famous inventor and manufacturer, known since 1820 for his mechanical calculating machines called arithmometers.

The five counters are part of a much larger donation of 179 objects representative of the company's production, including the 49 counters given to the CNAM museum in 1987 by the Darras family. Despite all the studied objects were produced by the Darras company and are composed of a rectangular case and a frame with a transparent window displaying the counting, their size, shapes, and materials differ as it can be observed in Table 1.

This donation followed an earlier gift of nine objects in 1972 which joined other Darras objects in the museum's collection, namely a phonograph purchased by the museum in 1896 (inv. 12860), an arithmometer (inv. 20968) donated by the Damascus-Hamah Railway Company in 1962, and a Claude-type electromagnetic relay for wireless telegraphy dated 1908 (inv. 21285), donated in 1963.

Table 1. The five selected totalizing counters; images and characteristics referenced in the CNAM collection.

Code in this study	**DAR1**	**DAR2**	**DAR3**	**DAR4**	**DAR5**
Image (topframe and window)					
Image (case frontside)					
Designation	*Compteur série "ED", alternatif à 7 chiffres*	*Compteur série "ED"*	*Compteur totalisateur à commande électrique*	*Compteur série "ED", alternatif à 6 chiffres, type F*	*Compteur totalisateur série "ED"*
Inv. number	40523-0000-	40519-0000-	4082-0000-	40522-0000-	40518-0000-
Size, weight	6 × 8 × 24 cm, 2kg	5.5 × 9 × 30 cm, 3.1kg	11 × 15 × 15 cm, 2kg	6 × 8 × 25 cm, 2.1kg	5.5 × 9 × 18 cm, 1.6kg
Materials	Lacquered copper alloy, glass, (painted) iron alloy	Lacquered copper alloy, synthetic material, (painted) iron alloy	Lacquered copper alloy, glass, iron alloy, painted wood	Lacquered copper alloy, glass, (painted) iron alloy	Lacquered copper alloy, glass, (painted) iron alloy
Inscriptions	*AD*	*ATELIERS DESCHIENS. Système breveté s.g.d.g., A. DARRAS Ing.^{r} construct.^{r} Paris, N° 8320* *3* is painted in black on the backside of the case	*COMPTEUR SYSTEME BREVETE S.G.D.G. N°3640 A. Darras Constructeur Paris*	*AD*	No mark, but a circular copper label is attached

The precise dating of these counters is very difficult, since these materials were already the specialty of Eugène Deschiens and remained such until the closure of the Darras company in 1963. Four of the five counters belong to the "ED" series, made of "lacquered copper", a general designation for copper alloys like brass. Their external design did not change much between 1875 and the 1930s, as shown in the two advertising plates reported in Figure 1a-b. The third one (DAR 3), whose case is also in "lacquered copper", was already visible on some leaflets of the Deschiens company, and still in the Darras catalog in 1900, as shown in Figure 1c.

As mentioned before, some objects were probably part of a small museum of the company. In fact, they have a small iron ring with an engraved number (303, 318...) which is probably the reason why very few of them have a serial number stamp. Moreover, there are no inventories of the firm, nor the list of the types and models of its successive productions.

From the inscriptions on the objects, one could estimate that DAR2 and DAR3 date back to the same period, as they carry the inscription "breveté S.G.D.G.", (*breveté sans garantie du gouvernement* – patented but without government warranty), a mention that appeared in a law of 1848 and that disappeared with a new law in 1968. This mention was chiefly used at the end of the nineteenth century and progressively disappeared along the twentieth century. DAR 1, 4, and 5, the first two showing the mark "AD", could form a more recent second group.

Because of this dating uncertainty, material characterization, especially the study of the lacquer finish of the counters, could integrate the lack of archival information and confirm or contradict the hypothesis previously formulated.

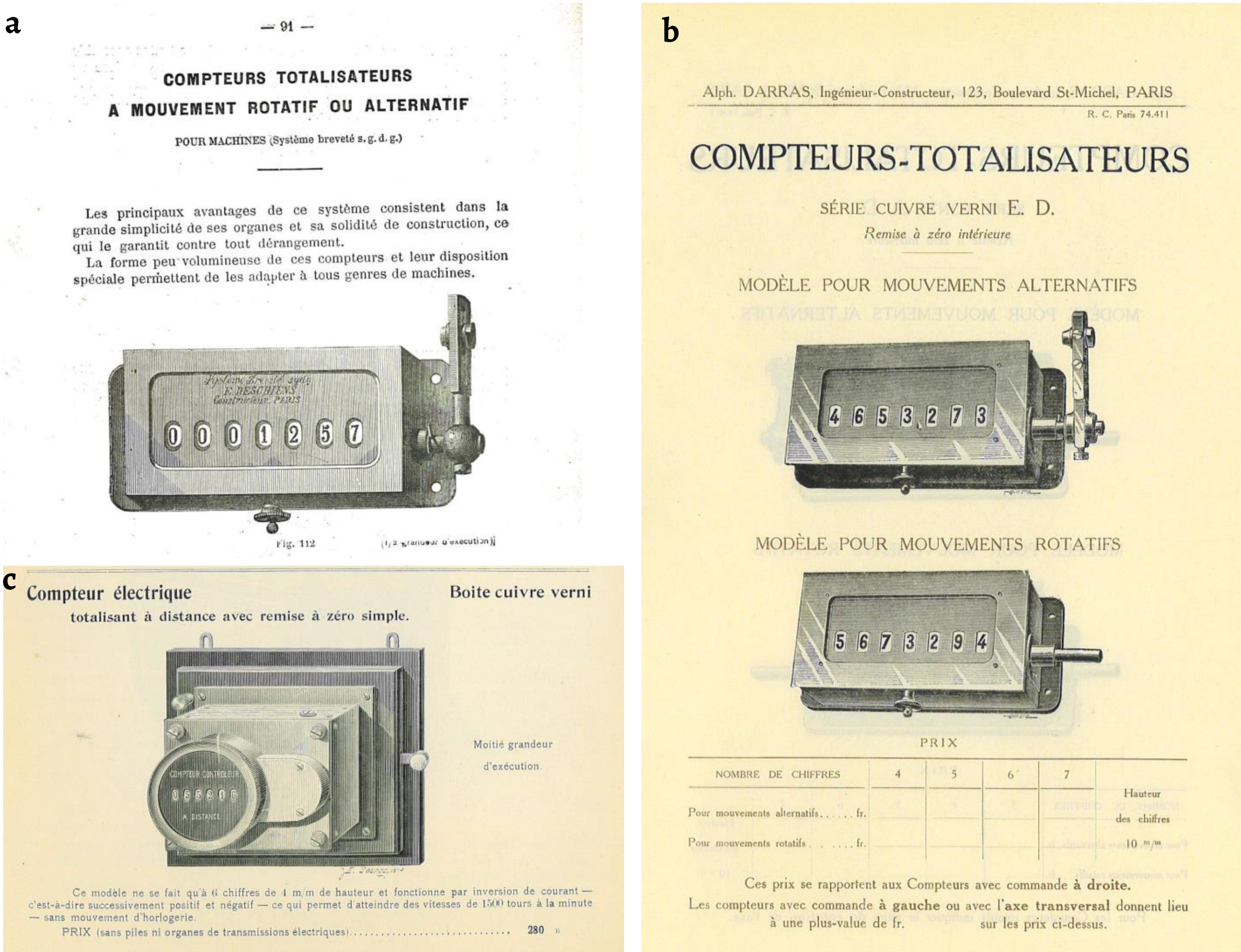


Figure 1. Excerpts from the catalogues: *a)* Deschiens *Catalogue général illustré en deux parties, 2e partie*, June 1876, p. 90; *b) Alph. Darras*, not dated, but after 1920; *c) Ateliers Deschiens-Alph Darras ingénieur constructeur*, 1900, 1st March, p. 11.

Materials and methods

Studied pieces and Analytical techniques

Observation and documentation under white light

The lacquered surfaces were documented under white light and observed under magnification. A short global condition report was produced for each object. White light images were acquired using a Canon Powershot G7X camera and an X-Rite Color Checker Passport target was used as reference. A portable Dinolite AM-413 ZT USB microscope was used for surface imaging at magnification ×50 with the *DinoCapture* 2.0 software.

Colorimetric measurements

Colorimetric measurements were carried out using a Minolta CM-2300d portable spectrophotometer with a D65 illuminant, a 10 ° observer, and specular component excluded (SCE), using CIELAB 1976 color space. An aperture of 3 mm diameter was chosen to acquire comparative data from objects of different size and shapes. On each totalizing counter, three measurements were carried out on three different points on the frame and the mean value and standard deviation calculated. The data were compared to measurements carried out under the same conditions on gilded brass samples of different gold colors: "lemon yellow gold", "orange gold", and "red gold". The reference material is made of gilded industrial UZ36 brass coupons, with mat and polished (M and P) finishing by Texier Company, Paris.

Fourier-Transfrom Infrared Spectroscopy (FTIR)

Infrared analyses were performed in specular reflectance configuration (SRefl) using an Alpha portable spectrometer (Bruker) with its R-Alpha module to obtain non-invasive, contactless measurement. The counters were placed in front of the spectrometer head at 15 mm working distance. The focusing and selection of areas was performed with an internal video camera and the analyzed area had a diameter of approximately 5 mm. 128 scans were acquired for each spectrum.

UV imaging

UV imaging was performed with an unfiltered Canon EOS 750D camera (Canon INC, Tokyo, Japan), using an 18-55 mm lens, a UV/IR cut (Baader Planetarium, Munich, Germany), and an X-Nite CC1 filter (LDP LLC, Carlstadt, NJ, USA). The counters and reference samples were placed on a black non-UV emitting cardboard background and illuminated by two UV lamps (Dominique DUTSCHER SAS, Bernolsheim, France) mounted at 45° on a custom-made stand. The main emission peak of the UV source is at 365 nm. The *UV Innovations Target* was used to calibrate the color of the pictures in *Adobe Photoshop* software. The pictures were taken in manual mode, ISO 200, and f/11 aperture; the target (low fluorescence side) was photographed with 1 s exposure time, whereas exposure was adapted for the objects and reference samples (15 s) according to a former study [22]. White balance correction was performed on the pictures in Camera Raw using the *Adobe Photoshop* Setup and Capture Workflows recommended by the calibration target manufacturer [23]. In order to assess the fluorescence color of each lacquer, the L* a* b* values of three spots on intact-looking zones of the topframe were then recorded using the color sampling tool (11 × 11 px) for each coupon in *Adobe Photoshop*.

XRF analysis

XRF analysis was performed using a Niton Thermo Scientific XL3t GOLDD+ XRF analyzer (analyze time 360 s, "mining mode" option) without specific surface preparation. This mode was chosen because we wanted to be able to identify the metal alloy, as well as chemical elements like barium, calcium, chlorine or potassium, which can be present depending on the technology used to produce the coating. In fact, fillers like barium sulfate, calcium carbonate or even chlorine may be residues coming from the lacquer manufacturing process or degradation products (like chlorides) possibly present on the artifacts. Data collection and post-processing were carried out using the *Thermo Scientific Niton Data Transfer* (*NDT*) software.

Thickness measurements

The thickness of the samples was measured with a *Phynix Surfix* Pro S gauge and FN 1.5 eddy-current probe (PHYNIX GmbH & Co. KG, Neuss, Germany) with a measurement range of 0-1.5 mm and an accuracy, with foil calibration, of ± 1.0 µm + 1 % of value. Measurements were performed both on the frame and on the case of the counters to compare the average values. Ten measurements were performed on each selected, intact-looking, lacquered spot. Thickness measurements were also carried out on lacquered reference coupons three times on each zone.

Reference material for UV imaging and FTIR

UV imaging and FTIR data of the counters were compared with the data acquired on reference material. Two lacquers based on the same recipe for precision instruments were produced with orange shellac in flakes [24]. The exact procedure for the preparation of shellac lacquers has been described before [22]. The coatings were applied to CuZn37 satin finished coupons (60 mm × 60 mm × 3 mm) by manual dip-coating. One of the two prepared shellac solutions was dewaxed before lacquering by filtering the orange shellac solution on 602H filter paper and by settling. Before application of the lacquer, the brass was degreased with ethanol. The metal was then heated around 30 °C before lacquer application. Temperature was selected according to the results of former experiments and the coated samples dried at ambient temperature [3]. Coatings of different thicknesses were produced with both the dewaxed and non-dewaxed solution. The non-dewaxed shellac solution had to be diluted with ethanol to obtain thinner layers. Additionally, two mirror polished brass coupons with a layer of bleached and dewaxed shellac, produced by industrial dipcoating, were used as references [22].

Results and discussion

Visual observations and documentation under white light

Different colors were detected at a first observation on the five counters. On the one hand, DAR2, DAR3 and DAR5 have frame and case of a similar color that can be defined as "brass-like". On the other hand, DAR1 shows frame and case of different colors, the latter manifesting a more reddish hue. Its case exhibits the same reddish color as DAR4 frame and case. The question remains whether the frame of DAR1 was replaced at a later period because its frame color differs from the case for an unknown reason. Moreover, a similar "AD" mark is present on DAR1 and DAR4, whereas DAR 5 does not present any mark at all (Table 1).

All frames and cases exhibit a satin finish, probably created by parallel machining and brushing of the metal. The cylindrical parts of the counters, like the small, knurled wheels, were manufactured using a lathe as shown by the visible circular traces on the metal. Parallel brush strokes in the lacquer are visible in raking light on the cylindric frame of DAR3. This element might have been coated with the help of a lathe.

Microscopic observations

The microscopic observation of the counters shows abraded and locally corroded lacquered surfaces. This suggests that the counters have not been relacquered during a long period before entering the museum's collections (Figure 2a-b). Brush strokes coming from lacquer application become visible with ageing and corrosion, indicating that the coating was applied manually in the longitudinal direction of each metal part. Dark corroded lines are less visible on DAR2 and DAR3. This might be due to the presence of thicker layers providing more efficient protection from corrosion. The coating on DAR3 exhibits small transparent excesses of lacquer (Figure 2c).

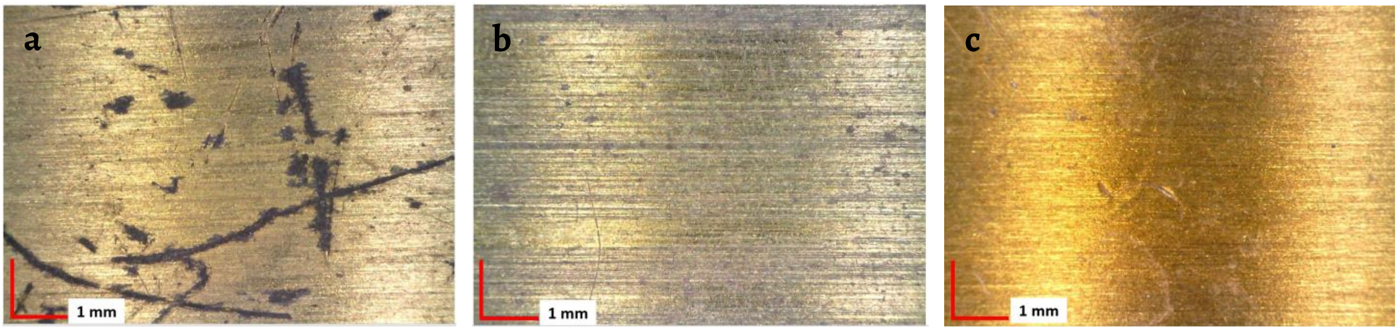


Figure 2. Detailed views of the lacquered surfaces (magnification 50×): *a)* DAR2, frame, corroded scratches and pits; *b)* DAR5, case, backside, abraded lacquer; *c)* DAR3, thick lacquer layer on the frame.

Colorimetric measurements

Colorimetric measurements performed on the counter's frames confirm the differences in surface appearance of the lacquered copper-alloy finishes detected during the visual observation and documentation under white light of the counters (Figure 3). DAR4 shows a more reddish color than the copper-alloy parts of the other objects, with a much higher red value on the a* axis. The four other counters can be, on the other hand, divided into two color groups: DAR1/DAR5, whose frame color is similar to the yellow gold reference, and DAR2/DAR3, closer to the orange gold reference. All three clusters tend systematically to a bluer hue on the b* axis and a greener hue on the a* axis compared to the reference gold color samples.

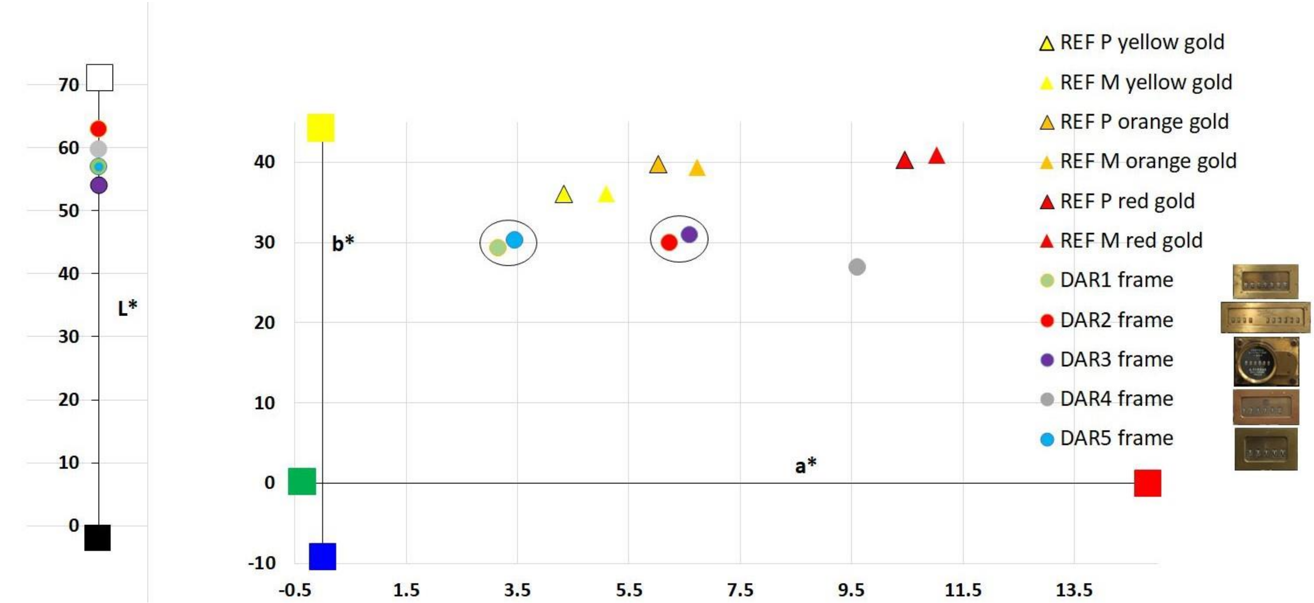


Figure 3. L* a* b* colorimetric coordinates for each object and zone on the frames.

FTIR

It was first assumed that the reddish color of DAR4, described in the previous paragraphs, could be related to a difference in lacquer composition and thickness. However, FTIR analysis did not confirm this hypothesis about the composition. In addition, no relation was found between this color and corrosion phenomena. All SRefl-IR signatures of the lacquers are similar and characteristic peaks can be attributed to the presence of shellac resin (Figure 4). Slight variations for some bands intensities ratios are visible, as, for example C-H/C=O peaks (DAR2 and DAR4 vs DAR1 and DAR5). Furthermore, FTIR analysis revealed shellac wax residues, as shown by the characteristic peak around 727 cm^{-1} in all signatures, but more visible for DAR3 (Figure 4, see arrows). Experiments showed that wax residues remain even when the resin is filtered and dewaxed by a traditional method like settling [22].

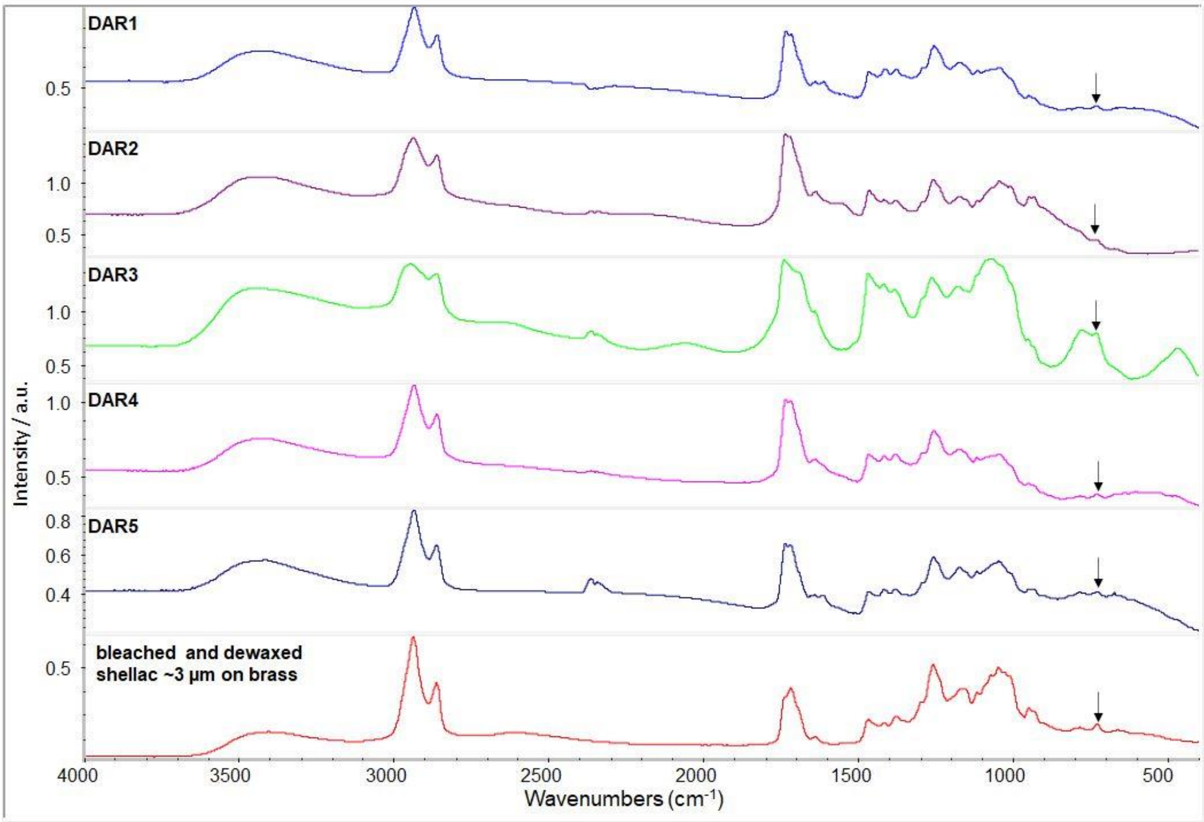


Figure 4. Representative infrared spectra for each totalizing counter compared with a reference lacquered coupon spectrum acquired under the same conditions. Residues of CO_2 are visible on the spectra of DAR3 and DAR5 around 2300 cm^{-1} due to incomplete background correction. The arrows indicate the band at 727 cm^{-1} highlighting wax traces.

Although shellac-based recipes for both copper-based decorative objects and technical instruments were often very complex, shellac and traces of shellac wax were the only materials detected by FTIR. For this reason, the question remained at this stage whether the natural color of a non-bleached resin might have influenced the visual result or if a dye may have been present. As pointed out before, the fact that a natural resin was used for the lacquering does not contribute significantly to the dating of the finish. However, the presence of different shellac grades is interesting as it points out object groups which may be related to specific production periods in the workshops. Additionally, other aspects like coating thickness were also explored in this study.

UV imaging

It has been shown in former studies that it is not possible to distinguish different shellac grades by means of non-invasive methods like FTIR [17], but that UV imaging can provide additional information [22]. The lacquered copper-based parts of the counters exhibit different hues and intensities of fluorescence (Figure 5 and Table 2). Colorimetric data for the fluorescence of these parts present a good reproducibility for all artefacts, except for DAR5 (Figure 6). This is due to the fact that the lacquer was applied in a very heterogenous way on this counter, and colorimetric data were acquired both on the thicker and thinner lacquered portions.

DAR2 and DAR3 show a uniform intense orange fluorescence. Their a* b* color coordinates tend clearly to the orange shellac references, whereas DAR4 and DAR5 tend more to blue and green on the blue-yellow and green-red axis, in the vicinity of the color coordinates of the bleached shellac reference. DAR1, on the other hand, presents even colder hues. It has been observed that bleached shellac coatings exhibit slightly colder fluorescence colors when aged artificially under UV [22].

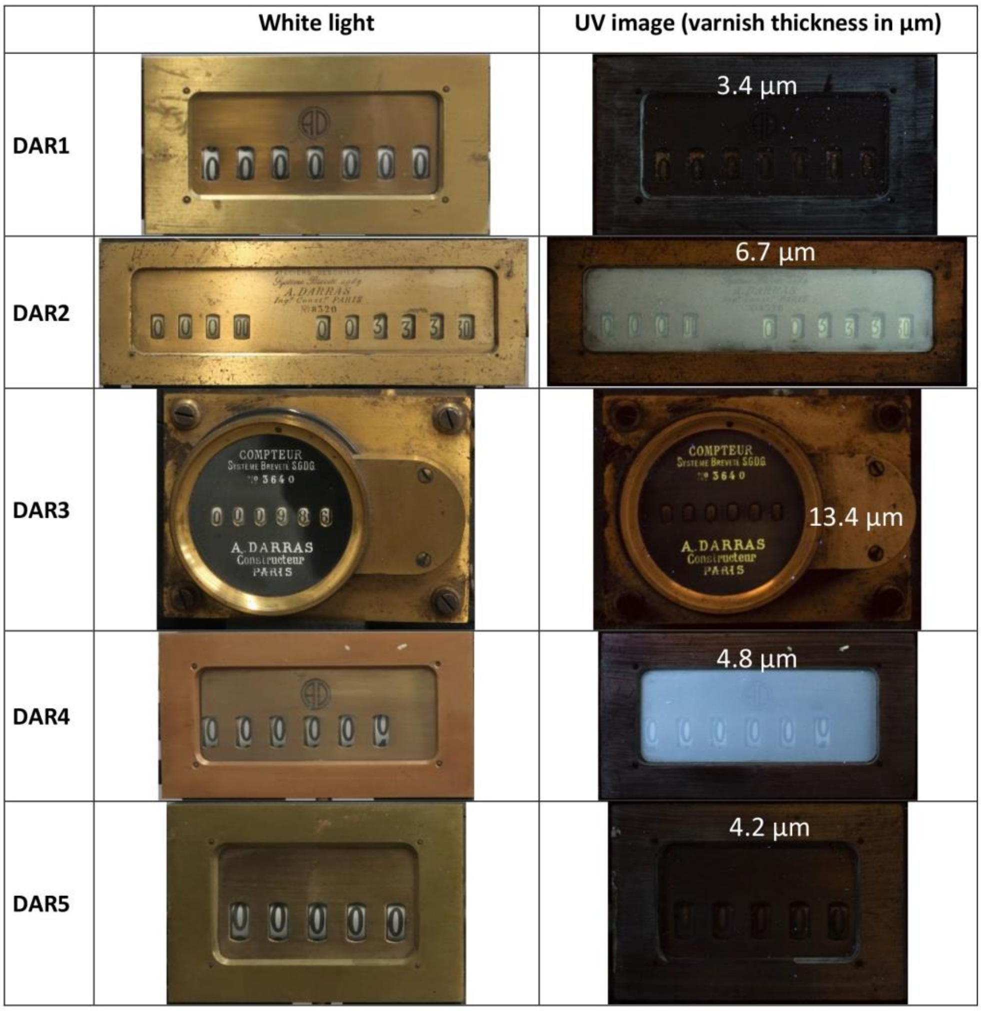


Figure 5. White light and UV fluorescence images of the frame of each totalizing counter (with average coating thickness indicated for a selected spot on the frame)

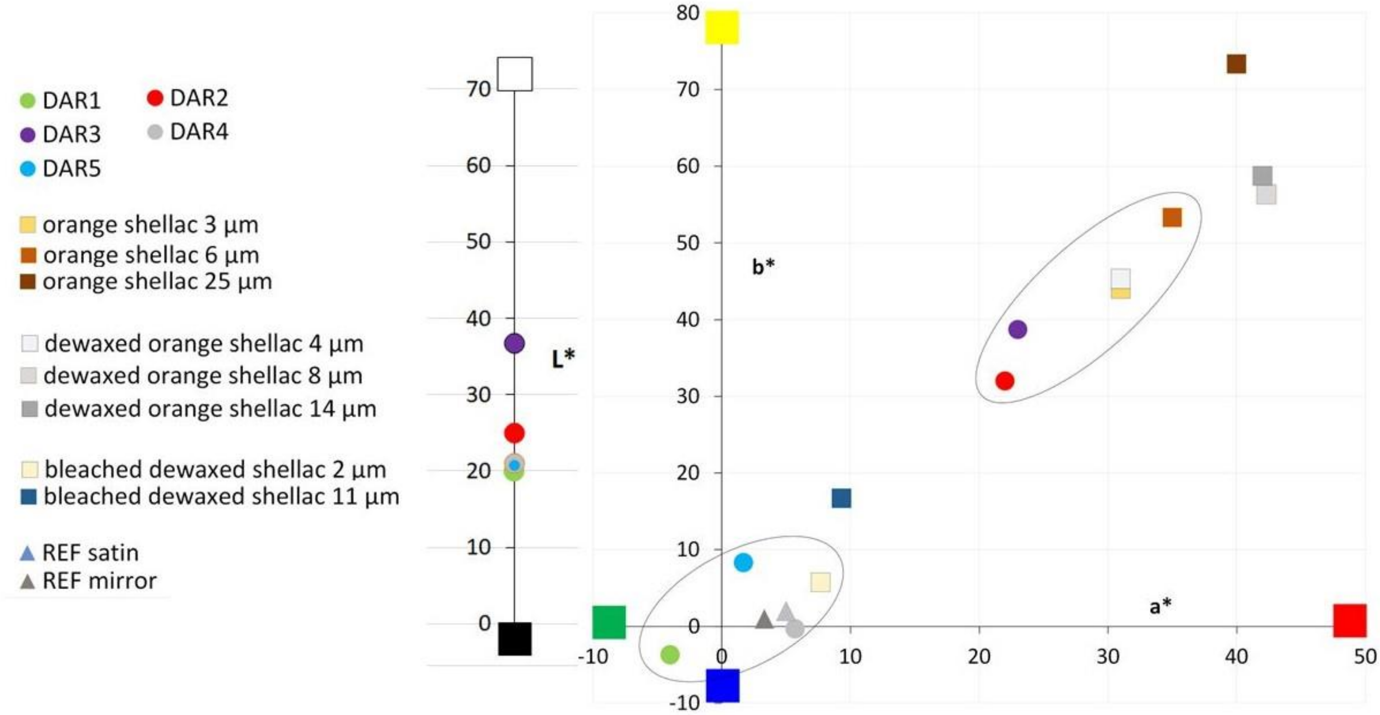
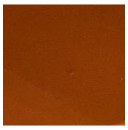
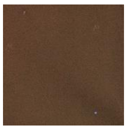


Figure 6. L* a* b* colorimetric coordinates of the lacquers' fluorescence (DAR1-DAR5, frame) compared to the reference samples of fresh shellac films.

Table 2. UV fluorescence images of diverse reference samples made of fresh shellac films with different coating thicknesses on brass.

Reference samples				
Orange dewaxed shellac			**Bleached dewaxed shellac**	
				
4.23 ± 0.06 µm	8.10 ± 0.10 µm	13.83 ± 0.15 µm	2.1 ± 0.3 µm	11.2 ± 0.6 µm
Orange shellac			**Brass (mirror)**	**Brass (satin)**
				
2.90 ± 0.36 µm	6.33 ± 0.4 µm	25.00 ± 0.89 µm	-	-

Observation and comparison under white light and UV radiation of the central windows provided additional information about the materials used for the counters (Figure 5). In the case of the transparent central window of DAR4, the icy blue color under UV radiation could be due to the presence of specific compounds in the glass like lead [25]. However, XRF or FTIR were not performed on the glass to confirm this hypothesis. DAR1, DAR3 and DAR5 counter windows are manufactured with non-fluorescent glass. Nonetheless, DAR2 central window shows a greenish-yellow fluorescence and it has slightly warped shape; for this reason it was analyzed by FTIR. The Srefl-IR signature reveals the presence of a cellulose nitrate-based material, which is consistent with the greenish-yellow fluorescence visible under long wave UV radiation [25]. Cellulose nitrate was introduced commercially in the 1860s in France and experienced an industrial decline in the 1960s [26].

XRF

XRF analysis of the metal alloy provided additional information about the surface colors (Table 3). All copper alloys are quaternary alloys, composed of copper (Cu), zinc (Zn), tin (Sn) and lead (Pb), with a high level of Zn (over 20 %). DAR4 and the case of DAR1 contains however a higher proportion of Cu, a very low concentration of Zn, and a higher amount of Sn and Pb compared to the other alloys. This explains why these surfaces look redder then on the other objects. It can be assumed that the cases of DAR1 and DAR4 are from a similar production period as they also show an identical ornamentation on the inner plate of the case, performed by circular brushing.

Table 3. Elemental composition in atomic percentage; analysis made by XRF (LOD = limit of detection).

	Object	**DAR1**		**DAR2**		**DAR3**		**DAR4**		**DAR5**	
	Spot	**Frame right side**	**Case frontside**	**Frame right side**	**Case frontside**	**Frame right side**	**Case frontside**	**Frame right side**	**Case frontside**	**Frame right side**	**Case frontside**
Elements	**Cu**	60.86	71.64	57.79	56.28	53.42	54.30	71.65	69.11	60.71	61.77
	Zn	20.51	2.17	20.25	25.97	23.95	24.49	1.54	1.02	21.60	20.53
	Sn	1.38	**6.34**	1.67	0.49	0.01	0.47	**9.00**	**7.90**	0.85	1.09
	Pb	1.66	**2.44**	1.37	0.94	0.41	1.65	**1.91**	**4.09**	1.24	1.22
	Cl	0.90	0.32	0.43	0.09	0.03	0.06	0.26	1.43	0.51	1.18
	S	0.46	0.24	1.17	0.42	0.33	0.62	0.28	0.57	0.32	0.59
	Fe	0.47	0.06	0.34	0.27	0.05	0.10	0.06	0.03	0.42	0.38
	Ni	0.15	0.16	0.07	0.06	< LOD	0.03	0.17	0.16	0.10	0.10
	Ca	0.10	0.11	0.22	0.03	0.04	0.11	0.14	0.19	0.04	0.09
	Sb	0.05	0.15	0.05	0.02	< LOD	0.01	0.15	0.19	0.03	0.04
	Ag	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.02
	Ti	0.01	0.02	0.07	0.00	< LOD	0.00	0.03	0.03	0.00	0.01
	K	< LOD	< LOD	0.09	0.03	0.18	0.17	< LOD	< LOD	0.02	0.03
	Cd	< LOD	< LOD	< LOD	0.01	0.01	0.01	< LOD	< LOD	0.01	< LOD

A direct relation can be observed between the alloy composition and the two color groups which had been highlighted for the frames (respectively DAR1-DAR5 and DAR2-DAR3). All object surfaces show a certain amount of chlorine, which is systematically higher on the frames when compared to the results obtained on the cases. This can be due to manipulation with bare hands and contamination of the surface. In the case of the DAR1, DAR4 and DAR5, its presence could also be related to the presence of bleached shellac containing chlorine residues from the bleaching process.

Thickness measurements

The global lacquer average thickness on frame and case for each counter is less than 5 µm. In general, the frame is coated with a thicker layer than the case, probably to protect it from a more frequent manipulation. DAR2 exhibits a slightly thicker lacquer on the frame than the other counters whereas the lacquer on DAR3 forms an exception with an average thickness around 12 µm (Figure 7). This confirms previous visual observations (Figure 2c).

As for DAR3, the case was mounted by assembling metal sheets with screws and not by soldering (Table 1). A hypothesis is that a thicker varnish – when applied before mounting of the plates – could also prevent from contact corrosion in these areas.

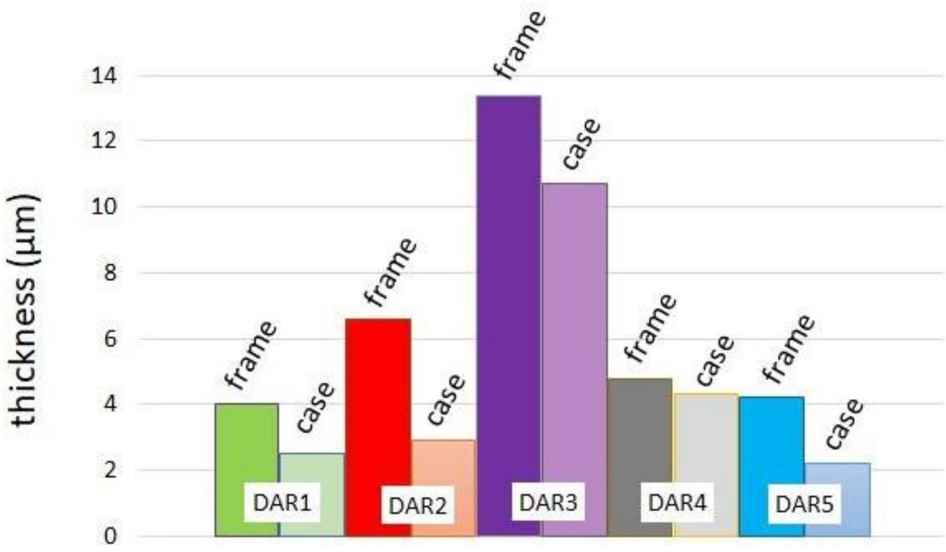


Figure 7. Average lacquer thickness on frame and case for each counter.

Conclusions

The investigation of this set of five counters from the collection of the CNAM in Paris, shows that a systematic approach to the characterization of lacquered copper alloys might be a promising additional tool for the historical study of the collection of technical and scientific objects. We conclude from visual observations that all lacquers were applied with a brush. The analytical results show that shellac coatings were systematically chosen for the copper-based parts of the studied counters, which is consistent with ancient written sources. Based on FTIR analysis and UV imaging performed on the objects, differences in the type and grade of resin can be pointed out and it can be assumed that at least two different grades of shellac were used (bleached shellac and orange shellac, both showing residues of shellac wax). It also appears that lacquer thickness is significantly higher for one counter model with a significantly different typology (DAR3), which might indicate that the lacquering technique was adapted to the manufacturing and mounting process of the metal parts and is not necessarily due to the production date of the object. Organic dyes were not identified in the lacquers by the analytical approach implemented, but XRF analysis of the alloy composition suggests that the different surface color of the cases and frames may be primary due to the alloy color and not to the color of the lacquer used.

Initially it was assumed that two counters, DAR2 and DAR3, which both present the legal mention “système brevet S.G.D.G”, might date from a similar more ancient manufacturing period in comparison to the other counters. XRF analysis shows that they present a similar alloy composition despite their different typologies. Furthermore, both counters are coated with a thicker orange shellac coating. Similarities can also be pointed out for the other group of counters. DAR1 is composed of two different copper-alloys for the frame and the case: the case composition is similar to the alloy of DAR4 and the frame composition is similar to the alloy of DAR5. Furthermore, the lacquer fluorescence under UV radiation indicates a different type of shellac coating (probably bleached) and a lower average coating thickness than for the first group (DAR2 and DAR3). The observations are compatible with the hypothesis, that these three counters may indeed have been produced at a later period than DAR2 and DAR3.

Additional information is provided by systematic observation under UV radiation of the transparent windows of the counters and additional FTIR analysis on one of them. A synthetic cellulose-based material was used instead of glass for the central window of DAR2. This kind of material was used during a long time in industry before it was replaced by more stable materials. Unfortunately, its use covers a period which is almost identical to the production span of the Darras Company. One hypothesis may be that it was experimented as an alternative to the glass windows when cellulose nitrate films were increasingly developed and used in the photo industry at the end of the nineteenth century. However, in a comparative study including a larger *corpus*, this aspect could be of help for dating the counters as well as the use of different glass types.

This study was carried out entirely on site in the conservation center with only completely non-invasive characterization methods. Despite the limitations of this approach, which does not give access to the stratigraphy of the metal-organic coating system (identification of different layers, especially in the case of the thicker lacquers) or does not allow to characterize the components present in very small amounts in the lacquers, it was possible to identify the type of coating used. It was also possible to group objects according to the metal alloy composition and the specificities of the thickness of the coatings. These findings also highlight the importance of the combination of metal and coating in producing the aesthetic appearance of these objects.

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REFERENCES

1. Brenni, P., ‘Cleaning and relacquering of Bras’, *Bulletin of the Scientific Instrument Society* **10** (1986) 2-3.
2. Brenni, P., ‘Restoration or repair? The dilemma of ancient scientific instruments’, in *Reversibility- Does it exist?*, eds. W. A. Oddy and S. Carroll, British museum occasional paper, London (1999) 19-24.
3. Schröter, J.; Michel, A.; Mirabaud, S.; Brambilla, L.; Paris, C.; Bellot-Gurlet, L., ‘Transparent varnishes on copper alloys dating from the 19th century: characterization and identification strategies’, in *Metal 2019. Proceedings of the interim meeting of the ICOM-CC metals working group*, eds. C. Chemello, L. Brambilla and E. Joseph, ICOM-CC, Paris (2019) 58-66.

4. Tingry, P.- F., *Traité théorique et pratique sur l'art de faire et d'appliquer les vernis ; sur les différents genres de peinture par impression et en décoration, ainsi que sur les couleurs simples et composées : accompagné de nouvelles observations sur le copal, de notes historiques sur la nature des matières et sur les procédés mis en usage par les compositeurs de couleurs et de vernis et par les peintres*, 2nd vol., G. J. Manget, Geneva (1803).
5. Roseleur, A., *Guide pratique du doreur, de l'argenteur et du galvanoplaste: manipulations hydroplastiques*, 3rd edition, M. de Plazanet, Paris (1873).
6. Hospitalier, E., *Recettes de l´électricien*, 2nd edition, G. Masson, Paris (1902).
7. Koller, J.; Baumer, U., 'Organische überzüge auf metallen, teil 1, lacke', *Arbeitsblätter für Restauratoren* **33**(1) (2000) 201-225.
8. Birnie, L., 'Special finishes on non-ferrous metals at the National Maritime Museum', in *Metal Plating and Patination*, eds. S. La Niece and P. Craddock, Butterworth-Heinemann, Oxford (1993) 148-154.
9. Cook, C. J., 'Lacquers for instrument parts', *Bulletin of the Scientific Instrument Society* **52** (1997) 36.
10. Steenhorst, P., 'Schellac varnishing on brass. A practical guide', *Bulletin of the Scientific Instrument Society* **96** (2008) 34-38.
11. Steenhorst, P., 'Het bewust kiezen van een vernis voor instrumenten', in *Uitgangspunten bij het gebruik van synthetische materialen voor conservering en restauratie: verstevigen, lijmen, vernissen,* eds. W. G. T. Roelofs and J. A. Mosk, Centraal Laboratorium voor Onderzoek van Voorwerpen van Kunst en Wetenschap, Amsterdam (1992) 97-100.
12. Schröter, J., *Les vernis or sur les bronzes d'ameublement: acteurs, pratiques et marchés à Paris au XIXe siècle*, PhD dissertation, Departement of History of Art, Sorbonne University, Paris (2021).
13. Lanterna, G.; Giatti, A., 'Caratterizzazione non invasiva delle vernici da ottone degli strumenti scientifici: ricette storiche, realizzazione di provini verniciati, ricerca analitica e applicazioni "in situ" su strumenti storici', *OPD restauro: rivista dell'Opificio delle pietre dure e laboratorio di restauro di Firenze* **26** (2014) 165-180.
14. Brenni., B., 'From workshop to factory: the evolution of instrument-making industry, 1850–1930', in *The Oxford Handbook of the History of Physics*, eds. J. Z. Buchwald and R. Fox, Oxford University Press, Oxford (2013) 584–650.
15. Stappel, M., 'Schellack. Eigenschaften, Verwendung, Untersuchungsmethoden', *Restauro, Zeitschrift für Restaurierung und die Erhaltung des Kulturerbes* **8** (2001) 596-603.
16. Gloess, P.; Bernard, R., 'Les produits chimiques à l'exposition universelle de 1900', in *Le Moniteur scientifique du Docteur Quesneville : journal des sciences pures et appliquées, compte rendu des académies et sociétés savantes et revues des progrès accomplis dans les sciences physiques, chimiques et naturelles*, vol. 57**,** tome 15, part II, Chez M. le Dr G. Quesneville, Paris (1901) 545-568.
17. Sutherland, K., 'Bleached shellac picture varnishes: characterization and case studies', *Journal of the Institute of Conservation* **33**(2) (2010) 129-145, https://doi.org/10.1080/19455224.2010.495242.
18. 'work file n° 40619', in Archival from Museum of the French National Conservatory of Arts and Crafts, Paris.
19. 'files D32U3 76 and D33U3 156', in *Archives of Paris*, Archives of the Commercial Court of Paris, Paris.
20. *Archives commerciales de France, journal hebdomadaire* **46** (1894) 713, https://gallica.bnf.fr/ark:/12148/bpt6k55912510 (accessed 2023-05-17).
21. *Archives commerciales de France, journal hebdomadaire* **66** (1915) 2017, https://gallica.bnf.fr/ark:/12148/bpt6k56649169 (accessed 2023-05-17).
22. Giachet, M. T.; Schröter, J.; Brambilla, L., 'Characterization and identification of varnishes on copper alloys by means of UV imaging and FTIR', *Coatings* **11**(3) (2021) 298, https://doi.org/10.3390/coatings11030298.
23. *UV Innovations*, https://www.uvinnovations.com/getting-started (accessed 2022-10-10).
24. Londe, A., *Aide-mémoire pratique de photographie*, J.-B. Baillière et Fils, Paris (1893).
25. Measday, D., 'A summary of ultra-violet fluorescent materials relevant to conservation', *AICCM National Newsletter* **137** (2017), https://bit.ly/3pjAq8U (accessed 2022-10-17).
26. Quye, A., 'Quality matters for historical plastics: the past-making of cellulose nitrates for future preservation', *Cahiers François Viète* **2** (2017) 45-65, https://doi.org/10.4000/cahierscfv.799.

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Data analysis techniques for the visualization and classification of historical vehicle engines' health status using data-driven solutions

Técnicas de análise de dados para a visualização e classificação do estado de conservação de motores de veículos históricos

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Abstract

In the field of cultural heritage, the use of non-destructive techniques to determine the state of conservation of an artifact is of the utmost importance, to avoid damage to the object itself. In this paper, we present a data pipeline and several machine learning techniques for the visualization, analysis and characterization of engines in historical vehicles. The paper investigates the use of vibro-acoustic signals acquired from the engines in different states of conservation and working conditions to train machine learning solutions. Data are classified according to their state of health and the presence of anomalies. The t-SNE algorithm is used for dimensionality reduction for data visualization. The machine learning algorithms tested showed encouraging performance in associating acoustic emission data with the engine signature, the type of anomaly and the working conditions. Nevertheless, a larger dataset would allow us to improve and strengthen the results.

KEYWORDS
Machine learning
Cultural heritage
Non-invasive monitoring
Acoustic emission

Resumo

Em património cultural a utilização de técnicas não destrutivas para determinar o estado de conservação de um artefacto é de extrema importância para evitar danos no próprio objeto. Neste artigo, apresentamos um canal de dados e técnicas de aprendizagem automática para a visualização, análise e caraterização de motores de veículos históricos. O artigo investiga a utilização de sinais vibro-acústicos adquiridos nos motores em diferentes estados de conservação e condições de funcionamento para treinar soluções de aprendizagem automática. Os dados são classificados de acordo com o seu estado de conservação e a presença de anomalias. O algoritmo t-SNE utilizou-se para a redução da dimensionalidade para a visualização dos dados. Os algoritmos de aprendizagem automática testados revelaram um desempenho promissor na associação dos dados de emissões acústicas com a assinatura do motor, o tipo de anomalia e as suas condições de funcionamento. Porém, um maior conjunto de dados permitir-nos-ia melhorar e reforçar os resultados.

PALAVRAS-CHAVE
Aprendizagem automática
Património cultural
Monitorização não invasiva
Emissão acústica

Introduction

As known, employing non-destructive techniques is fundamental in the field of cultural heritage when ascertaining the state of conservation of an artifact and monitoring it in order to prevent damaging the object itself. When considering technical, scientific and industrial heritage, the artifact's state of conservation is not limited to the conditions of the constituting materials (e.g., the presence of corrosion on a metallic object), but includes also the functioning status of the mechanisms [1-5].

For this, Non-Destructive Testing (NDT) methods are one of the possible techniques that can be used to provide data in order to support the expertise of the conservators to decide if a mechanism can be reactivated. One of the most versatile NDT methods is Acoustic Emission (AE). AE techniques are based on the principle that when there is a sudden release of energy inside a solid caused, for instance, by an impact between moving parts, corrosion phenomena or the growth of a crack, then some energy is dissipated in the form of elastic waves travelling inside the material itself. This release of energy can be captured by piezoelectric sensors placed in contact with the surface to be analyzed [6].

The ACUME_HV project (Acoustic Emission Monitoring of Historical Vehicles), conducted at HE-Arc between 2018 and 2020, was the first attempt to use Acoustic Emission techniques as NDT, to diagnose and monitor the state of preservation of engines in historical vehicles. AE is commonly used in the automotive industry to test the performance, in terms of mechanical and combustion fulfillments, of newly produced engines [7-13]. However, the technique has not been used before on ancient engines, where scaling of lubricants, long periods of inactivity, wear of the moving parts and presence of oxide scales can significantly affect the engine mechanism's performance. AE therefore needs to be adapted for this purpose.

AE has also been extensively used in the industrial field in the last 70 years for the detection and monitoring of a wide variety of phenomena ranging from corrosion of metal structure to the stability of buildings [6]. In the field of cultural heritage, this technique has gained acceptance since it was introduced in the 1990s [14]. Being non-invasive, it is used for the monitoring of ongoing processes, such as crack development and propagation in different materials such as wood and enamel, or the activity of insects in wooden instruments, just to cite some examples [15-16]. AE can therefore be considered a technique with high potentiality for the application in the field of cultural heritage and in particular of heritage with mechanisms (technical, scientific and industrial artefacts), but the three main drawbacks are the cost of the equipment, the expertise necessary to perform the measurements and the data post-processing. The latter is part of the focus of the present paper.

The developed methodology and the results of the ACUME_HV project have been previously published in different journals and conference proceedings [17-21]. The ACUME_HV project showed that acoustic emission can be used to establish the state of preservation of historical engines before their reactivation and to detect the most common faults [17-21]. Obtained AE data can be post-processed and interpreted in different ways, based on the extraction of specific features, such as peak amplitude, duration, rise time, frequency, and energy [14]. In the first phase of the project, the data analysis was limited to the detection and evolution over time of AE events' amplitude (also called "hits"), as a function of the rotational speed of the engine [17-21]. Those events are produced by the movement of the different contact pairs during the functioning of the engine and are directly related to the thermodynamic cycle of the engine itself (fuel injection, ignition, expansion, and exhaust) [17-21]. Interpretation of the data in this phase was limited to combining the obtained measurements with a good knowledge of the system and with the expertise of conservation professionals. When anomalies are detected in the data, only the competence and previous knowledge of the operators, as well as the combination with other types of tests, could lead to a correct interpretation of the curves. It remained therefore a human-dependent methodology.

For this reason, in the following phase of the project, it was decided to process the collected data using advanced data analysis methods, thanks to the collaboration between the conservation-restoration and the engineering departments of HE-Arc. The latter had previous experience in the application of machine learning (ML) techniques to AE data [22]. Supervised ML techniques learn from expert-labelled data the pattern and characteristics intrinsic to the signals and how they relate to normal and anomalous behavior. Once the algorithms are trained, the resulting models can be automatically applied to novel unseen data without the need for human supervision. This short paper presents this second, data-driven, phase of the study.

Goal and research questions

In this paper, we investigate the use of data analysis techniques for the visualization and classification of the engine health status using data-driven solutions such as supervised machine learning. The paper focuses on the analysis of vibro-acoustic signals for the characterization of engines in different conditions (data presented in previous publications [17-21]). Research questions studied in this article focus on the use of AE signals and machine learning, and can be summarized as: 1) identify the engine that produces the signal; 2) determine if an engine has an anomaly; 3) determine which engine a record belongs to and if it has an anomaly.

Research goals 1 and 3 aim at verifying if data analysis techniques can, per se, distinguish data produced by different engines of the same type (in this case, Renault AG1). In fact, every engine is unique and produces peculiar vibro-acoustic signatures but, in this study, we wanted to verify if the techniques used are able to differentiate those unique peculiarities. If a database of AE signals from different engines is produced (which would be the natural development of this study), the method should be able to identify precisely which engine has produced the signals. In particular, the type of engine as well as the precise engine should be identifiable.

Related work

The proposed approach is inspired by Zhe Li et al. [23] dealing with the detection of anomalies from vibration data on mechanical equipment. The authors focus on the detection of anomalies in the context of unsupervised learning, and with unclassified data, on mechanical equipment.

An important point to note is that the sample rate of the data used is 4096 Hz [23], where our audio recordings are sampled at 2 MHz. In addition, the data used are accelerometer recordings [23], while we investigate the usage of acoustic emission sensors. We decided to focus on AE because these signals are commonly used in the automotive industry to test the performance, in terms of mechanical and combustion fulfillments and have the potential to detect physical phenomena that could be missed at lower frequencies [7-13]. Nevertheless, due to the analog nature of the signal in both cases, the approach proposed by Zhe Li et al. [23] can be adapted to the current use case.

The method used is based on two deep learning models: Stacked Autoencoders (SAE) and LSTM (Long Short-Term Memory) [23]. The SAE role is to find an encoded representation of the input signals by forcing the extracted features into an encoder-decoder structure. The encoder will force the reduction of the signal dimensionality while the decoder aims at reconstructing the original data. Then, the LSTM model is used in an unsupervised fashion in order to detect anomalies in the reconstructed signal. LSTMs are predominantly used to learn, process, and classify sequential data because these networks can learn long-term dependencies between time steps of data. In our scenario, time dependencies are less relevant since we want to classify if an engine has an anomalous behavior, but we do not need to characterize its evolution over time. A faulty engine in our dataset will produce anomalous data from the beginning. For this reason, in this study we limit our implementation to the feature extraction steps and SAE model. The LSTM is not used.

Methods

Data acquision

AE signals were acquired using an AE system from Vallen. The set-up includes an MB2-V1 chassis equipped with four AE and four parametric input channels. The system included four broadband AE sensors VS900-M (between 100 and 900 kHz) and respective AEP5 preamplifiers (+ 34 dB). AE signals were recorded with the sampling frequency set to 2 MHz. A 1 MHz low pass filter was applied to the input signals, aiming to reduce the noise from the high frequencies. Additionally, the angular position of the engine's crankshaft was measured by means of a full continuous 360° VISHAY Spectrol 601-1045 smart position sensor (output signal 0-5 V) with sampling rate of 1.25 kHz [17-21].

The engine type used for this project is a two-cylinder AG1 by Renault, dating from the 1910s [17-21]. Three identical engines (hereafter indicated as ENG0, ENG1 and ENG2) were used: two of them are in working conditions (ENG1 and ENG2) [17] and one, ENG0 [17-21] that was previously bought as spare part for possible reparations. The location of the AE sensors around the engine was established during the first part of the ACUME_HV project [17-19, 21].

The engine's mechanisms were operated manually, at a relatively low rotating speed, by means of an external handle to move the crankshaft. This procedure allowed to maintain good control of the interaction of the different parts during pistons slow motion, therefore avoiding possible damage to the mechanism, which is a museum standards requirement. During these so-called "cold tests" the mechanical and air compression signatures of the engine were extracted [17-21]. During those tests, the influence of the rotational speed, as well as the reproducibility of the measurements were verified [17-21].

Moreover, some malfunctions, commonly encountered in this type of engine, were simulated on one of the available AG1 engines: ENG0. The engine was removed from a vehicle and mounted on a test bench, in order to have complete access to all the parts of the engine itself [17, 20].

The whole procedure and set-up for AE measurements on AG1 engines have already been described in previous publications [17-21]. To summarize four categories of failure were introduced: removal of a spark plug (F0), added clearance between the connecting rod and the crankshaft (connecting rod failure) (F1); wear of the piston rings (F2); clearance between the piston pin and the connecting rod (F3) [20]. Table 1 summarizes the different conditions and the labelling used for classification (see "Predict both the presence of an anomaly and the engine", below).

Table 1. *Classes for anomaly and engine prediction.*

Engine	Configuration	Class (label)
ENG0	No anomaly, with spark plugs	0
	No anomaly, without spark plugs (F0)	1
	F1	2
	F2	3
	F3	4
ENG1	No anomaly, with spark plugs	5
	No anomaly, without spark plugs (F0)	6
ENG2	No anomaly, with spark plugs	7
	No anomaly, without spark plugs (F0)	8

Data analysis technique – overview

There is a wide range of machine learning (ML) techniques utilized for detecting anomalies in time series data [24-26]. However, there is a lack of approaches that specifically target the identification of anomalies in AE signals. In a recent study, Zhe Li et al. [23] proposed a deep learning-based approach that demonstrated promising results for detecting anomalies in accelerometer data. Given that the underlying nature of accelerometer time series and AE time series is comparable, we investigated the potential feasibility and necessary procedures for adapting the aforementioned architecture to our use case and signal data. In the article by Zhe Li et al. [23], from a signal recorded by an accelerometer mounted on the machine which has X-Y-Z acceleration components, the characteristics of these signals are extracted by means of a Wavelet Packet Decomposition solution (WPD) [27] (see "Wavelet Packet Decomposition", below). These characteristics are 33 in number (11 per component) and contain the following information:

- Features 1 to 6 represent the two largest peaks in the frequency domain of each of the components (e.g., features 1 and 2 represent, respectively, the largest frequency along the X-axis signal as well as the second largest).
- Features 7 to 18 represent the standard deviation of the detail of the coefficients of the wavelets.
- Features 19 to 21 are the energy percentages of the approximation in the three directions.
- Features 22 to 33 are the energy percentages of the details in levels 1 to 4, again for each of the coordinates.

The characteristics are then normalized with a *Unity Based Normalization*, which simply corresponds to a normalization between 0 and 1 of the values (Equation 1).

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}} \qquad \textbf{(1)}$$

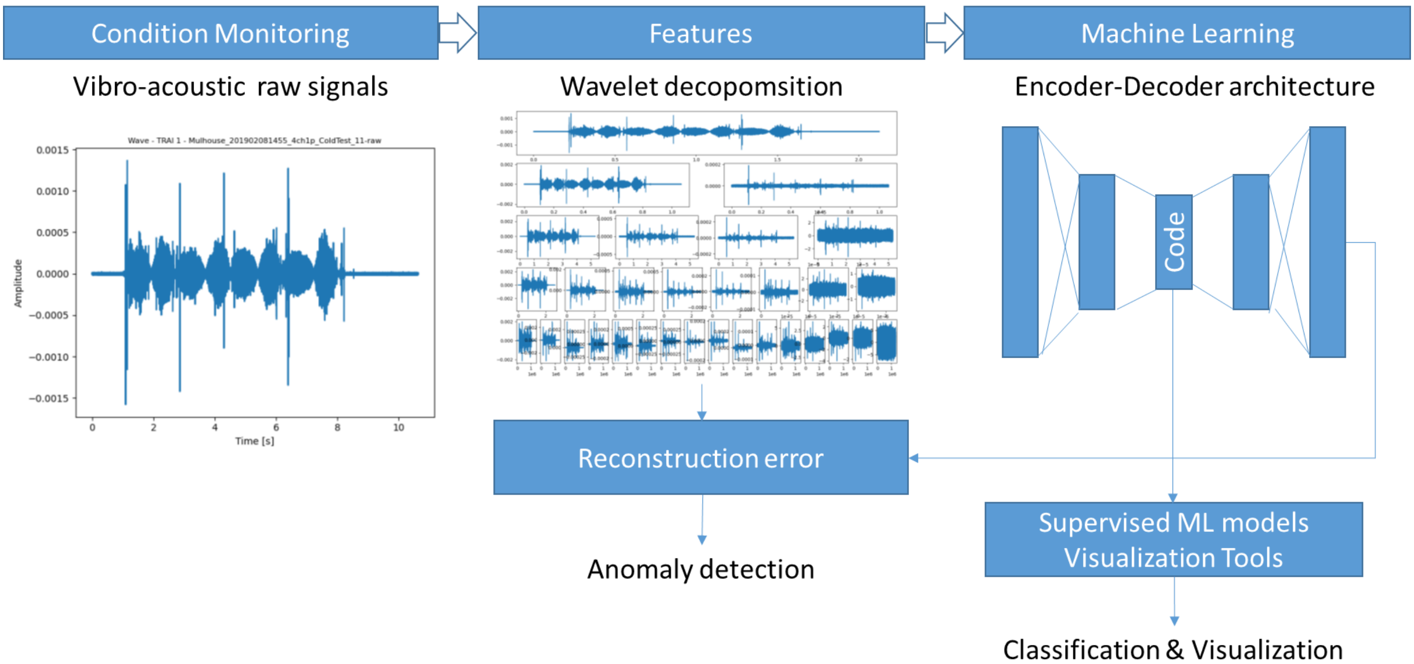

Figure 1. The used data engineering pipeline, adapted from Zhe Li et al. [23].

The extracted features are then sent through an encoder-decoder machine learning solutions. In Zhe Li et al. [28] a LSTM model is used for the automatic thresholding and anomaly detection. The LSTM is not used in this paper, in which we focus on AE analysis. The main difference from a traditional accelerometer sensor or microphone is the much higher sample rate (up to 2 MHz).

Features extracted from the raw signals are passed to a machine learning module using an encoder-decoder architecture. The “code” created by the model is used to compute a reconstruction error. The reconstruction error is the difference between the input signal and the signal reconstructed by the decoder. The underlying hypothesis is that bigger errors are observed in the case of anomalies. Figure 1 depicts the different steps.

The following sections describe the data pipeline implemented to realize such an approach and highlight the differences from the original article.

Feature extraction

No data pre-treatment

Some signals in the dataset are noisy. Filters can be applied to mitigate the impact of noise on the informative part of the signal. Since feature learning is one of the major advantages of deep learning approaches, in this study, we decided to let the machine learning logic filters it out on its own.

Fast Fourier Transform

The Fast Fourier Transform (FFT) allows a signal to be decomposed into its component frequencies and the data to be visualized and analyzed in the frequency domain. An anomaly in mechanical equipment can take the form of a frictional force that can generate high frequencies and therefore would be visible on an FFT graph (Figure 2).

Engine problems can produce signal changes that are not easily detected by a human, such as a shift in the frequency peak, or a combination of other factors that a machine learning algorithm would be able to detect.

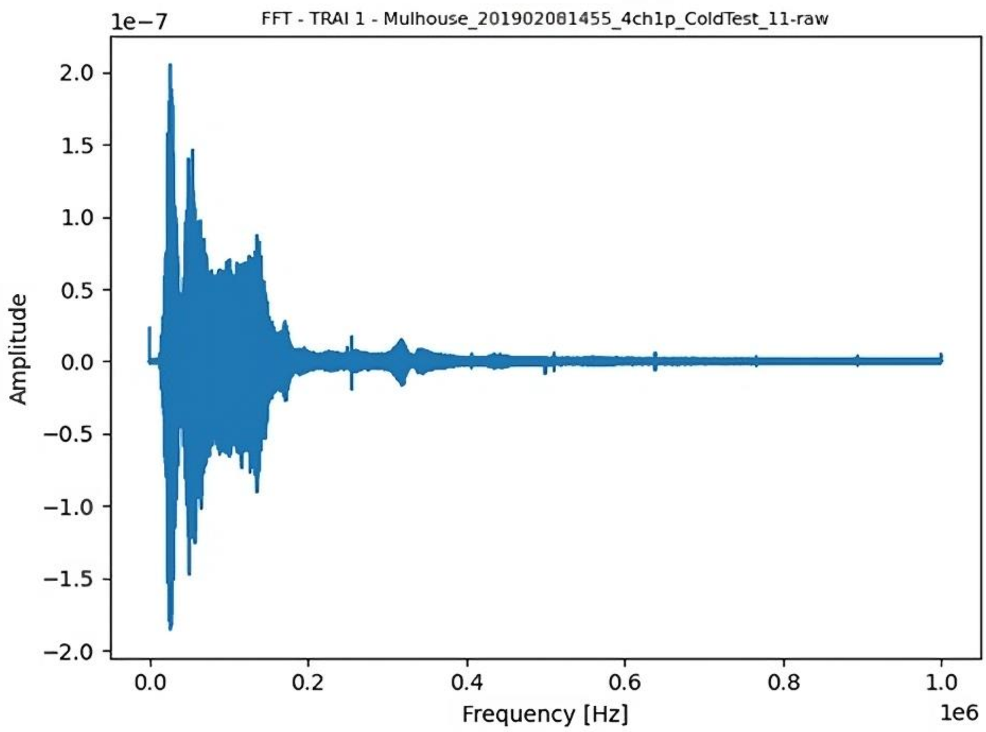

Figure 2. FFT of an input signal.

Spectrogram

A spectrogram is a visual representation of the frequency spectrum of a signal as it varies with time. This representation visualizes the distribution of frequencies and their evolution over time. The amplitude of a frequency is represented by a color code (Figure 3). Logarithmic values are used to visually highlight changes in the values.

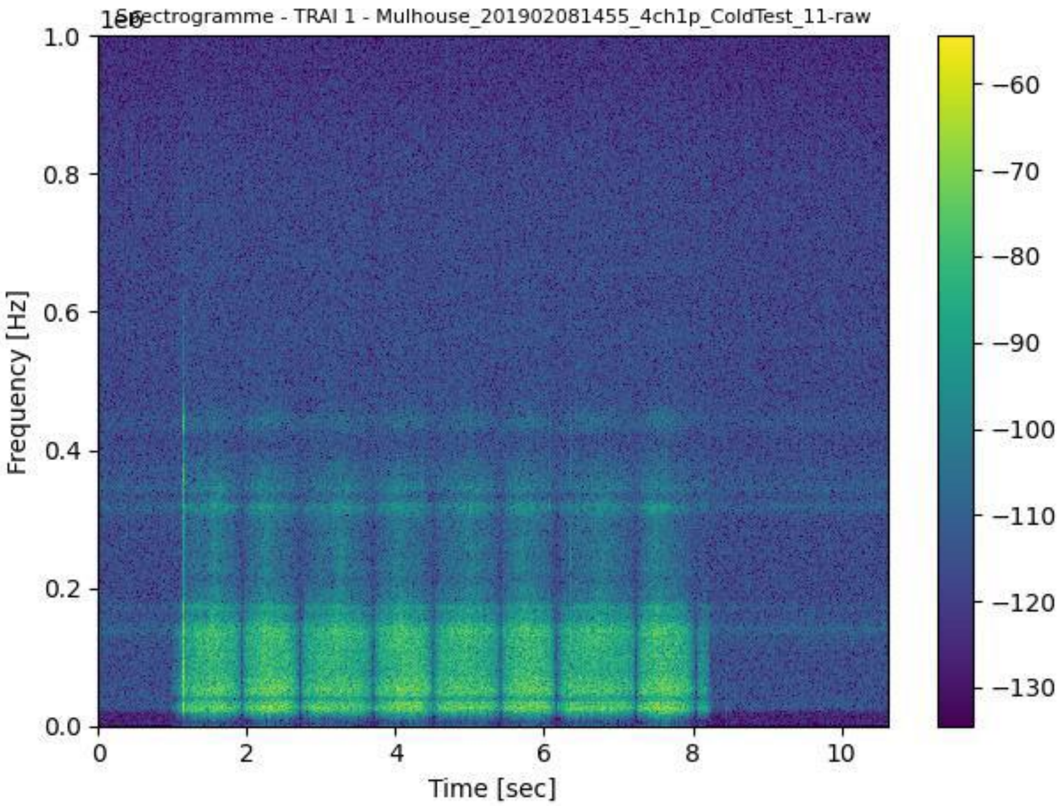

Figure 3. Spectrogram of the acoustic signal, yellow is used to represent higher amplitudes and blue represents the portion of the spectrum without relevant signals.

Discrete Wavelet Transform

The Discrete Wavelet Transform (DWT) [29] is, as the name implies, a signal transformation technique based on wavelets, which are simple waveforms with an amplitude that begins at zero, increases or decreases, and then returns to zero one or more times. The DWT decomposes a given signal into several sets, where each set is a time series of coefficients describing the time evolution of the signal in the corresponding frequency band. The original signal can be reconstructed as a linear combination of wavelets and weighting wavelet coefficients. In the case of our project, we worked with the Daubechies 4 (DB4) wavelet.

For example, a DWT decomposes the signal into two equal parts, a high-frequency part and a low-frequency part. Each additional level of decomposition divides the lower part into an upper part and a lower part, as illustrated in the image below (Figure 4).

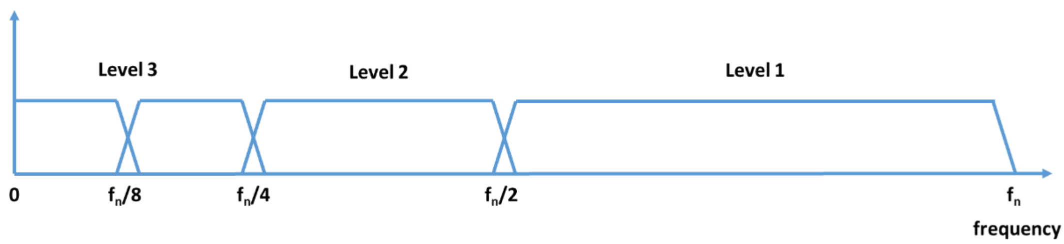

Figure 4. Frequency structure of a DWT.

Wavelet Packet Decomposition

In our case, we did not use the DWT, but the Wavelet Packet Decomposition (WPD). DWT and WPD are relatively similar, with the major difference that WPD also breaks the high part into a high part and a low part. More precisely the lower part is called Approximation (A) and the upper part Detail (D). In other words, WPD is identical to DWT except that the detail coefficients are further decomposed as well.

The structure thus generated is that of a binary tree. It is possible to access a decomposition level by specifying its path. For example, the path "A" indicates the first approximation. The access "the approximation of the detail" of the original signal will be indicated using the path "DA".

For illustration, a WPD decomposition into three levels gives the following structure, with each of the elements of the tree, leaves or not, being accessible with their path (Figure 5).

In the case of the data of our project, the analysis of one of the files in WPD on four levels gives the following result, with the original signal at the very top, and at each line an additional level of decomposition. We therefore notice that at the fourth level we have 16 (= 2^4) coefficients (Figure 6).

In our case, we use the WPDs to calculate the energy level in certain regions of the signal. This allows us to determine if most of the energy is in the high or low frequencies.

To summarize the following features are extracted:

- The two most significant frequencies of the FFT of the whole recording (frequencies where the FFT has the higher magnitude). Frequencies are stored as a multiple of the transient sample rate (dynamically retrieved) divided by 2. In effect this is a multiple of 1 MHz since the recordings were made at 2 MHz.
- The energy levels (WPD coefficients) of the WPD decomposition of the signal at the A, D, AD, AAD and AAAD levels. These values are normalized per channel between 0 and 1 as previously mentioned. These features allow the model to determine at which level is most of the energy in each channel.
- The distribution of the energy of the level A of the WPD of the signal between the four sensors. For example, a value of 0.34 indicates that the channel in question has 34 % of the energy of the total approximation recorded by all the sensors.

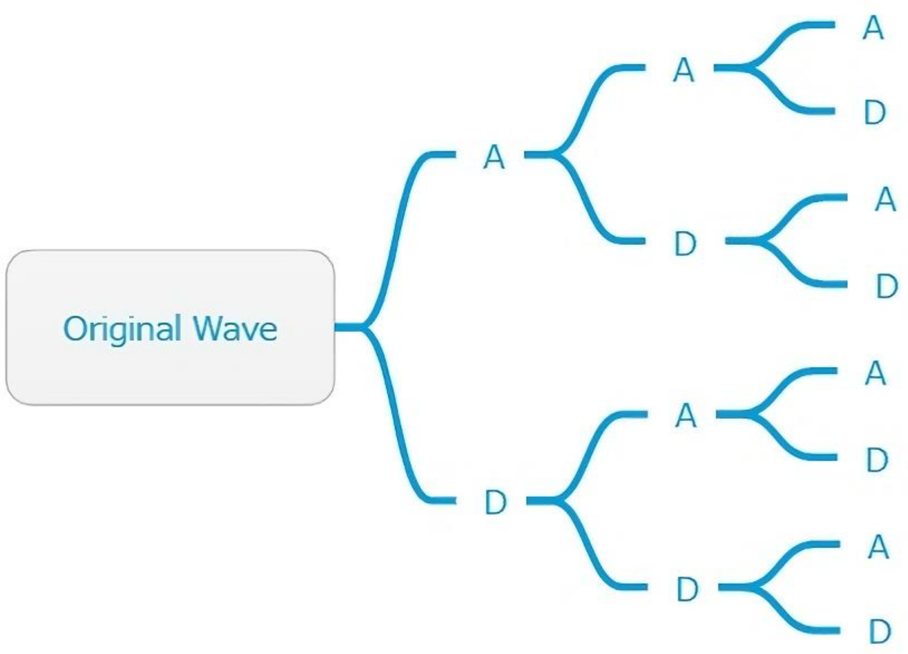

Figure 5. WPD 3-level decomposition.

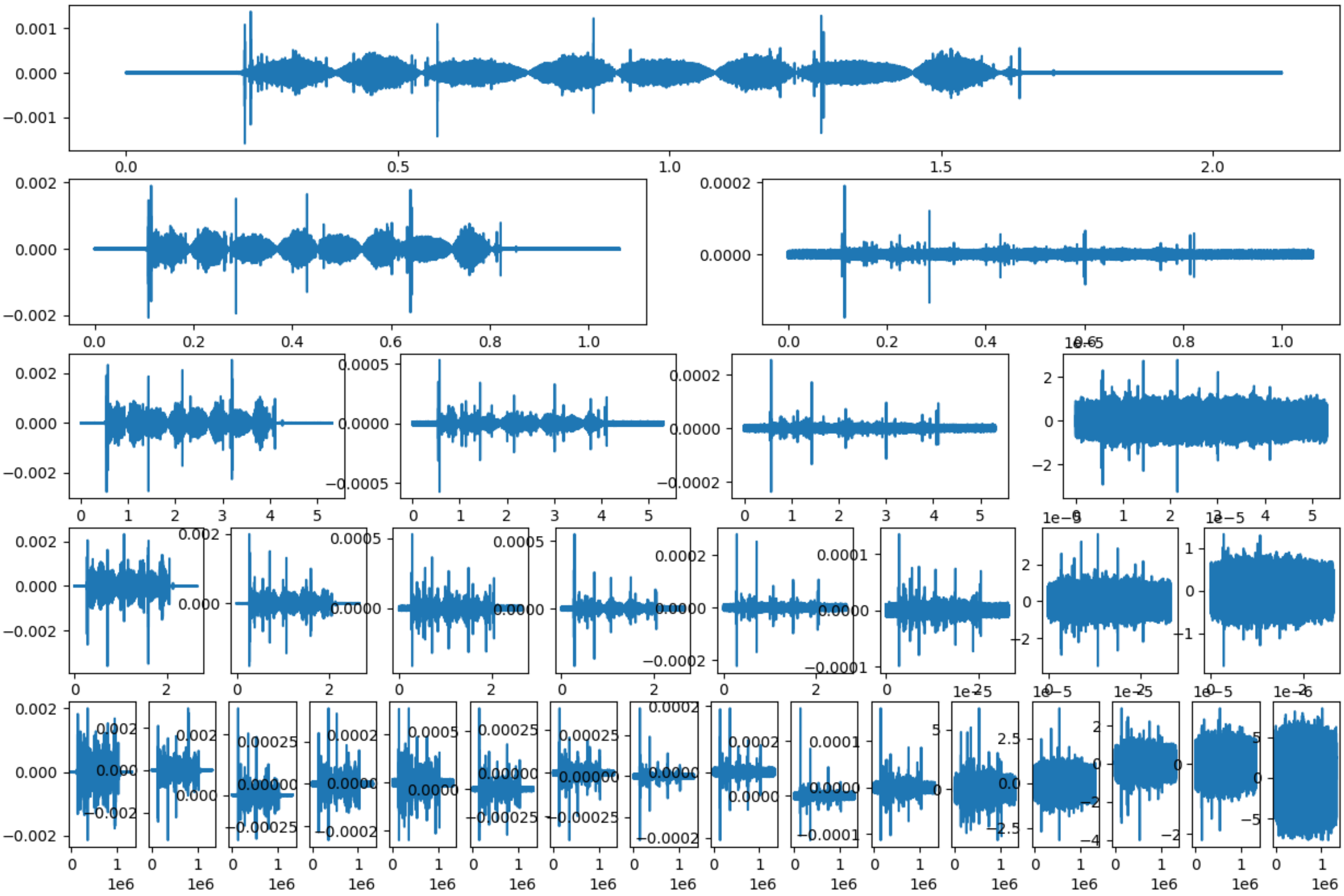

Figure 6. WPD decomposition applied to the studied dataset.

Clustering visualization using t-distributed Stochastic Neighbor Embedding

A data clustering and visualization step is then performed in order to visually assess the quality of the selected features. The approach used is based on t-SNE [30]. The acronym t-SNE stands for *t-distributed Stochastic Neighbor Embedding*. t-SNE makes it possible to represent datasets with many dimensions and reduce them to a low-dimensional graph, while keeping a large amount of the original information.

The principle of functioning is as follows: the algorithm first calculates the similarity between the two points to give them greater or lesser importance. The similarities used in t-SNE are based on a Gaussian kernel that measures the similarity between pairs of high-dimensional data points. The similarity between two data points is higher if they are close to each other in the high-dimensional space, and lower if they are far apart. This is done between each pair of points in the original dataset. It then places them randomly in a lower dimensional space (e.g., 2D) and then calculates the similarity of these points in this new space. At the first iteration the similarity will be very low, so the algorithm proceeds to bring similar points closer together in small steps and move away those that are not similar. The algorithm repeats this step several times until it obtains similarity values closest to those of the original dataset. t-SNE still takes an additional parameter called "perplexity" which gives it an additional indication of the size of the groups it should form.

This approach, not presented in the original paper has been added, to facilitate the understanding of the data. The assumption is that clusters visible using such an approach can later be identified using machine learning.

Classification using machine learning – methodology overview

Classification using machine learning typically consists of three main phases: feature extraction, algorithm training and evaluation. The first phase is to extract the features used by the algorithm from the engine records (the approach used is presented in the previous section). The second phase is the training of a machine learning algorithm using the extracted features and the labels. Labels associate the features to a class. This phase is typically repeated iteratively to tune and optimize the algorithm hyperparameters. Finally, the third step consists in evaluating the performances of the trained algorithm on a test set of data unseen by the algorithm during the training phase. This split of the data in training and test set is a typical approach in ML required to demonstrate the generalization of the model and reducing the risk of overfitting the model to the data.

Results

Visualization with t-SNE

Figure 7 shows the results of the clustering done with t-SNE. Signals representing the behavior of an engine are represented by a point in a 2D space. Points with the same color belong to the same class, a number is introduced to link the cluster to the selected class ("0" stands for ENG0, etc.). Points that are displayed in proximity indicate that t-SNE considers such points similar. In other words, if points of the same color are close, it means that also the associated signals are similar.

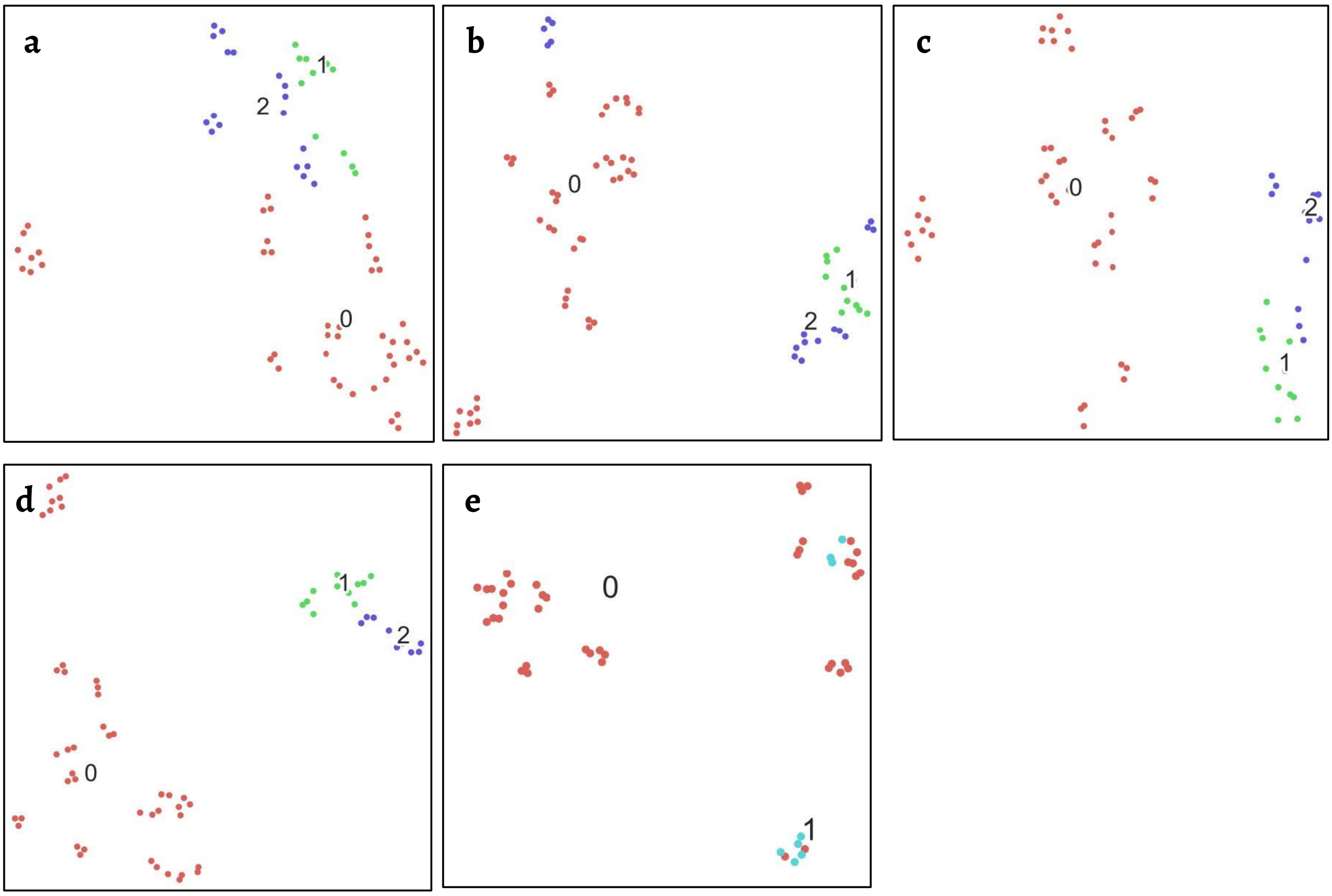

Figure 7. t-SNE visualization in a 2D space, datapoints from the same class (number) have the same color (0-red: ENG0; 1- green: ENG1; 2-blue: ENG2): *a)* engine classification using only 2 features - FFT picks and WPD coefficients; *b)* same but using power distribution between sensors as additional feature; *c)* data obtained without spark plugs are removed from ENG0; *d)* data obtained without spark plugs are removed from all the engines' data; *e)* visualization differentiating engines without (0) and with anomalies (1).

Discussion

Although the dataset that has been used is quite small and heterogeneous (for instance, ENG0 sensor positioning differs from ENG1 and ENG2, the recordings in general are not all made under the same conditions), t-SNE allowed us to clearly identify some special cases and to isolate them. For instance, a sub-cluster of points was associated to engines data obtained with the removal of spark plugs. This is a good first result at the level of machine learning and confirms our hypothesis that classification seems to be a viable option for detecting anomalies in engines and motivate our next step. Nevertheless, it could be necessary to increase the quantity of extracted features from the signals for the clusters to be more distinct from each other.

Classification using machine learning

Libraries and metrics

LazyPredict [31] is a Python library that makes it easy to test a large number of models to determine their effectiveness on the data provided. The data is loaded into a matrix (or more precisely into an array of arrays) and the library takes care of testing the combinations.

The different datasets previously tested with t-SNE are also used to investigate how effectively the different classes could be predicted. With a dataset with a sample size of 50 labelled instances, 70 % of the data is used for training and 30 % for testing. This split has been selected experimentally. We needed at least 30 % of the data to obtain statistically significant results and as much as possible of the data for the training. As for the metrics used for evaluate the algorithms' performance we selected the accuracy, the balanced accuracy and the F1-Score.

Accuracy is a measure of how many predictions the model got correct out of the total number of predictions made (Equation 2). It is defined as the ratio of the number of correct predictions (true positives and true negatives) to the total number of predictions made:

$$accuracy = \frac{TP + TN}{TP + TN + FP + FN} \qquad (\mathbf{2})$$

Where, TP – number of true positives (number of samples from the positive class that are correctly classified as positive); TN – number of true negatives (number of samples from the negative class that are correctly classified as negative); FP – number of false positives (number of samples from the negative class that are incorrectly classified as positive); FN – number of false negatives (number of samples from the positive class that are incorrectly classified as negative).

The F1-score is a harmonic mean of precision and recall, two metrics that describe the classifier's performance with respect to each class separately (Equation 3).

$$F1\text{-}score = \frac{2 * (precision * recall)}{precision + recall} \qquad (\mathbf{3})$$

Where, precision = TP / (TP + FP) is the fraction of true positives among all the samples that the model classified as positive; recall = TP / (TP + FN) is the fraction of true positives that the model correctly classified as positive out of all the positive samples.

The F1-score is a useful metric when dealing with imbalanced datasets, where one class has fewer samples than the other. It provides a balanced measure of precision and recall that takes into account the class distribution.

Similarly, "balanced accuracy" is a performance metric that measures the accuracy of a classifier in a dataset that has imbalanced class distribution. It is defined as the average of the sensitivity and specificity of the classifier, which are the true positive rate and true negative rate respectively, calculated for each class (Equation 4). More formally, if we have a binary classification problem with classes A and B, and N_A and N_B are the number of samples in each class, the balanced accuracy can be calculated as:

$$balanced\_accuracy = (sensitivity_A + specificity_B)/2 \qquad (4)$$

Where: $sensitivity_A = TP_A / N_A$ is the true positive rate for class A, i.e., the fraction of samples from class A that are correctly classified as A; $specificity_B = TN_B / N_B$ is the true negative rate for class B, i.e., the fraction of samples from class B that are correctly classified as B; TP_A – number of true positives for class A; TN_B – number of true negatives for class B. In a multiclass classification problem, the balanced accuracy can be computed as the average of the per-class balanced accuracies.

Predict which engine a record belongs to

It is in this scenario that the classification works best, as many ML algorithms are able to classify the engines and the AE signal with an accuracy of 1.0. As a baseline, we also note the score of 0.36 for the "Dummy Classifier", which simply predicts the most frequent class for all data points. Therefore, the classification seems to provide valuable results (Table 2).

Table 2. *Classification results for engine identification (output of the LazyPredict library). Results are sorted by "balanced accuracy".*

Model	Accuracy	Balanced accuracy	F1 score
LinearSVC	1.00	1.00	1.00
LogisticRegression	1.00	1.00	1.00
XGBClassifier	1.00	1.00	1.00
SGDClassifier	1.00	1.00	1.00
RidgeClassifierCV	1.00	1.00	1.00
RidgeClassifier	1.00	1.00	1.00
RandomForestClassifier	1.00	1.00	1.00
Perceptron	1.00	1.00	1.00
PassiveAggressiveClassifier	1.00	1.00	1.00
NearestCentroid	1.00	1.00	1.00
LGBMClassifier	1.00	1.00	1.00
ExtraTreesClassifier	1.00	1.00	1.00
BernoulliNB	1.00	1.00	1.00
BaggingClassifier	0.95	0.97	0.95
GaussianNB	0.95	0.96	0.96
CalibratedClassifierCV	0.95	0.96	0.95
LinearDiscriminantAnalysis	0.95	0.92	0.95
ExtraTreeClassifier	0.95	0.92	0.95
KNeighborsClassifier	0.91	0.88	0.91
AdaBoostClassifier	0.91	0.88	0.91
DecisionTreeClassifier	0.86	0.84	0.87
SVC	0.91	0.83	0.90
LabelSpreading	0.86	0.79	0.85
LabelPropagation	0.86	0.79	0.85
QuadraticDiscriminantAnalysis	0.64	0.54	0.59
DummyClassifier	0.36	0.32	0.29

Predict if an engine has an anomaly

The dataset is divided into two classes, one containing only signals without problems and the other containing signals with an anomaly. In this scenario, it does not matter which dataset the signal belongs to.

In contrast to the t-SNE results, the accuracy of the different models is very promising (Table 3), with the majority of classifiers outperforming the Dummy Classifier. Note that the amount of data in the class with anomalies is much smaller than in the class without anomalies, hence the high accuracy of the Dummy Classifier (which, as a reminder, always tries to predict the most frequent class).

Table 3. *Classification results for anomaly detection (output of the LazyPredict library). Results are sorted by "balanced accuracy".*

Model	Accuracy	Balanced accuracy	F1 score
AdaBoostClassifier	0.93	0.96	0.94
XGBClassifier	0.93	0.96	0.94
DecisionTreeClassifier	0.93	0.96	0.94
ExtraTreesClassifier	0.93	0.96	0.94
GaussianNB	0.87	0.92	0.88
LabelPropagation	0.87	0.79	0.87
PassiveAggressiveClassifier	0.87	0.79	0.87
NearestCentroid	0.87	0.79	0.87
BaggingClassifier	0.87	0.79	0.87
LabelSpreading	0.87	0.79	0.87
Perceptron	0.87	0.79	0.87
RandomForestClassifier	0.87	0.79	0.87
BernoulliNB	0.87	0.79	0.87
LinearDiscriminantAnalysis	0.67	0.67	0.70
GOClassifier	0.80	0.62	0.78
RidgeClassifier	0.80	0.62	0.78
SVC	0.80	0.62	0.78
RidgeClassifierCV	0.80	0.62	0.78
LinearSVC	0.80	0.62	0.78
LogisticRegression	0.80	0.62	0.78
KNeighborsClassifier	0.80	0.62	0.78
ExtraTreeClassifier	0.80	0.62	0.78
CalibratedClassifierCV	a.89	0.62	0.78
DummyClassifier	0.73	0.58	0.73
QuadraticDiscriminantAnalysis	0.80	0.50	0.71
LGBMClassifier	0.80	0.50	0.71

Table 4. *Classification of both anomalies and engines (output of the LazyPredict library). Results are sorted by "balanced accuracy".*

Model	Accuracy	Balanced accuracy	F1 score
RidgeClassifier	0.73	0.84	0.75
PassiveAggressiveClassifier	0.73	0.84	0.75
ExtraTreesClassifier	0.73	0.84	0.75
LinearSVC	0.73	0.84	0.75
SOClassifier	0.67	0.77	0.66
RandomForestClassifiep	0.67	0.77	0.68
LabelPropagation	0.67	0.70	0.70
RidgeClassifierCV	0.67	0.70	0.67
LogisticRegression	0.67	0.70	0.70
LinearDiscriminantAnalysis	0.60	0.70	0.59
LabelSpreading	0.67	0.70	0.70
DecisionTreeClassifier	0.67	0.69	0.68
SVC	0.53	0.64	0.46
CalibratedClassifierCV	0.53	0.64	0.41
BaggingClassifier	0.60	0.63	0.61
NearestCentroid	0.60	0.63	0.63
Perceptron	0.53	0.56	0.57
XGBClassifier	0.53	0.51	0.53
GaussianNB	0.53	0.49	0.54
BernoulliNB	0.40	0.43	0.33
ExtraTreeClassifier	0.40	0.39	0.39
KNeighborsClassifier	0.33	0.36	0.31
AdaBoostClassifier	0.13	0.14	0.03
DummyClassifier	0.07	0.14	0.04
LGBMClassifier	0.13	0.14	0.03

Predict both the presence of an anomaly and the engine

In the results presented below, the machine learning algorithms aim to predict which engine a dataset belongs to, whether the engine in question had its spark plugs or not, whether it had an anomaly or not, and which anomaly it was. The different classes are summarized the Table 4.

The results should be considered preliminary due to the small amount of data (150 samples distributed in 9 classes) available per class, as we could see in the same experiment with t-SNE. In such scenarios, a bias in the data could strongly affect the results (positively or negatively).

First, we note the base value of the Dummy Classifier, which is very low given the large number of classes and the fair distribution of the data, as well as the relatively good performance of most of the algorithms. Despite the limitations of the dataset, the results seem to confirm that it is possible to establish a link between the data and the classes, which is quite promising and encourages further exploration.

Conclusion

This paper presents the use of data-driven approaches to visualize and classify the condition of historic engines. Combined with acoustic emission data, these techniques appear to be a viable solution for assessing the condition of an engine in a non-destructive manner. In fact, the chosen data analysis method allows us to classify the measurements in an objective, human-independent manner. However, data is key to the success of machine learning. The amount of data currently available is limited, with significant differences between datasets. A larger database should be created and used to improve the significance of the results and allow the exploration of other techniques. After the acquisition of additional data, the next steps will be the integration of a deep recurrent neural network for automatic thresholding of the signal and the study of an algorithm for multi-class anomaly detection solution.

REFERENCES

1. Ashton, J.; Hallam, D., 'The conservation of functional objects – An ethical dilemma', *AICCM Bulletin* **16**(3) (1990) 19-26, https://doi.org/10.1179/bac.1990.16.3.003.
2. Lemos, M.; Tissot, I., 'Reflections on the conservation challenges of scientific and technological objects', *Conservar Património* **33** (2020) 24-31, https://doi.org/10.14568/cp2018044.
3. Wain, A., 'The importance of movement and operation as preventive conservation strategies for heritage machinery', *Journal of the American Institute for Conservation* **56**(2) (2017) 81-95, https://doi.org/10.1080/01971360.2017.1326238.
4. Newey, H., 'Conservation and the preservation of scientific and industrial collections', *Studuies in Conservation* **45**(sup1) (2000) 137-139, https://doi.org/10.1179/sic.2000.45.Supplement-1.137.
5. Pye, E., 'Challenges of conservation: working objects', *Science Museum Group Journal* **6** (2016), https://dx.doi.org/10.15180/160608/001.
6. Scruby, C. B., 'An introduction to acoustic emission', *Journal of Physics E Scientific Instruments* **20**(8) (1987) 946-953, https//doi.org/10.1088/0022-3735/20/8/001.
7. Delvecchio, S.; Bonfiglio, P.; Pompoli, F., 'Vibro-acoustic condition monitoring of internal combustion engines: a critical review of existing techniques', *Mechanical Systems and Signal Processing* **99** (2018) 661-683, https://doi.org/10.1016/j.ymssp.2017.06.033.
8. Kaul, B. C.; Lawler, B.; Zahdeh, A., 'Engine diagnostics using acoustic emissions sensors', *SAE International Journal of Engines* **9**(2) (2016) 684-692, https://doi.org/10.4271/2016-01-0639.
9. Douglas, R. M.; Steel, J. A.; Reuben, R. L., 'A study of the tribological behaviour of piston ring/cylinder liner interaction in diesel engines using acoustic emission', *Tribology International* **39**(12) (2006) 1634-1642, https://doi.org/10.1016/j.triboint.2006.01.005.
10. Nivesrangsan, P.; Steel, J. A.; Reuben, R. L., 'Source location of acoustic emission in diesel engines', *Mechanical Systems and Signal Processing* **21**(2) (2007) 1103-1114, https://doi.org/10.1016/j.ymssp.2005.12.010.
11. Wu, J.-D.; Liu, C.-H., 'An expert system for fault diagnosis in internal combustion engines using wavelet packet transform and neural network', *Expert Systems with Applications* **36**(3) (2009) 4278-4286, https://doi.org/10.1016/j.eswa.2008.03.008.
12. Johansson, S.; Nilsson, P. H.; Ohlsson, R.; Rosén, B.-G., 'Experimental friction evaluation of cylinder liner/piston ring contact', *Wear* **271**(3-4) (2011) 625-633, https://doi.org/10.1016/j.wear.2010.08.028.

13. Wei, N.; Gu, J. X.; Gu, F.; Chen, Z.; Li, G.; Wang, T.; Ball, A. D., 'An Investigation into the acoustic emissions of internal combustion engines with modelling and wavelet package analysis for monitoring lubrication conditions', *Energies* **12**(4) (2019) 640-659, https://doi.org/10.3390/en12040640.
14. Łukomski, M.; Bratasz, Ł; Hagan, E.; Strojecki, M.; Laudato Beltran, V., 'Acoustic emission monitoring for cultural heritage', Getty Conservation Institute, Los Angeles (2020).
15. Thickett, D.; Cheung, C. S.; Liang, H.; Twydle, J.; Maev, R. G.; Gavrilov, D., 'Using non-invasive nondestructive techniques to monitor cultural heritage objects', *Insight - Non-destructive testing and Condition Monitoring* **59**(5) (2017) 230-234, https://doi.org/10.1784/insi.2017.59.5.230.
16. Le Conte, S.; Vaiedelich, S.; Thomas, J. H.; Muliava, V.; de Reyer, D.; Maurin, E., 'Acoustic emission to detect xylophagous insects in wooden musical instrument', *Journal of Cultural Heritage* **16**(3) (2015) 338-343, https://doi.org/10.1016/j.culher.2014.07.001.
17. Chalançon, B., *Les mesures d'émission acoustique appliquées aux moteurs d'automobiles de collection patrimoniale comme outil de diagnostic avant la remise en fonctionnement*, Master dissertation, Haute Ecole Arc Conservation-restauration (HES-SO), Neuchâtel (2019) https://doc.rero.ch/record/327368 (accessed 2023-03-30).
18. Roda Buch, A.; Cornet, E.; Rapp, G.; Chalançon, B.; Mischler, S.; Brambilla, L., 'Development of a diagnostic tool based on acoustic emission techniques', in *500 ans de tribologie*, Presses des Mines, Paris (2021) 147-152.
19. Roda Buch, A.; Cornet, E.; Rapp, G.; Chalançon, B.; Mischler, S.; Brambilla, L., 'Fault detection and diagnosis of historical vehicle engines using acoustic emission techniques', *Acta Imeko* **10**(1) (2021) 77-83, https://doi.org/10.21014/acta_imeko.v10i1.853.
20. Brambilla, L.; Chalançon, B.; Roda Buch, A.; Cornet, E.; Rapp, G.; Mischler, S., 'Acoustic emission techniques for the detection of simulated failures in historical vehicles engines', *The European Physical Journal Plus* **136**(6) (2021) 641, https://doi.org/10.1140/epjp/s13360-021-01611-9.
21. Chalançon, B.; Roda Buch, A.; Cornet, E.; Rapp, G.; Weisser, T.; Brambilla, L., 'Acoustic emission monitoring as a non-invasive tool to assist the conservator in the reactivation and maintenance of historical vehicle engines', *Studies in Conservation* (2023), https://doi.org/10.1080/00393630.2023.2183808.
22. Carrino, S.; Guerne, J.; Dreyer, J.; Ghorbel, H.; Schorderet, A.; Montavon, R., 'Machining quality prediction using acoustic sensors and machine learning', *Proceedings* **63**(1) (2020) 31, https://doi.org/10.3390/proceedings2020063031.
23. Li, Z.; Li, J.; Wang, Y.; Wang, K., 'A deep learning approach for anomaly detection based on SAE and LSTM in mechanical equipment', *The International Journal of Advanced Manufacturing Technology* **103** (2019) 499-510, https://doi.org/10.1007/s00170-019-03557-w.
24. Malhotra, P.; Vig, L.; Shroff, G.; Agarwal, P., 'Long short term memory networks for anomaly detection in time series', in *Proceedings of European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, ESANN*, i6doc.com publ., Bruges (2015) 89-94, https://www.esann.org/proceedings/2015 (accessed 2023-07-03).
25. Kim, D.; Antariksa, G.; Handayani, M. P.; Lee, S.; Lee, J., 'Explainable anomaly detection framework for maritime main engine sensor data', *Sensors* **21**(15) (2021) 5200, https://doi.org/10.3390/s21155200.
26. Kim, J-M.; Baik, J., 'Anomaly detection in sensor data', *Journal of Applied Reliability* **18**(1) (2018) 20-32, https://koreascience.kr/article/JAKO201815565837435.pdf (accessed 2023-07-03).
27. Gokhale, M. Y.; Khanduja, D. K., 'Time domain signal analysis using wavelet packet decomposition approach', *International Journal of Communications, Network and System Sciences* **3**(3) (2010) 321-329, https://doi.org/10.4236/ijcns.2010.33041.
28. Yu, Y.; Si, X.; Hu, C.; Zhang, J., 'A review of recurrent neural networks: LSTM cells and network architectures', *Neural computation* **31**(7) (2019) 1235-1270, https://doi.org/10.1162/neco_a_01199.
29. Shensa, M. J., 'The discrete wavelet transform: wedding the a trous and Mallat algorithms', *IEEE Transactions on Signal Processing* **40**(10) (1992) 2464-2482, https://doi.org/10.1109/78.157290.
30. Van der Maaten, L.; Hinton, G., 'Visualizing data using t-SNE', *Journal of Machine Learning Research* **9**(11) (2008) 2579-2605, https://www.jmlr.org/papers/volume9/vandermaaten08a/vandermaaten08a.pdf (accessed 2023-07-05).
31. 'Shankarpandala - lazypredict', in *Github*, https://github.com/shankarpandala/lazypredict (accessed 2023-07-03).

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Patrimônios (quase) esquecidos: cervejarias entre reusos, salvaguarda e abandono – os casos da Portugália em Lisboa e da Antarctica em Joinville, Brasil

Heritage (almost) forgotten: breweries between reuse, safeguard and abandonment – the cases of Portugália at Lisboa and Antarctica at Joinville, Brazil

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Resumo

O presente artigo propõe um estudo comparativo envolvendo duas cervejarias: a Portugália em Lisboa e a Antarctica em Joinville, Brasil. Desativadas e com seus prédios em estado de degradação, propomos uma análise dos diferentes planos de reuso e dos projetos de requalificação urbana que envolveriam esses dois exemplos de património industrial. Diferentes fontes foram consultadas: documentos oficiais, matérias jornalísticas, registros literários e uma bibliografia específica. Articulamos conceitos dos campos da arqueologia e património industrial, da arquitetura e urbanismo, da conservação e restauro, com a intenção de fundamentar questionamentos a respeito das circunstâncias que possam ter impedido tanto o reuso dos espaços, quanto a salvaguarda das antigas edificações e seus componentes industriais. Inicialmente abordamos o impacto da Revolução Industrial sobre a fabricação da cerveja e em seguida os planos de reuso de cada cervejaria, ressaltando os contextos e a maneira como em cada caso a política de preservação foi elaborada.

PALAVRAS-CHAVE
Patrimônio industrial
Requalificação urbana
Cervejaria
Reutilização
Musealização

Abstract

This article proposes a comparative study involving two breweries: Portugália in Lisbon and Antarctica in Joinville, Brazil. Deactivated and with their buildings in a state of degradation, we propose an analysis of the different reuse plans and urban regeneration projects that would involve these two examples of industrial heritage. The sources used are varied: official documents, journalistic articles, literary records and a specific bibliography. We articulate concepts from the fields of archaeology and industrial heritage, urbanism, conservation and reuse and restoration with the intention of substantiating questions and problems regarding the circumstances that may have prevented both these industrial spaces, as well as the adequate reuse and safeguard of old buildings and their industrial components. Initially, we address the impact of the Industrial Revolution on brewing and then the reuse plans of each brewery, highlighting the contexts and the way in which the preservation policy was developed in each case.

KEYWORDS
Industrial heritage
Urban requalification
Brewery
Reuse
Musealization

Introdução

O século XIX viu a produção cervejeira passar por grandes transformações, acompanhando os processos de industrialização e urbanização que marcaram muitas cidades, mas, apesar do relevante papel desempenhado durante a introdução da mecanização e modernização industrial, as cervejarias ainda não são devidamente reconhecidas como ícones do património industrial. E como indicado por Cossons, além de uma "tecnologia específica, a indústria cervejeira oferece ao arqueólogo industrial a oportunidade de examinar o funcionalismo no projeto e na construção de edifícios em sua forma mais pura" [1]. É de acordo com esse pensamento que propomos uma abordagem sobre a industrialização da produção de cervejas e, pontualmente, sobre as condições de salvaguarda e os planos de reutilização das cervejarias *Antarctica* e a *Portugália*.

Industrialização e ciência na produção cervejeira

A descrição de uma cervejaria no conto de Asher Barash [2] fornece indícios dos processos e das edificações que abrigavam fábricas de cerveja no final do século XIX, nos servindo de parâmetro para algumas colocações:

> *Na cervejaria em si, [...] três ruídos estão sendo produzidos: o barulho das grandes rodas de madeira girando; o barulho do fogo na fornalha que fica no fundo do prédio; e o barulho borbulhante da enorme cuba de cobre [...], que se estende sobre a fornalha, alcançada por uma escada de ferro fixada na lateral. Tanques de madeira [...] ficam sob um deck suspenso, é a "bacia de resfriamento". Alguns dos tonéis estão cheios de água com um brilho frio e sinistro; outros contêm uma mistura forte que borbulha e efervesce, com uma espuma flutuando na superfície. [...] Portas pesadas e cravejadas de ferro levam aos porões escuros [...]* [2].

Na parte superior da construção ficavam os moinhos para triturar os grãos de malte. Dali, o malte triturado desce para a cozinha onde era aquecido com água em chaleiras formando o mosto; nessa fase inicial de fermentação, o amido do malte é transformado em açúcar. Nos tonéis borbulhantes ocorre a separação dos componentes sólidos dos líquidos, tornando o mosto mais claro e refinado para receber o lúpulo aromatizante. Posteriormente, o mosto é filtrado e drenado em tanques de madeira para resfriamento seguindo, então, para os tanques de fermentação, onde as leveduras são inoculadas transformando os açúcares em álcool.

Antes das máquinas de gelo, após a fermentação as cervejas eram acondicionadas em barris e transferidas para adegas localizadas, geralmente, em "porões escuros" [2]. Mas, durante o século XIX esses métodos de produção artesanal da cerveja foram alterados por procedimentos mecânicos e industriais.

Segundo Hobsbawm, as cervejarias e moinhos representaram "gigantescos monumentos da modernidade" na medida em que aplicaram e ampliaram o uso de novos maquinismos, inclusive oferecendo demandas para novas invenções [3]. A máquina de tiragem de cerveja sob pressão e o uso do motor a vapor de *Boulton & Watt* na Cervejaria londrina Whitbread em 1785, são exemplos de inventos pioneiros aplicados em cervejarias [4].

Eventualmente os avanços tecnológicos sofriam resistência por parte dos cervejeiros tradicionais, como as bobinas a vapor usadas para substituir o fogo à lenha, que além de garantir estabilidade na produção, economizava combustível e mão de obra; porém, muitos cervejeiros declararam que isso comprometia o sabor final da bebida [5].

Outras invenções (ventiladores de secagem, tonéis de infusão, sistemas pneumáticos, melhoria na vedação de tampas, agitadores mecânicos), supriam as novas necessidades. Como as máquinas frigoríficas desenvolvidas por Carl von Linde [6], inicialmente para as cervejarias *Dreher* (Hungria) e *Heineken* (Holanda). Com maior durabilidade as bebidas poderiam alcançar mercados distantes. Até então, o resfriamento consistia em recolher gelos durante o inverno e armazená-los em porões [6]. No verão, as temperaturas eram nocivas ao processo de fermentação podendo alterar a qualidade da cerveja. Como as cervejas Porter toleravam mais o calor, seus produtores possuíam uma vantagem, mas a chegada dos dispositivos de refrigeração permitiu a produção de outros tipos de cerveja em qualquer estação.

Revolucionando os processos de fermentação, Louis Pasteur desvendou os agentes ativos nesses fenômenos. Contestou a teoria de que os gérmens de fermentação eram gerados espontaneamente e desenvolveu o método de pasteurização, aplicado na produção de bebidas lácteas e fermentadas, eliminando germes e prolongando a validade do produto [7].

Diferentes invenções foram divulgadas pela revista *Engineering* como, por exemplo, pás mecânicas em bandejas de trituração de malte, elevadores hidráulicos de barris, máquinas de lavar barris. Essas invenções buscavam realizar atividades em menos tempo e com o mínimo de trabalho manual [8-9]. Esse momento, entendido por Arnold Hauser como a "Idade da Máquina", marcou o surgimento de um "sistema de trabalho condicionado por métodos mecânicos", por uma "divisão de funções e uma produção adaptadas às necessidades de consumo de massas" [10]. Era o início de um processo de fabricação que culminaria com a linha de montagem do Ford T.

Um novo contexto social e urbano, em virtude do aumento da demanda, propiciou a fabricação de cerveja em escala industrial [11]. Assim, a emergência das cervejarias dentro de um quadro de produção industrial estava relacionada aos avanços tecnológicos e às diversas alterações urbanas decorrentes da industrialização.

Em Lisboa, a construção de cervejarias parece ter acompanhado o crescimento da população (que passou de 187 mil habitantes, em 1878, para 301 mil, em 1890), e as alterações urbanas, como abertura de novas ruas e instalação da eletricidade que se expandiu da iluminação pública para o transporte, indústrias e moradias [12]. Até 1850 havia apenas a *Cerveja Trindade*, mas, após 1880, eram seis fábricas. Em 1855 surge a *Cerveja Jansen*; em 1865 a *Cervejaria Leão D'ouro*; depois, a fábrica *Cerveja Leão* (1878), a *Peninsular* (década de 1890) e a *Germânia* (1913) que assume o nome *Portugália* em 1916, património alvo deste estudo [13].

Algo parecido aconteceu no Brasil. A cervejaria *Antarctica* de São Paulo (1888) e a *Brahma* (1894) no Rio de Janeiro foram criadas a partir da ampliação e modernização de pequenas fabriquetas. Mas, para atingir o padrão industrial foi necessário investimentos tecnológicos, técnicos competentes (ambas tiveram entre seus fundadores imigrantes alemães), e recursos urbanos disponíveis, como ferrovias, energia elétrica, consumidores e mão-de-obra operária [14]. E na cidade de Joinville, de colonização fortemente alemã, a produção artesanal de cerveja era comum durante o século XIX, sendo a fabriqueta do imigrante Alfred Tiede uma das primeiras a industrializar sua produção. Em funcionamento até 1998, seu processo de patrimonialização e seus planos de reuso e salvaguarda são analisados aqui em comparação com o caso da *Cervejaria Portugália*.

Cervejaria Antarctica de Joinville e os paradoxos da preservação

O cervejeiro Tiede esteve entre os milhares de imigrantes que, entre 1851 e 1890, aportaram no sul do Brasil para viver na Colônia Dona Francisca (atual Joinville), fundada em 1851. Produzida artesanalmente, as primeiras propagandas da sua cerveja apareceram no jornal local em 1889. Após a disponibilização de garrafas aos editores, seguiram as declarações: "[...] apresenta gosto forte, é clara e encorpada como nós, consumidores, desejamos. Está acima das melhores cervejas aqui criadas e pode colocá-las em segundo lugar" [15]. Outro registro, de 1901, destacou a influência da tradição germânica na produção local:

> *Onde quer que os alemães morem no exterior, também se bebe cerveja alemã, por isso, seu consumo é grande na Colônia Dona Francisca. Três cervejarias foram erguidas em Joinville, a dos Irmãos Kühne, os Irmão Berner e a de Alfred Tiede. Ali são fabricadas cervejas de alta fermentação, tem que se acostumar com o sabor, mas é leve e de grande pureza.* [16]

Figura 1. Rótulos de cervejas (década de 1920): *a)* Cerveja de Kuhne & Cia; *b)* Berner Irmãos; *c)* Alfred Tiede & Cia (Arquivo Histórico de Joinville – Livro de Rótulos, Typographia Otto Boehm).

Rótulos da década de 1920 revelam a permanência dessas cervejarias anos depois desse registro (Figura 1). A cerveja de Tiede chegou a ser premiada em exposições estaduais e nacionais, e com a associação de 1925 a *Cervejaria Catharinense de Tiede, Seyboth & Cia* inaugurou sua primeira construção fabril.

Passando por ampliações, em 1935 foi construída outra casa de máquinas e em 1939 inaugurou-se uma nova cozinha. Após a II Guerra Mundial a *Companhia Antarctica Paulista* comprou a *Cervejaria Catharinense*. Assumindo o nome *Cervejaria Antarctica* manteve sua produção até 1998.

Após seu fechamento, permaneceram na fábrica maquinários, arquivos administrativos, ferramentas e mobílias. E no ano de 2001 o poder público comprou o complexo (fábrica e outros galpões), para usos culturais e artísticos batizando o espaço de *Cidadela Cultural Antarctica*. A partir daí, tiveram início os problemas com a preservação da edificação principal da fábrica.

Para a ocupação da área fabril cogitou-se: a criação do Museu da Cerveja; a criação do Museu de Arte Contemporânea; e a disponibilização dos galpões e prédios administrativos para associações culturais. Apenas a última perspectiva se consolidou, com a instalação de associações e setores da prefeitura municipal nessas áreas.

O projeto inicial apresentava o Museu da Cerveja como uma "exposição real do maquinário" abordando sua história e seu "processo de produção" [17]. Mas, dos planos do Museu, que foi alvo de outro estudo relacionado à arqueologia industrial, sobraram apenas as plantas do projeto [18].

De acordo com as plantas desejava-se manter áreas expositivas da fábrica em conjunto com o Museu de Arte Contemporânea (MAC), confrontando diferentes expectativas de uso: exposição industrial e sede de acervo artístico. Enquanto o Museu da Cerveja almejava um museu *in situ*; o MAC desejava uso exclusivo do espaço, importava instalar-se na fábrica, porém, sem interesse na manutenção do maquinário em seu interior. O prédio serviria como mera casca abrigando atividades ou eventos artísticos, em detrimento dos componentes industriais; entretanto, o acervo industrial é o ponto relevante para entendimento do processo industrial, pois remete às técnicas e processos de produção de uma determinada época, como destacado na Carta de Nizhny Tagil:

> *[..] o património industrial apresenta um valor científico e tecnológico, para além de [..] um valor estético [...].*
> *Estes valores são intrínsecos aos próprios sítios industriais, às suas estruturas, aos seus elementos constitutivos, à sua maquinaria, à sua paisagem industrial, à sua documentação e também aos registos intangíveis contidos na memória dos homens e das suas tradições.* [19]

Como os projetos dos museus não se efetivaram, foram desprezados a conservação da edificação, da memória e do acervo industrial ligado à cervejaria. Nem um inventário dos objetos e máquinas presentes na fábrica foi realizado, sendo difícil mensurar o que se perdeu nessas últimas décadas.

A *31ª Coletiva de Artistas de Joinville* (2001) foi a primeira ocupação artística da cervejaria. Promovida anualmente pelo Museu de Arte de Joinville (MAJ), a *31ª Coletiva*, empregou o conceito de apropriação da cervejaria. As criações deveriam dialogar com o espaço fabril e para confeção das obras e intervenções os artistas exploraram seus ambientes (Figura 2). O curador relatou as dificuldades desse processo, já que se tratava de "um espaço com particularidades arquitetônicas e densa memória para a cidade. Não é um espaço neutro, mostra-se repleto de contaminações visuais a cada porta que abrimos" [20]. Diferentes estratos do tempo marcariam às instalações, embaralhando passado e presente, enquanto a memória da cidade e da fábrica eram acessadas por sentimentos criados a partir da fusão entre concepção artística e reapropriação do espaço industrial.

Imagens captadas durante o evento revelaram no interior da fábrica, ferramentas, mobílias, iluminação e espaços higienizados; embora, denunciassem a ausência de mecanismos de preservação para com o acervo industrial. Esta articulação entre expressão artística e espaço industrial é válida. O *Museo Centrale Montemartini* em Roma, que combinou peças arqueológicas e maquinário de uma termoelétrica desativada; e a área expositiva do BRASS em Bruxelas, na casa de máquinas da *Cervejaria Wielemans*, são exemplos dessa "convivência". Mas, no caso da Cervejaria em Joinville os custos de manutenção e a indefinição sobre qual órgão público assumiria as despesas impediu o desenvolvimento dessa fusão [21].

A obra *Permanência do espaço/tempo* de Alberto Franzoi apropriou-se de livros administrativos do arquivo da Cervejaria questionando a "vontade de preservar dados, a precariedade e a insignificância do que realmente permanece" [22]. Abandonados em seu interior, os livros foram perfurados com pregos e espalhados sobre o chão e paredes, num cômodo da fábrica; com os livros pisoteados a historicidade do arquivo serviria de passagem para o público. Expunha o desprezo dos órgãos públicos em relação àquele acervo declarando que "o património da cidade estava abandonado" [22]. Criticado pela instalação, Franzoi indagou: "por que é que os responsáveis pelo património não providenciaram a retirada dos documentos, antes?" [23]. Soando por duas décadas, além de problematizar a falha das políticas de preservação em relação àquela documentação, as palavras e a obra foram fatídicas.

Em 2021 um incêndio atingiu o arquivo da antiga cervejaria (Figura 3). Com pisos e estantes de madeira, um farto acervo (documentos administrativos, registros de trabalhadores, revistas e livros técnicos, projetos arquitetônicos, cartões, fotografias, cartazes propagandísticos) foi incinerado.

Figura 2. *31ª Coletiva de Artistas : a)* Esculturas na esteira de engarrafamento remete a produção em série de bebês, 2001; *b)* instalação *Permanência do espaço/tempo*, 2001 (Arquivo Museu de Arte de Joinville, pasta "31ª Coletiva de Artistas").

Figura 3. Arquivo da cervejaria: *a)* durante mutirão de organização, em 2008 (Fundação Cultural de Joinville) [17, 24]; *b)* após incêndio em 2021.

A Carta Manifesto (2003) do Comitê pela Preservação do Património Industrial no Brasil relatava a incompreensão de órgãos preservacionistas, que "subestimam o património industrial, considerando-o pouco relevante no conjunto a ser preservado"; e de "proprietários", que "encaram esses espaços fabris apenas como fonte de recursos" [25]. No caso da cervejaria, os antigos proprietários renunciaram ao seu acervo documental [23].

Paradoxalmente, foi a preocupação com essa documentação e a necessidade de se estabelecer normas para reuso da cervejaria que motivou a Coordenação do Património Cultural (CPC - setor responsável pela abertura de processos de tombamento), a propor o Tombamento da Cidadela Cultural Antarctica em 2006, a partir do Parecer nº. 30-2006.

Entre 2001 e 2006 outras áreas do complexo foram ocupadas, enquanto a área fabril permanecia ociosa. Mas, em 2006, o MAC recebeu "permissão de uso" desta área, iniciando estudos para sua instalação. Como a abertura do processo de tombamento ocorreu meses depois da concessão, poderia ser uma tentativa de limitar intervenções arquitetônicas inadequadas que o MAC demandava.

Apesar de, geralmente, não ser considerada, a "adaptação de um sítio industrial a uma nova utilização como forma de se assegurar a sua conservação" [19], desde que se respeite "o material específico e os esquemas originais de circulação e de produção", é uma recomendação da Carta de Nizhny Tagil [19].

Consequentemente, o Parecer nº 30-2006 para a abertura do processo de Tombamento do complexo, propôs normatizar reusos e definir áreas para demolição, alterações ou nenhuma alteração arquitetônica. Apresentou, também, a relevância histórica e o valor do bem para a comunidade, destacando o vínculo entre a cervejaria e os habitantes da cidade como "importante referencial urbano", em razão da sua localização no "corredor de acesso principal à cidade" [17]. Apontaram a superioridade da cerveja produzida na cervejaria, "considerada por muitos anos a melhor cerveja do país devido, principalmente, à excelência de sua água, proveniente de fonte própria", e sua importância para a economia da cidade [17]. Relatos do cervejeiro Curt Zastrow que atuou na fábrica, mostraram que o antigo maquinário limitava a quantidade de produção e exigia procedimentos diferentes de outras filiais mais modernas, alterando o sabor da cerveja local [26].

Como valor arquitetônico apontaram: as "coberturas de tesouras de madeira", de "tipo shed" e "de água simples"; "paredes autoportantes"; "pilares de madeira"; e "vigas de concreto armado" [17]. As coberturas tipo "shed" foram adaptações arquitetônicas desenvolvidas para incorporar a "iluminação natural [...] obtida através de janelas" e fizeram parte de um movimento arquitetônico estético e funcional que pleiteavam a "organização do espaço interno" e a busca por "menores custos" na produção [27].

O Parecer nº. 30-2006 estipulou três níveis de preservação (Figura 4), prevendo que as intervenções "atuem reabilitando e animando os espaços para usos atuais da Cidadela", sendo elas:

> *Preservação Integral (vermelho): preserva características arquitetônicas internas e externas do imóvel.*
> *Preservação Estrutural (azul): preserva características arquitetônicas externas do imóvel.*
> *Preservação cautelar (amarelo): proteção/integração do entorno: reconstituição, adequação e renovação.* [17]

De acordo com a Figura 4, a manutenção da volumetria da fábrica (áreas em azul) e a *preservação integral* da chaminé e cozinha da cervejaria (em vermelho), viabilizaria a reabilitação do prédio, unindo possíveis alterações com a preservação da arquitetura industrial. A chaminé símbolo da paisagem industrial era ostentada comumente em rótulos de cervejarias, como na Figura 5. Há, entretanto, um contraste com a situação precária da chaminé atualmente.

Figura 4. Apresenta os níveis de preservação do complexo. Em laranja o perímetro do setor fabril. Fundação Cultural de Joinville [17].

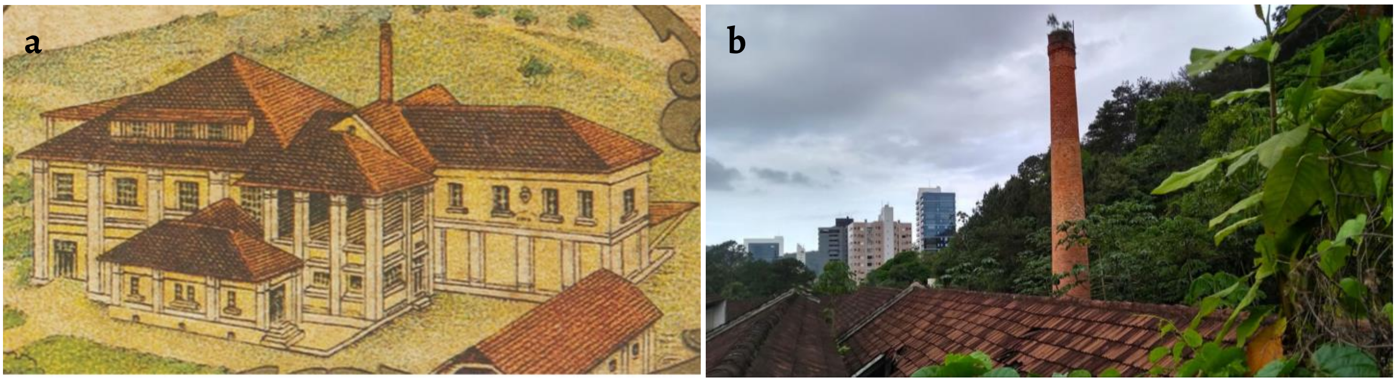

Figura 5. Chaminé da cervejaria: *a)* Detalhe do rótulo da *Cervejaria Catharinense* (década de 1920). Arquivo Histórico de Joinville - Livro de Rótulos, Typographia Otto Boehm. *b)* Fotografia 2020.

Figura 6. Cervejaria ao longo do tempo: a) em 2001 [28]; *b)* em 2021.

Deve-se considerar, na reabilitação de edifícios industriais, a conservação de componentes, como: "elementos estruturais e singulares"; "materiais e sistemas construtivos", "manutenção do espaço industrial" e a "imagem global da construção" [29]. Sobre projetos de reuso, a Carta de Veneza indica que a "conservação dos monumentos é sempre facilitada pela sua utilização para fins sociais. Esta utilização, embora desejável, não deve alterar a disposição ou a decoração dos edifícios [...]" [30].

Somou-se à falta de verbas e equipas para manutenção do espaço, a queda em 2008 de parte do moro localizado nos fundos da cervejaria, forçando sua interdição, que permanece até o momento sem nenhuma proposta de restauro. Na medida em que o tempo passou, a degradação e abandono se acentuou, agravando a queda de estruturas do telhado e a dispersão vegetal no interior da fábrica, como demonstra a Figura 6. Em 2013 o MAC retomou a ideia de implementação do museu, mas o orçamento de 30 milhões de reais para as obras de restauro do prédio impediu sua consolidação [31].

Infelizmente, mesmo com a conclusão do tombamento em 2010, não foi executado, até o momento, nenhum plano de intervenção no prédio da cervejaria e nem para a concretização de seu reuso. Movimentos civis tentaram chamar a atenção para a degradação da antiga cervejaria, através dos *Ocupes* (em 2014 e 2016), mas não obtiveram resultados. Desse modo, a fábrica com sua cobertura danificada, maquinários, laboratórios, adegas e um arquivo transformado em cinzas, jaz na negligência da gestão municipal.

Vemos que a falta de um plano de conservação preventiva da edificação gerou perdas significativas. Destarte, os estudos no campo de património devem dirigir-se para a fiscalização e cobrança de cumprimento da legislação preservacionista formando grupos para orientar e participar das articulações sobre: o destino e seleção de acervos industriais; a concepção de exposições e cartilhas educativas elucidando o valor desses elementos. Essas seriam tentativas de evitar o apagamento do passado industrial, como expressou Rix "estamos tão alheios à nossa herança que, além de algumas peças de museu, a maioria desses marcos são negligenciados ou destruídos" [32].

A Fábrica de Cerveja Portugália e os dilemas de reuso

Talvez, as palavras do escritor Mário de Carvalho "[...] é um privilégio viver nesta cidade [...] cheia de ressonâncias. Em cada esquina encontra-se qualquer coisa que vem de trás, que evoca outras coisas" [33], expliquem porque o projeto de requalificação urbana destinado à área da antiga Portugália foi tão contestado.

"Em Arroios ninguém quer uma torre na Portugália", anunciava uma manchete sobre requalificações no quarteirão daquela cervejaria [34]. Reportagens de 2005 já abordavam os planos de demolição da área, que visavam a desobstrução, quase, total do terreno, poupando apenas a *Cervejaria Portugália* [35].

A história da Portugália remete à *Fábrica de Cerveja Leão*, criada em 1878 na Rua dos Arroios. Com a fusão entre a *Leão* e a *Companhia Portuguesa de Cerveja*, em 1912, construiu-se a fábrica para abrigar a *Sociedade Portuguesa Germânia* no quarteirão da Avenida Almirante Reis (Figura 7 e Figura 8).

Figura 7. Projeto Arquitetônico (1912), casa de máquinas, frigorífico, escritório, fachada para Avenida Almirante Reis. Arquivo Municipal de Lisboa - Obra 2476 - Proc 1874-DAG-PG-1912 - Folha 3.

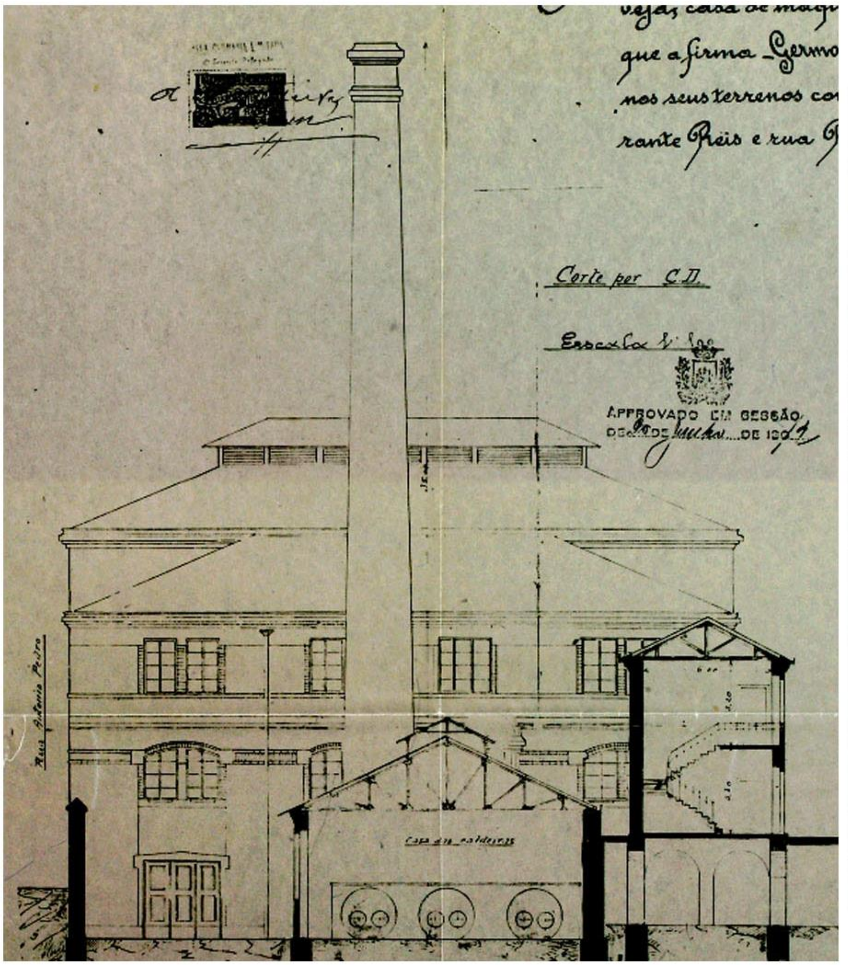

Figura 8. Projeto Arquitetônico (1912), fachada lateral Rua Pascoal de Melo. Arquivo Municipal de Lisboa - Obra 2476 - Proc 2642-DAG-PG-1912 - Folha 4.

Segundo a revista *A Construção Moderna* a edificação foi criada utilizando os "mais modernos e melhores processos de construção", com ornamentos artísticos pintados a óleo, cantarias de qualidade e azulejo decorativo [36]. A edificação unia fundamentos da arquitetura tradicional (azulejos, cantarias), com elementos e técnicas construtivas modernas baseadas no ferro, cimento e vidro.

Em razão do sentimento antigermânico alimentado durante a 1ª Guerra Mundial, em 1916 alterou-se o nome para *Fábrica de Cerveja Portugália*. Assumindo o nome *Companhia Productora de Malte e Cerveja Portugália*, na década de 1920, a fábrica foi ampliada ganhando edifícios para a produção do malte e para a produção de garrafas. E visando atender os clientes que abasteciam seus barris diretamente na fábrica, foi aberto um espaço para degustação anexo à fábrica, nascia assim a *Cervejaria Portugália*.

Nos anos de 1930 a Sociedade Central de Cervejas uniu as cervejarias *Portugália*, *Jansen*, *Estrela* e *Cerveja Coimbra*. E na década de 1950 novas estruturas foram construídas no quarteirão da Portugália, alterando parte das antigas edificações (Figura 9). De arquitetura modernista, os novos prédios abrigaram a malteria e os salões da nova cervejaria, incluindo terraço para projeções cinematográficas, que estiveram em funcionamento até a década de 1990, quando a produção foi transferida para filial em Vialonga.

Décadas depois, o extenso conjunto arquitetônico, já ocioso, ganharia novas perspectivas de requalificação e reconversão. Mas os dilemas de reabilitar antigas construções e requalificar seus entornos, oportunizando empreendimentos e preservação de bens patrimoniais, podem se mostrar controversos. Do ponto de vista preservacionista, as demolições das áreas fabris do quarteirão da Portugália são problemáticas, pois não contemplaram estudos em que a reutilização das antigas estruturas fosse considerada (Figura 10).

Instrumento capaz de criar nova dinâmica urbana, a requalificação urbana procura reorganizar o espaço público incentivando novos empreendimentos com apoio e, em partes, para benefício da iniciativa privada, uma vez que por trás de interesses públicos (como construção de novas vias, embelezamento de áreas, arborização, construção de praças, etc.), existem nessas ações, objetivos de valorização monetária dessas regiões [37].

Sabemos que os inconvenientes, no que diz respeito a preservação industrial, são as "demolições impensadas", as descaracterizações desses complexos. Há, também, o apagamento de memórias operárias ou a pasteurização dos elementos e práticas fabris em projetos museais que fazem com que os reusos desses espaços sejam "discutíveis" [38].

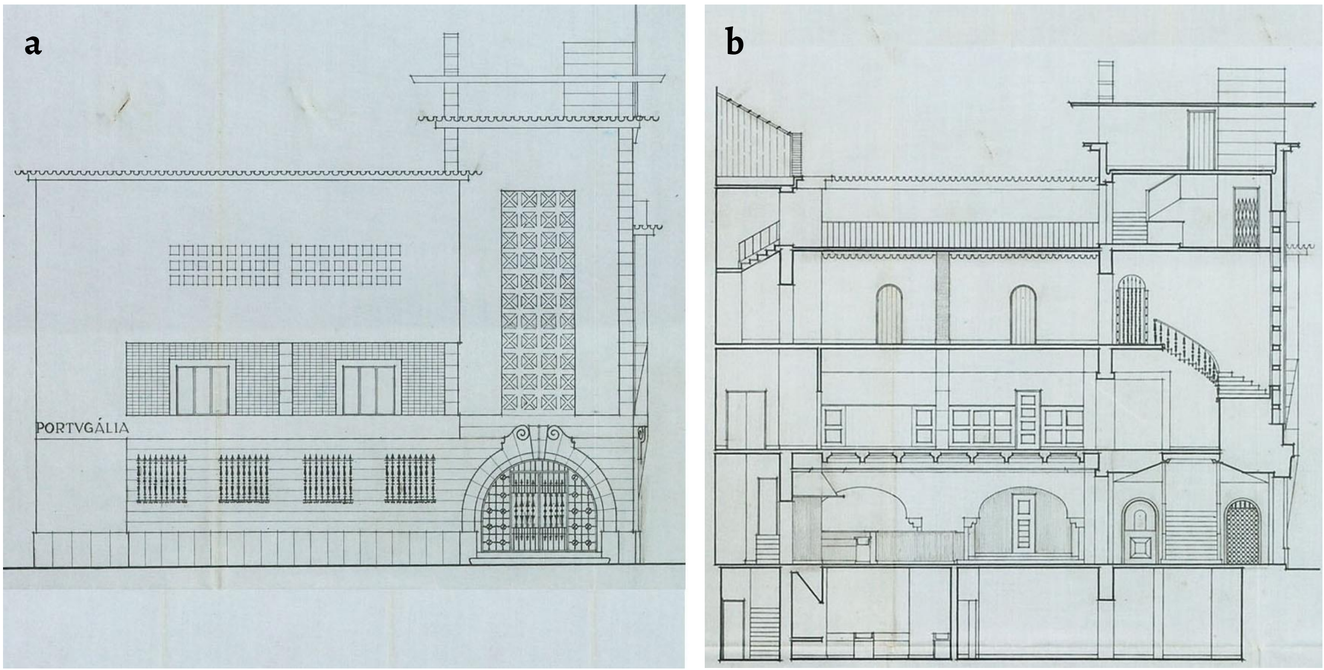

Figura 9. Projeto Arquitetônico (1947), cervejaria, bilhar, terraço: *a)* Fachada Av. Almirante Reis; *b)* áreas internas e subsolo. Arquivo Municipal de Lisboa - Obra 2476 - Proc 13960-DAG-PG-1950 - Folha 4 e Folha 13.

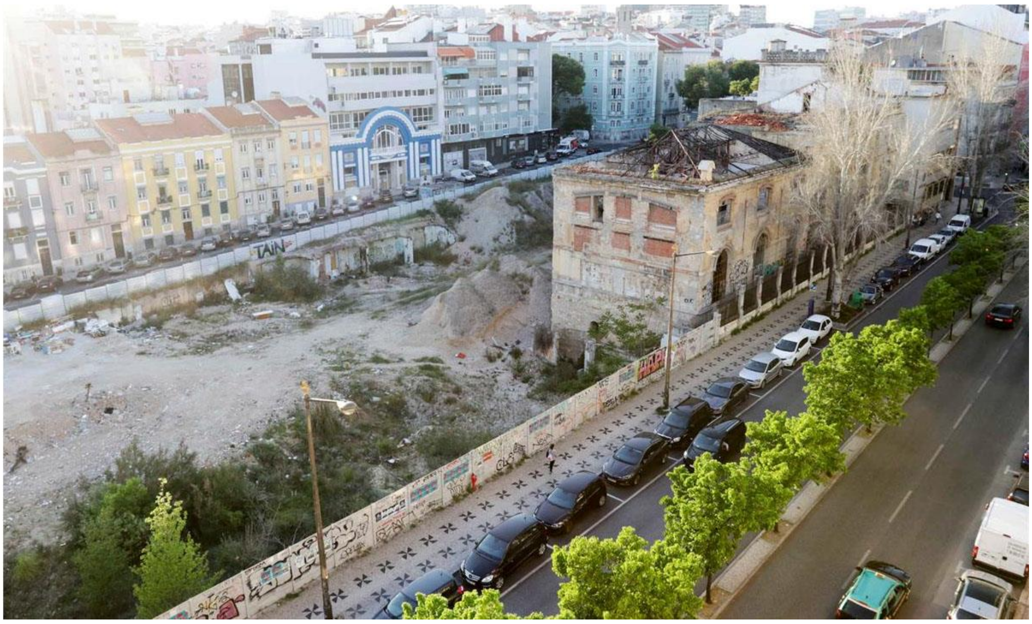

Figura 10. Área do quarteirão em 2019, com as ruínas da fábrica e cervejaria [34].

Segundo a jornalista Inês Boaventura [39], o projeto de requalificação para o quarteirão previa a demolição de "[…] escritórios, adegas e áreas de fabrico" devido às formas obsoletas das estruturas e as dificuldades de "adaptação […] às novas funcionalidades" [39]. As reconversões arquitetônicas, que compreendem a conservação volumétrica da edificação, além de custos maiores, podem significar restrição de funcionalidade e fruição do projeto em voga – problemas solucionados com os terrenos baldios.

A previsão de construção da torre de 16 andares (60 metros) denominada de Portugália Plaza, acendeu o debate que colocou a comunidade local contra o projeto. As perspectivas de desconfiguração e interferência na paisagem, o aumento do fluxo de veículos, a obstrução da claridade solar e a descaracterização arquitetônica da região foram argumentos de oposição. Em contrapartida, os defensores da obra justificavam o uso público das áreas (alamedas e praças) como espaços de "descompressão" das vias urbanas [34].

Além da preservação do património cultural e a memória industrial da cidade, estava em jogo a transformação da área central de Lisboa e a imposição do interesse privado sobre o público. Ocasionalmente, os planos de requalificação urbana são travestidos de melhorias sociais e de vantajosa reabilitação do espaço público, enquanto os interesses privados delineiam o processo de especulação imobiliária. Foi, justamente, por isso que a palavra *gentrification* passou a ser usada para nomear o processo de enobrecimento de uma área, principalmente, quando o interesse econômico de exploração lucrativa suplanta outras iniciativas.

Ao mesmo tempo, os processos de ressignificação de espaços públicos expõem as redes de sentidos acionados na comunidade que está inserida, conforme o impacto que os reusos e práticas sociais assumem nas propostas de revitalização. Se por um lado, o conteúdo simbólico é incorporado nos processos de gentrificação para subverter usos tradicionais e definir novas fronteiras espaciais entre áreas, ele é responsável, também, por correntes que resistem ao enobrecimento. Foi o caso do movimento *Stop Torre 60m Portugália*, uma organização popular que contestou o projeto de reuso do quarteirão.

Em reuniões com o poder público e representantes do empreendimento, o movimento questionou o projeto, forçando o diálogo e a possibilidade de alterações no projeto inicial, como a diminuição de andares e o realinhamento (recuos) dos acessos referentes às distâncias das ruas [40]. O movimento questionou também: o crédito aprovado, em 2013, pelo governo municipal ao empreendimento através do Sistema de Incentivos a Operações Urbanísticas com Interesse Municipal (RSIOUIM); o precedente aberto para a região da "Almirante Reis, constituindo um verdadeiro 'erro histórico'" com "omissões grosseiras na análise"; os "comportamentos facilistas" por parte da CML para aplicação deste projeto; e a "falta de espaço público e de espaços verdes, [...], o excesso de ruído, as dificuldades ao nível da higiene urbana, a falta de equipamentos culturais, a inexistência de ciclovias, os problemas de índole social" [41].

A atuação do *Stop Torre 60m Portugália*, vem ao encontro das teorias expressas no livro *O direito à cidade* de Henri Lefebvre. Escrito em 1968, apontava o impacto dos movimentos de contestação daquele período buscando romper com "estratégias urbanas" ligadas às ideologias dominantes. Lefebvre sugeriu o papel do urbanismo como ferramenta de transformação e interferência na vida urbana [41]. E o movimento *Stop 60*, reivindicando o espaço público no "coração da cidade" revive essas expectativas, se apropriando de "locais de encontro e de trocas", propondo "a realização da vida urbana como reino de uso" e promovendo estratégias para reclamar demandas da cidade [42].

Como expresso na manchete "Moradores ganham batalha contra torre de 60 metros na Portugália" (23 jul. 2023), a interferência do movimento levou ao então, Vereador do Urbanismo Ricardo Veludo, a destacar a importância do debate na elaboração de projetos de requalificação [43]. O projeto da Portugália chegou a ser indeferido pela Câmara Municipal de Lisboa (CML), mas em 2021, novo projeto foi aprovado [44].

O caso do *quarteirão* ganhou a imprensa fomentando a opinião pública sobre a preservação do património e a necessidade da participação coletiva nas decisões que envolvem as reabilitações. Entretanto, as demolições ocorridas no início dos anos 2000 não receberam a mesma atenção. Supressões de edificações, incluindo a chaminé e o abandono das edificações ainda existentes (fábrica e cervejaria), são frustrações diante do que almejam as políticas de preservação referentes ao património industrial. Com o projeto de reuso ainda não concretizado; talvez, as demolições pudessem ter sido evitadas se outras propostas de reuso fossem consideradas inicialmente.

Embora a CML afirme que a fábrica e a cervejaria serão restaurados e integrados aos reusos do quarteirão, o projeto não concebeu a musealização dos espaços. Segundo a CML, "a fábrica albergará espaços de restauração no piso térreo" e nos pisos superiores às salas de escritórios. Uma passagem formada por "um volume em vidro e cobre procurando afirmar pela sua linguagem contemporânea a oposição com as pré existenciais" ligará os dois edifícios [45].

Organismo em constante transformação, como remete Le Corbusier "a cidade é um redemoinho, você tem que classificar suas impressões, reconhecer suas sensações e selecionar métodos curativos e benéficos"; e certamente as requalificações urbanas e as possibilidades de reuso de espaços industriais são oportunidades de aplicar "métodos curativo e benéficos" no tecido da cidade, como possibilidade de reabilitar áreas degradadas [46]. Contudo, não raro, a memória industrial, resquícios fabris e tecnológicos são esvaziados de seus sentidos com prédios demolidos e acervos descartados, como aconteceu com os fornos Hoffmann e a fábrica de papel de Tomar [47]. Por isso, a necessidade de exercitar a percepção da cidade, de sua fisionomia e construções como rastros da trajetória humana, marcos de diferentes temporalidades. Assim poderemos alargar as perspectivas de compreensão da formação do património urbano e industrial, sua salvaguarda e transformação, em oposição aos interesses voltados apenas para a conveniência econômica.

Conclusões

Os casos investigados demonstram os conflitos envolvidos nas políticas de salvaguarda, de diferentes modos: por interesses privados voltados para empreendimentos lucrativos como o caso do "quarteirão da Portugália", sublimado pelo discurso de reuso e a valorização de áreas urbanas a partir desses planos; pela apatia da gestão pública permitindo demolições sumárias; ou, como no caso da Cervejaria Antarctica, por omissão enquanto agente responsável pela conservação e salvaguarda do bem.

Dentro das perspectivas de preservação de patrimónios industriais — seus acervos, edificações e sua história — consideramos que a musealização é uma solução oportuna para a preservação, ainda mais quando a fábrica desativada dispõe de seus maquinários. Joinville teve oportunidade de musealizar sua fábrica de cerveja ainda com seus acervos, mas, foi o projeto de abandono e degradação das estruturas quem triunfou. O incêndio de 2021 impossibilitou qualquer expectativa de estudo da documentação fabril, perdida para sempre. Por isso a necessidade de se inventariar, recolher, estudar e proceder a projetos de valorização que contemplem programas de reutilização envolvendo interesses e comunidades locais.

Em relação às edificações da Fábrica e Cervejaria Portugália, quase em ruínas, manifestações artísticas que adornam sua fachada e partes internas (esculturas e azulejarias) também sofrem com a degradação material, necessitando de intervenções urgentemente. O restauro desses edifícios, mantendo sua volumetria e, se possível, sua originalidade é uma alternativa positiva, como preservação arquitetônica e da paisagem; entretanto, enquanto património industrial permanece uma lacuna. É sobre essa lacuna que as visões preservacionistas habituais devem rever seus posicionamentos. E suprimi-la envolve assumir uma postura que desmistifique a noção de património industrial, percebendo-o como uma categoria de conhecimento que atravessa diversas as ações humanas, da criação das primeiras ferramentas de pedra aos avanços da inteligência artificial.

REFERÊNCIAS

1. Cossons, N., *The BP book of industrial archaeology*, David & Charles, London (1975).
2. Barash, A., *Pictures from a brewery; a novel*, Bobbs-Merrill Company, Indianopolis (1971).
3. Hobsbawm, E. J., *Da revolução industrial ao Imperialismo*, Forense Universitária, Rio de Janeiro (2000).
4. Whitbread's Brewery, *Founded 1742, House of Whitbread*, London (s.d.), https://www.gla.ac.uk/media/Media_399719_smxx.pdf (acesso em 2023-06-26).
5. Western Brewer Journal, *One Hundred Years of Brewing*, Rich & Co, Chicago (1903).
6. Linde, *125 Years of Linde*, LeadIng., Munich (2005), https://www.linde-healthcare.nl/nl/images/chronicle_e%5B1%5D14_9855_tcm170-233340.pdf (acesso em 2023-06-26).
7. Santos, J. M. dos, *A vida e a obra de Louis Pasteur*, Imprensa da Universidade de Coimbra, Coimbra (1923).
8. 'Cask raising machine at messrs allsopp's brewery, Burton on Trent', *Engineering January 01-June 25* **7** (1869) 29, https://archive.org/details/sim_engineering_january-01-june-25-1869_7/page/28/mode/1up?q=brewery (acesso em 2022-12-13).
9. 'Continuous cask-washing machine at messrs. Truman's brewery', *Engineering January 01-June 25* **7** (1869) 90 https://archive.org/details/sim_engineering_january-01-june-25-1869_7/page/28/mode/1up?q=brewery (acesso em 2022-12-13).
10. Hauser, A., *História Social da Arte e da Literatura*, Martins Fontes, São Paulo (2003).
11. Slater, J. N., *A brewer's tale: the story of Greenall Whitley & Company limited through two centuries*, City Press Services, Warrington (1980).
12. França, J. A., *Lisboa: Urbanismo e arquitectura*, Livraria Bertrand, Amadora (1980).
13. 'A nossa história', in *Central Cervejas*, https://www.centralcervejas.pt/pt/sobre-nos/a-nossa-historia/ (acesso em 2022-12-13).
14. Sousa, D. R. de, *Cidade e cerveja: Companhia Antarctica Paulista e urbanização em São Paulo*, Dissertação de mestrado, Departamento de Arquitetura e Urbanismo, Pontifícia Universidade Católica, Campinas (2017), https://repositorio.sis.puc-campinas.edu.br/handle/123456789/16435?show=full (acesso em 2022-12-13).
15. 'Alfred Tiede Bier', in *Reform*, Joinville (1889-01-09).
16. Gernhard, R., *Dona Francisca, Hansa und Blumenau, drei deutsche mustersiedelungen im südbrasilischen staate Santa Catharina*, B. S. Schottlaender, Leipsig (1901), https://archive.org/details/donafranciscaha00gerngoog/page/n7/mode/1up?q=brauerei (acesso em 2022-12-13).
17. Fundação Cultural de Joinville, 'Processo de Tombamento Municipal - Rua XV de Novembro, nº 1383', FCJ.CPC.2006-001, 2010.
18. Moraes, T. C., 'Reconversão e arqueologia industrial', *Arqueologia Industrial* **3**(1-2) (2021) 80-121.
19. 'Carta de Nizhny Tagil sobre o património industrial', in *TICCIH Brasil* (2003), https://ticcihbrasil.org.br/?page_id=675 (acesso em 2023-01-10).
20. Moreira, J. M., '31º coletiva de artistas de Joinville', in Catálogo de exposição, Museu de Arte de Joinville, Joinville, 2001.
21. Moraes, T. C., *Património industrial em Joinville: sobre políticas de preservação e requalificação (1998-2020)*, Dissertação de Mestrado, Departamento de História, Universidade do Estado de Santa Catarina, Florianópolis (2020), https://www.udesc.br/arquivos/faed/id_cpmenu/5062/Tiago_Castano_Moraes___Final_16139966734317_5062.pdf (acesso em 2022-12-15).
22. Age, M. P. J., *José Rufino: arqueologia e memória*, Dissertação de mestrado, Departamento de Artes Visuais, Centro de Artes, Universidade do Estado de Santa Catarina, Florianópolis (2015), http://tede.udesc.br/bitstream/tede/799/1/124461.pdf (acesso em 2023-1-10).
23. 'Marcas do tempo', in *A Notícia*, Joinville (2001-11-20).
24. 'Documentos da cervejaria antarctica estão desde 2001 na cidadela aguardando análises do arquivo municipal', in *A Notícia*, Joinville (2008-11-27).
25. 'Carta Manifesto', in *TICCIH Brasil* (2003), https://ticcihbrasil.com.br/cartas/carta-manifesto-2003/ (acesso em 2023-1-5).

26. ‘Onde era feita a melhor’, in *A Notícia*, Joinville (2009-03-01).
27. Folgado, D., *A nova ordem industrial: da fábrica ao território de Lisboa: 1933- 1968*, Dissertação de doutoramento, Departamento de História, Universidade de Lisboa, Lisboa (2010), http://hdl.handle.net/10451/2238 (acesso em 2023-1-5).
28. ‘Complexo começa a tomar forma’, in *A Notícia*, Joinville (2001-12-15).
29. Alvarez-Areces, M., ‘Patrimonio industrial: un futuro para el pasado desde la visión europea’, *Apuntes* **21**(1) (2008) 6-25.
30. ‘Carta de Veneza', in *II Congresso Internacional de Arquitetos e Técnicos de Monumentos Históricos*, ICOMOS, Veneza (1964). https://www.culturanorte.gov.pt/wp-content/uploads/2020/07/1964-carta_de_veneza-ii_congresso_internacional_de_arquitetos_e_tecnicos_de_monumentos_historicos_icomos.pdf?x69634 (acesso em 2023-1-5).
31. ‘Museu de Arte Contemporânea espera construção da sede oficial em Joinville’, in *A Notícia*, Joinville, 21 out. 2013, https://gauchazh.clicrbs.com.br/geral/noticia/2013/10/museu-de-arte-contemporanea-espera-construcao-da-sede-oficial-em-joinville-4305399.html (acesso em 2023-1-10).
32. Palmer, M.; Neaverson, P., *Industrial archaeology: principles and practice*, Routledge, London (1998).
33. Carvalho, M. de, ‘Entrevista. Os bairros dão identidade única a Lisboa’, *Lisboa* **26** (2019) 40-43, https://issuu.com/camara_municipal_lisboa/docs/revista_lisboa_26 (acesso em 2023-1-10).
34. Rodrigues, R. J., ‘Em Arroios ninguém quer uma torre na Portugália’, in *Diário de Notícias* (2019), https://www.dn.pt/cidades/em-arroios-ninguem-quer-uma-torre-na-portugalia-10926026.html (acesso em 2023-1-10).
35. ‘Portugália vende fábrica à A. Silva & Silva’, in *Casasapo* (2005), https://casa.sapo.pt/Noticias/Portugalia-vende-fabrica-a-A.-Silva-Silva/?ID=24 (acesso em 2023-1-10).
36. Silva Junior, A. R. da, ‘Edifício da fábrica de cerveja “Portugália Ltda”’, *A Construção Moderna*, Lisboa **18** (1916), http://ric.slhi.pt/A_Construcao_Moderna/visualizador?id=11214.017.018&pag=1 (acesso em 2022-12-18).
37. Peixoto, P., ‘Requalificação urbana’, in *Plural de cidade: novos léxicos urbanos*, eds. C. Fortuna, R. P. Leite, Almedina, Coimbra (2009) 41-52.
38. Silva, A. F. da; Rodrigues, W. do N., ‘As ruínas do futuro e o novo património industrial. Entrevista Cristina Meneguello’, *Revista Contexto* **4** (2013) 249-255, https://www.academia.edu/37327384/As_Ru%C3%ADnas_do_Futuro_e_o_Novo_Patrim%C3%B4nio_Industrial_Entrevista_com_Cristina_Meneguello (acesso em 2022-11-23).
39. Boaventura, I., ‘Portugália vai ser integrada em projecto imobiliário’, in *Público* (2009), https://www.publico.pt/2009/06/01/jornal/portugalia-vai-ser-integrada-em-projecto--imobiliario-308476 (acesso em 2023-1-3).
40. Lança, F., ‘Manuel Salgado defende que a torre da Portugália "é um bom projeto"’, in *Jornal de Negócios* (2019), https://www.jornaldenegocios.pt/economia/detalhe/manuel-salgado-portugalia-e-um-bom-projeto (acesso em 2022-11-23).
41. ‘Movimento Stop Torre 60m Portugália’, in *Participação no processo de debate público do Movimento Stop Torre 60m Portugália* (2019), https://www.am-lisboa.pt/documentos/1562682363V0oKE6dk6Iy16HB7.pdf (acesso em 2022-12-01).
42. Lefebvre, H., *O direito à cidade*, 5° ed., Centauro, São Paulo (2008), https://monoskop.org/images/f/fc/Lefebvre_Henri_O_direito_a_cidade.pdf (acesso em 2022-12-01).
43. ‘Moradores ganham batalha contra torre de 60 metros na Portugália’, in *Sapo* (2020), https://visao.sapo.pt/imobiliario/2020-07-23-moradores-ganham-batalha-contra-torre-de-60-metros-na-portugalia/?utm_source=copy_paste (acesso em 2022-12-01).
44. Francisco, S., ‘Projeto da Portugália aprovado. Esquerda votou contra’, in *Diário de notícias* (2021), https://www.dn.pt/local/projeto-da-portugalia-aprovado-esquerda-votou-contra-13574195.html (acesso em 2022-12-01).
45. Guerreiro, J. L. S., ‘Licenciamento de obras de edificação - Apreciação técnica’, *Departamento de licenciamento de Projetos Estruturantes*, Câmara Municipal de Lisboa, Lisboa (2019), https://www.lisboa.pt/fileadmin/cidade_temas/urbanismo/gestao_urbanistica/licenciamentos/pro_destacados/lic_pro_312_EDI_2019/proc312EDI2019_par_7590INFDMURB_DepLPEGESTURBE2019.pdf (acesso em 2022-12-01).
46. Le Corbusier, *La Ciudad del Futuro*, Ediciones Infinito, Buenos Aires (1985), https://archive.org/details/le-corbusier.-la-ciudad-del-futuro-ocr-1985/page/n3/mode/2up (acesso em 2022-12-01).
47. Santos, M. L., ‘Entrevista concedida à Telma Bessa Sales’, in *Conversando sobre Património Industrial e outras histórias: palavras, espaços e imagens*, eds. A. C. Matos, T. B. Sales e R. A. Rodrigues, Edições UVA, Évora (2018) 107-122, http://dspace.uevora.pt/rdpc/bitstream/10174/24425/1/ebook%20conversando%20sobre%20patrimonio%20industrial.pdf (acesso em 2022-12-01).

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CONSERVAR PATRIMÓNIO

Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
ARTICLE / ARTIGO

“Rare and vital”: positive terminology, contemporary relevance and robust teaching options for heritage maker trades

“Raro e vital”: terminologia positiva, relevância contemporânea e opções de ensino sólidas para os ofícios criadores de património

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Abstract

Manual trades from the past are often referred to negatively as “lost”, “dying” or “forgotten”, driving perceptions that such skills are unimportant in the present and future. Such trades, however, remain vital in some industries, promote wellbeing and social empowerment and are important for meeting United Nations Sustainable Development Goals (SDGs). This paper puts forward constructive and positive alternative terminology for these skills, including “rare”, “vital”, “heritage” and “maker trades”. The second section engages with issues in teaching these skills effectively. This includes educational and economic contexts, student and teacher expectations and issues such as accreditation and certification. The third section of this paper discusses practical solutions for teaching these skills in contemporary educational settings. Options include embracing work integrated learning (WIL) paths within broader tertiary courses, targeting mid-career learners, and splitting skill acquisition into base maker skills and specific industry skills for more distributed teaching opportunities.

KEYWORDS
Trades
Makers
Heritage
Skill
Training
Conservation

Resumo

As profissões manuais do passado são muitas vezes referidas negativamente como “perdidas”, “moribundas” ou “esquecidas”, levando a pensar que não são importantes no presente e futuro. Estas profissões continuam a ser vitais em algumas indústrias, promovem o bem-estar e a capacitação social, e cumprem os Objetivos de Desenvolvimento Sustentável (Nações Unidas). Propomos uma terminologia alternativa construtiva e positiva para estas competências, incluindo os termos “raras”, “vitais”, “patrimoniais” e “ofícios criadores”. Abordamos questões relacionadas com o ensino destas competências. Incluindo contextos educativos e económicos, expectativas dos alunos e dos professores e questões como a acreditação e certificação. Finalmente, discutimos soluções práticas destas competências para o ensino atual. As opções incluem: a adoção de percursos de aprendizagem integrada no trabalho com cursos de formação mais amplos, visando estudantes a meio de carreira; e garantir oportunidades de ensino mais distribuídas, separando a aquisição de competências em competências básicas do criador e competências específicas da indústria.

PALAVRAS-CHAVE
Ofícios
Criadores
Património
Competência
Formação
Conservação

Introduction

Trades and manual skills with a long history – and little contemporary uptake – are often labelled as “lost trades” or “dying arts” [1-4]. These negative terms contribute to perceptions that these skills are no longer relevant in either the contemporary world or the future, devaluing them in the eyes of education institutions, government agencies, companies, students, employers, and society at large. This means that there is a significant risk that such skills will not be transferred to future generations. This paper argues that the continuation of heritage skills and traditional trades is vital, both for heritage and practical reasons. The paper focuses on the trades represented in our research, with an emphasis on making and repairing physical things in the worlds of construction, artisanal production and manufacturing. Our arguments, however, apply more generally, encompassing other rare trades, skills and maker practices.

Firstly, we propose the development of more positive terminology for such skills, including the use of terms such as “rare”, “vital”, “heritage” and “maker trades”. Secondly, we identify practical and aspirational issues that affect the teaching of heritage maker trades, and look for ways to increase participation and satisfaction for teachers and learners. Thirdly, we discuss structures for economically viable teaching of such skills, including through work integrated learning (WIL) paths within broader tertiary courses. Ultimately, this paper aims to open a wider conversation about how we might identify and teach rare and vital maker trades and how we can find a robust place for them within education systems.

This paper draws together interdisciplinary knowledge from the three authors’ backgrounds in heritage preservation, Australian manufacturing and design, and heritage skills training. First author Alison Wain specialises in the preservation of large heritage machinery, engaging with tradespeople who have the knowledge to maintain such machinery and keep it operational, thus preserving both the tangible and intangible aspects of machinery heritage [5]. Second author Jesse Adams Stein is a design researcher who has spent the past 12 years undertaking empirical research into manufacturing tradespeoples’ experiences [6-7]. Third author Mitch Cleghorn is a built and cultural heritage professional who has prepared and delivered short courses in heritage maker trades, working with Applied Building Conservation Training (the training division of building restoration company HSR (SA)), and on the development of the Certificate III in Heritage Trade Skills accredited by the Australian Skills Quality Authority (ASQA) [8].

As well as drawing on our previous research, we have undertaken targeted interviews and focus groups with tradespeople and heritage workers (details of interviewees and projects are provided in the acknowledgements and references). While our analysis draws principally from Australian examples, we have looked towards international programs to identify alternative models.

Developing positive terminology

Previously we suggested the use of terms such as “rare”, “vital”, “heritage” and “maker trades” to describe the skills and trades that we are discussing in this paper, as we believe that the terminology used to describe them is critically important. Here we further explore these terms to provide a definitional framework for this discussion.

Maker trades

In the Australian context, a “trade” usually relates to a qualification: tradespeople train through formal employer-based apprenticeships, which typically feature shorter periods of theory training alongside workplace experience. We need, though, to also define skillsets beyond formalised apprenticeships, as “trades” have often been gendered as masculine pursuits, with "feminine" arts and crafts historically regarded as less skilled or deserving less remuneration [9]. We therefore use the additional term "maker" to include capacities developed through less formal and/or self-taught pathways, which nonetheless result in highly honed skillsets. We also acknowledge that the term "skill", which has a long and contested history in a number of academic disciplines (for example [10-13] among many others), is both a socially constructed phenomenon and a measurable, practical set of human abilities.

A defining aspect of "maker trades" is that they are not based on the use of automated tooling and digital diagnostics. Automated tooling, which facilitates bulk processing, tends to eliminate difference and devalue judgement. Maker trades may involve the use of powered tools, but their use is mediated by human capacities for care, understanding and specificity, using judgement to design solutions that accommodate difference in materials, needs and preferences. In this context we include industrial manufacturing skillsets, where they are based on a human understanding of materials and their behaviour [7, 14].

The affordances identified above bring us to our other positive terms for maker trades: "heritage", "rare" and "vital". These words are positive descriptors that provide context and add value, as described below.

Heritage

Historical maker trades have relevance for the preservation of tangible heritage, such as buildings and objects, as well as themselves being important bodies of intangible heritage [15]. Artisans and heritage-focused tradespeople have a profound understanding of materials and techniques that embodies a significant body of practical and cultural knowledge. As Grace Barrand [16] points out: "A master chairmaker doesn't just work with wood, but has a library of knowledge about dozens of tree species, growth patterns, shrinkage characteristics, colour, density, grain and so on".

Rare

Heritage maker trades were not rare during their "heyday", and they are not qualitatively distinct just because they are rare now. The word rare is useful in our context because it connotes something that is unusual, special and of value, rather than something that is obsolete and dying. As Stein found in her empirical research into the steelmaking and textiles industries, manufacturing in Australia is in a situation where rare skills – such as engineering patternmaking, moulding, or garment patternmaking – are still prized and in demand by employers [7].

Vital

Maker trades are vital resources for the present and future. The "one size fits all" approach of automated practices does not provide an adequate response when things do not go to plan. Rather than just a basic applied understanding of their own discrete area, skilled tradespeople and experienced makers have in-depth production knowledge across a broad range of industrial and craft processes, and are able to anticipate issues before they occur, solve problems, and create practical, manual solutions when technologies break down or produce poor results. Their understanding of layers of complexity provides skill bases that are resources for adapting to change in uncertain times [17].

Maker trades are especially vital where monetary, educational and physical resources are minimal and the infrastructure to support highly automated systems is not available. For example, such trades have particular use in areas disrupted by natural disasters or conflict, in remote regions, in regions with less economic and technological development, and for use by individuals or small businesses. These skills are therefore vital for meeting the United Nations Sustainable Development Goals (SDGs), in particular Goal 9 to "promote inclusive and sustainable industrialization and foster innovation" and Goal 12 to "Ensure sustainable consumption and production patterns" [18].

Understanding issues, imagining possibilities

Course duration and structure

In the previous section, we identified the affordances of rare and vital heritage maker trades – the reasons we should preserve them. Preservation, however, requires new generations of people to learn and practice these trades and unfortunately, there are few opportunities to do this. In this section, we examine issues affecting rare trades teaching and identify factors that can improve success rates in this space.

A twentieth century trade apprenticeship in Australia took approximately four years, combining trade school attendance with work placement at a company or government department. A 2010 report on heritage trades teaching undertaken for the Heritage Chairs and Officials of Australia and New Zealand (the HCOANZ Report) concluded that this format is pedagogically beneficial but relatively costly and inflexible. Shorter courses were considered more accessible and achievable, but were not seen to provide enough skills for a student to become “fully qualified” [19].

Our research suggests that while a person’s initial apprenticeship provided good foundational skills in a particular area, tradespeople commonly added to this with “post-trade” training, enabling them to curate personal skillsets, take on more challenging work, achieve promotion, and improve self-esteem [20]. Full-time apprenticeships were geared towards young people with minimal commitments outside their studies, while short courses and night school accommodated mature workers with existing commitments.

More recently in the heritage sector in Australia, however, this tradition of adding skills through short and flexibly taught courses seems to have been forgotten, replaced by an assumption that all “proper” courses in heritage trades should follow the traditional “first trade” format of full-time training over three-four years [19]. However, the tertiary education market has changed enormously in recent decades and there are now large numbers of mature students wanting to study, including those interested in rare and vital skills. Some want to build on existing skillsets, some want a career change, some are returning to work after having children, and some just want the skills to undertake the general maintenance, repair and re-use work that is increasingly being recognised as vital to a sustainable society (see for example M. Andrew [21]).

Our research also suggests that a diverse repertoire of niche skills is relevant for an experienced professional who already has established personal and business interests. It is perhaps less relevant for a young person who is just starting their professional journey. Stonemason Richard Senior [22], for example, noted that: “Your mature person… takes an interest in the heritage skills, it’s something that grows on you over time. A 25 year old guy just out of his apprenticeship – and I’ve been there – just wants to make the money, buy the car, buy the house, and make the dollars”.

To take advantage of current demographic shifts in the age and gender of students, the teaching of rare and vital trades should be pitched at both younger and mature student cohorts, and should provide the flexibility that mature students need. This opens up the question of what length of time and depth of engagement would provide a student with a useful level of skill, while also allowing flexibility.

Joeri Januarius runs a Belgian program (*Beurzen voor het doorgeven van vakmanschap in een meester-leerlingtraject*, meaning grants for the transmission of craftsmanship in a master-apprentice model) that provides funding for individual masters and students to work together to transfer rare skills and knowledge. Masters and students collaboratively negotiate their training schedules, with most settling on one or two days a week over 18 months [23].

Senior, working in the Australian context, observed that only one day per fortnight would be too low, but that a full time intensive could be valuable:

> *[To] get your hands dirty so to speak, something more fulltime than just sort of one day a fortnight, would [be necessary] … because by the time you've shown somebody how to do one small task, a week or two later they probably need refreshing … I'd lean to more of the full engagement … Now, if that was a short, sharp two or three weeks, maybe that would work full time.* [22]

The private Longford Academy in Tasmania, Australia, runs week-long courses aimed at broadening the skillsets of people working in building conservation, such as architects and heritage officers. Asked whether these people could develop a useful practical skillset from attending these shorter courses, Senior responded:

> *They'd certainly have a very good understanding of the materials and the principles involved … [although] the actual physical trade skills … take years to perfect. But in the heritage field, you're not looking for somebody to plaster hundreds of square metres of a wall, you're doing repairs. It would give them a good start*. [22]

Januarius felt that the two-year grants provided by the Belgian program provided "a certain basis, but you still need to work on your skills, because … you're not a master yet" [23]. In the Australian context, however, Neil Hogg [24] worried that opportunities for emerging practitioners to continue their development were limited as "the range and scope and number of jobs that they're working on is much reduced … they're not getting those really complex jobs that challenge people".

Opportunity and accessibility

Trades teaching needs to be broader than just trade-specific skills, as students' intentions can range from developing a personally satisfying creative practice to making a living wage from their work. Emerging tradespeople wanting to work in the heritage industry need to understand the governance processes required for compliance with heritage standards, which in Australia includes knowledge of the *Australia ICOMOS Burra Charter* [25], *Conservation Management Plans* [26], *Significance 2.0* [27] and other risk management and health and safety regulations.

In Australia, though, there is relatively little work available in the heritage space [19] and museums and other heritage organisations usually have very limited funding. In a successful business, therefore, Jenny Edmonds noted that rare trade work is usually combined with other work to provide a living wage [28]. Jenny Fawbert noted that the Conservatoire National des Véhicules Anciens program in France [29] had found that integrating the teaching of heritage skills with modern technologies such as CAD, CAM and 3D printing can attract new generations to develop new processes [30], thus melding the affordances of human judgement and automated reproduction and providing the capacity to take on both heritage and modern projects. Achieving this melding of old and new, however, is likely to require the combination of a variety of teachers and teaching frameworks.

There is evidence that students are more likely to continue their involvement with a trade if they feel they are part of a shared, accepting community [31], but finding one's place in an established community of practice can be challenging. Stephanie Moore, who trained as a heritage steamfitter commented that "As a younger person who has entered the heritage industry, there tends to be like an old guard, and they keep the knowledge and they hold on to it." [30]. She noted that when people could share their skills and experiences in supportive environments the reluctance to cross social boundaries was significantly reduced, citing the impact of a community motorcycle workshop in Sydney where people could use the facilities to work on their bikes or have work done, and where there was also a café. These facilities meant that there's vintage stuff and new stuff in there all the time, so there is quite a mix of people kind of floating through [32].

Environments that encourage mixing between people from different trades have particular potential for creating overarching communities of practice, especially where there are too few practitioners in a trade (or region) to maintain a robust community in a single specialisation, and when many practitioners are of retirement age. One option is to bring people from different trades together: for example an event to which all the masters and students from the Belgian program were invited, regardless of their specialist trade, enabled shared experiences to come to light across trade backgrounds.

The challenges of passing on skills

For students to learn there need to be masters who are willing to teach, and it is important to understand the incentives and barriers to teaching in this space. Both our Australian and Belgian participants said that while money was an enabler, the real incentive for masters to teach was their desire to see their trade continue, and they were often disappointed if a student chose not to pursue the trade they had taught them. Neirinckx [33], however, found that requiring students to make a post-training commitment to the trade was a disincentive, even when masters “are willing to transfer their entire knowledge and equipment to an apprentice who is willing to continue the business”. Part of this reluctance is students’ fears of being trapped in a trade with a limited future, which is a particular problem for trades that are so niche that they are generally supported by heritage institutions, with little opportunity for acquiring other clients [33]. This reflects the earlier point that, to support a robust business, heritage trades need to be innovatively integrated with more commercial practices.

It is important for both students and teachers to recognise the differences in expectations of people who are “dipping their toes” into a trade, versus those who know that they want to study that trade in depth. For masters, this can affect not only how they teach, but whether they are prepared to teach at all. Cleghorn and Barrand [34] and Neirinckx and Januarius [23, 33] had all experienced masters who were not interested in teaching the rudiments of their trade to beginners, or teaching people who only had a passing interest, but who felt that the complexity of what they wanted to teach required students with significant existing knowledge, as well as the passion to take that to a higher skill level. Modern regulatory requirements can also be frustrating for masters who have a lifetime of experience. Cleghorn and Barrand describe the case of a master who had previously taught through the Australian TAFE (Technical and Further Education) vocational system, and sought to return to part-time teaching after retirement. He found, however, that new regulations required him to undertake six months of training to renew qualifications at his own expense, which was a significant disincentive to his participation in teaching [34].

Time and flexibility are other important factors. Hogg [24] commented that even retiree volunteers often do not have the availability to teach a student full-time, and Jennifer Edmonds [28] noted that teaching could severely impact productivity in a professional workplace. Both Edmonds and Senior [22, 28] commented on the advantage of being able to draw on a network of teachers to manage demand for placements, and to match different expectations, personalities and workplaces.

Accreditation and certification

Another issue that impacts the teaching of rare trades is certification and/or accreditation. The precise definition of these terms varies, but certification is generally the process of providing written assurance “that a person, product, or process conforms to specified requirements and standards” and accreditation is generally “an attestation by a third party that an agency has demonstrated competence” [35].

In Australia, trades require the completion of standardised certificates, a process regulated and managed by TAFE or its regional equivalent. While this works for more common trades, it does not suit rare trades where the pool of qualified assessors can be very small. In Australia, distances between major centres also mean that assessors can be unavailable in remote areas.

The TAFE system also does not allow for variations within the teaching of "skill families". For example, steam trades qualifications are still available, but the skills taught, assessed and certified do not include much knowledge that is critical to the safe running and maintenance of heritage steam engines. The development and implementation in Australia of the Certificate III in Heritage Trade Skills is of particular value here, as it supplies a traditionally certified course that actually is focused on skills required for heritage work.

In the United Kingdom the Trailblazer Apprenticeship system was developed to ensure teaching aligns with industry [36]. Under this system, vocational courses are no longer designed by a centrally administered education body, but by groups of a minimum of 10 employers who collaboratively develop a proposal for an apprenticeship, followed by standards and an assessment plan. This provides the opportunity to develop and deliver certified courses that are focused on the skills required for rare trades, and to run them when and where they are needed.

Hogg [24] notes that in Australia there is a proposal currently under discussion to allow approved heritage bodies to become Registered Training Organisations (RTOs), so that they can develop, implement and assess training in the area of operating heritage machinery. Hogg has concerns, however, about the ability of a largely volunteer sector to be able to manage the administrative requirements of such self-regulation, and to provide the number and quality of teachers that will be required, on an ongoing basis [28].

An alternative to certification is accreditation. In the Australian heritage context, accreditation is commonly used by peak bodies to attest to the competency of individuals in professions where training and experience can vary widely between individuals, and where the provision of formal qualifications is not the only way to assess a practitioner's skill. For example, the Australian Institute for the Conservation of Cultural Material (AICCM) has a Professional Member category, and the Australian Archaeological Association provides an Australian Archaeology Skills "Passport" for professionals deemed to be competent practitioners. Again, however, the extensive administration required by these systems is undertaken by existing members on a voluntary basis, which can cause problems for consistency and efficiency.

Developing robust teaching structures

Teaching organisations need their courses to be economically viable, which means they must attract enough student enrolments to cover their costs and, often, make at least a small profit. As discussed earlier, the relatively small number of people interested in learning rare trades often falls below "viability". It is therefore necessary to think creatively about how existing opportunities might be woven into flexible, composite structures that provide certainty, flexibility and appropriate levels of skill for industry purposes. The following sections analyse different training options for rare trades teaching, with a focus on opportunities in the Australian context.

Short course teaching

The HCOANZ report noted that a range of short courses are run on an ad hoc basis by a variety of organisations, including heritage agencies, peak bodies, training organisations, amenity societies and private commercial providers. Respondents to a survey undertaken as part of the HCOANZ report listed short courses as one of the two most popular modes for training (Section 4.1) with the other being "on-the-job" training [19]. The HCOANZ report noted that short courses could be:

> *…highly flexible, organised quickly to reflect new needs, delivered in more than one location, and often delivered economically … However, there are also obstacles … including the cost*

> *and drain on resources of individuals involved … challenges in logistics and publicity, limited national coordination and a lack of any framework for assessment …*

Short courses are excellent for filling gaps, addressing short term needs, and assembling personal skillsets for niche businesses, and they are relatively low risk commitments for both providers and participants. Their principal drawback from a teaching point of view is that they tend to only cover specific aspects of the overall skillset required to train a rare trade practitioner. Nonetheless, short courses have the potential to fit well into a flexible professional accreditation framework.

TAFE courses

Formal vocational courses in Australia are run by TAFE (or in the Australian Capital Territory the Canberra Institute of Technology [CIT]), and are centrally driven by government mandate, according to industry demand. Small volume specialist TAFE courses are therefore vulnerable to centralised cuts because of perceived low demand.

One possible solution is that a first-year unit providing, for example, general maker skills, might be successfully run by TAFE, feeding students with basic skills into more advanced units in a number of heritage trade "families". There is precedent for this, as the first years of apprenticeships in Australia are often generic. Currently, however, most TAFE introductory (Certificate I-III) training packages are focused on being safe and helpful around the workplace, not on developing good manual skills.

One disadvantage of the TAFE model is the length of the commitment required for a full apprenticeship, which does not provide much flexibility for students. Conversely an advantage of the TAFE model is the reliance on work placements, which ensures that students begin real-world involvement with industry early in their studies.

University courses

Universities are free to teach what they want, and are keen to differentiate from each other, which provides some advantages. As with TAFE, however, their need to make a significant profit means that low-enrolment courses and subjects are vulnerable, unless packaged as electives within broader degrees. Also like TAFE apprenticeships, degrees take a significant amount of time to complete, which is a disincentive for students given the impact of the current cost-of-living crisis on the financial challenges of studying.

One advantage of the university model, however, is flexibility, and therefore capacity to offer the opportunity to incorporate choice for individual students, as well as adapt to industry needs. Wain, first author on this paper, who teaches at the University of Canberra (UC), sees potential opportunities for using existing university teaching structures creatively to accommodate rare trades teaching. Fundamental heritage concepts and materials conservation, for example, are already taught in heritage focused degrees, while in Australia existing work integrated learning (WIL) units can provide a structure for students to undertake practical placements with businesses (or masters) of their choice. In Australia universities also usually provide the option for students to take – with the approval of their course convenor – elective units chosen from either courses and faculties within their own university, units from other universities (through a university wide cross-institutional study arrangement), or units from overseas universities (through student overseas study programs). The university need not, therefore, specifically commit to providing rare trades training, but instead create pathways for students to undertake their chosen rare trade specialisation within an existing, broader degree structure.

Conclusion

Heritage practices in manufacturing, construction, artisanal craft and engineering maintenance remain alive and important. Consigning them to the paradigmatic dustbin of "lost" and "dying" is a defeatist position that will both discourage people from wanting to learn them, and discourage educational institutions and industry bodies from providing training in these areas.

We therefore advocate for positive terminology that highlights the benefits of continuing to pass on heritage skills and trades to new generations. Core to our proposal is the notion that such skills are "rare" and "vital" and remain relevant, being founded on material making, manual skill and production knowledge. Heritage building trades are still required for the repair and reconstruction of heritage sites and monuments, while high level understandings of materials and process in trades such as garment patternmaking and engineering patternmaking are sought after for precision and innovation in contemporary manufacturing. There are also other benefits that relate to increasing concerns about human and environmental wellbeing: there are demonstrated social and psychological benefits to being trained in a manual skill.

The second section of this paper examined in detail how we might develop more robust teaching structures for viably transferring such skills in the future, managing the tension between shaping course content with heritage preservation in mind versus the need to deliver content that will be seen to be relevant to contemporary issues, for example in repair, maintenance and disaster recovery. Heritage skills and trades can be separated into skill structures and hierarchies for more efficient teaching: for example from more general and basic understandings of safety, materials, machinery and tools, towards more specific skill areas pertinent to a particular trade or practice. In order to plan such forms of training well, it is important to take into account the ambitions and expectations of not only students, but also the "masters" who want to pass on their skills. Issues of expectations, access, certification and accreditation must be considered in the context of existing education systems, with an awareness that much of the existing training in rare heritage skills currently happens informally.

The third section of this paper identified practical and robust teaching structures that could make such skills training possible in the future. There are avenues for rare skills training to be taken through flexible, composite structures that include combinations of short courses, vocational (TAFE) and university environments, to build skillsets and manual capacities over time, in an economically viable manner.

Above all, a realistic understanding of the financial limitations of the Australian educational landscape means that courses need to be economically viable, and to demonstrate relevance to contemporary needs and developments. These relevancies must include not only past expectations of skill outcomes, but also the potential for positive impacts on current concerns, such as the mitigation of materials shortages, waste minimisation, right to repair, skills shortages, wellbeing and lifelong learning, disaster recovery and the fulfilment of Sustainable Development Goals.

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REFERENCES

1. Romensky, L., 'Hard, dirty foundry work copes with digital disruption and lack of apprenticeship courses', in *ABC News* (2018), https://www.abc.net.au/news/2018-09-30/hard-dirty-foundry-work-coping-with-digital-disruption/10303254 (accessed 2023-07-30).
2. Harvey, H., 'The dying art of the blacksmith living on in Stratford', in *Taranaki Daily News* (2019), https://www.stuff.co.nz/taranaki-daily-news/news/115493689/the-dying-art-of-the-blacksmith-living-on-in-stratford (accessed 2023-07-30).
3. 'Forgotten Trades: selected records of early Australian trades', in *Australian National University Archives Library*, https://archives.anu.edu.au/exhibitions/forgotten-trades-selected-records-early-australian-trades (accessed 2023-07-30).
4. Gonzales, D., 'Lost Trade', in *Apple Podcasts* (2023), https://podcasts.apple.com/us/podcast/lost-trade/id1534727047 (accessed 2023-07-30).
5. Wain, A.; Sherring, A., 'Changeability, variability, and malleability: sharing perspectives on the role of change in time-based art and utilitarian machinery conservation',. *Studies in Conservation* **66**(8) (2021) 449-462, https://doi.org/10.1080/00393630.2020.1860672.
6. Stein, J. A., *Hot metal: material culture & tangible labour*, Manchester University Press, Manchester (2016).
7. Stein, J. A., *Industrial craft in Australia*, Palgrave Macmillan/Springer, Singapore (2021).
8. '10858NAT – Certificate III in Heritage Trade Skills', in *Training - a joint initiative of the Australian and State Territory Governments*, https://training.gov.au/Training/Details/10858NAT.
9. Callen, A., 'Sexual Division of Labor in the Arts and Crafts Movement', *Woman's Art Journal* **5**(2) (1985) 1-6, https://doi.org/10.2307/1357958.
10. Patchett, M.; Mann, J., 'Five advantages of skill', *Cutural Geographies* **25**(1) (2018) 23-29, https://doi.org/10.1177/1474474017739024
11. Shields, J., 'A matter of skill: the revival of apprenticeship in early twentieth-century NSW', *Journal of Industrial Relations* **37**(2) (1995) 236-262, https://doi.org/10.1177/002218569503700020.
12. Wajcman, J., 'Patriarchy, technology and conceptions of skill', *Work and Occupations* **18**(1) (1991) 29-45, https://doi.org/10.1177/0730888491018001.
13. Cockburn, C., 'The material of male power', *Feminist Review* **9** (1981) 41-58, https://doi.org/10.1057/fr.1981.19.
14. Shales, E., *The shape of craft*, Reaktion Books, London (2017).
15. Taksa, L., 'Machines and ghosts: politics, industrial heritage, and the history of working life at Eveleigh workshops', *Labour History* **85** (2003) 65-88.
16. Gadd, J., 'Heritage Skills Initiative: Grace Barrand', in *One Hour Out*, https://onehourout.com.au/melbourne/everywhere/art-and-craft/heritage-skills-initiative-grace-barrand/ (accessed 2023-07-30).
17. Carr, C., 'Repair and care: locating the work of climate crisis', *Dialogues in Human Geography* **0** (2022) https://doi.org/10.1177/20438206221088381.
18. 'The 17 Goals', in *United Nations - Department of Economic and Social Affairs*, THE 17 GOALS | Sustainable Development (un.org) (accessed 2023-07-30).
19. Godden Mackay Logan, *Heritage Trades and Professional Training Project—Final Report*, Heritage Chairs and Officials of Australia and New Zealand, Melbourne (2010), http://www.environment.gov.au/system/files/resources/faa70eb8-56ed-4a5e-9030-6afe3ad46f17/files/heritage-trades-training.pdf (accessed 2023-07-30).
20. Wain, A., Interview with Col Ogilvie, in *Mind the Gap* project, July 31, 2022.
21. Andrew, M., 'Making mending visible', *Axon: Creative Explorations* **11**(2) (2021) 207-221, https://doi.org/10.54375/001/hgrxkgtlyf.
22. Wain, A., Interview with Richard Senior, in *Mind the Gap* project, November, 9, 2022.
23. Wain, A., Interview with Joeri Januarius, in *Mind the Gap* project, November, 10, 2022.
24. Wain, A.; Rooney, T., Hogg, N., Interview with Neil Hogg, in *Mind the Gap focus group*, November, 18, 2021.
25. 'The Burra Charter: the Australia ICOMOS charter for places of cultural significance' (2013), in *Australia ICOMOS*, http://australia.icomos.org/ (accessed 2023-07-30).
26. Kerr, J. S., *The Conservation Plan*, 7th ed., Australia ICOMOS (online) (2013), https://australia.icomos.org/publications/the-conservation-plan/2013 (accessed 2023-07-30).
27. Winkworth, K.; Russell, R., *Significance 2.0: a guide to assessing the significance of collections*, 2nd ed., Collections Council of Australia, Adelaide (2009), http://nla.gov.au/nla.arc-1124432009 (accessed 2023-07-30).
28. Wain, A.; Rooney T., Interview with Jenny Edmonds, in *Mind the Gap focus group*, September, 22, 2021.
29. 'Formation longue', in *CNVA - L´École des Véhicules Anciens*, https://www.le-conservatoire.com/?lang=en (accessed 2023-07-30).
30. Wain, A.; Rooney, T., Interview with Jenny Fawbert, in *Mind the Gap focus group*, August, 18, 2021.
31. Struthers, K.; Strachan, G., 'Attracting women into male-dominated trades: Views of young women in Australia', *International Journal for Research in Vocational Education and Training* **6**(1) (2019) 1-19, https://doi.org/10.13152/IJRVET.6.1.1.
32. Wain, A., Interview with Stephanie Moore, in *Mind the Gap* project, August, 2021.
33. Wain, A., Interview with Pieter Neirinckx, in *Mind the Gap* project, November, 10, 2022.
34. Cleghorn, M.; Barrand, G., 'Connecting with spirit at the home of heritage: a case study in building conservation training in Burra, SA.', ms., 2019 AICCM National Conference - Making Conservation (2019), https://www.conservatora.com/post/connecting-with-spirit-at-the-home-of-heritage (accessed 2023-08-04).
35. Knake, M., 'What's the Difference? Accreditation, Certification, and Related Terms', in *AASHTO re:source Newsletter* (2015), http://aashtoresource.org/university/newsletters/newsletters/2016/08/05/what's-the-difference-accreditation-certification-and-related-terms (accessed 2023-07-30).

36. Team, A. T., 'What are trailblazer apprenticeships?', in *Aspire training Team* (2016), https://www.aspiretrainingteam.co.uk/what-are-trailblazer-apprenticeships/ (accessed 2023-07-30).

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CONSERVAR PATRIMÓNIO
Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
NOTE / NOTA

The Scottish transport and industry collections knowledge network (STICK)

A rede escocesa de conhecimento sobre coleções de transportes e indústria (STICK)

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Abstract

The Scottish Transport and Industry Collections Knowledge Network (STICK) brings together a range of organisations and individuals who share a common interest in transport and industrial collections and promoting their care and enjoyment. While a multi-disciplinary steering group drives it forward, STICK is its members and their passion and knowledge. STICK facilitates shared learning and knowledge exchange through projects, events and active communication that have drawn on the knowledge and expertise of participants to achieve the aims of the group. STICK's engaged membership and the success of its projects demonstrate the network's strengths but, as an informal body, it faces various challenges as well. It is looking to use learning from its work to date, along with the combined experience and needs of its steering group and members, to address these challenges and continue to bring people together and achieve good outcomes for the sector in the future.

KEYWORDS
Collections
Network
Training
Industry
Transport

Resumo

A rede *Scottish Transport and Industry Collections Knowledge Network* (STICK) reúne um conjunto de organizações e pessoas que partilham o interesse pelos transportes e coleções industriais e que promovem a sua manutenção e usufruto. A STICK define-se pelos seus membros, o seu entusiasmo e conhecimento, estimulada por uma direção multidisciplinar. A STICK facilita a aprendizagem partilhada e a troca de conhecimentos através de projetos, eventos e comunicação ativa, baseados no conhecimento e perícia dos participantes, para alcançar os objetivos do grupo. O empenho dos membros da STICK e o sucesso dos seus projetos demonstram os pontos fortes da rede, mas como órgão informal, enfrenta também vários desafios. Para enfrentar estes desafios, a STICK procura utilizar os conhecimentos adquiridos do seu trabalho, conjuntamente com a experiência e as necessidades da sua direção e dos seus membros, para continuar a reunir pessoas e alcançar no futuro bons resultados para o sector.

PALAVRAS-CHAVE
Coleções
Rede
Formação
Indústria
Transportes

Introduction

The Scottish Transport and Industry Collections Knowledge Network (STICK) was formed in 2006 after work by the Scottish Museums Council and National Museums Scotland identified a need for greater collaboration in the Scottish science and technology heritage sector. It was agreed to form a network to increase public engagement with Scotland's transport and industrial heritage, to improve information about these and to work together to develop higher standards of care for collections. In other words, a network that would encourage members to work together to safeguard industrial and technological heritage [1].

The network was formed by some of the most prominent figures in the industrial heritage sector in Scotland, including representatives from the Royal Commission on the Ancient and Historical Monuments of Scotland and Historic Scotland. However, while the founders and steering group members may have included some well-known names, from the beginning, the network was intended to support anyone with an interest in the subject matter, and all were welcome, whether they were from a large museum service or heritage organisation or were an individual with their own collection.

Despite being an informal network, STICK did have a clear purpose and key aims from its early days, with the minutes from a very early meeting stating that:

> *The STICK network aims to promote Scotland's rich technological and industrial heritage and work together to establish confidence, skills, good-practice and innovation in the care and enjoyment of, access to and engagement with technological and industrial collections across Scotland.* [2]

The meeting also set out the following objectives [3], which remain part of the constitution:

- Develop opportunities to advance acquisition, care, development, research and interpretation of transport and industry collections in Scotland.
- Identify key issues facing the long-term stewardship and development of transport and industry collections and work together to tackle them.
- Promote, encourage and advance access to Scottish transport and industrial collections through a variety of mechanisms.
- Support informed, efficient and confident decision making in the acquisition and long-term care of transport and industrial heritage across Scotland.

These objectives have remained unchanged throughout STICK's life, as has the informal ethos.

There has never been a membership fee or need for formal registration as a member. STICK has a mailing list that can be subscribed to – or unsubscribed from – as people wish, and the subscribers are loosely considered to be the membership, although STICK also engages with an audience through Twitter, and being on the mailing list is not a prerequisite for attending events.

The number of subscribers to the mailing list has been around 200 for most of the course of STICK's life and these have ranged from big museums, as mentioned, through academics, to tiny volunteer-run organisations and private individuals with an interest. At the time of writing, there are 243 subscribers.

The diversity of the membership, combined with the dedication and enthusiasm of the steering committee, are the things that have kept STICK going for so long, and it is an excellent example of collaborative working. STICK has achieved a lot, but this has only been done by a variety of people – with complementary skills and a lot of good will – working together (Figure 1).

Figure 1. The STICK committee at an early meeting (c. 2006).

Projects

Some of STICK's key achievements to date have been its funded projects, undertaken as a partnership and involving many of the network's members.

"Old Tools, New Uses"

The early committee members were particularly interested in carrying out collections mapping and "master cataloguing" work that was a natural follow on from work many of them had been involved in previously that identified Scotland's Distributed National Collection. This audit, carried out by the Scottish Museums Council (now Museums Galleries Scotland), worked on the theory that many star objects of significance to Scotland's heritage were held in collections outside of the designated national collection and aimed to signpost them for researchers and the public. The STICK committee felt that there were various collecting areas within the interest of the network that would benefit from a similar national audit approach, and it was from this idea that the "Old Tools New Uses" project emerged and became the defining piece of work of STICK's early years.

The collecting areas chosen for the project were hand tools, typewriters and sewing machines. They were chosen because many museums and individuals across the country held examples of these sorts of objects, and it was suspected that hidden treasures would likely come to light.

The Museums Association's Effective Collections scheme awarded STICK £25,000 to employ a project officer to carry out a nationwide collections review of these objects, produce a master catalogue showing what objects were held where, and create learning resources that would enable anyone working with similar objects to identify and care for them [4].

As well as discovering important sewing machines and typewriters in collections of all sizes across the country, the collections review highlighted a large number of duplicates. The project then supported the owners of these duplicates to make decisions about whether they wished to retain or dispose of them. If they wanted to go down the disposal route, they were supported through the process, which can often be a delicate and complicated one for museums.

In addition to this work, STICK built a partnership with a charity called Tools for Self-Reliance. It identified typewriters and sewing machines that were still of practical use and sent them to artisan communities in Africa. In this way, many of the objects disposed of by Scottish museums went on to serve a useful purpose elsewhere (Figure 2).

The project left a legacy of written work that is available on the STICK website. There are master catalogues showing where hand tools, typewriters and sewing machines can be found in collections across Scotland. These are useful resource for curators who care for these collections, but who may not be specialists, as it allows them to quickly identify what items are held in other institutions. This can be a key stage in the acquisition process. Guidance was also produced as part of the project about how to identify and care for these kinds of objects. Again, this is very helpful legacy for curators and other collectors who may not have specialist knowledge or skills.

Figure 2. Items disposed of by Scottish Museums as part of the "Old Tools, New Uses" project were repurposed for use in the developing world, with assistance from Tools for Self-Reliance.

Figure 3. Where possible, machine tools were demonstrated as part of the "Machine Tools" project.

"Machine Tools"

The next major project that STICK undertook, in 2015, built on the success of the master cataloguing element of the "Old Tools New Uses" project. This time the focus was on machine tools and, again, a key aim was to research what was held where in collections across Scotland. This time, in addition to cataloguing the national collection, the project aimed to use machine tools as a resource for understanding basic engineering principals and processes. This was done through a series of events that were open to museum curators, engineering students and professionals as well as the wider public. These included talks by engineers, curators and conservators, and also demonstrations of machine tools where possible (Figure 3) [5].

Again, the main legacy of this project is another catalogue that maps where machine tools are held in museums and other collections across Scotland. This was originally available as a searchable database on a custom-built website, but following issues around the maintenance of the website, it was moved and became a simple PDF on the main STICK website.

"Industrial Object Conservation Training"

The last major funded project that STICK ran was in 2017 and was an industrial object conservation course, funded by Museums Galleries Scotland. It was the result of a skills audit of the STICK membership which revealed that only 45 % of members who cared for industrial collections had access to specialist conservation advice and, for many of the 45 %, access was limited. For example, advice might come through external contractors and require funding. In addition, conservation work was frequently carried out by volunteers with engineering skills but with no training in conservation approaches. 82 % of the membership felt that engineering conservation training would help them progress the aims of their organisation. Respondents also indicated a need for training in assessing risk, recording conservation processes, and understanding conservation ethos [6].

STICK was able to meet some of these needs by running a three-day training course aimed at non-specialist museum staff and volunteers tasked with caring for industrial collections with complex needs. The intention was to upskill and give confidence to these individuals, enabling them to better care for their collections and manage and document preventative conservation projects in their organisations.

The course was delivered by Jim Mitchell of Industrial Heritage Consulting, and it took place at the National Mining Museum Scotland in Newtongrange, just outside Edinburgh (Figure 4). Some of the time was spent in the classroom discussing the meaning of conservation, ethics, hazards, safety and techniques, among other topics. However, the majority of the course was spent in National Mining Museum Scotland's large object store where the group got hands-on with several different items from the collection, applying learning directly, receiving direction from Jim and documenting their work on paper and through photographs and film.

Legacy was, again, important for this project, so films of the processes and techniques were made available on the website, along with template forms for correctly documenting conservation, and the slides from Jim's presentations.

This course was one of the most popular projects that STICK has ever run. Only a small number of people were able to take part due to space and resources and, as soon as the course was over, requests were received to run it again. Frustratingly, the STICK committee did not have the capacity to do this as the fundraising and the logistics had been time consuming. Fortunately, however, the Industrial Museums Scotland federation was able to use the success of the STICK training course to make a case to fund further, similar training [7] and the first of their courses took place in 2022, following a delay caused by the COVID-19 pandemic.

Figure 4. Jim Mitchell works with a course participant in the National Mining Museum Scotland's stores.

Conferences and events

As well as funded projects, STICK runs short conferences and other events. The conferences are usually one day events and have become popular among the industrial, transport and engineering heritage sectors in Scotland. The themes of the conferences have been quite diverse over the years, tending to focus on history and curation rather than conservation. Themes have included: "Steam Engines in Scotland", "Form or Function: What is more important?", "The Scottish Diaspora: International Mobility of Industry, Technology, Ideas, Products and People", "Unsung Heroes of Our Industrial and Technological Heritage' and 'Old Heritage: New Uses" [8].

In 2019, STICK marked the centenary of the Women's Engineering Society by holding its conference at the Glasgow Women's Library. The theme was 100 years of women in engineering and, as well as looking at women's engineering roles historically, women who currently work in engineering were invited to attend and to speak. These included Alison Nuttall, an assistant chief engineer with BAE Systems, who reflected on how the contribution of women in engineering had influenced and changed her industry, and how technology influences working lives, providing both inclusion and division in the workplace [9]. This was quite a different approach to the traditional STICK conferences and attracted a new audience while still retaining many regular attendees.

The 2020 and 2021 conferences were held online due to COVID-19 and, while this approach undoubtedly presents some challenges, STICK benefitted from the reach of these events, drawing audiences of over one hundred for the first time, and being joined by people from a diverse range of countries. The theme of the 2020 conference was 'Art and Industry' and the 2021 theme was "Photography and Industrial Heritage". Being very visual, these themes lent themselves to being online and, again, were a departure from STICK's usual subject matter so continued to broaden the audience. This was reflected in an increase in people signing up to receive the newsletter and following STICK on Twitter.

Another very successful online event held in 2021 was part of the AGM rather than a conference. As the AGM fell on International Earth Day, the theme of the event was the future of fossil fuels in heritage. The event explored justifying, offsetting or sustainably running engines, navigating new climate regulations at local and national levels, funding partnerships, and the future of running heritage engines. It also explored the role of industrial museums and collections in STEM and environmental education and how learning outcomes can balance emissions. A summary of the discussion was uploaded to the STICK website, and STICK intends to pick this theme up again at future events [10].

Communication and networking

While all these events bring people together and have a lasting impact and legacy, possibly the most important elements of what STICK does are communication, networking and making resources available to the membership and beyond. This is done through a mailing list and Twitter. A monthly mailout serves as a roundup of information that the committee is aware of and think would be of interest to members. This can include, for example, job adverts and information about publications, conferences and other events. The newsletter can also be used to highlight issues of concern within industrial and transport heritage. STICK does not claim to be the one stop shop for information about industrial and transport heritage in Scotland, and there are other networks that do similar things, but STICK has become established as the Scottish network with the broadest scope in terms of interest and content, and the majority of people working in the sector in Scotland are aware of STICK and subscribe to the newsletter.

The Twitter account currently has over 1000 followers, so is one of the most efficient ways of sharing information and engaging with a wide audience. STICK made particular use of

Twitter using the COVID-19 lockdowns to demonstrate that the network was still active, and to provide entertainment and interest.

While the STICK website does contain information about upcoming STICK events and some news items, its most useful function is hosting all of the resources that have been produced by STICK projects and, in recent years, an effort has been made to ensure that there is a legacy from conferences and events. A good example of this is the write up of the fossil fuels event which included a summary of the discussion and a link to the recording. This is something that has been much easier to produce in the "Zoom Age".

Strengths and challenges

STICK's key strength since it was formed in 2006 is that it meets a need that was clearly defined then and that continues today. STICK is a body that unites people with related interests and facilitates them to work together to share information, understand and care for the objects that they look after and make those objects accessible and available to the public through improved stewardship.

STICK is supported by some of the main heritage bodies in Scotland, including the National Museums, Historic Environment Scotland and Museums Galleries Scotland. Having a good relationship with these organisations makes it easier to advocate for the importance of transport and industrial collections and to keep them on the agenda of cultural policy makers and funders. This is done more effectively as a united organisation than as individuals.

The (loosely defined) membership is diverse, ranging from large institutions to small volunteer-run museums and interested individuals. It is encouraging to note that the full range of members tend to be represented at events and participate in projects. One of the most important things that STICK does is allow people to network and share knowledge. It unlocks the skills and expertise held by all of the members in a mutually supportive and collaborative way. It provides the means for people to share their knowledge and the website is a place to deposit or signpost that knowledge.

Being an informal network means that STICK is accessible and approachable. Anyone can get in touch and come to events. Projects are open to all, and the committee welcomes anyone who has time and skills to contribute. Being an informal body rather than a constituted organisation or charity means that STICK is not bureaucratic. There is no hierarchy in STICK and it is relatively paperwork-free.

Another key strength throughout STICK's lifetime is the commitment and enthusiasm of the committee. The committee members all care about STICK and want it to succeed because they care about the heritage and the collections at its heart. The committee members enjoy taking part in STICK events and enjoy the company of the other committee members and wider membership.

However, it is interesting to note that some of its strengths are also STICK's weaknesses, and these have been consistently challenging since the formation of the network. Not being a formal organisation or registered charity means that it is unable to make use of the benefits that would bring. This is particularly frustrating when it comes to fundraising. STICK is not eligible to access most charitable grants, so grant funding applications must be through one of the committee's organisations, on STICK's behalf. This can be complicated, and places pressure on both the organisation and on STICK.

The informal membership arrangement and lack of membership fee does not help the financial situation. While charging a membership fee has been discussed on several occasions, the committee has concluded that it would cause loss of members and that it would be necessary to offer more exclusive member benefits, which would not be practical and would exclude those who were unable to pay a fee. The committee members also have other commitments that take up most of their time, so it would be risky to commit to generating more STICK content or guaranteeing a certain number of members' events per year.

The time commitment required to run a good quality project is also something that STICK struggles with. Completing a funding application can take days or even weeks, and running a project can be a full-time job. The "Old Tools New Uses" and "Machine Tools" projects funding covered the costs of having a project officer which certainly contributed to their success. As funding is increasingly hard to obtain, running projects on this scale, and employing the staff to do so, has become harder. This is one of the key reasons why STICK has not run a large project for the last few years.

Another issue that is related to lack of committee time, and to the changeover of committee members, is the maintenance of online resources which, as mentioned, are a major part of STICK's offer. There have been issues with ensuring that the website and domain are renewed properly and on time, and not every committee member is skilled or confident in updating and maintaining digital resources. The development of meaningful content for Twitter and the newsletter is also demanding.

The future

The COVID years caused the STICK committee to scale back operations, reflect on what STICK does best and start to consider how to address the challenges. Rather than having a conference in autumn 2022, a series of tours that allowed people to come together in person to see behind the scenes at various museums and heritage sites was arranged, complemented by online talks that allowed a wider audience to participate. This was successful but organisation-heavy, so the committee is considering whether to continue this format in future.

Practical project work is more challenging to address, for the reasons discussed above. While STICK may seek funding to run its own projects again in due course, it is likely that, for the foreseeable future, it will play a more supportive role for other organisations. It will do this by, for example, sharing the learning from its successful projects and distributing publicity material.

Figure 5. Participants in the 2017 Industrial Object Conservation training course, STICK enables the care and sharing of industrial and transport heritage.

Recent changes to the STICK committee, with increased academic representation and different perspectives, combined with a new chair taking the lead in autumn 2022, mean that it will be interesting to see STICK's future direction of travel. In the meantime, the committee continues to listen to the membership and the sector, and to continually work to facilitate communication and collaboration that will enable the network to keep on caring for and sharing our industrial and transport heritage (Figure 5).

REFERENCES

1. Burns, J., 'Scottish Transport and Industry Collections Knowledge Network', Conference, National Museums Scotland (2010).
2. STICK Committee, 'Item 3: STICK purpose and key aims', *Minutes of STICK committee meeting*, National Museum of Scotland, Edinburg (2007).
3. STICK constitution, https://stickssn.org/wp-content/uploads/2021/09/STICK-constitution-2020.pdf (accessed 2022-12-20).
4. 'Old Tools New Uses', in *STICK*, https://stickssn.org/old-tools-new-uses/ (accessed 2022-12-21).
5. 'Machine tools', in *STICK*, https://stickssn.org/machine-tools-project/ (accessed 2022-12-21).
6. 'Industrial object conservation training', in *STICK*, https://stickssn.org/industrial-object-conservation-training/ (accessed 2022-12-21).
7. 'Industrial Museums Scotland launches nationwide project to address skills gap and ensure future for nationally significant heritage collections', in *go industrial*, https://www.goindustrial.co.uk/our-blog/blog-post/industrial-museums-scotland-launches-nationwide-project--to-address-skills-gap-and-ensure-future-for-nationally-significant-heritage-collections (accessed 2022-12-21).
8. 'Events', in *STICK*, https://stickssn.org/events/ (accessed 2022-12-21).
9. 'STICK conference 2019 summary: "100 years of women in engineering"', in *STICK*, https://stickssn.org/stick-2019-conference-summary/ (accessed 2022-12-21).
10. 'Burning issues: the future of fossil fuels in heritage', in *STICK*, https://stickssn.org/stick-agm-2020-burning-issues/ (accessed 2022-12-21).

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CONSERVAR PATRIMÓNIO

Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
NOTE / NOTA

Things rust but memories last forever: creative conservation in the industrial heritage

Os objetos degradam-se mas memórias duram para sempre: conservação criativa no património industrial

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Abstract

The concept of creative conservation began to be developed in 2012 by conservators from the Polytechnic Institute of Tomar. This approach, which begins with a process of resignification of fragmented objects, those apparently without possible recovery and on the verge of being discarded, has the goal to develop actions that encourage reflective thinking on preservation and collective memory. This article explores its application in industrial heritage through two case studies: *Cartão de Ponto* project (2012), based on the conservation of a set of timecards of former workers of the Spinning Mill of Tomar, and the ongoing *POR1FIO* project, which seeks to create an educational tool from preserved objects from the Torres Novas Nacional Spinning & Weaving Co. These projects demonstrate that creative conservation approach can be a new strategy to help the local community to establish positive memories based on their industrial heritage and to manage the trauma from the de-industrialization processes.

KEYWORDS
Industrial heritage
Creative conservation
Preservation
Community

Resumo

O conceito de conservação criativa começou a ser desenvolvido em 2012 por conservadores-restauradores do Instituto Politécnico de Tomar. Partindo de um processo de re-significação de objetos fragmentados, aparentemente sem recuperação e prestes a serem descartados, procura-se desenvolver ações que culminem numa reflexão sobre a preservação e a memória coletiva. Este artigo analisa a sua aplicação no património industrial através de dois estudos de caso: o projeto *Cartão de Ponto* (2012), baseado na intervenção num conjunto de cartões de ponto dos funcionários da Fábrica de Fiação de Tomar, e o projeto *POR1FIO*, em curso, que pretende criar ferramentas de mediação cultural a partir de objetos da antiga Companhia Nacional de Fiação e Tecidos de Torres Novas. Procura-se demonstrar que a conservação criativa pode ser uma nova estratégia para ajudar a comunidade local a estabelecer memórias positivas assentes no seu património industrial e a lidar com o trauma dos processos de desindustrialização.

PALAVRAS-CHAVE
Património industrial
Conservação criativa
Preservação
Comunidade

Introduction

Creative conservation emerges as a distinctive and innovative approach to heritage preservation, demonstrating that creativity can be an important advantage in complex and difficult decision-making processes. Its concept and main objective can be defined as follows:

> *Creative Conservation means that artistic creativity is intentionally applied to aid the creation of a new and innovative conservation (by)product, which might be an installation, an exhibition, a performance or an object, among many other, yet to be devised, possibilities. This new creative approach brings together original materials and an innovative interpretation that establishes new meanings for those materials fostering their sustainable preservation.* [1]

This new approach concept emerged in 2012, from the investigation of conservators-restorers and researchers from the Polytechnic Institute of Tomar (IPT), in Portugal [1-4]. The research on remains of industrial heritage [3-4], has already originated other projects in this topic. This paper focuses on two projects of two hundred-year-old spinning mills.

The first project, *Cartão de Ponto* (Timecard), was developed in 2012 at IPT's laboratories of conservation and restoration and the *Real Fábrica de Fiação de Tomar* (Royal Spinning Mill of Tomar). Founded in 1789 and ceasing activity in 1993 [5-7], the *Real Fábrica de Fiação de Tomar* was once considered the largest textile company in Portugal [5], and is where timecards of the factory workers were collected and studied. The goal was to generate awareness of the degradation, enhancement and preservation of this heritage, with the ultimate goal of preserving the collective memory of past workers or what can be called the "memory of work" [8].

The other project, *POR1FIO*, is currently underway at the Center for Technology, Restoration and Enhancement of Arts (TECHN&ART) at IPT. In this case, the focus is the *Companhia Nacional de Fiação e Tecidos de Torres Novas* (CNFTTN,Torres Novas Nacional Spinning & Weaving Co., Portugal), founded in 1845 and closed after 166 years of activity, in 2011 [9-12]. The goal of this project is the preservation of what still are the "lived experiences" from several generations connected to the factory "through the conception of a heritage education tool, the «Memories Builder»" [2]. With this tool, educational activities will be carried out for children and young people [2].

Both companies, from Tomar and from Torres Novas, share some similarities and some differences in their "de-industrialization" processes. The abandonment of the industrial complexes and the job loss, due to the global condition of the post-industrial era and the technological lag in the textile industry in Portugal [13-14] are common aspects.

In Tomar's example, all the company's mobile assets were auctioned, in 1999, by judicial order. At that time, Tomar's City Council acquired all the historical objects previously collected in the archive and in the factory's "museum" [15]. Also the Council collected all the machinery corresponding to a complete production line, recognizing the cultural relevance of this heritage. In line with the 2003 recommendations of the International Committee for Conservation of the Industrial Heritage (TICCIH), in *The Nizhny Tagil Charter for The Industrial Heritage*: "Preservation of documentary records, company archives, building plans as well as sample specimens of industrial products should be encouraged" [16].

However, abandonment and successive attacks of vandalism put this heritage at risk (Figure 1). Therefore, Tomar's City Council was forced, in 2003, to remove the assets from the factory in an attempt to safeguard them. Although thousands of objects were collected including archives, technical drawings, photographs, fabric samples, yarn samples, product labels and many others, many objects were left behind. The buildings, which at the end of the twentieth century were in a good state of conservation, are now in a state of ruin, after several years of abandonment and successive acts of vandalism.

Figure 1. Historical archive of Tomar's Spinning Mill, in 2003, after being vandalized.

In Torres Novas the buildings do not have a significant architectural value, but considering the building complex, it becomes unique. Not only for its location along the river and valley but also by the evolution of materials used and construction techniques throughout the time [17]. In 2016, five years after closing down, the damage was already noticeable, with occasional vegetation invasion, destruction of some roofs, water infiltrations from the absence of windows and some acts of vandalism. Part of this damage was caused by the removal of equipment and machinery [17]. In 2022 the municipality acquired the factory's building.

The closing of these two factories, especially in these cities so reliant on the textile industry, left the population extremely vulnerable. In fact, the deindustrialization processes had a great impact on the lives of the local community. These generally lengthy processes are challenging, not only because of their economic and social implications but also, because of the necessary "cultural-trauma management" that deindustrialization undoubtedly brings to the scene [18].

In both cases, what can be seen is a generalized lack of broad public engagement with this industrial heritage. This lack, as Paz Benito del Pozo and Pablo Alonso González mentioned regarding industrial heritage in Spain [19], may be the result of a vision more concerned with the use of this heritage as "a future-oriented economic resource, neglecting emotional and popular potential for the generation of new identities and connections with the past".

This paper aims to analyse how the approach of creative conservation can be an innovative and disruptive tool for these cases. Being aware that not all material remains can be saved for the future, this article wishes to contribute to a new approach to the conservation of industrial heritage and simultaneously to the well-being of local communities. The article helps to understand how creative conservation and industrial heritage could be interpreted and be a positive influence on the population's/community's experiences, memories and emotions.

Methodology

The application of the creative conservation approach starts with the preservation of the heritage at risk. There are a few risks, like dissociation, demolition or theft of assets or structures. Deactivated industrial complexes, which play a significant role in the development of these communities, are vulnerable to this type of risk. They are a testimony and major influence of social and economic impact in the recent past and are very present in the communities' memory, giving them meaning [20]. They are usually associated with traumatic closure processes, without classification or heritage recognition and without a preservation plan. These spaces are very vulnerable to the speculative market and the risk of loss is significant.

Based on these assumptions, the approach (Figure 2) follows these steps: 1) Identification of the conservation problem; 2) Study and research, the objects are collected, selected, diagnosed, and analysed their importance and significance to the community, trough surveys, interviews, and/or others; 3) Identification and definition of the creative conservation options; 4) the intervention, that can be both a traditional and creative conservation intervention, or just a creative one. With the creative conservation approach the intention is create awareness of the heritage at risk through the use of these "symbolic" assets by developing installations, performances, exhibitions, informal education activities, or others, among the communities [2].

In this context of industrial heritage at risk, this approach was applied in the two cases of the spinning mills described above. Although the context of each one is distinct, both approaches are similar regarding the use of the creative conservation approach. In both cases, the dissemination actions are focused on the community, seeking to recover and stimulate the memories of the activity of these places.

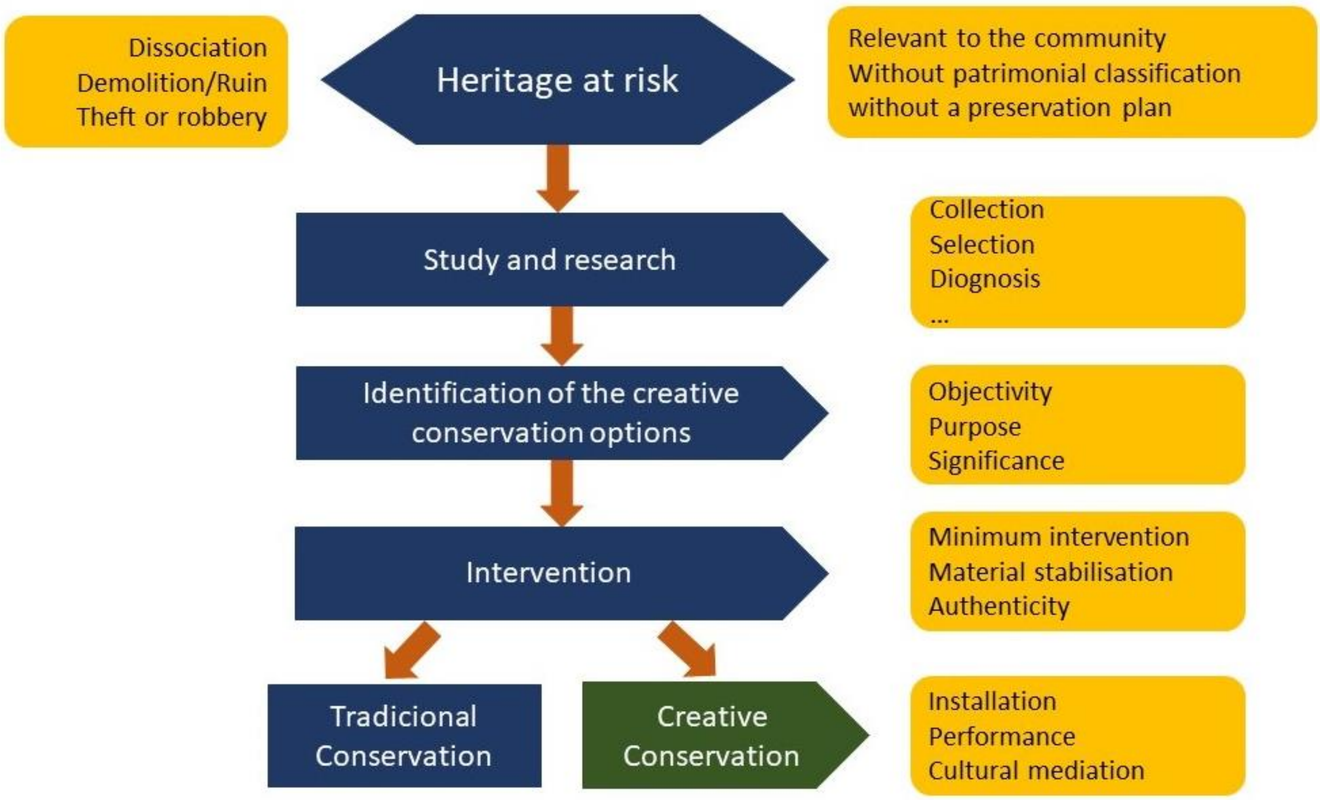

Figure 2. Diagram of the creative conservation methodology.

Results

"Cartão de ponto" (Timecard) – Evocation of collective memory from the Spinning Mill in Tomar

This project began with the collection of around 1500 timecards that were part of the factory workers' historical archive. Left abandoned for several years, this archive was in very poor condition, with little able to be rescued by the City Council in 2003. This project allowed the preservation of this set of historical documents that otherwise would have disappeared.

The timecards were made of small, coloured cardboard cards measuring approximately 22 cm × 9 cm (Figure 3). The colour of the cards was different each year. Information gathered through timecards helps in determining a key part of the history of an organization since each card contains relevant information about a particular worker: name, identification number, job position and working hours [2].

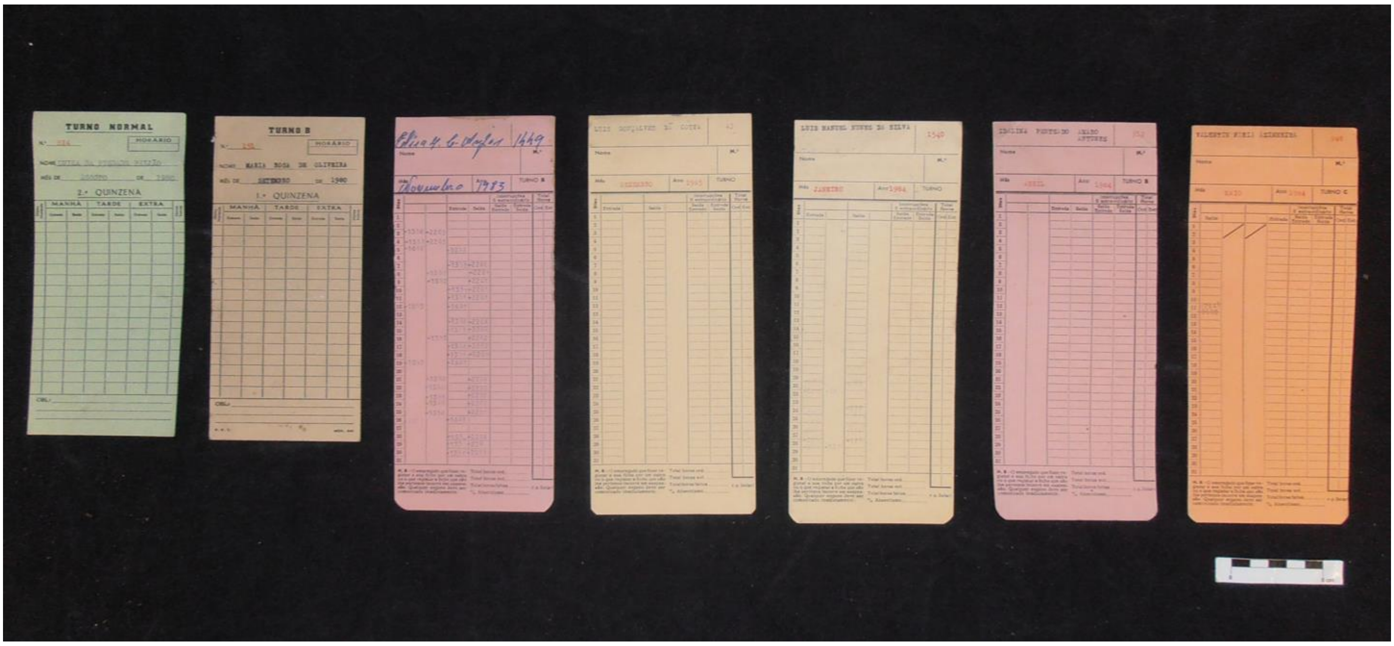

Figure 3. Some examples of timecards selected for intervention.

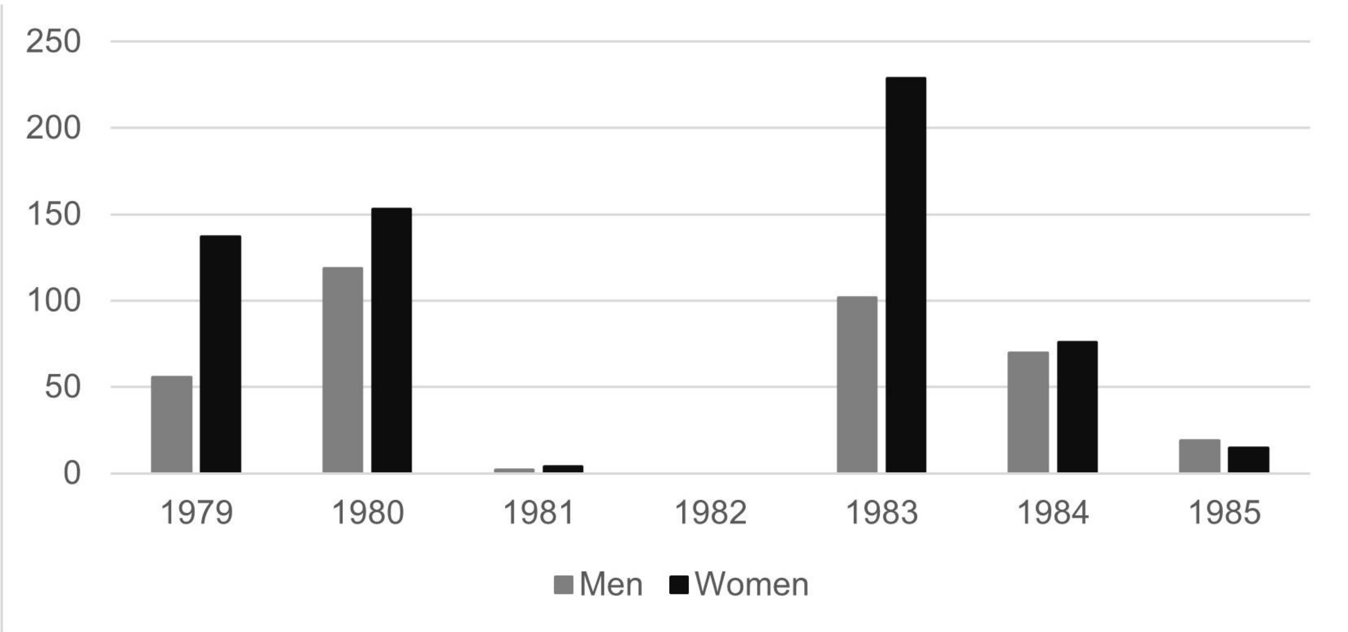

Figure 4. The number of timecards, collected and recorded during the project, with data between 1979 and 1985, divided according to gender.

For this reason, the next step was the recording and inventorying of the intrinsic data contained in the cards. A data sheet was created to record data from 982 cards, dated between 1979 and 1985. This constitutes a support base for future research work oriented towards the memory of work at the Spinning Mill of Tomar. From this data it will be possible to carry out anthropological research, augmented by the collection of testimonies of workers' experiences and life stories, to recreate a journey through the daily life of industrial hustle and bustle [21].

The analyses of information contained in the timecards made it possible to characterize the employees who worked at the factory in that period. For example, of the total number of cards, 368 (37 %) correspond to men and 614 (63 %) to women. This confirms previous knowledge of the great importance of women's work in the textile industry [22]. The graph below (Figure 4) shows the number of timecards collected and registered, by year, and according to gender.

Besides the recording of the contextual data from each timecard, the materials were identified and their condition was assessed. This stage allowed the definition of the best approach for the conservation process. The cleaning and stabilization of each card were essential to allow a better perception/interpretation and contribute to its preservation and exhibition. The cleaning process consisted of dry-cleaning using brushes and rubbers. The individual encapsulation bags were designed to accommodate the size of the cards and the manner of exhibition. A polyester film (Melinex) was used to make the bags for each card. This allowed the creation of the installation and the conditions for their future preservation (Figure 5).

After finalizing the conservation process, the goal was to present the result to the local community. The creative and innovative aspect of this approach was revealed with the use of timecards in an installation with the title: *Cartão de Ponto – A unidade de trabalho: Evocação da memória coletiva da Fábrica da Fiação de Tomar* (Timecard – a work unit: Evoking the collective memory of the Tomar Spinning Factory) (Figure 6). The exhibition was on display at the Complexo Industrial da Levada, in Tomar, during the event *Há trabalhos na Fábrica* (There are works at the Factory), between April 30 and May 12, 2014 [23].

The installation consisted of a "curtain" of timecards, suspended, and interconnected. The cards' distribution was random. The only criterion followed was the colour of the cards, according to the creative scheme conceived. The aim was to remove from the exhibition any pre-established interpretive proposal. Being suspended and protected in polyester bags allowed the manipulation of the timecards by visitors. In this way, an interaction was achieved between the installation and the visitors, including former factory workers. The timecards were stored at IPT after the exhibition and are now available for public consultation.

This project contributes to rescuing part of the collective and personal memory that materializes in the preservation of these assets. Each card, which identifies a worker, becomes a tribute to the anonymous group of men and women who, generation after generation, contributed to developing an important activity in the city.

Figure 5. Conservation of the timecards: a) dry cleaning using a brush; b) execution of the encapsulation bags.

Figure 6. The installation "Timecard – a work unit: Evoking the collective memory of the Tomar Spinning Factory".

"POR1FIO"

In the *POR1FIO* project, currently under development, the main goal with the application of the creative conservation approach is to perform an activity to enhance the heritage within the community. This activity is founded on the study of the old factory (CNFTTN) and the estate still existing in the municipality of Torres Novas. Considering the state of conservation of the building, the lack of a safeguard plan for the assets and the poor perception of the social impact and valorisation of this heritage by the community, this project was conceived as *POR1FIO - The creative conservation of industrial heritage in the construction of the social memory of Torres Novas*.

The first step was to understand the factory's history and which objects were available for informal education activities in the community. It was not possible to develop any activity in the building, given its state of conservation. The assets collected at the factory, namely the documentation, technical drawings, photographs, and other similar documents are on deposit at the Municipal Library, with some of them still being digitized and catalogued. Only a small part of the objects is available, in storage next to the machines. It was only based on this collection that the project could be built. This set is composed of machines and small objects, such as spinning cones, spools, yarn shuttles, and fabric samples, among others. These materials are stored in an old sports pavilion without any preservation plan and without conditions to slow their degradation. Taking these aspects into account, a first selection of objects was made (Figure 7) that could be used in informal education sessions in the community.

During the initial tasks of the project there was also the opportunity, not initially planned, to understand the social impact of the factory on the local community after its closure. A survey was developed to understand what meaning the community still preserves about the factory [24] and how it could be relevant to the project development.

Figure 7. Selection of objects from the CNFTTN factory: a) selection for the "memories builder"; b) process of selection of objects.

Following the approach of creative conservation, after the collection of the objects, they were duly documented and are currently in the process of intervention. The approach will be identical to the previous project, consisting of the cleaning of superficial deposits that, in most cases will be sufficient to allow their use. These are objects that were still in the machines themselves at the moment of their collection or in boxes without any reference (Figure 8). The most sensitive materials are yarns and paper elements, such as labels, which are very dry and fragile. After cleaning and stabilization, it will be possible to determine which items can be handled during the informal education sessions.

Figure 8. Objects from the CNFTTN factory: a) in the boxes; b) in the machines.

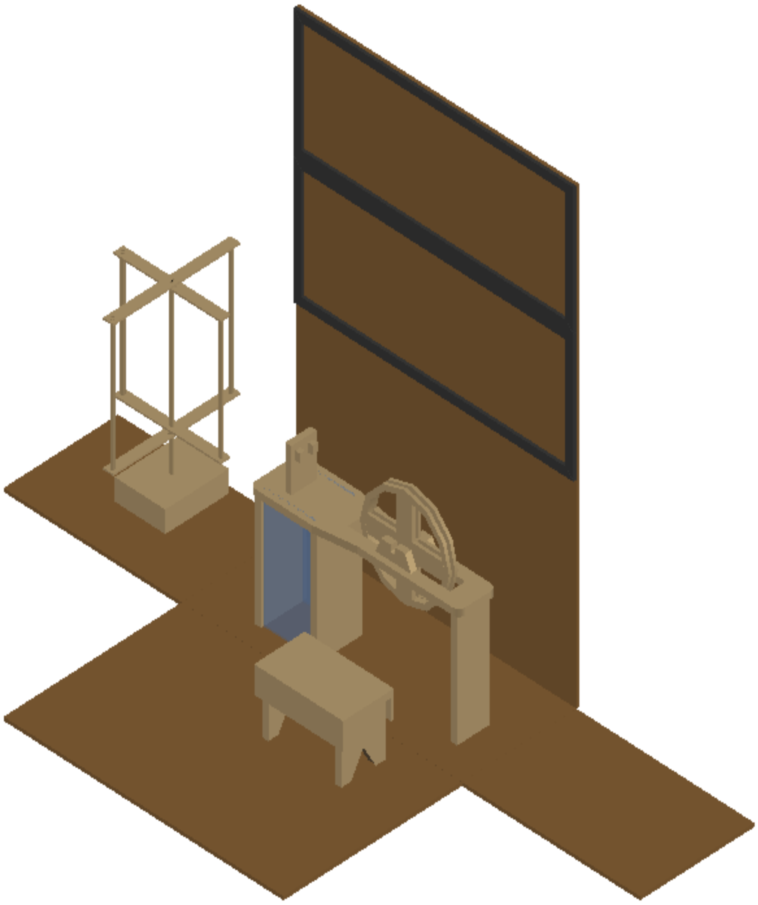

Figure 9. The prototype of the "Memories Builder".

For these informal education sessions, it was decided to select the school community as the target audience, specifically those born after the factory's closure. In this way, the need to create memories became the central motivation for interaction with the public. In order to realize this interaction, it was decided to make use of the affordances of the "Memories builder" (Figure 9). It is a box that carries the selected objects, as well as a small apparatus to spin a yarn that each participant can successively add. The box can be disassembled when it is not needed. The idea that this is expected to induce in the public is exactly that of adding memories of the factory and the relevance of preserving this heritage [25]. Still being finalised, it is expected that the "Memories builder" will be both a tool for the storage and display of the assets as well as a symbolic tool for the preservation of the intangible legacy of the factory.

Discussion of results

The two cases presented are very different, although there are many similarities regarding the conservation of their buildings and objects. Firstly, in both cases, the materials' remains are dissociated, poorly recorded, and in a continuous degradation process. Secondly, there is no preservation strategy for this industrial heritage. There is already a reduction of value and authenticity at both sites, due to the removal of the machinery, components and subsidiary elements which form part of the whole. Also, it is urgent to preserve these heritage sites, as they are in a state of abandonment and imminent demolition. Thirdly, since both factories closed relatively recently, many active memories are present in local communities that have not yet been called upon to be part of the solution.

The two projects developed using the creativity present in the methodology contributed to the greater objective of preserving the collective memory that this industrial heritage evokes. The objects preserved in both projects can be interpreted as "traces". Deprived of their original functions, and far from the safety of a museum, these objects were collected from a heap of ruins or in a forgotten building. For Marc Guillaume, a "trace" is fundamentally what a person leaves behind, irreversibly, and in particular after death [26]. Therefore, conserving traces is always, for this author, a choice, individual or collective, based on the prevailing system of beliefs and values. Collecting these objects, in both cases, was dependent on that subjective system of values. However, it is believed that the choice was oriented towards the possibility of these objects: the timecards, on the one hand, and the selected objects of the CNFTTN, on the other, function as what Marc Guillaume calls "suture objects" [26]. This is particularly important to cultural-trauma management due to the de-industrialization processes, mentioned earlier. More important than the materiality of the objects is their ability to record and fix a narrative in a lasting and incontestable way, and from this narrative, it is possible to activate memories, develop the ritual of remembrance and grieve for the loss.

The selection of objects is therefore a fundamental phase in creative conservation projects. This can be particularly challenging in the case of industrial heritage where the scope of heritage is vast [18]. On the other hand, the current society's voracity for constant updating poses the problem of what to save for the future [27]. Can we keep it all? It is known that this would not be possible or sustainable. As Françoise Choay [28] mentions, however, the collection of objects is a means of defense against loss, in a quest for an illusory permanence. Thus, in these projects, the collection and conservation of objects or remains are not understood as ends in themselves, but rather as part of an approach that has broader objectives.

Through these two projects, it was possible to establish a better connection between partners in the region and to innovate in the area of industrial heritage. The application of the creative conservation approach promoted engagement with the community, enhancing the reflection on the values and meaning of heritage through its use [2, 23-25].

Conclusions

Creative conservation used in the context of industrial heritage requires not only the use of traditional conservation methods, but also semiotic research to recognize the significance of material elements that can have a greater effectiveness in subsequent communication activities. There is also a need for an interdisciplinary approach. In addition to the analysis of the materials, other areas must be considered, such as the anthropological and social spheres. The connection with the community plays a fundamental role in these projects. It was found to be desirable for creative conservation projects, in contexts of de-industrialization, to start from an inquiry into the community's positioning in relation to its industrial heritage and its memories. Only in this way is it possible to define creative conservation strategies that truly consolidate the interdependent relationship between industrial heritage and the community.

However, benefits always emerge from the creative conservation methodology: a set of objects on the verge of being discarded are conserved and the opportunity for the creation of positive memories involving industrial heritage and reflective thinking on their preservation is created.

Acknowledgements

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REFERENCES

1. Triães, R.; Nogueira, A.; Chasqueira, Â., ms., 'The power of creativity in nurturing sustainable development', in *Proceedings 20th ICOM-CC Triennial Conference*, València, Spain (2023).
2. Triães, R., 'Área de ação prioritária – conservação e segurança: Projeto Conservação criativa: uma metodologia alternativa para a interpretação e conservação da memória', *Nova Augusta* **32** (2020) 301-309.
3. Loureiro, L.; Triães, R.; Falcão, C, 'Educational tools for involving higher degree students within the project Creative Conservation', *New Trends and Issues Proceedings on Humanities and Social Sciences* **2**(7) (2016) 32-40, https://doi.org/10.18844/gjhss.v2i7.1177 (accessed 2023-01-20).
4. Triães, R.; Falcão, C.; Loureiro, L., 'Conservação criativa. Edifícios e vestígios – Projecto-ensaio sobre espaços pós-industriais', in *Edifícios e vestígios – Buildings & remnants*, ed. I. Moreira, Imprensa Nacional Casa da Moeda, Lisboa (2013) 217-232.
5. Francisco, M., *O património industrial do rio Nabão: contributo para a salvaguarda da antiga Fábrica de Fiação de Tomar*, Master dissertation, Department of Architecture, Universidade do Porto, Porto (2021).
6. Guimarães, M. S., *História de uma Fábrica. A Real Fábrica de Fiação de Thomar*. Junta Distrital de Santarém, Santarém (1976).
7. Custódio, J.; Santos, L., *A Real Fábrica de Fiação de Tomar e a 1.ª geração europeia e americana de fábricas hidráulicas*, Coimbra Editora, Coimbra (1990).
8. Castilho, J. J., 'The memory of work and the future of industrial heritage: new issues five years later', *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research* **12**(3) (2011), http://nbn-resolving.de/urn:nbn:de:0114-fqs110333 (accessed 2023-01-19).
9. Bicho, J. R., *A Fábrica Grande. Subsídios para a história da Companhia de Torres Novas*, Câmara Municipal de Torres Novas, Torres Novas (1997).
10. Rocha, F. C., 'Companhia Nacional de Fiação e tecidos de Torres, 150 anos de atividade', *Nova Augusta* **9** (1995) 29-44.
11. Oliveira, F., *Torres Novas industrial 1784-1999*, Câmara Municipal de Torres Novas, Torres Novas (2005).
12. Rocha, F. C., *Para a história do movimento operário em Torres Novas. Durante a Monarquia e a I República (1862-1926)*, Câmara Municipal de Torres Novas, Torres Novas (2009).
13. Freeman, C.; Louçã, F., *Ciclos e crises no capitalismo global – das revoluções industriais à revolução da informação*, Edições Afrontamento, Porto (2003).
14. Nogueira, P. M. R., *A ciência e a indústria têxtil e do vestuário. Uma abordagem historiográfica ao setor em Guimarães*, PhD dissertation, Universidade de Coimbra and Universidade de Aveiro, Coimbra e Aveiro (2020).
15. Ferraz, A.; Faria J., 'Museus em Tomar no século das intenções', *Boletim Cultural da Câmara Municipal de Tomar* **24** (2005) 150-160.
16. 'The Nizhny Tagil charter for the industrial heritage', in *The International Committee for the Conservation of the Industrial Heritage* (2003), https://ticcih.org/about/charter/ (accessed 2023-01-19).
17. Correia, M., *Reabilitação da antiga fábrica da Companhia Nacional de Fiação e Tecidos de Torres Novas*, Master dissertation, Departament of Architecture, Universidade de Coimbra, Coimbra (2016).
18. Wicke, C., 'Introduction: industrial heritage and regional identities', in *Industrial heritage and regional identities*, eds. C. Wicke, S. Berger and J. Golombek, Routledge, London (2018) 1-12, https://doi.org/10.4324/9781315281179 (accessed 2023-01-19).
19. Benito del Pozo, P.; Alonso González, P., 'Industrial heritage and place identity in Spain: from monuments to landscapes', *The Geographical Review* **102**(4) (2012) 446-464, https://doi.org/10.1111/j.1931-0846.2012.00169.x.
20. Muños Viñas, S., *Teoría contemporánea de la Restauración*, Editorial Síntesis, Madrid (2003).
21. Tavares, C. G.; Leite, R., 'O projeto Picar o Ponto: Memórias orais de operários da Fábrica Robinson', *Midas – Museus e Estudos Interdisciplinares* **3** (2014), https://doi.org/10.4000/midas.531 (accessed 2023-01-19).
22. Nogueira, P. R., 'Mulheres de fábrica: história da feminização da indústria têxtil em Guimarães', *Boletim de Trabalhos Históricos* **19** (2020) 47-127, https://www.amap.pt/r/article/bth-2020-3 (accessed 2023-01-19).
23. Há Trabalhos na Fábrica - Tomar, https://trabalhosnafabrica.wordpress.com/ (accessed 2023-01-19).
24. Chasqueira, Â.; Triães, R.; Barbosa, R., 'How to preserve industrial heritage - the memory and significance', in *(In)tangible heritage(s): a conference on design, culture and technology – past, present, and future*, ed. H. Griffin, AMPS Proceedings Series 29.1, University of Kent, Canterbury (2022) 479-487, https://amps-research.com/wp-content/uploads/2023/04/Amps-Proceedings-Series_29.1.pdf.

25. Chasqueira, Â.; Ferraz, Â.; Triães, R., "Memories builder': A contribution to the sustainable preservation of industrial heritage', in *Actas del IX Seminario – Tensión sostenible El patrimonio en la transición energética*, Aula de Formación: Gestión e Intervención en el Patrimonio Arquitectónico e Industrial, Madrid (2022) 95-112, http://gipai.aq.upm.es/index.php/actas-del-ix-seminario-tension-sostenible/.
26. Guillaume, M., *A política do património*, Translated by J. Caspurro, Campo das Letras, Porto (2003).
27. Folgado, D., 'Património industrial. Que memória?', in *Conservar Para Quê*, 8ª Mesa-redonda de Primavera, coord. V. O. Jorge, FLUP, DCTP, CEAUC, Porto e Coimbra (2005) 355-366.
28. Choay, F., *Alegoria do património*, Translated by T. Castro, Edições 70, Lisboa (2008).

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CONSERVAR PATRIMÓNIO

Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
NOTE / NOTA

Is historic working machinery up to 21st century sustainability demands or are we stuck in time?

Os equipamentos históricos em funcionamento estão à altura das exigências de sustentabilidade do século XXI ou estamos parados no tempo?

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Abstract

The Science and Industry Museum have embarked on an ambitious decarbonisation project to become net zero by 2030. As part of this plan, the Power Hall Gallery (historic working engines) is undergoing a redevelopment to improve and conserve the historic listed building and run the engines more efficiently, cutting carbon emissions by 60 %. The historic engines pinpoint a pivotal moment in history; the birth of the steam engine, when fossil fuel ruled. In the 21st century we are looking for ways to be more sustainable. The Science and Industry Museum have been working with external specialists and researching more efficient ways of running the historic engines. Looking at adapting and applying a different approach to running the historic engines. Will they be able to withstand the change and adapt to 21st century demands? Can the Museum balance sustainability with the care and preservation of the historic collection?

KEYWORDS
Historic engines
Sustainability
Running
Decarbonisation
Gallery

Resumo

O Museu da Ciência e da Indústria iniciou um projeto de descarbonização para atingir zero emissões líquidas até 2030. A remodelação da Galeria *Power Hall* (motores históricos em funcionamento) faz parte deste projeto, para conservar o edifício histórico classificado e fazer funcionar os motores de forma mais eficiente, reduzindo as emissões de carbono em 60 %. As locomotivas históricas assinalam um momento crucial da história: o nascimento da máquina a vapor, quando os combustíveis fósseis dominavam. No século XXI, procuramos formas de nos tornarmos mais sustentáveis. O Museu da Ciência e da Indústria está a trabalhar com especialistas externos e a investigar formas de funcionamento dos motores histórico mais eficientes, procurando adaptar e aplicar uma abordagem diferente ao seu funcionamento. Serão estes motores capazes de resistir à mudança e adaptar-se às exigências do século XXI? Poderá o Museu equilibrar a sustentabilidade com o cuidado e a preservação da coleção histórica?

PALAVRAS-CHAVE
Motores históricos
Sustentabilidade
Operacionalidade
Descarbonização
Galeria

Introduction

This paper discusses the decarbonisation work that the Science and Industry Museum's Power Hall redevelopment is undergoing to create a more sustainable gallery not only in its environmental control for the collection, but in the running of the historic engines that once stood proud in the birthplace of the Industrial Revolution. Running on fossil fuels to power a city of production and manufacture, can this historic collection evolve to still tell their story of where they came from and inspire wonder and curiosity amongst visitors whilst running more sustainably to meet the twenty first century demands on them?

Becoming net zero

The Science Museum Group is on a journey to decarbonise all areas by reducing the carbon emissions from its operations, procurement, and supply chain, and using resources more efficiently, while still investing in and developing the estate in a sustainable way.

The Science Museum Group collection reflects the scientific innovations which have made the world we have today. Intrinsic to these stories is the impact of innovation on the natural world, in particular climate change.

Fast forward the historically important collection to the twenty first century, where the world has warmed by 1 °C since the birth of the industrial revolution when the collections were built and changed industry forever. The Science Museum Group's Sustainability Strategy has set a net zero target and pathway, underpinned by science-based absolute emission carbon reduction targets that are consistent with limiting warming to 1.5 °C above pre-industrial levels.

One of the many ways in which the Science Museum Group is linking decarbonisation with the collection, is by reviewing and changing how the historic working machinery in the Power Hall Gallery at the Science and Industry Museum, Manchester is powered and maintained.

Site history

The site of the Science and Industry Museum, Manchester is the site of the world's oldest surviving passenger railway, dating back to 1830, and comprises of a series of four historic listed buildings deemed to be of significant historical importance (Figure 1).

Today, the historic site tells the story of an industrial city in the North West of England and the museum collection is just as significant, representing a varied cross section of world class firsts in science, technology, innovation, and industry. Through this world class collection, the museum aims to tell authentic stories, encourage visitors to think big, encourage exploration in science and innovative technology, to grow science capital, and to reveal the wonder.

Originally built in 1855 by the London & North Western Railway Company, the Power Hall Gallery was a former Shipping Shed for the purpose of processing goods and it was further developed in 1881 with the external gantry crane, also Grade 2 listed (Figure 2 and Figure 3).

In 1980 the London & North Western Railway Company sold the site to Manchester City Council and restoration of the building began. The plan for the Power Hall Gallery was to install several large exhibits including steam, gas, diesel, and electric engines, as well as locomotives, all with a strong Manchester connection in their history. Many of the engines were installed in full working order and are still in running condition. They were selected to show the pivotal moment when steam engines were first created and how they changed the world and our relationship with fossil fuels forever.

Figure 1. Former Liverpool Road Station, Science and Industry Museum (source: Board of Trustees of the Science Museum, London).

Figure 2. Former Liverpool Road Station view of the Shipping Shed, Science and Industry Museum (source: Board of Trustees of the Science Museum, London).

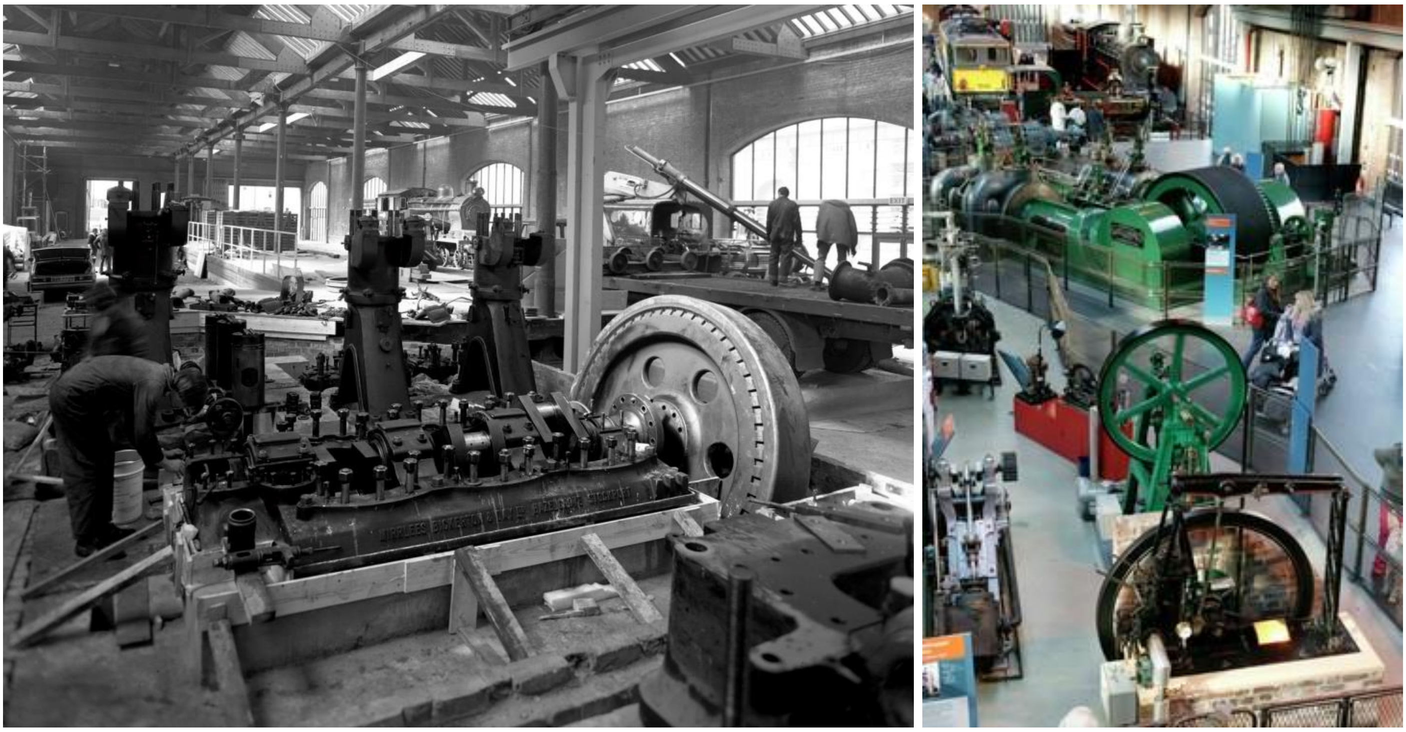

Figure 3. Former Liverpool Road Station: *a)* inside the former Shipping Shed during 1983 redevelopment; *b)* Science and Industry Museum, c. 2014 (source: Board of Trustees of the Science Museum, London).

In total there are 11 steam engines, six gas engines, four diesel engines, and two hot air engines, and the museum intends to make running the engines, and their fuel source, more sustainable in the future.

To set the scene, the gallery is an impressive testament to engineering and to the passion behind the people who have built and maintained these machines. There is a 1/3 scale model of a Newcomen engine, lovingly constructed by the museum founders and an 1830 colliery beam engine which towers over the gallery. At the core of the narrative of the Manchester engines are three large mill engines; the Durn Mill engine is the oldest and simplest, the Firgrove mill engine is a standard type used in the Manchester cotton industry, and the Galloways is the most advanced steam mill engine.

In the central compound there is a group of five small steam engines, which show a variety of shapes and types, all with different purposes; a double diagonal, A=frame, grasshopper, a very small engine with dynamo and an engine with generator set.

There is also a Ferranti vertical steam engine with alternator and fly wheel, rare in its arrangement. This demonstrates the overlap of steam engines for motive power with early electricity generation. This engine is going to be the testbed and pilot engine for the museum to run engines oil-free and use more sustainable products and methods.

Together, these machines showcase engine design and their development from the nineteenth century and have been a staple of the museum's collection, inspiring visitors with the sights, smells and sound of the historic working engines since the early 1980s. It is essential to keep the wonder running moving forward for future visitors, to keep the history alive (Figure 4).

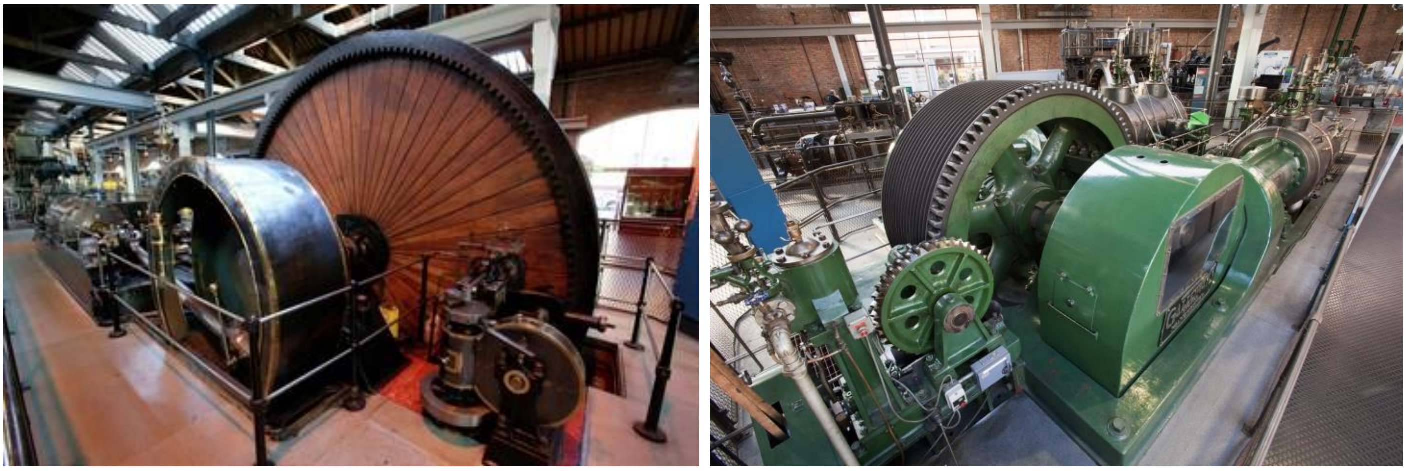

Figure 4. Firgrove Mill tandem compound condensing engine, made by J. & W. McNaught, Rochdale,1907 *(a)* and horizontal cross-compound condensing uniflow engine, made by Galloways Ltd, Manchester, for Elm Street Mill, Burnley, 1926, Science and Industry Museum *(b)* (source: Board of Trustees of the Science Museum, London).

Redevelopment

The Power Hall gallery has been under refurbishment since 2019. An opportunity to refresh the gallery and the narrative, with the idea to incorporate a more sustainable approach to energy efficiency, the materials used and how we operate the working historic machinery.

A new roof offering better insulation, and the addition of modern glazing with built in UV filters offering better thermal properties, with well-sealed new doors are all ways in which the gallery will improve environmental performance for the collection and reduce 515 tonnes of carbon emissions per year for the museum (the equivalent of 30 UK households).

The Science Museum Group's environmental control on gallery is based on the Bizot Green Protocol. For most classes of objects housed in the Power Hall Gallery, passive environmental control will suffice in offering a stable environment for the metal-based engines. Air conditioning and other high-energy mechanical ventilation are not required.

Powering the engines

To help accomplish the group's bid to be carbon neutral by 2033 and to provide power to the engines, technology such as the introduction of a ground source heat pump network across the site has been implemented. The existing steam infrastructure to run the machinery dates to the 1980's refurbishment and has been out of service since 2018. A whole new steam system is being installed to bring the engines back to life once more, but with a more energy efficient sustainable approach. The new boiler to power the engines is powered by electricity, removing the old inefficient gas boiler.

The new electric boiler will sit inside the gallery (the previous boiler was housed in its own building, hidden away) and fit the industrial appeal of the gallery with its own interpretation linking to the sustainability strategy.

Rather than using external heat dissipaters to condensate the returned steam from the engines (previously there were external cooling towers), a similar system will be installed internally on gallery which will use water from bore holes created for the heat pumps. Being located inside the gallery the heat dissipated by the condensing system will be used in the new gallery heating system.

Part of the sustainability plan is to run the steam engines on a closed-loop water system to reduce the amount of water being used and discharged to foul drainage. Even with filtration in place the water could not be returned successfully fully clean if oils were used for lubricating internal cylinders, pistons and valve gear.

Method

The use of wet steam to lubricate the historic working machinery internal moving parts that encounter steam under pressure was first suggested to the museum by external conservation consultant *Industrial Heritage Consultants*. IHC have a breadth of knowledge and experience working with engines, and notably with paddle steamers P.S Waverly and P.S Kingswear, where this is usual practice as fresh water is in short supply and the engines are required to run on a closed-loop system. External lubrication can still go-ahead but needs to be minimised as a tendency to over-oil comes with its own set of issues for the object. "In engines using saturated steam, the particles of moisture in the steam plus what cylinder oil enters the cylinders and steam chests of the piston rods and valve stems are generally sufficient lubrication for the piston rings and valves" [1].

Saturated steam occurs when liquid and gas phases of water exist simultaneously at a given temperature and pressure. The rate which water is vaporised is equal to the rate condensed.

This approach sparked an interest in the museum, and we have been looking into if this could successfully be translated to our historic mill engines. Are the different engines so different after all? The key benefits of wet steam lubrication are that this resolves the problem of oil contamination in the water and the subsequent damage to the systems boiler. Also, if steam condensate cannot be returned to the boiler because of the oil content, it would need to be discharged to foul drains instead, therefore increasing water consumption.

Research beyond working with IHC and looking at steam ship engines as models was broadened out. A nearby museum, Bolton Steam Museum, uses a hybrid model of running via external electrical power drive and the option to run on steam with very low oil consumption, not entirely oil free. Their decision is based on running time and costs versus resource and found that this model works best with no notable issues for the engines being created by the choice of operation.

My research and discussions also took me to a discussion seminar hosted by the *Big Stuff Network*, where I had reached out to the global community on the subject, this helped me to understand the science of engines and potential associated risks in the change of running.

This work is still in its infancy, and we are working with external specialists and Tribologist to see what is possible with either oil-free running or minimal oil/different lubricants such as natural products. We know that vertical engines (as a pose to horizontal operating ones) are similar to the diagonal engines of steam ships. There is less load applied to the cylinder walls and piston in the vertical position. So, this seems like the logical place to start. If the trial is successful, the museum will look to roll out trials on the horizontal engines. There is less load applied to the cylinder walls and piston in the vertical position.

The museum created a wish list for running the engines and their priority order, each engine was then assessed for suitability to run/made recommendations for running. For some of the engines this means a change in method of running. We are looking at a bold mixture of steam, externally run by electric drive, and a hybrid of the two, and the decommissioning of some engines to preserve them as they are.

The museum has the bold decision not to run any engines on diesel or gas, and to remove the fossil fuels from scope when the engines are brought back to working life. This will instead be replicated through an external electrical drive.

The first engine selected to move to oil free running or low oil/different lubrication is the S. Z de Ferranti inverted vertical cross-compound engine, made in Hollinwood 1900 (Figure 5).

Figure 5. Ferranti inverted vertical cross-compound engine, Science and Industry Museum (source: Board of Trustees of the Science Museum, London).

Now that we have a plan of action for each individual engine and know which engines are more suited to different methods of running, it is key to prevent any future damage. The first treatment is to apply colloidal graphite to the internal working, this is an embedded lubricant to reduce friction on moving parts and to act as a barrier to the moisture in the steam from settling on metal surface and causing internal corrosion.

Colloidal Graphite is a liquid suspension of graphitic carbon in either water or various organic solvents used as a conductive coating and an industrial lubricant. It creates a quick drying film that provides long-lasting lubrication. It's recommended as a general maintenance lubricant on moving parts like gaskets, transfer belts, rollers, wheels and gears.

The piston rings and pads will be replaced with a modern heat resistant material such as Polytetrafluoroethylene (PTFE). These will be fitted without intrusion and original parts (the parts removed as part of this work) will be documented and kept within the collection.

To measure the success of the proposed method of running, all engines will be condition reported and documented, measurements recorded to measure wear and photographs taken before work commences. All changes will be reviewed periodically, and this will act as a benchmarking exercise to monitor this trial.

After an agreed number of running hours, the engines will be reassessed. The museum will also document and compile daily activity such as logging start and stop times, warm-up times, hours run, oil consumption and any maintenance issues.

All this combined information will be the indicator of if this pilot of different running and changes to the engine's running life has been successful. If things work well, we will look to move on the next engine the following year.

Cultural preservation balanced with physical preservation

There is an argument to say that the atmosphere of the engines running is lost if not run in an authentic way, using the authentic fuels. The sights, the sounds, the smells are not quite the same. But the engines are already in a replicated environment of the museum, and run at slower speeds, rather than running at top speed in a Manchester cotton mill during the Industrial Revolution. Equally, none of the engines are housed in its original location; all the engines were brought to the Power Hall in the 1980s. The object output has already been changed from production performance to engagement performance.

Scholte discusses the experience of immersive art in a 2011 paper but translates to any kind of operating art or operating historic machinery in museums and galleries "as a spectator, one physically enters the space of the installation and undergoes a combination of sensory, aesthetic, and psychological experiences. Inside that space anything can happen: projections, machines making noises and motions, an accumulation of countless objects, smells or other sensations" [2].

The task of a conservator can be a tricky one, the balance of preserving original material with preserving the function and narrative of the object, ensuring the object history and the skills to operate is not lost. It is important to consider the whole history, not what is just in front of our eyes. When looking at changing materials such as the piston ring material and the way we approach running the engines, a large consideration has been what percentage of the object is original versus the replacement parts and the significance of those parts. Also understanding what knowledge and skills might be lost if engines were mothballed and the impact of this, we are using this balanced approach across Science Museum Group working machinery,

> *For both changeable artworks and machines, change is fundamental to understanding their meaning and to sustaining their social value. Preventing change in these objects causes immediate loss of the intangible experience of their movement and function, and in machines it also causes rapid loss of the intangible and embodied knowledge of how to maintain and operate the object, as well as the cultural practices based around the understanding and maintenance of the objects ability to change. This creates a dilemma for people caring for changeable objects; if the objects are not kept active, the intangible heritage that is a major part of their identity and significance will be lost. If they are kept active, however, their original components and material will become worn, requiring interventions such as restoration or replacements that are frequently identified as unprofessional conservation practice.* [3]

Conclusions

It is the responsibility of the heritage sector to preserve both the material of historical objects and the authenticity of the story it is charged with for future generations. The object and its story need to be considered in its entirety to reach successful conclusions and compromises. In the twenty first century this responsibility is further complicated by the responsibility of sustainability, which is everyone's task to try to slow global warming. This paper demonstrates how museums can strike the balance of preserving its national heritage along with responding to contemporary change and action that is needed. Museums are not just history; they can embrace new thinking and still preserve history successfully.

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REFERENCES

1. 'Liberty Ship Jeremiah O'Brien', in *Maritime Parks Association website* (2013). https://www.nps.gov/parkhistory/online_books/butowsky1/jeremiahobrien.htm (accessed 2022-04-22).
2. Scholte, T.; Wharton, G., *Inside installations: theory and practice in the care of complex artworks*, Amsterdam University Press, Amsterdam (2011).
3. Wain, A.; Sherring, A., 'Changeability, variability and malleability: sharing perspectives on the role of change in time-based art and utilitarian machinery conservation', *Studies in Conservation* **66**(8) (2021) 449-462, https://doi.org/10.1080/00393630.2020.1860672.

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Comparative assessment of paint systems for use on heritage artillery at coastal forts in England: experimental design and interim report

Avaliação comparativa de sistemas de pintura para artilharia histórica exposta em fortificações costeiras em Inglaterra: projeto experimental e relatório intercalar

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Abstract

This work aims to harmonise conservation practises for 20th century artillery housed in forts around the English coast by identifying a suitable protective coating for the nation-wide collection. Groups of analogue samples of five coating systems are undergoing 15 months of accelerated aging in the laboratory and three years real-time *in situ* exposure at two coastal sites in the UK. The impact of this on their chemical, physical, aesthetic and protective properties is being measured using pull-off tests, impact testing, colourimetry, FTIR, oxygen consumption and EIS. Results of the physical tests at three and six months accelerated aging and one year *in situ* exposure are reported in this paper. Based on set criteria and this data set, the Sherwin Williams 1 epoxy coating system is currently the best performing system.

KEYWORDS
Ferrous metals
Corrosion
Coatings
Conservation
Artillery
Analysis

Resumo

Este artigo visa uniformizar as práticas de conservação de artilharia do século XX exposta em fortes da costa inglesa, identificando um revestimento protetor adequado para a coleção nacional. Amostras com cinco sistemas de revestimento estão a ser envelhecidas artificialmente em laboratório, durante 15 meses, e naturalmente em dois locais costeiros do Reino Unido, durante três anos. O impacto do envelhecimento nas propriedades químicas, físicas, estéticas e de proteção dos revestimentos está a ser medido através de ensaios de adesão e de impacto, colorimetria, FTIR, consumo de oxigénio e EIS. O artigo considera os resultados dos ensaios físicos de três e seis meses de envelhecimento acelerado e de um ano de exposição *in situ*. Com base nos critérios estabelecidos e neste conjunto de dados, o sistema com melhor desempenho é o revestimento epoxídico Sherwin Williams 1.

PALAVRAS-CHAVE
Metais ferrosos
Corrosão
Revestimentos
Conservação
Artilharia
Análises

Introduction

The project aims to identify the most suitable coating system for the English Heritage collection of twentieth century artillery pieces exposed outdoors. Due to the proximity of these pieces to a coastline producing a C5M environment, as specified in ISO 12944 [1] (Table 1), the steel substrate is at significant risk of rapid corrosion [2]. Wet/dry cycles [3-4] and deposition of chloride ions create conditions ideal for formation of oxy-hydroxide corrosion products [2-4], preventing the formation of any protective patina [5] and favouring the chloride bearing corrosion product akageneite (β-FeOOH) [6] which drives further corrosion.

Developing a streamlined and efficient management system is essential for the care of a national collection comprised of large objects, situated in difficult to access locations along the full length of England's extensive coast line, A coating suitable for use across the whole collection must meet several requirements, including: 1) longevity; 2) retention of aesthetic properties; 3) damage resistance; 4) light resistance.

These characteristics are being investigated for selected coating systems during a programme of real-time and accelerated ageing to determine their suitability for use in the conservation of the collection.

Table 1. Categorisation of corrosion risk as a function of environment, as specified in ISO 12944 [1].

Category	Environment
C1 – Very Low	Environmentally controlled buildings
C2 – Low	Rural areas and non-environmentally controlled building
C3 – Medium	Average urban environment, or high humidity indoor environment
C4 – High	Industrial areas and medium salinity, indoor areas with liquids and high humidity
C5I – Very High (Industrial)	Industrial areas with high humidity, aggressive atmospheres, and constant condensation
C5M – Very High (Marine)	Inshore or offshore areas with high salinity or high condensation

Sample selection

A wide variety of coating systems are used in the conservation of metal objects, such as polysiloxanes, oil based paints, waxes, and fluoropolymers. Polysiloxanes ($[R_2SiO]_n$ where R is usually CH_3) would appear to be a good choice for a coating. They have greater resistance to the effects of ultraviolet (UV) radiation than organic polymers containing a carbon-carbon backbone, adhere well, resist abrasion, have good chemical and corrosion resistance, and do not pick up dirt easily [7]. Epoxy polysiloxanes are used as topcoats due to their hydrophobicity and are recommended for potential use over primers in marine environments [8]. Despite having stronger physical properties than many other coating systems, they become brittle with age and damage is not easily repaired, often requiring retreatment of larger areas [7]. Fluoropolymers influence surface energy to produce water repellent coatings, being difficult to apply and to repair means limits their use in marine environments. Oils and waxes are easy to apply, easily damaged and readily repaired but have aesthetic disadvantages, collect dirt, are temperature sensitive and unsuitable for public display where physical interaction might be expected.

Five systems were selected for testing (Table 2), based on a combination of manufacturer and conservator recommendations for the marine environment, as well as compliance with industrial standard ISO 12944 [1]. Four systems follow the industry standard of a high build zinc primer, a micaceous iron oxide (MIO) mid-layer bound by epoxy, and a polyurethane topcoat. A fifth system differed in being alkyd-based and was chosen due to its similarity to systems currently used on wrought iron cannons. Due to the length of time before the best performing system(s) will be introduced into practice following this experimental study, it was important to select products that are commercially viable and ongoing, hence established and currently available brands and systems were given preference over newer or more experimental systems.

Table 2. Coating systems used in this experimental study.

System name	Primer	Mid layer	Top layer
Sherwin Williams #1 (SW1)	Macropoxy L425	Macropoxy K267	Acrolon 7300
Sherwin Williams #2 (SW2)	Macropoxy C400	Macropoxy M905	Acrolon C237
Hempel (H)	Hempadur Avantguard 750	Hempadur Multi-500	Hempathane HS 55610
International (I)	Interzinc 52	Intergard 475HS	Interthane 990
Cromadex (C)	Cromadex 395	N/A	Cromadex 233

Sample preparation

The samples for the experiment were made from cold rolled mild steel, 2.5 mm in thickness, cut to the required sizes with a metal guillotine. The surfaces were prepared to a standard of Sa 2.5 [9], using grade 3 aluminium oxide (53-micron particle size) applied with a Texas Instrument Model AJ-1 abrasive machine. They were then placed in a sealed plastic box containing desiccated silica gel (3 % Relative Humidity – RH) prior to being coated.
The coatings were spray-coated by a contractor commonly used by English Heritage. A 2.5 mm hole was drilled in one corner to allow the samples to be suspended during coating. Cromadex was applied with a gravity fed pot using a B.E.N. Patents Ltd spray with a 1.3 mm jet size and polyurethane systems were applied with a Devilbliss GTI spray with a 1.8 mm nozzle from a Binks pressure pot, using manufacturer application guidelines.

Real-time weathering

Samples for real-time ageing (100 × 100 mm) were mounted in plastic u-shaped runners top and bottom within a custom-made rack angled at 30 degrees to the vertical. These were oriented southeast facing at two English Heritage coastal forts, Pendennis Castle in Cornwall and Dover Castle in Kent. The Pendennis Castle sample rack was 120 m from the sea at an elevation of 50 m and Dover Castle was 130 m from the sea at an elevation of 115 m. At each site, fifteen 100 × 100 mm samples of each coating system were mounted on the rack. Every 12 months for 36 months, five 100 × 100 mm samples of each system were removed for analysis in the laboratory.

Accelerated aging

The accelerated ageing is ongoing and has been set up in a Binder KBF 240 climate chamber set at 60 °C (±0.5 °C) and 70 % RH (± 2 % RH) [10]. Using the Arrhenius equation as an approximate guide, this elevated temperature would increase ageing by a factor of 16 when compared to 20 °C [11], while providing an RH typical of the coastal environment in which it will be displayed. Light banks within the chamber e continuously supply UV of wavelength 370 nm, with intensity of 0.5 mW/cm^2. Wavelength was recorded using a Konica Minolta CL-500A, and intensity was measured using a RTR 574H datalogger. This arrangement is limited in terms of alignment with in-situ performance of the coating systems, as exposure at coastal sites will involve variable RH, wet/dry cycles and a less UV intense light range. Accelerated ageing will therefore offer a worst-case scenario for UV exposure and may provide insight into how aged polymeric coatings perform.

Thirty samples 100 × 100 mm and 50 × 50 mm of each coating system were subjected to accelerated ageing. These were further divided into six groups of five for destructive testing at ageing intervals of 0, 3, 6, 9, 12, and 15 months. The 0 months sample set was tested unaged to act as a comparator. The remaining samples were removed after their respective ageing intervals and subjected to the appropriate experiments. A 40 × 40 mm sample set of all coatings was also included for the oxygen consumption tests. This was not destructively tested but was removed from ageing at the 0, 3, 6, 9, 12, and 15 months to record oxygen consumption values.

Data collection

The samples were exposed to a series of quantitative and qualitative tests to assess their performance (Table 3). This paper describes the methodology used for recording the thickness of the coatings and the changes in their colour, impact resistance and pull off values during the initial periods of in-situ exposure and accelerated ageing. Further reporting of data generated by these tests, along with descriptions of the methodology and full reporting of the Fourier-transform infrared spectroscopy (FTIR), Electrochemical Impedance Spectroscopy (EIS) and the oxygen consumption testing, will be provided in a later publication.

Testing involved either multiple samples or multiple test sites on one sample to offer a degree of statistical viability and to assess the value of averaging datasets. Where a single sample could provide more than one reading, data was recorded at the same locations on each sample to standardise data sets for comparison. The test sites were assigned Roman numerals, observing the sample as a square, site I is closest to the drill hole top left-hand corner, II top right-hand corner, III in the centre, IV bottom left-hand corner and V bottom right hand corner (Figure 1).

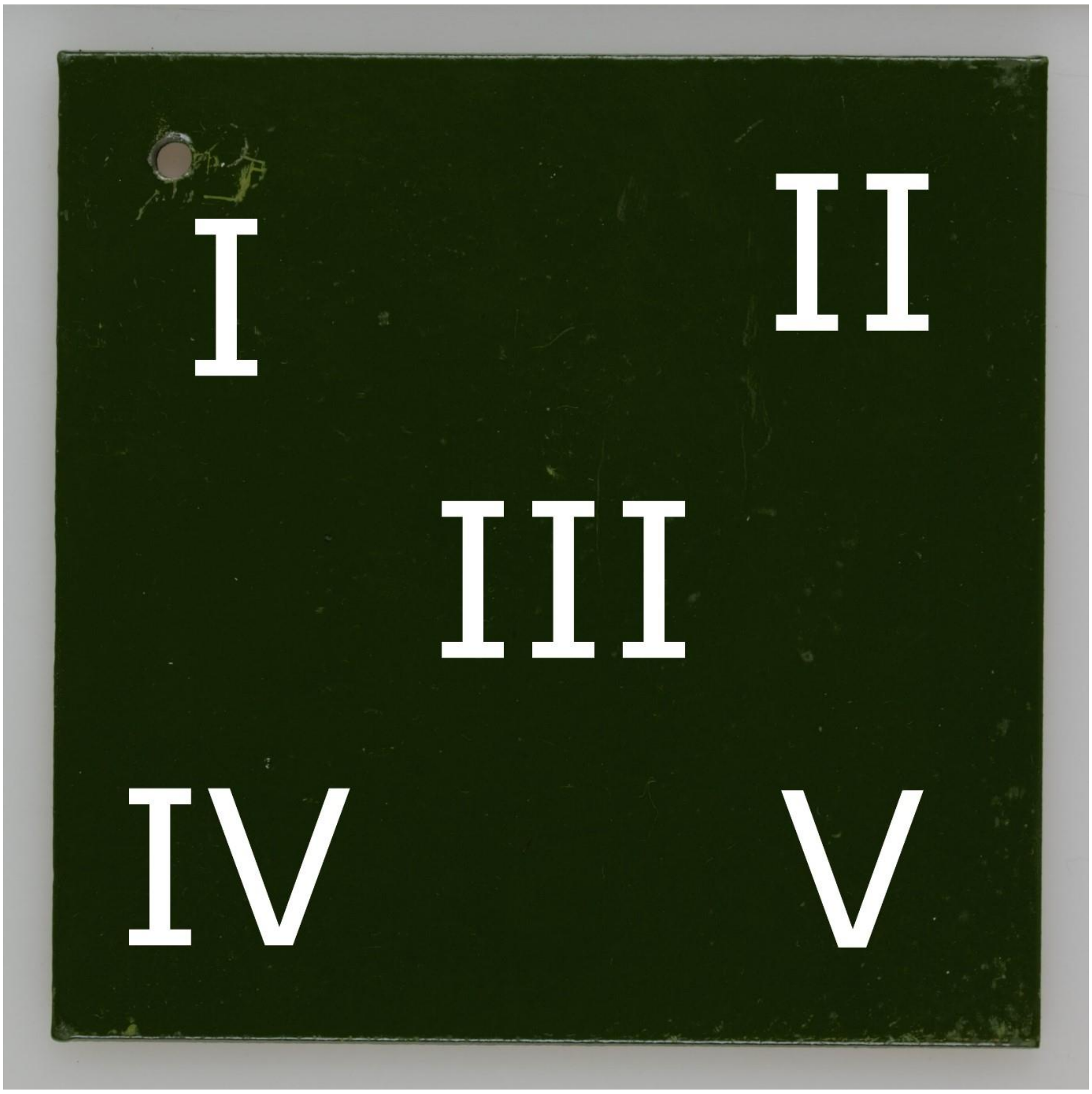

Figure 1. Standardisation of test areas on each sample.

Table 3. Test procedures, equipment, and data outputs.

Test or variable measured	Aging		Data and context
	In-situ	Laboratory	
Mass – Mettler Toledo XS205 balance (±0.005 g)	✓	✓	Variable required for oxygen consumption calculations
Colour – Konica Minolta Spectrophotometer CM-700d	✓	✓	Colour change as aesthetic
Dry Film Thickness – Positector 6000 FNS3 DTF meter	✓	✓	ISO 12944 thickness compliance for coating systems and changes to physical properties with aging
Gloss – Rhopoint IQ-S Gloss Meter	✓	✓	Aesthetic and textural change
FT-IR – Perkin Elmer Frontier 400 FT-IR	✓	✓	Chemical changes in topcoats
Pull off tests – PostiTest AT-A Automatic Adhesion Tester	✓	✓	Inter-coating adhesion and adhesion to substrate
EIS – PARSTAT3000 Single Channel Potentiostat/Galvanostat 30V, 1A, 7MHz	✓	✓	Assess reduction in corrosion protection with aging
Oxygen consumption – PreSens OXY-1 SMA; OXY-4 SMA	×	✓	Detecting metallic corrosion to identify degradation of coating
Impact tests – 301 DuPont Impact Tester	×	✓	Changes in physical properties of coating such as embrittlement or softening

Dry film thickness

Three readings were carried out at each of the five test sites, on both the front and reverse face of all 100 × 100 mm samples using a Positector 6000 FNS3 DTF meter, which was recalibrated using a flat steel plate prepared to Sa 2.5 after reading five samples.

Colour

The Konica Minolta CM-700d spectrophotometer with MAV 3 mm attachment was used to collect colour data on the front and back of the samples. It was calibrated to record five consecutive readings at a test site and determine their average. The results are recorded as values which represent different dimensions of colour. These are L* (lightness), a* (red/green), b* (yellow/blue), C* (Chroma), and h (hue), which are then used to calculate Spectral Component Excluded (SCE) and Spectral Component Included (SCI) data using the Equations 1 and 2.

$$SCE\ (E*) = \sqrt{L*^2 + a*^2 + b*^2} \qquad \text{(Equation 1)}$$

$$SCI\ (E*) = \sqrt{L*^2 + C*^2 + h^2} \qquad \text{(Equation 2)}$$

SCE is an accurate reading of pigment colour but SCI offers a more accurate representation of how the human eye perceives colour, including the effect of surface texture in its measurement. Therefore, SCI values provide a more accurate measurement of how colour changes produced by ageing would be perceived by a viewer. Five test sites were used on 100 × 100mm samples but only a single measurement from the centre was taken on the 50 × 50 mm samples due to the size of the spectrophotometer aperture.

Pull off tests

Pull off tests were carried out at the five test sites on each sample. The sample surface was roughened with 240 grain emery paper and an alloy dolly roughened with wire wool was adhered to a test site using a cyanoacrylate adhesive (Loctite). To promote adhesion, pressure was applied to the dollies by resting a flat plate of mass 650 g on top of all five dollies simultaneously for a minimum of one hour. The coating around the circular edge of the dolly was scored down to bare metal using the PosiTest tool supplied and the PosiTest was attached to the dolly. A pulling force was incrementally applied until the dolly released free from the surface. The value at which this occurred and the residue of coating attached to the dolly, which must be 50 % or more for the test result to be considered valid, were recorded.

Impact tests – accelerated ageing

Impact testing determined the minimum force required to damage to the coating system. A single sample from the group being tested was used to determine the calibrate the impact tester. This involved placing the impact hammer on the sample, raising a 300 g weight 100 mm above the hammer, then releasing it so it transferred its kinetic energy to the impact hammer and the sample beneath. This was repeated incrementally raising the height by 25 mm until the impact produced visible damage to the coating. This was used as the initial test height for the next sample in the group, which was impacted five times at the initial test height, five from a height 25 mm higher (the high-end test height), and five from a height 25 mm lower (the low-end test height). An inspection process then determined whether damage had occurred to the coating and according to the outcome, the hammer was raised or lowered to increase or decrease the impact force and detect the minimum height at which damage occurs. This process informs impact test procedure for the remaining samples in the test group. The mass of the weight and its height is used to calculate force, which is used for intra and inter sample comparison, pre and post aging.

Results and discussion

Initial dry film thickness

Comparing initial dry film thickness using the average at each of the measurement sites I to V across the samples reveals a consistent trend across all the systems. Sites I, and III are consistently the thickest, closely followed by V, with sites II and IV the thinnest. This effect is likely due to the samples being suspended from the drilled hole during spraying. Hanging the coupon from the hole in the top left-hand corner creates a rhombus shape, which vertically aligns test sites I (top), III (centre) and V (bottom) during spraying, with sites II and IV at the edges of the horizontal drawn through the centre of the coupon.

Figure 2 records the spread of thickness measurements as box plots with the mean thickness recorded as X on the plot. Comparing average thickness of the five coating systems identifies that International produces the thickest layer and Cromadex the thinnest by a significant margin. Considering both the average readings and the spread of data, the Hempel and Sherwin Williams 1 and 2 systems return similar thicknesses. All coatings produce inconsistent thickness. Identifying the highest value recorded in a fourth quartile and the lowest in a first quartile for each coating system, indicates the thickest coatings have the greatest range. Representing these ranges as a percentage of the maximum thickness value recorded in a fourth quartile, reveals Cromadex (63 %) has the greatest range with the other four coating systems being similar (48-56 %). Cromadex has the most outliers (17), closely followed by International (16), with Hempel having the fewest (2).

Considering thickness, Cromadex can be discounted as performing significantly worse than the other four coatings. International may be the better choice of coating system simply because although its thickness varies over a greater range, it has a significantly higher average thickness and, despite having a high number of outliers, even the thinnest outlier lies within the fourth interquartile of Sherwin Williams 2 system.

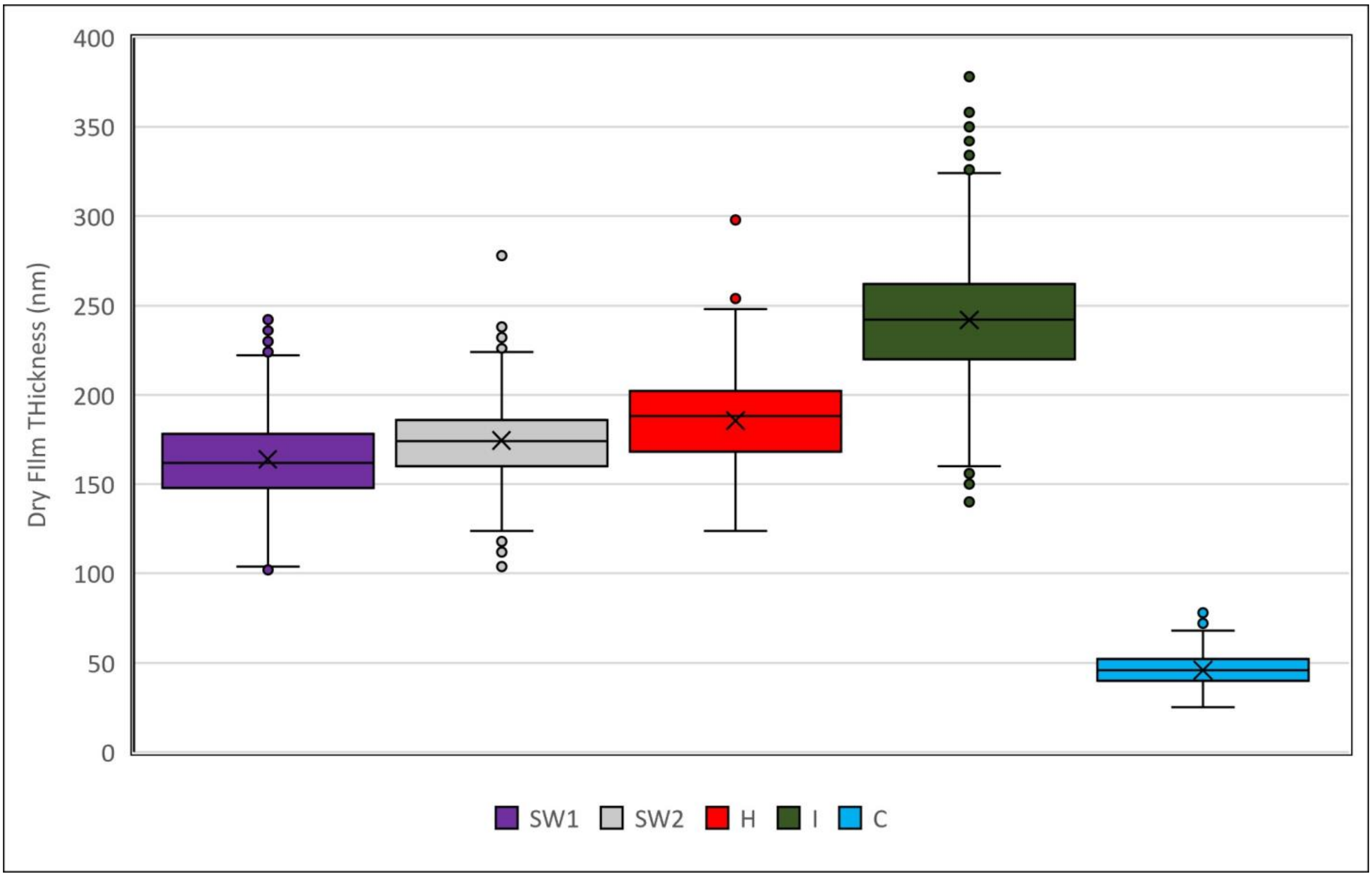

Figure 2. Dry film thickness of the five coatings. Box plots incorporate thickness readings taken from 60 (100 × 100 mm) samples of each coating at 5 measurement points (sites I to V) on each sample (total 300 measurement points per sample set).

The importance of the dry film thickness can be seen through the recommendations made by the manufacturers in their supporting documents. Almost all systems in a C5M environment are specified to be 320 nm thick [12-15]. The same or similar coating systems are recommended with reduced thickness requirements, typically 280 to 260 nm for less aggressive environments (C3 or C4 in Table 1), indicating systems are designed to withstand more aggressive environments by increasing their thickness, identifying this as an important characteristic. The failure of all these coating systems to reach the 320 nm specified for C5M environments that exist at Dover and Pendennis castles, may mean none are ideally suited to be used at those locations and are unlikely to reach their expected working life time. More quality control in application may be required, even when applying in accordance with manufacturers guidelines. Only International approaches C5M thickness (Figure 1) and Cromadex is far below it.

This data identifies the difficulty of obtaining consistent and even coverage over smooth flat surfaces hung vertically and sprayed in a standardised manner indoors. This will be compounded by the complex shape of the coastal artillery and the need to apply the coating in-situ for some pieces. Achieving manufacturer-specified thicknesses over the surface of a single piece of artillery is unlikely, hence longevity specifications may have limited meaning where thickness is one of the major controlling variables. This immediately makes definitive recommendations on performance, generated by any experimental study, difficult to provide for the English Heritage operational contexts.

Ranking the paints in terms of the resulting thickness of coating produced by following manufacturer instructions is difficult, as ranges overlap (Figure 1). International is the thickest but Sherwin Williams 1 and 2 and Hempel are all similar when the box plots are compared but Cromadex is the thinnest by far. Equal ranking was used for Sherwin Williams 1 and 2 and Hempel.

Ranking:

1. International
2. Sherwin Williams 2 + Sherwin Williams 1 + Hempel
3. Cromadex.

Colour change

SCI colour after ageing intervals is compared to the original colour reading of each individual sample before they were exposed to the ageing environment. It is considered that a change of 1.5 in the E value of SCI is visible to the naked eye [16]. Figure 3 records the change in ΔE values recorded at the specified test points on the accelerated ageing (3 and 6 months) and in-situ (1-year) samples, with the average ΔE recorded as X within the box plot.

Using average ΔE to compare the systems and considering the spread of data, the International coating system is the worst performer. It exceeds 1.5 ΔE by significant margins after in-situ exposure and accelerated ageing. The best overall performer is the Sherwin Williams 1 with all values below 1.0 ΔE except for two outliers within the accelerated ageing. Hempel and Sherwin Williams 1 were the best performing coating systems during in-situ ageing but Hempel exceeded 1.5 ΔE during accelerated ageing. Cromadex had a large spread of data but generally performed well in-situ. Sherwin Williams 2 performs poorly in-situ but well during accelerated ageing, which is the reverse of what is expected when extrapolating the accelerated ageing data. It indicates that short wavelength UV, elevated temperature and a damp 70 % RH are not the variables that cause it to change colour. Another variable such as time of wetness, pollutants such as salts or fluctuating or low temperatures may influence discolouration.

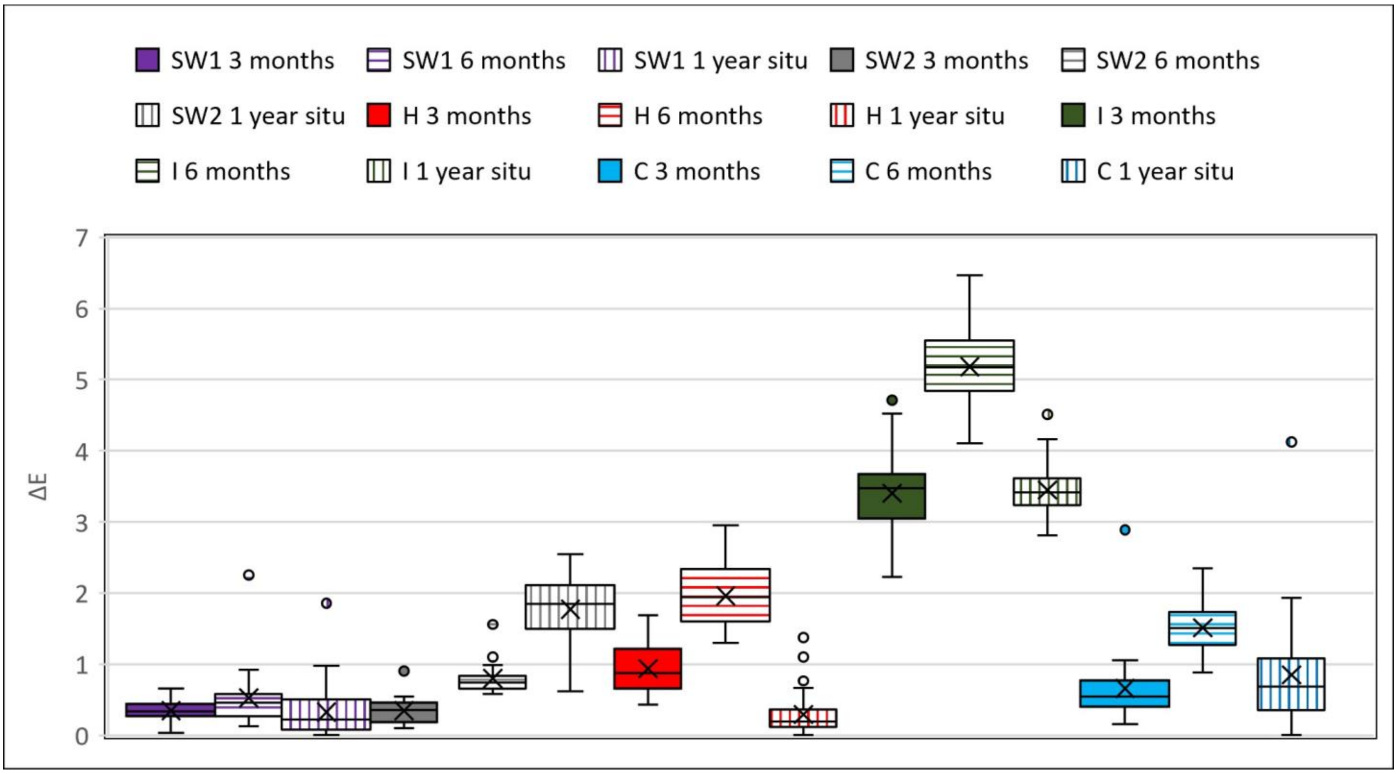

Figure 3. Box plots incorporating change in ΔE for accelerated aging (3 and 6 months) and 1 year in-situ recorded at five different points (sites I to V) on five (100 × 100 mm) sample coupons for each paint system (25 data points per box plot).

If this study was based only on accelerated ageing as a guide for choosing the coating likely to experience colour change in-situ, using data from this experimental study at this point in its progress, would favour choosing Sherwin Williams 1 closely followed by Sherwin Williams 2, which performed badly in-situ. Hempel would be rejected as exceeding ΔE 1.5 during accelerated ageing, yet it performed well in-situ. At present, accelerated ageing, as described here, is not providing suitable guidance for accurately identifying coatings resistant to colour change at coastal site environments in the UK. The importance of real time in-situ testing is evident when viewing this data. The coatings can be ranked for colour change on current data but with a further two years of testing ahead, new data may change this ranking (Table 4).

The results from pull off tests were returned in two forms: the force required to overcome the inter-coating adhesion of the system recorded in mega pascals for samples subjected to accelerated ageing (3 and 6 months) (Figure 4) and in-situ exposure (12 months) (Figure 5) and where the failure point in the coating system occurred (Table 5).

Table 4. Ranking of performance in colour change.

Ranking	In-situ 1 year	Accelerated ageing
1	Hempel	Sherwin Williams 1
2	Sherwin Williams 1	Sherwin Williams 2
3	Cromadex	Cromadex
4	Sherwin Williams 2	Hempel
5	International	International

Table 5. Pull off failure points within the coating systems.

	Initial failure	3-month failure	6-month failure	1 year in-situ failure
SW1	Within topcoat	Within topcoat	Within topcoat	Within topcoat
SW2	Between mid and topcoat	Between mid and topcoat	Between mid and topcoat	Between mid and topcoat
H	Within topcoat	Within primer and mid coat	Within primer	Within topcoat
I	Within topcoat and mid coat	Within primer	Within primer	Within all layers and at primer and substrate interface
C	Within mid coat and primer	Within mid coat	Within mid coat	Within mid coat and primer

Sherwin Williams 1 was the best performing coating system in terms of exhibiting no change in its adhesive properties. Overlap in the spread of data at all test points for both accelerated and in-situ ageing indicated no significant change in adhesion occurred (Figure 3 and Figure 4). The average values also indicated this and the failure point within the coating system remains unchanged (Table 4). It did not have the highest average initial adhesion value (5.9 MPa) but it exceeded Sherwin Williams 2 (3.5 MPa) and Cromadex (4.1 MPa) and was not much lower than the Hempel (7.2 MPa) and International systems (7.7 MPa). However, its spread data was wide (7.6 to 3.3 MPa for the in-situ sample) making the actual initial adhesion value hard to forecast accurately.

The Sherwin Williams 2 system had the lowest initial adhesion (3.5 MPa) but it is likely that it retains this value, as the accelerated ageing readings at 3 months appeared to be anomalous, being skewed to exceed the initial unaged starting value (Figure 3). This may indicate changes after 3 months that are not producing effects after 6 months accelerated ageing or that the readings were either a misapplication of the measurement system or a user error. Impact testing revealed the hardness of this coating increased significantly after 3 months accelerated ageing but then reduced at 6 months (Figure 5), potentially indicating a property change at 3 months that is not lasting. The in-situ range after 12 months reflected initial starting values and returned a similar average (Figure 4). Failure points in the system remain unchanged (Table 4).

The International and Hempel systems had high initial adhesion averages (7.7 MPa and 7.2 MPa) which reduced rapidly with accelerated ageing and after 12 months in-situ (Figure 3 and Figure 4). Hempel had the worst adhesion of all coating systems after 6 months accelerated ageing. The failure point changes from the topcoat to the primer for both these systems after 6 months accelerated ageing, which aligns with the major loss of adhesion and signifies a change in coating morphology (Table 4). Cromadex has the weakest initial adhesion, which reduces significantly following both accelerated and in-situ ageing (Figure 4).

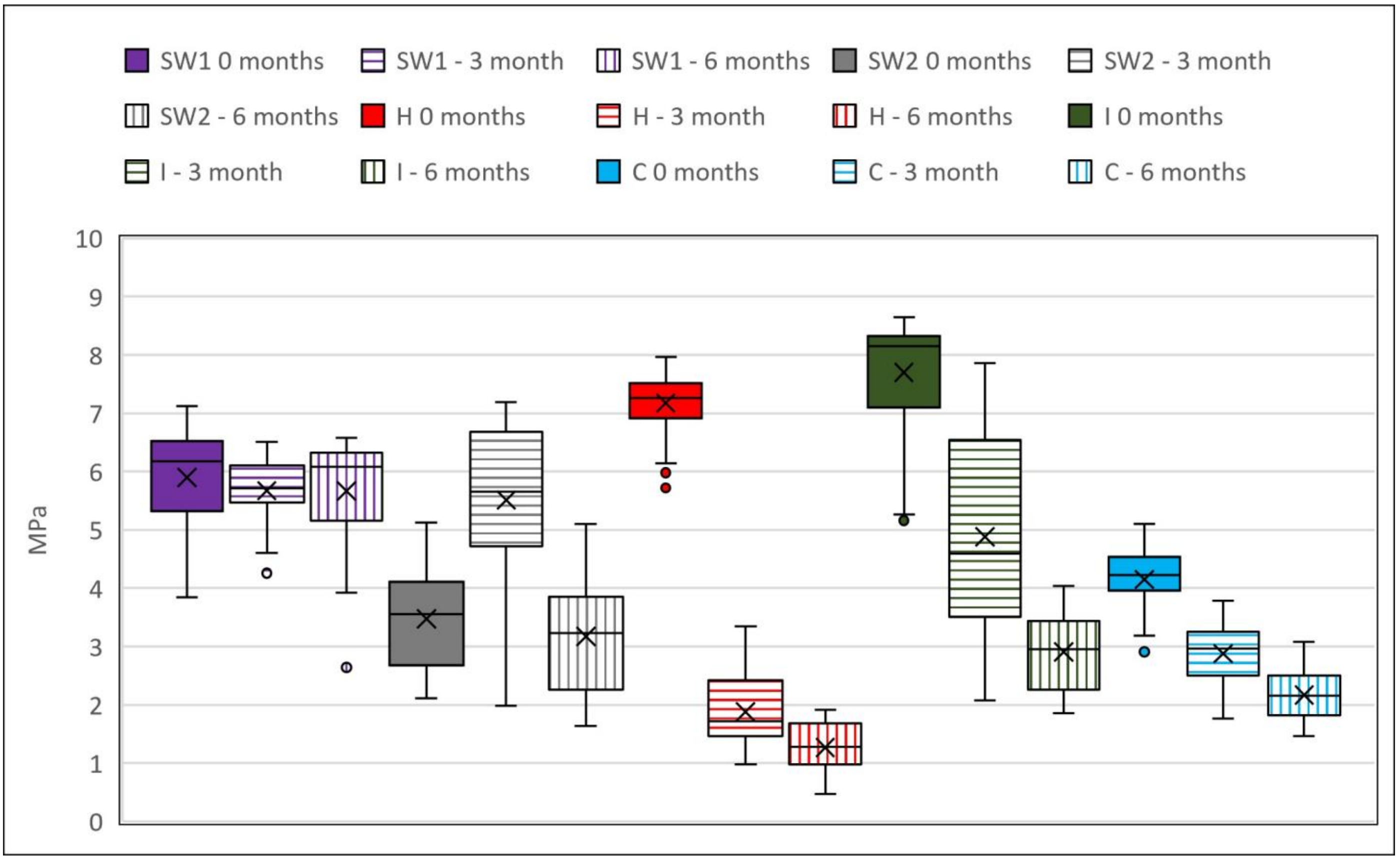

Figure 4. Box plot of pull off test data for samples subjected to accelerated aging (3 and 6 months). Five samples and five pull off values per sample.

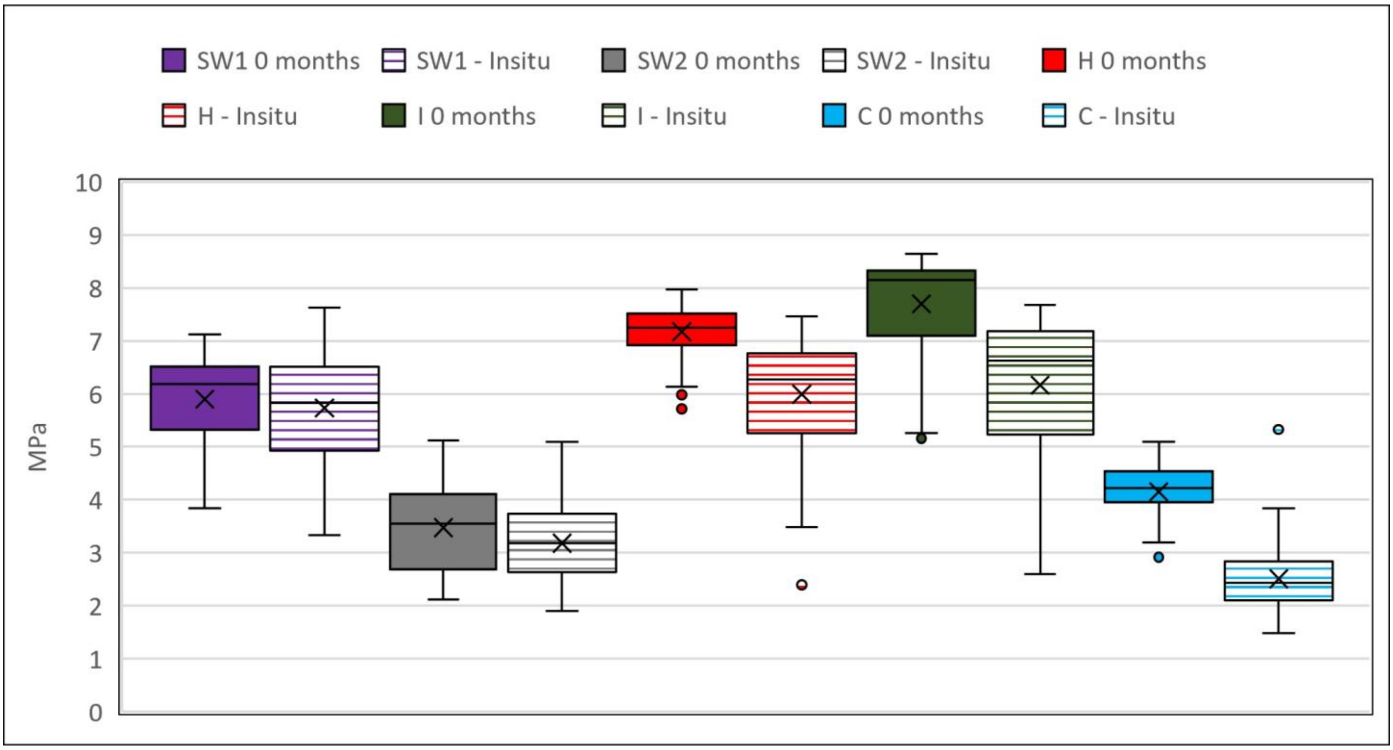

Figure 5. Box plot of pull off test data for samples exposed in-situ (1 year). Five samples and five pull off values per sample.

The retention of initial adhesion values by the Sherwin Williams systems during accelerated ageing and in-situ exposure under accelerated ageing indicate they are less prone to light and heat ageing than the other coating systems. Despite not having the best initial pull off values they remain unchanged, making their performance predictable and hence the coatings to choose. In contrast, the other coatings significantly degrade in light ageing and in-situ. Whether they reach values as low as Sherwin Williams 2 initial adhesion value remains to be seen. Even if this does not occur, the changes that caused adhesion loss and changes to the separation point in these systems likely make these coatings worse and unpredictable performers. All the coating systems recorded wide ranges within their data sets, making it difficult to offer a precise value for their adhesive ability but trends in adhesion are evident. Sherwin Williams 1 and 2 are good coating choices for retaining their initial adhesion to substrates in high UV environments. In this instance, accelerated ageing offers useful information on coating performance.

Ranking of retention of adhesive properties of coating systems: 1 – Sherwin Williams 1; 2 – Sherwin Williams 2; 3 – International; 4 – Cromadex; 5 – Hempel.

Impact test

The impact resistance of each coating system subjected to accelerated ageing is reported as average values of successful impact tests on four samples in each paint group (Figure 6), with the fifth sample determining the initial starting height for the test (Figure 6).

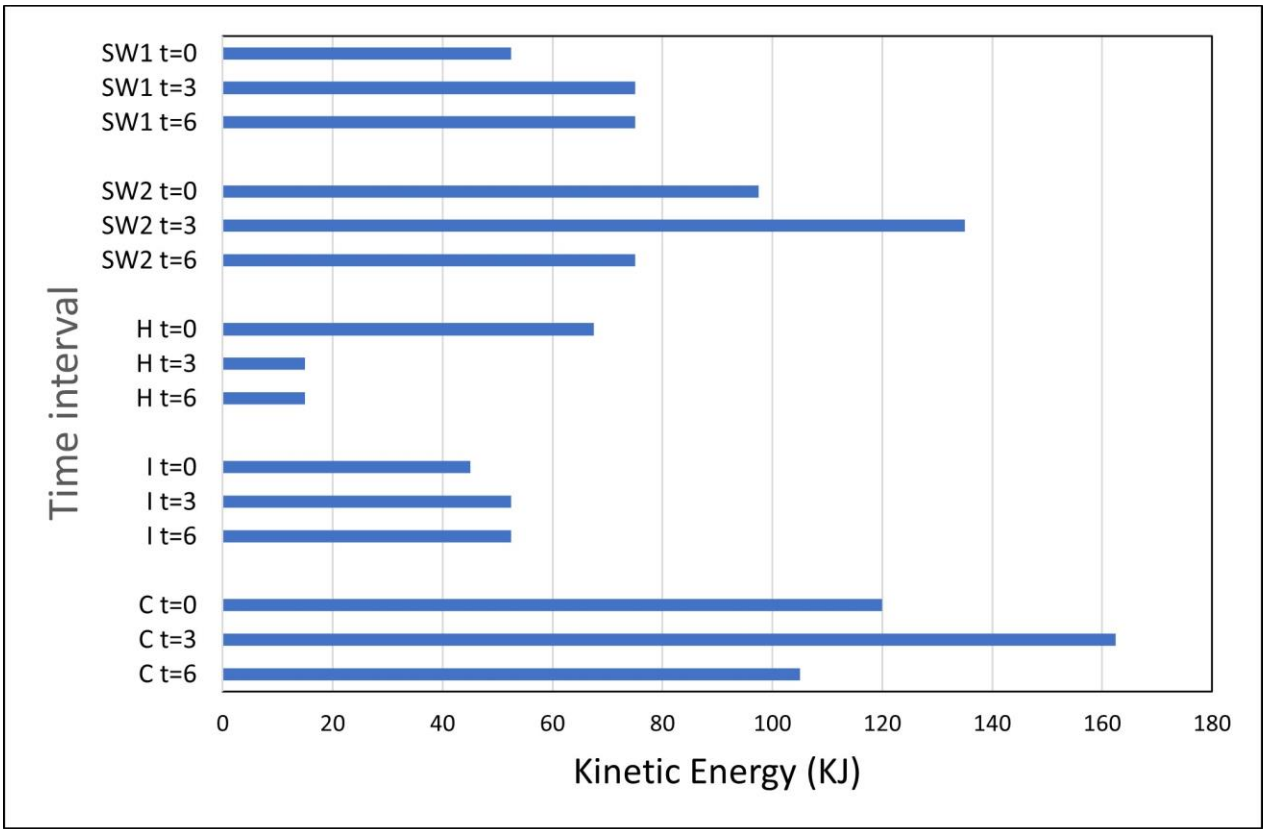

Figure 6. Bar chart showing the force required to compromise the surface of the coatings via impacts after aging periods.

Table 6. Ranking for performance in impact tests.

Ranking	In-situ 1 year	Accelerated ageing
1	Cromadex	Sherwin Williams 1
2	Sherwin Williams 2	International
3	Hempel	Cromadex
4	Sherwin Williams 1	Sherwin Williams 2
5	International	Hempel

Six months accelerated ageing significantly embrittled the Hempel system and Sherwin Williams 2 and Cromadex lost some resistance. At 3 months, all paint systems except Hempel either retained or increased their impact resistance beyond their unaged values. At 6 months, only Sherwin Williams 1 and International systems retained this value, both Sherwin Williams 2 and Cromadex fell below their initial starting value after 6 months ageing. Considering all the paint systems, Cromadex had the highest initial and 6 month impact values, although its degradation during ageing suggests that this is unlikely to persist after the full 15 months of exposure. Its high impact resistance may relate to its alkyd base, as the polyurethane topcoats on the other systems are often considered to be quite brittle, particularly after ageing [7]. Hempel was consistently damaged at the lowest force that the testing equipment would allow and its resistance to heat may be a problem since occasionally its surface blisters during accelerated ageing.

Ranking impact resistance of coatings is difficult. Is a coating with a low but unchanging impact resistance preferable to one with a much higher initial impact resistance value that diminishes with age? It may not resist damage sufficiently well to fulfil a long-term performance brief. A simple ranking is offered in Table 6 but with the above reservations.

General discussion

Tests are ongoing and so data reported here cannot provide a comprehensive view of coating performance and longevity. Discrepancies between in-situ and accelerated aging results indicate data interpretation will be complex and its extrapolation to context difficult. Will the current excellent performance of the Sherwin Williams coating systems in UV light and high temperatures translate to its performance in-situ?

Specific factors may carry more importance for the end user and will skew its importance in a ranking system. Decisions must be made on a contextual basis. For example, whether significantly better initial adhesion that reduces with time is preferred to a lower initial value that does not change over time. Colour change may not affect the degree of protection afforded by a coating, but it may be a critical priority for an end user who is prepared to sacrifice longevity for colour retention. Similarly, resistance to impact may be considered the number one requirement to avoid application of unsightly inpainting repairs that spoil the aesthetic of an object and to avoid the cost of frequent maintenance. With a differing balance of criteria, a coating system may become unfit for purpose before its protective ability is degraded to the point of requiring replacement. Stating which of the five coatings tested here is currently offering the 'best' performance relates to context, which is for English Heritage to decide.

Balancing the extent of failure within any one of these test procedures makes a holistic assessment of 'best performance' difficult, if not impossible and the extent of failure in a single category, may eliminate a coating as an option. Current data based on best performance in a specific test (listed at the close of the discussion of each test) indicates Sherwin Williams 1 as the best overall performer.

Conclusion

Data from real time in-situ testing and accelerated ageing, using short wavelength UV, 60 °C and 70 % RH to test selected properties of five coating systems identified the challenges of using accelerated ageing to predict the working environment. One coating system produced the best results in most of the tests and a ranking process identified it as the best overall performing coating based on film thickness, colour change, adhesion to substrate and resistance to impact. This was the Sherwin Williams 1 coating system.

The timeframe for testing is only one third completed and some tests are not reported here. The data here reports only physical properties. EIS and oxygen consumption will examine protective properties of the coatings and FTIR will explore chemical change. Increasing data may change the ranking of reported here. The final decision on the best coating to use on their coastal artillery lies with English Heritage, aided by this data set.

REFERENCES

1. BS EN ISO 12944-6:2018, *Paints and varnishes. Corrosion protection of steel structures by protective paint systems* (2020), https://www.iso.org/standard/51378.html (accessed 2023-08-19).
2. Alcántara, J.; de la Fuente, D.; Chico, B.; Simancas, J.; Díaz I.; Morcillo, M., 'Marine Atmospheric Corrosion of Carbon Steel: A Review', *Materials* **10**(4) (2017) 406, https://doi.org/10.3390/ma10040406.
3. Alcántara, J.; Chico, B.; Díaz, I.; de la Fuente, D.; Morcillo, M, 'Airborne chloride deposit and its effect on marine atmospheric corrosion of mild steel', *Corrosion Science* **97** (2015) 74–88, https://doi.org/10.1016/j.corsci.2015.04.015.
4. Asami, K.; Kikuchi, M., 'In-depth distribution of rusts on a plain carbon steel and weathering steels exposed to coastal–industrial atmosphere for 17 years', *Corrosion Science* **45** (2003) 2671-2688, https://doi.org/10.1016/S0010-938X(03)00070-2.
5. Chico, B.; Alcántara, J.; Pino, E.; Díaz I.; Simancas, J.; Torres-Pardo, A.; de la Fuente, D.; Jiménez, A.; Marco, J.; González-Calbet, J. M.; Morcillo, M., 'Rust exfoliation on carbon steels in chloride-rich atmospheres', *Corrosion Reviews* **33**(5) (2015) 263-282, https://doi.org/10.1515/corrrev-2015-0025.
6. Rémazeilles, C.; Refait, P., 'On the formation of β- FeOOH (akaganéite) in chloride-containing environments', *Corrosion Science* **49**(2) (2007) 844–857, https://doi.org/10.1016/j.corsci.2006.06.003.
7. Jarman, J.; Salvatin, J., *Comparison of Polyurethane and Polysiloxane coating systems in marine environments*, Bachelor dissertation, Department of material engineering, California polytechnic state University, San Luis Obispo (2013), https://digitalcommons.calpoly.edu/matesp/87/ (accessed 2023-06-24).
8. Arukalam, I.; Oguzie, E.; Li, Y., 'Nanostructured superhydrophobic Polysiloxane coating for high barrier and anti-corrosion application in marine environment', *Journal of colloid and interface science* **512** (2018) 674-685, https://doi.org/10.1016/j.jcis.2017.10.089.
9. BS EN ISO 8501-1:2007, *Preparation of steel substrates before application of paints and related products* (2007), https://www.iso.org/obp/ui/#iso:std:iso:8501:-1:ed-2:v1:en (accessed 2023-08-19).
10. Binder, Model KBG 240, Constant climate chamber with large temperature/humidity range, in *Technical data sheet* (2022), https://www.binder-world.com/uk-en/product/asset/180638?cHash=701d3078ba34b5ecc1edd17bcce81618 (accessed 2023-08-07).
11. Hemmerich, K. J., 'General ageing theory and simplified protocol for accelerated ageing of medical devices', *Medical Device and Diagnostic Industry Ind Qual Assur*, (1998), http://www.mddionline.com/article/general-aging-theory-and-simplified-protocol-accelerated-aging-medical-devices (accessed 2023-08-07).
12. International, ISO 12944, *Corrosion protection of steel structures by protective paint systems* (2019), https://international.brand.akzonobel.com/m/5f44067b30402a97/original/ISO12944_UK_LR.pdf (accessed 2023-08-07).
13. Sherwin Williams, *Iso 12944, Systems Guide 2020 edition*, online (2020), https://protectiveemea.sherwin-williams.com/Documents/InformationCentre/iso-12944_coatings-system-guide.pdf (accessed 2023-08-07).
14. Hempel, *How to select the right paint system: Guidelines for corrosion protection in accordance with ISO 12944*, online (2019), https://asset.source.thenbs.com/api/pdf/78cc1a4a-2ae7-4615-b787-7e29fa790a3f (accessed 2023-08-07).
15. *Steelkote by Baril*, Product brochure (2017), http://www.baril.cz/dokumenty_ostatni/17_1-01112017_SteelKote_Brochure_WEB_EN.pdf (accessed: 07/08/23).
16. Pretzel, B, 'Now you see it, now you don't: lighting decisions for the Ardabil carpet based on the probability of visual perception and rates of fading', in *Proceedings of ICOM-CC 15th Triennial Meeting*, vol. II, Allied Publishers, New Delhi (2008) 759-765, file:///C:/Users/CHAM/Downloads/ICOM-CC_2008_New%20Delhi_122.pdf (accessed 2023-06-24).

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CONSERVAR PATRIMÓNIO

Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
INTERVENTION / INTERVENÇÃO

Replacement of cast iron piers on an 1886 wrought iron truss bridge in New South Wales, Australia – the challenge of preserving heritage significance during major rehabilitation work

Substituição de pilares de ferro fundido numa ponte de treliça de ferro forjado de 1886 em New South Wales, Austrália – o desafio de preservar o significado do património em grandes obras de reabilitação

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Abstract

The Namoi River Road Bridge is a colonial era high level wrought iron lattice truss bridge crossing the Namoi River (Manilla) built in 1886 to replace a dangerous river crossing. The bridge was part of the main road between Sydney (New South Wales – NSW), and Brisbane (Queensland), with the opening of the bridge allowing wool trade from the northern extents of the colony of NSW to be exported via the Port of Sydney. The six approach spans crossing the southern flood plain have history of differential settlement due to ground conditions which has resulted in damage to five bridge piers and variations to the vertical alignment of the bridge. This paper describes the method employed to restore the vertical alignment of the bridge and replace the damaged piers whilst ensuring retention of the structure's cultural heritage significance, enabling the bridge to continue to operate as part of the NSW State Road network.

KEYWORDS
Bridge
Cast iron
Wrought iron
Pier replacement
Manilla NSW

Resumo

A ponte rodoviária do rio Namoi em Manilla, New South Wales (NSW), é uma ponte em treliça de ferro forjado da era colonial, construída em 1886 para substituir uma perigosa travessia do rio Namoi. A ponte fazia parte da estrada principal entre Sidney, (NSW) e Brisbane (Queensland) e a sua abertura permitiu que o comércio de lã da zona norte da colónia de NGS fosse exportado através do porto de Sidney. Os seis vãos de aproximação que atravessam a planície de inundação a sul têm um assentamento diferencial devido às condições do solo, resultando em danos em cinco pilares e em variações no alinhamento vertical da ponte. Este artigo descreve o método utilizado para restaurar o alinhamento vertical da ponte e substituir os pilares danificados, assegurando simultaneamente a preservação da importância cultural da estrutura, e o funcionamento da ponte como parte da rede rodoviária estatal de NSW.

PALAVRAS-CHAVE
Ponte
Ferro fundido
Ferro forjado
Substituição de pilares
Manilla New South Wales

Introduction

The Namoi River Road Bridge at Manilla in New South Wales (NSW) is a rare and State significant heritage wrought iron lattice truss road bridge designed by the eminent colonial bridge engineer John A McDonald. The bridge represented a significant engineering achievement and financial investment for the Colony of NSW at a time when the vast majority of road and rail bridges were constructed from timber. The bridge has previously been assessed as being of State heritage significance, the highest level of significance afforded under NSW heritage legislation.

The bridge is a large, high-level crossing over a wide river with a severe flood regime. It is an 11-span lattice truss structure with five main spans and six approach spans supported on cast iron piers. The five approach span piers have a history of settlement, with routine bridge inspections recording general differential settlement and pier rotation and cracking at the cross-braced connections between the pier cylinders since 1949. A bridge load performance test undertaken in 2017 found that the pier foundations were insufficiently firm, that there was settlement-related cracking in the pier columns and the diagonal braces on all the approach span piers and that some structural steel members were unduly loaded because of differential settlement. The differential vertical settlement also resulted in variations to the alignment of the approach span undertrusses and an uneven ride on the bridge deck. It was recommended that Piers 1 to 5 be underpinned to prevent further settlement, that the original vertical alignment of the piers be restored and that all damaged pier elements be repaired or replaced. The construction of new pier foundations was successful, however given the extent of cracking observed in the pier columns whilst attempting to restore the vertical alignment, a decision was made to fully replace the damaged piers.

This paper explores how the need to repair the bridge in order to maintain a vital piece of road infrastructure was balanced against the need to respect the heritage significance of the structure and to undertake the work in such a way that the bridge could continue to operate without load restrictions, halt the ongoing settlement of the piers and return the approach spans to their original alignment, and incorporate new elements into the structure without compromising its heritage significance

History of Namoi River Road Bridge

The Namoi River Road Bridge is located at Manilla, a small town with a population of 2,500 people located in northern NSW, 460 km north-west of Sydney. In 1886 when the bridge was constructed Manilla was on the main inland road route from northern NSW to Queensland. At the time, Queensland was a separate British colony and wool was a valuable export commodity. The lack of a bridge over the often deep and fast flowing river at Manilla meant wool grown in northern NSW was sent to Queensland for export, resulting in loss of revenue for NSW.

Most colonial-era road and rail bridges in NSW were constructed from native hardwood timber - abundant and well suited to the construction of large and small bridges. Timber bridges could be built quicker and cheaper than those of iron as the NSW iron industry was in its infancy and unable to produce the quality and quantity of material needed for metal bridge construction, with structural iron needing to be imported from Britain or Belgium. The early metal bridges cost up to six times more per sq/m than an equivalent timber truss bridge and were only constructed on major roads. Of the 27 wrought iron lattice truss road bridges built in NSW between 1871 and 1893, 18 are still in use today [1].

During its construction a major newspaper reported that:

> *a contract has been taken by the firm of G. H. Royce and Co., of Sydney, for the erection of an iron lattice bridge over the Namoi River at the above-named township. Such bridge consists of some five main spans, each about 120 feet long, resting upon cylinders sunk*

into the rock to the number of ten, thus forming five piers for the main girders to be connected with and bolted down to. It is also composed of six spans of approach, each 60 feet long, also having large … cylinders for the formation of those piers, thus making a thorough and strongly constructed bridge for the requirements of the main Government road right through to the borders of Queensland. [2]

The Manilla Bridge is unique amongst all the wrought iron truss road bridges built in NSW in having all its spans, not just the main spans, of lattice construction, with all other bridges of this type having simpler and lighter approach spans of timber or iron beam construction. It is not documented why lattice spans were chosen for the approaches on this bridge however the use of trusses meant that each approach could achieve a longer span than if timber or iron beam options had been used. In February 1864 the township was destroyed by a large flood with loss of life due to both the sudden rise of the river and the fact it occurred at night [3]. It is thought that the designers of the bridge opted for longer spans, and therefore fewer piers, to reduce potential flood effects on the bridge, particularly the piers which are vulnerable to damage from flood debris (Figure 1 and Figure 2).

The bridge was still considered a significant achievement 50 years after its completion, in 1936 with an article in the local newspaper dedicated to it:

It is fifty years since the building was started of that huge work of steel that spans the Namoi at Manilla, known far and wide as the Manilla bridge. Work was commenced on the bridge in 1885 and it was completed and opened for traffic in 1886. During that fifty years the structure has withstood the floods that have swept down the Namoi and between its huge steel cylinders billions of tons of water has passed on its way to the ocean at Adelaide, via the network of the Western inland streams of this State. Despite this strain and the ravages of time not a bolt or a rivet has given way and the bridge stands today a monument to the engineering skill of its designers and to the contractor, whose faithful workmanship has been largely responsible for its success. As appearances go at the present time, there seems every likelihood that another 50 years hence will find this steel structure as stout and serviceable as it is to-day. [6]

Figure 1. The bridge at time of opening. Note that the approach spans are to the left side of this image after the main truss spans (Photo: NSW Department of Public Works).

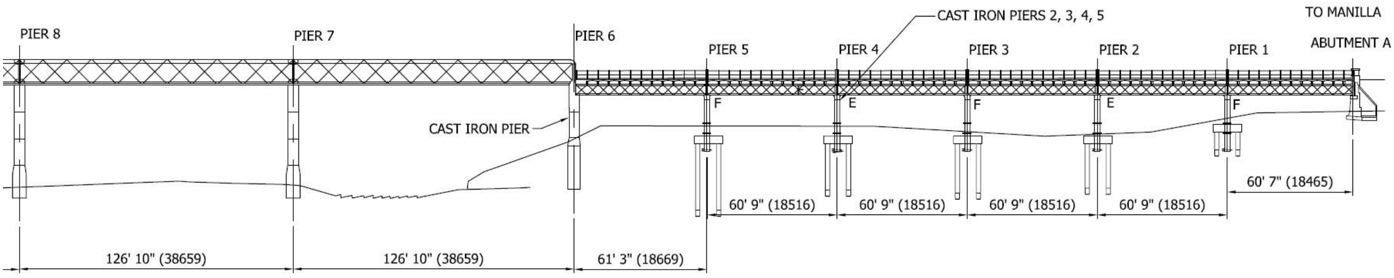

Figure 2. Original bridge configuration [5].

Figure 3. Buckled metal brace, Pier 1 (photo: C. Everett, 2017).

Maintenance records for the bridge only date back to 1949. A routine inspection of the bridge at that time reported settlement in Piers 1 to 4 and cracking at Piers 1 and 3. Repairs were suggested in the report but were never undertaken. Over the following decades inspection records reported distortion of the metal bracing (Figure 3) as well as additional cracks forming in the pier columns (Figure 4).

Figure 4. Crack in Pier 3 column (photo: C. Everett, 2017).

A bridge load performance test undertaken in July 2017 found the foundations of piers 1 and 2 were not sufficiently firm, which had resulted in differential settlement of those piers. The report concluded that if the differential settlement of the approach spans was not halted the settlement would continue and result in further damage to the piers and eventually damage the approach spans above. It was recommended that:

- Piers 1-5 be underpinned;
- Damaged braces and connections be repaired or replaced;
- All bearings on the approach span piers (1-5) be reset to level.

In 2020 new reinforced concrete foundations were installed under all the five approach span piers, with Piers 2-5 jacked and retained with a grouted shear key to restore the original approach span design levels. Additional cracks were identified in the columns of those piers during the jacking process.

It became apparent that these additional cracks as well as the cracks identified previously meant the piers were no longer strong enough to support the load of the spans above and that additional cracks were likely to form. An immediate load limit was applied on the bridge and temporary supports installed at each pier.

The challenge to restore a significant bridge

The bridge is a highly significant heritage structure as well as a major piece of road infrastructure. The approach span piers add to this significance due to their design, the substantial diameter of cast iron columns (760 mm) to support the wrought iron lattice trusses spanning 18.5 metres between piers. The piers and trusses are highly visible in the landscape, with the riverbank and floodplain adjacent the bridge used as a recreational campground. Further, this is a popular location for walking and picnics and recreational fishing.

Any option selected to remedy the cracks in the piers had to balance the operational requirements of the bridge with the need to retain its heritage significance. In developing these options and in selecting the preferred option, Transport for NSW (TfNSW), the owner of the bridge, needed to apply the principles of the Australia ICOMOS *Burra Charter*, which provides guidance to heritage practitioners and owners of heritage items when making decisions on the management of places of cultural heritage significance [4]. The principles considered when developing options included: 1) having respect for original fabric through changing as much as is necessary but as little as possible; 2) continued use of a heritage item where its function contributes toward its heritage significance.

The bridge had previously been assessed as being of State heritage significance. As part of the significance assessment the contribution of each component of the bridge to that significance had also been determined in accordance with the *NSW Heritage Manual* [7]. The approach span piers were determined to be of high heritage significance, while the wrought iron trusses, the defining feature of the bridge, were determined to be of exceptional significance. The determination of high heritage significance for the approach span piers was based on their aesthetic properties and unusual design, unique to this bridge. The understanding of what gave the piers their heritage significance as well as the contribution the piers made to the overall significance of the bridge was the starting point for developing a solution to either repair or replace the piers.

Non-destructive testing of the cast iron in the damaged piers was undertaken to see if the damage could be repaired. The testing found the cast iron was not weldable and thus repair of the damaged fabric was not possible.

As the damaged piers could not be repaired, four options were considered to address the cracking and allow the bridge to function free of the temporary support system. The options included iterations of individual element replacement through to full replacement of all pier columns and bracing. It was determined that full pier replacement would produce the best project outcome, noting that all other options, whilst retaining greater quantities of original fabric, would result in higher and avoidable permanent structural risk and would also not permit restoration of the bridge's original vertical alignment. Pier 1 was undamaged and did not require replacement.

As the damaged fabric could neither be retained nor replicated, one of the design criteria was for the form of the replacement piers to resemble the original piers to a large extent whilst also meeting current bridge design requirements. The high visibility of the piers in the landscape and the one remaining original pier adjacent meant that any major changes in form or detail would be visually jarring and negatively affect the overall aesthetics of the bridge. The replacement piers also needed to be designed in a manner that would enable them to be installed without damaging the temporary support system supporting the approach spans. TfNSW considered constructing the replacement piers from spheroidal graphite cast iron to provide consistency with the original pier fabric, however this material could not meet the structural requirements of the current Australian standard for bridge design hence the new piers were fabricated from steel [8].

Design

Temporary support system

Temporary supports were required to carry the bridge and traffic loads and allow the bridge to remain open to traffic until the pier replacement works could be completed. The temporary supports used a combination of proprietary modular components designed and verified by the supplier and custom fabricated sections.

Original piers vs new piers

The damaged piers comprised two vertical concrete filled cast iron columns connected by horizontal and vertical bracing. Each column comprised an upper segment and a lower segment connected with a bolted flange joint. Horizontal and diagonal bracing was secured to the columns via an oversized lug cast integral with the columns. The top of the upper segment connected to the approach span bearings, and the bottom of the lower segment connected to a cast iron screw pile approximately 150 mm above the buried concrete pile cap. The cast iron screw piles were the original bridge foundations; however, the new columns were to be attached to a reinforced concrete pile and pile cap arrangement to halt the differential settlement of the piers that had plagued the bridge since opening.

The permanent design needed to be completed in such a way that it met both structural and heritage criteria. This differed from a typical design process where the most efficient form is determined by engineering theory, whereas for this project the form was set by the original design and the designer needed to reverse-engineer the piers to ensure compliance with Australian Standards and TfNSW technical requirements.

The new piers were designed entirely out of new steel using a combination of off-the-shelf sections and custom milled sections. Many hours were spent analysing the minutia of the original details and resolving variations between the work as executed drawings and the piers as constructed to ensure that the replacement piers were faithful to the original design detailing. However, it was also important that the new piers could be identified as new and not just a replica of the original piers. Vertical weld seams on the columns and changes to the bearing guide plates are visible to the astute observer, and in the case of the guide plates, enabled changes to be made to facilitate maintenance of the bearings between the piers and the spans above.

The new columns were constructed from steel tubes with the same external diameter as the existing elements. The spacing between columns was retained and the new elements were custom colour matched to the existing bridge. The length of the upper column segment and the bolted flange joint arrangement between segments was also retained. However, the length of the lower segment was extended to allow the new columns to be connected directly to the reinforced concrete pile cap, thereby leaving the original cast iron screw piles structurally redundant.

The top of the original upper column section featured a top plate which was cast integral with the column. The plate included a large hole to permit installation of mass concrete into the column after erection. Above the top plate was a fixed plate with shoulders that acted as guides for movement of the trussed superstructure. This arrangement affixed directly to the undertruss bottom chord plate through bearing bolts. These plates were the same material and size at both the fixed bearing piers and the expansion bearing piers. The expansion bearing plates were slotted to facilitate movement. There were variations between the work as executed (WAE) drawings and site measurement of the extant piers in most of these elements, in which case the site measurements were considered original as there was no evidence of prior modification to the bridge.

The original top plates were cast with the pier columns with a casting radius of 45 mm between the top plate and the column wall. The new top plates were machined from a single piece of 100 mm thick steel plate to allow this detail to be retained, with the arrangement then welded atop the new steel tube sections. The hole in the top plate was removed to allow the new column segments to be hermetically sealed to prevent internal corrosion.

The guide plate was replaced with a new steel plate with 40 mm thick shoulders to guide the articulation of the bottom chord. The expansion bearings require periodic maintenance to remove dirt, debris and install additional grease, so the shoulder section of each plate was made removable to allow better access (Figure 5).

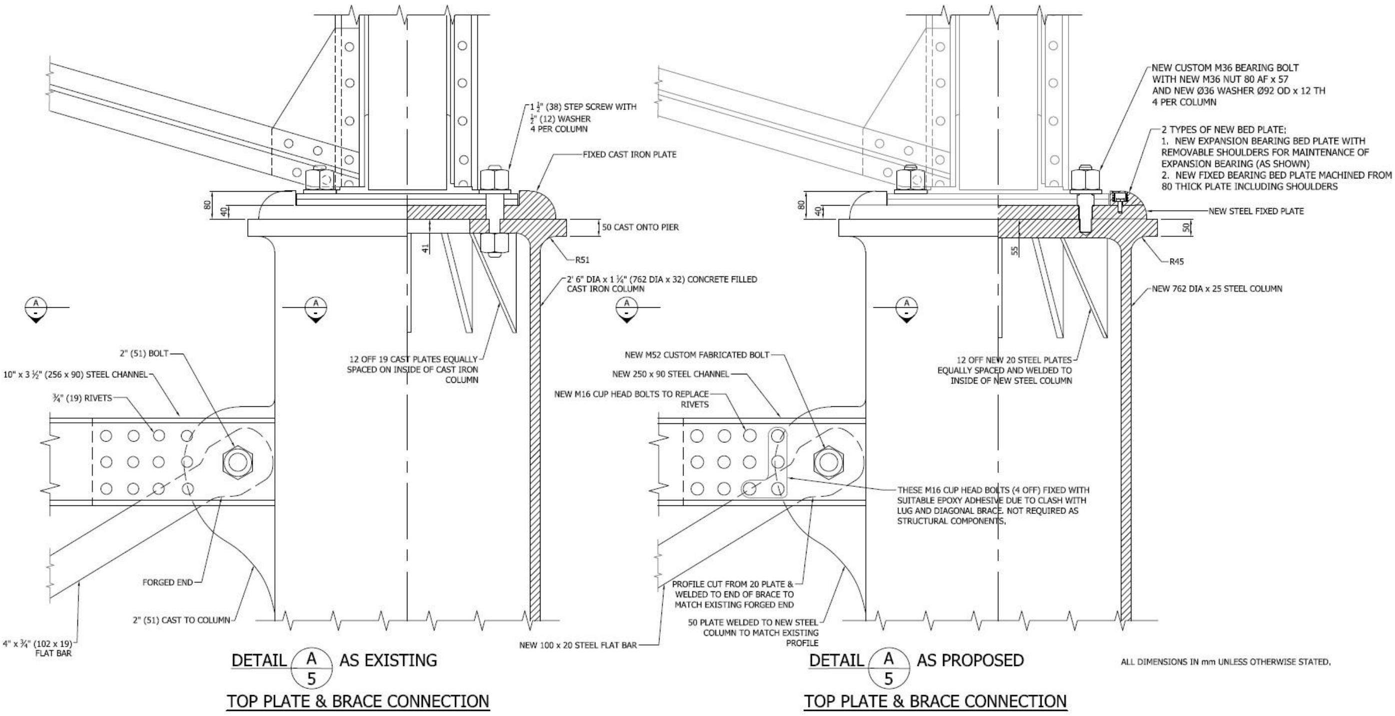

Figure 5. Comparison between original and new pier column top detailing [5].

No changes to overall bridge articulation were required. The existing bearing bolts, which secured the fixed or sliding plates at piers, were replaced with custom fabricated threaded stud bolts installed into threaded holes in the top plate of the column. The original wrought iron and gunmetal bearing plates affixed to the bottom chords of the under truss were in fair condition and were retained.

The original columns were braced with a combination of horizontal channel iron sections and diagonal steel plate bracing. All bracing elements were doubled and placed back-to-back and connected to the columns via a bolted cast iron lug affixed to the column section.

The horizontal braces ran directly between the lugs at the top and bottom of each upper column section and were held together by hex head bolts and an internal spacer tube. The diagonal braces ran diagonally between opposing lugs on each column. They consisted of steel plate for most of their length, however the final 8” (103 mm) was enlarged to connect to the column lug. These braces were significantly warped due to settlement of the bridge.

The horizontal bracing was replaced with the equivalent metric steel section (250 Parallel Flange Channel) and the diagonal bracing was machined from new steel plate to retain the geometrical features of the original elements. All bracing was connected to the new steel columns via new fabricated steel lugs and custom bolts used for connections to replicate original detailing. The new lugs were constructed from 50 mm steel plate and connected to the steel column via a large radius weld to provide visual similarity to the original casting process. The new pier columns replicated the above features to the greatest possible extent but on close inspection can be differentiated from the original design visible in the remaining original Pier 1 (Figure 6).

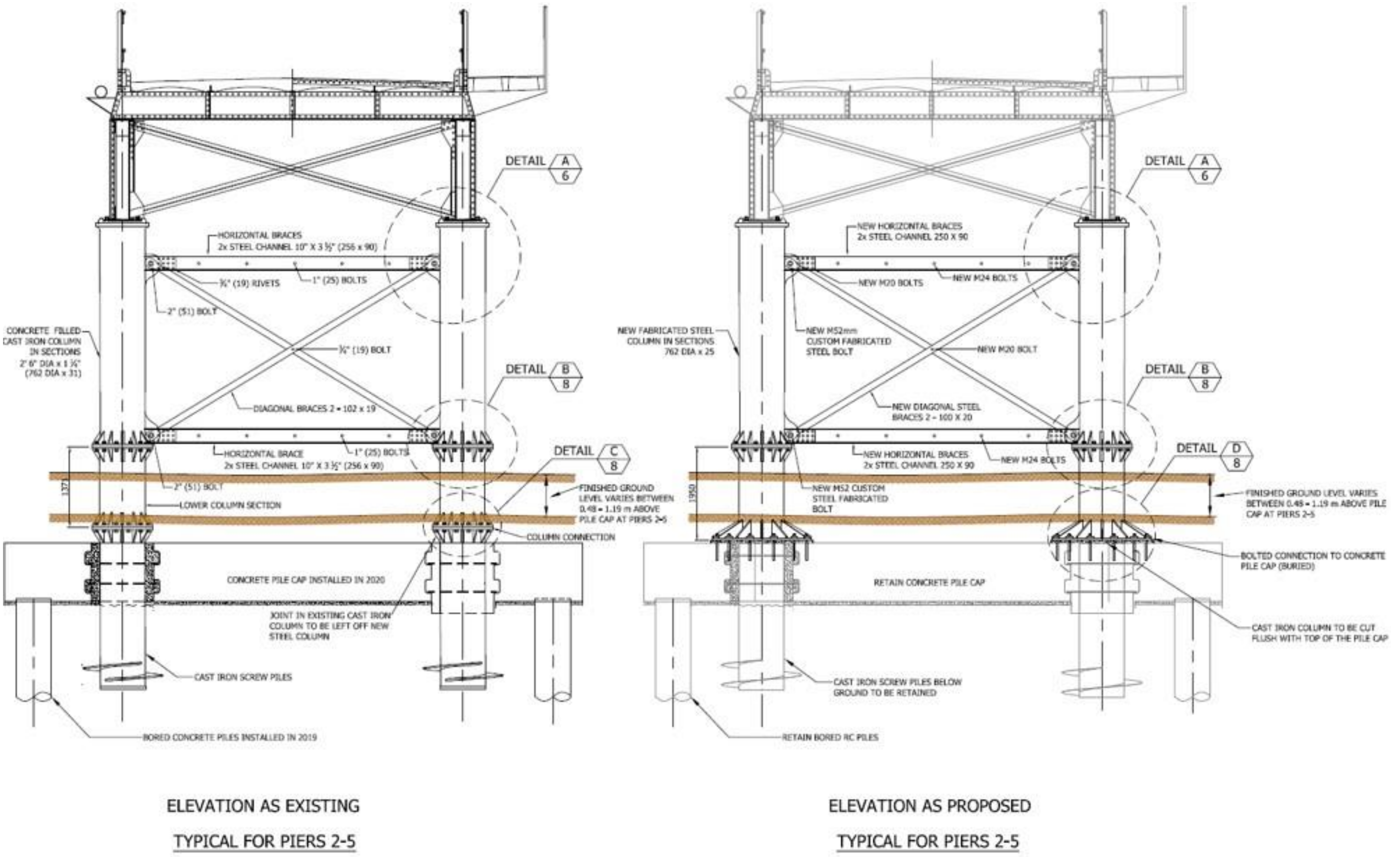

Figure 6. Design of original piers vs new [5].

Construction

Construction sequencing was generally well defined with a single critical path with mostly finish-start relationships. The high-level methodology was logically sequential, however the detailing and precision required within each construction step introduced an interesting level of complexity into the project.

The construction methodology was itemised into four main work fronts: 1) installation of temporary supports; 2) removal of the damaged piers; 3) jacking the bridge to the original vertical levels; 4) installation of the new steel piers.

Temporary supports

Temporary supports were installed to carry the bridge and traffic loads and allow the bridge to remain open to traffic until the pier replacement works could be completed. The temporary supports utilised a combination of proprietary modular components and custom fabricated sections which were delivered to site and assembled. The bridge was originally designed so the upper bearing plates attached to the undertruss bottom chord bore evenly on the lower bearing plates atop the pier columns. Synchronously linked jacks were used to create a 15 mm air gap between these two plates (the gap then being retained with inserted steel plates), thereby relieving the pier columns of their duty in supporting the bridge and associated live loads. The temporary support frames supported the truss at the first node in from the piers, with the introduced air gap then becoming a constructability constraint for the pier removal activities. This constraint required the columns to be separated into sections and for each section to be removed smoothly on a near horizontal plane.

Heavy vehicles were detoured around the bridge until the temporary supports were installed. Installation of the temporary support system was completed within two weeks of the cracking being discovered.

Removal of damaged piers

The columns in the piers were surrounded by the temporary support frames which provided horizontal working constraints, magnified by the concern the damage to the support frames during removal of the column sections may induce collapse of the bridge. The constraint required the pier sections to be removed in a consistent horizontal trajectory with minimal ability to make side-to-side adjustments during extraction.

These physical constraints resulted in diamond wire sawing being selected to separate the piers into three sections for removal. Steel bars were installed to provide fixity between the cast iron column wall and the mass concrete infill, after which each column was cut into three sections and extracted by either a 24 t excavator with a hydraulic grab or mobile crane (Figure 7), with the place selection based on the mass of each section and available working room.

Figure 7. Pier removal using mobile crane (photo: A. Rosnell, 2021).

Jacking the bridge to the original vertical levels

The temporary support frames incorporated two horizontally parallel steel beams to permit vertical jacking of the bridge superstructure to transfer bridge loading from the original piers to the temporary supports. With the damaged piers now removed, the same system was employed to incrementally jack and restore the bridge to its original design level to allow the new columns to be placed. Eight synchronously linked hydraulic jacks were installed to concurrently raise the bridge at each pier. Each lift was limited to 35 mm at a time, and sequenced across piers, to limit the translation or rotation of the superstructure at each end of the span. The bridge span was then resecured to the temporary support frame upon completion of each jacking operation. Traffic was detoured around the bridge during the jacking.

Installation of new steel piers

The new piers were installed under strict dimensional tolerances to ensure that they would perfectly mate with the existing bridge at its restored vertical alignment. The piers were fabricated off-site and installed using a mobile crane (Figure 8a). New chemical anchors were match-drilled into the reinforced concrete pile cap, with the finishing touches including grouting under the new column base plates and patch painting of all field connections. The bridge was then lowered onto the new column top plates using a reversal of the jacking operation, thereby rendering the new piers functional and allowing the temporary support system to be removed (Figure 8b).

Figure 8. Bridge: *a)* completed column; *b)* new piers in place (photos: A. Rosnell, 2021).

Conclusion

The bridge realignment and pier replacement was completed successfully, with the vertical alignment restored, temporary supports and load limits were removed. The authors consider this project to be the first documented example of replacement of colonial era cast iron piers on a road bridge with new steel piers without compromising the heritage value of the structure. The integration between physical engineering standards and non-tangible values is a fine example of multi-disciplinary coordination producing a superior community outcome.

The project has enabled a highly significant heritage bridge to remain in use on the NSW State road network for many years to come.

REFERENCES

1. Cardno, M. B. K., *Study of heritage significance of pre-1930 RTA controlled metal road bridges in NSW*, Roads and Traffic Authority, New South Wales (2001).
2. 'Manilla Bridge', *The Maitland Mercury and Hunter River General Advertiser*, 17 September 1885, 17 Sep 1885 - MANILLA. - Trove (nla.gov.au) (accessed 2023-08-18).
3. 'The Parliament', *The Armidale Express and New England General Advertiser*, 24 September 1859, 24 Sep 1859 - THE PARLIAMENT. - Trove (nla.gov.au) (accessed 2023-08-18).
4. 'After 50 years', *Manilla Express*, 2 July 1935, https://trove.nla.gov.au/newspaper/article/193860429?searchTerm=Manilla%20Bridge (accessed 2023-08-18).
5. CDE Design Solutions, *Bridge over Namoi River at Manilla Replacement of Piers 2 to 5 Heritage Drawings DS2021/000151*, Prepared for Transport for NSW (2021).
6. Australia ICOMOS, *The Burra charter: The Australia ICOMOS charter for places of cultural significance*, 2013, https://australia.icomos.org/wp-content/uploads/The-Burra-Charter-2013-Adopted-31.10.2013.pdf (accessed 2023-08-18).
7. NSW Heritage Office and Department of Urban Affairs and Planning, in *NSW Heritage Manual* (1996), https://www.environment.nsw.gov.au/research-and-publications/publications-search/assessing-heritage-significance (accessed 2023-08-18).
8. CDE Design Solutions, *Design Report Fossickers Way (Main Road 63) B3655 Bridge over Namoi River at Manilla Approach Span Pier Rehabilitation*, Prepared for Transport for NSW (2021).

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CONSERVAR PATRIMÓNIO
Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
INTERVENTION / INTERVENÇÃO

A study of timber frame repair and the case of Gunns Mill's old blast furnace

Um estudo sobre o restauro de estruturas de madeira e o caso do antigo alto-forno de Gunns Mill, Reino Unido

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Abstract

This article provides a critical summary of repair techniques employed for timber frame and an analysis of factors which might determine the adoption of a particular approach, in this case, a brief analysis at Gunns Mill. Gunns Mill is a remaining blast furnace from the 17th century, located in the Forest of Dean, which was the leading iron-making area in the UK since the medieval ages. The 18th-century half-timbered paper drying house endured, however, it is in a dilapidated state. The knowledge from the first part is applied to an aspect of the paper house and discussed approaches for its repair. Repairing does not only depend upon structural considerations, historic value and visual appearance influences, but also on the conservation philosophy adopted, which might restrict the range of options of repair.

KEYWORDS
Forest of Dean
Timber frame repair
Blast furnace
Gunns Mill
Buildings at risk

Resumo

Este artigo fornece um resumo crítico das técnicas de restauro empregues para estruturas de madeira e uma análise dos fatores que podem definir a adoção de uma determinada abordagem, neste caso, uma análise sobre Gunns Mill. Gunns Mill é um alto-forno remanescente do século XVII, localizado na Forest of Dean, que foi a principal área de produção de ferro no Reino Unido desde a Idade Média. A casa de secagem de papel meio-enxaimel do século XVIII sobreviveu, no entanto, encontra-se num estado degradado. O conhecimento na primeira parte é aplicado a um aspecto da casa de papel e são discutidas as abordagens para o seu restauro. O restauro não depende apenas das considerações estruturais, do valor histórico e do aspeto visual, mas também da filosofia de conservação adotada, que pode restringir as opções.

PALAVRAS-CHAVE
Forest of Dean
Restauro de estruturas de madeira
Alto-forno
Gunns Mill
Edifícios em risco

Introduction

A set of principles for historic building and timber frame conservation has been largely covered by the Society for the Protection of Ancient Buildings (SPAB) [1-2] as well as the ICOMOS International Wood Committee's document: *Principles for the Preservation of Historic Timber Structures* [3]. These principles emphasize repair over restoration, minimal and reversible intervention, and the use of traditional repair methods. The Burra Charter [4] also emphasizes the use of traditional materials and techniques, while acknowledging the potential for contemporary methods. To prevent or hinder decay without causing unnecessary damage to the historic fabric or altering the architectural or historical character of the building, Brereton and Pickard [5-6] suggest that repairs should be carried out.

A basic principle of repair for historic buildings is to understand the significance of a place to ensure that any proposed repairs will be beneficial and not harmful to its significance [7]. This article aims to consider Gunns Mill's paper drying house as a case study to the discussion of historic timber frame repair techniques. The text is divided in a critical study and repair techniques for timber frame and an analysis of factors that determine the adoption of a particular approach in a specific case study, and, secondly, the case study itself. The article will focus on the timber structure of the paper drying house, review its current state, then, apply understanding from the first part to be used as a reference to recommend an approach to be followed. It also includes background information on the study location and its historical significance.

Gunns Mill is a remaining blast furnace dating from 1625, situated 2.6 km North of Littledean, England [8-9]. The blast furnace was prominent in ironmaking in the United Kingdom, as this was the location which had more furnaces active. However, in 1740 the site was converted into a paper mill. The Former eighteenth-century timber charging house and half-timbered paper drying house impressively persisted, nonetheless, it is currently in a dilapidated state. Its importance as a historic building lies in both the typology and the relatively fair condition of the blast furnace itself.

In terms of methods of research, an extensive desktop study, literature review and documentary research were fundamental to write the first part of this article, and site visits, photographic and building surveys helped with the analysis of the case study.

According to Douglas Kent, technical secretary of the Society for the Protection of Ancient Buildings (SPAB), inappropriate maintenance or alterations are the main factors causing problems in historic timber buildings. These problems can be divided into two types: decay from beetle or fungal attack caused by dampness, and distortion from overloading or removal of frame members [1]. For this reason, this report will start discussing decay and infestation, its treatment, to later, considerations about assessing and surveying timberwork and repair techniques, weatherproofing and applied finishes.

As the first part of this article serves as the basis for the case study, it consists of a summary of types of decay and infestation most common. Due to space limitations, a detailed discussion of all possible types of beetle and fungi attacks is not included. The case study will cover Gunns Mill's background history and significance, a brief survey of the building, and focus on the half-timbered drying paper house to discuss possible repair methods for the south-east and west walls of the timber drying loft, while considering the advantages and drawbacks of intervening in a significant and historic structure. The proposed method will adhere to the conservation principles outlined in the first part of the report.

Decay and infestation

For centuries, timber structures and elements, including windows and doors, have been widely used in Britain for their structural and aesthetic properties, as well as being an energy-efficient and renewable resource [10]. The way timber was shaped or arranged can aid in dating historic buildings, as different types of joints, carpentry, and framework design evolved over time [11]. However, timber also has a biological role and can be a food source for organisms such as fungi or beetles, which can attack and decay the wood if certain environmental conditions are present (moisture content and temperature) [12-13]. The most common beetle responsible for timber decay is *Anobium Punctatum*, also known as woodworm. *Xestobium rufovillosum*, known as death watch beetle, *Lyctus* spp., powder post beetle, and *Hylotrapes Bajalus*, house longhorn beetle, are also commonly found in historic buildings.

Fungi decay is different, as it degrades wood into simple edible material, resulting in loss of weight and strength. Mainly, there are two types of fungal attacks: wet rot and dry rot [12]. In the past, chemicals and biocides were commonly used to treat infestations, but this approach only treated the symptoms and not the underlying cause. If the problem is solved by removing the source of dampness, then, the timber will dry, and further decay will not be likely to happen again if environmental factors are controlled. Consequently, chemicals are unnecessary [14].

Remedial treatments frequently involve loss of structural fabric or irreplaceable details on floors and ceilings. In addition, they are expensive, not sustainable, and unsafe for the specialists that apply it and inhabitants of the building. Accordingly, during the last century conservators realized that biocides are not the answer for all infestation problems. Environmental control and preventative maintenance are the best alternative, as they are less destructive, retain more historic timber, and align with principles of historic conservation [12].

Systematically surveying and assessing the timberwork using non-destructive techniques is also important, as well as effectively discovering the cause and extent of dampness. British Standards [15, pp.22-23], reinforce the importance of this approach, stating that chemical treatment is unnecessary, and the best approach is to keep timber dry. A specialist consultant or surveyor should conduct an examination to effectively discover the cause and extent of dampness. In buildings, moisture can increase through penetrating or rising damp, condensation, leakages, or from mortars, concrete, and plaster. It is crucial to reduce the moisture content of all timber to below 16-18 %, which is the desired level not to benefit organisms to multiply. To accomplish this, it is necessary to isolate the timber from damp masonry using a damp proof membrane, ensure adequate ventilation, and provide air movement around walls and roofs. Additionally, other sources of water should also be removed, such as poor rainwater goods, gutters, leaking plumbing, condensation and rising or penetrating damp [12]. By following these guidelines, the future health of historic buildings can be ensured while retaining their unique character and historical significance.

Woodboring beetles

Most of woodboring beetles have similar life cycles, they vary in type of time attacked and the extent and damage caused, which is what helps to identifying them. Correct identification is extremely important to avoid mistreatment, since they are all commonly divided in three groups regarding treatment required. The first category may need insecticidal treatment. If active: few insects require it. Structural survey is necessary. If inactive: do not require treatment. Insects may have died of natural causes or eaten by parasites (spiders); as regards the second group, treatment necessary to control allied fungus, some beetles feed on wood rotted by fungi. Therefore, to prevent it, controlling wood rot first should solve the issue. Finally, the third, which requires no treatment, if beetles attacked green timber, they are likely to have been killed during drying process of wood, so no treatment is needed. These insects do not require pesticides [16, p. 52].

***Anobium punctatum* (woodworm)**

The furniture beetle, also known as *Anobium punctatum*, has been a significant cause of damage to timber in Britain for over a century. According to Hutton "at least 50 per cent of buildings in the UK have had some prior infection and decay by *Anobium punctatum*" [17]. Woodworm often attacks scarcely ventilated structures and, these types of infections are easy to assess. If the moisture content of the timber is below 12 %, then it is too dry for infestation to occur. However, if the moisture content falls between 16-30 %, it is likely to occur. If this level of moisture is present in the sapwood, it is recommended to investigate whether the moisture is likely to continue for over two years, if this is the case, eggs may be able to fully develop, and treatment should be considered [17].

To determine necessary repairs for damaged historic buildings, experts must assess the extent of damage using non-destructive imaging methods such as X-rays. Repairs may involve replacement or scarfed new timber. Preventing future decay requires ensuring moisture content stays below 16 % for longer than a year. Signs of previous woodworm attacks should not be a major concern, but dust and tunnel appearance can indicate active infestation, if the tunnels are dark and dirty, the attack is likely to be historic. Conversely, if the tunnels are clean or light-coloured, the attack is likely to be recent or active [14].

Fungi infestation

In summary, there are two types of infestation caused by fungi which infest timber structures: dry rot and wet rot. Wet rot fungi thrive in consistently moist environments, with an ideal moisture content range of 50-60 %. Therefore, wood-rotting fungi differ in their optimum temperature, between 20-30 °C. In contrast, dry rot occurs in minimum moisture content in timbers of about 20 %. Optimum growth occurs at 30-40 %. Spore germination requires wood moisture content of 30 %. The optimum temperature for growth in building is about 23 °C, maximum temperature for continued growth about 25 °C and the fungus is killed above 40 °C [12].

Surveying timber and repair techniques

The deterioration of timber-framed buildings is not limited to biological decay and requires different repair techniques to address various causes. Some potential problems are caused by dampness and structural failures, such as overloading of lintels and beams due to excess weight or subsequent alterations, as well as the cutting of timbers during past interventions, can result in potential problems [11-12]. For instance, [14] cites a timber-framed house in Sussex that underwent an intervention in its infill panels, where original wattle and daub was replaced with flint and stone. This alteration, without proper consideration of weight, may lead to distortion of the historic frame. It is important to conduct detailed structural assessments to avoid any harm to the historic fabric. Another aspect of structural failure to be considered is the joints between timber elements, which are crucial to the performance of the structure and are connected through timber-to-timber mortise and tenon joints.

To identify timber construction issues and develop repair methods, expert surveys and assessments are crucial. Before intervention, honesty, minimal intervention, structural integrity, documentation, reversibility, and like-for-like repairs must be considered. Honesty means repairing without changing the historic building's appearance. Minimal intervention retains as much historic timber as possible and minimize the introduction of new elements, and conservation architects should consider moving timber for repair to avoid damage. Structural integrity depends on joint condition. Documentation records the condition of the fabric before intervention and document all alterations or repairs to ensure that future conservation or maintenance work is properly executed. Reversibility enables undoing repairs without harm to the original fabric [11]. Like-for-like repairs, as specified in the International Woods Committee principles for the preservation of historic timber by ICOMOS (1999), require using the same materials, construction, and jointing techniques as those used in the building's history [18].

After considering these conditions, then it is necessary to survey the historic timberwork and the information collected should aid in understanding the overall condition and strategy for conservation and a repair schedule. When assessing it, SPAB [1], Hunt and Suhr [14] and Boutwood [19] advise to test if timber is sound by poking with a penknife. However, there are alternative, non-intrusive methods for assessing the structure, such as infrared thermography, micro-drilling, fiber optic surveying, as noted by Brentnall and Wilson [10, 20]. Dendro-dating can also assist in dating when the wood fell and reviewing past carpentry or joinery. To create an effective repair schedule, a comprehensive understanding of the construction and condition of the building is necessary.

Repair techniques

Generally, repair techniques include replacement of a whole element, or a portion of it (generally its end), or if there are structural failures, reinforcing the structure with other materials, such as steel. The process of replacing a part of the timber involves removing a damaged section and joining a new piece to the old one, often through a scarf joint. The sill plate is the bottom component of the timber frame located near the ground. It is particularly susceptible to moisture and degradation and is therefore often in need of restoration. Regarding structural failures, such as cracking, bending, or crushing that occur against the direction of the wood grain, indicate overloaded structural members, which can be caused by decay, poor design, or excessive loads [11, 18]. This article divided timber repair techniques into the following: 1) timber to timber repairs; 2) repairs using resins; 3) use of metal in repair work; 4) repair of Sill plates; 5) repairing holes and shakes in historic timbers.

Timber to timber repairs

This method often uses traditional carpentry approaches or like-for-like replacements, but extensive decay may require cutting the original part to sound timber, resulting in loss of historic material. This should be taken into consideration when selecting a repair method. Scarfs typically have 75 % of the strength of a full timber, but in high-stress zones, they should be bolted or glued for best results. The type of joints used in historic structures can provide valuable information about their age and history, and the new scarf should mimic the original joint to preserve this information. Figure 1 illustrates two typical scarf joints, with the only drawback being the required size of timber. If the new scarf is likely to receive greater stress, all joints should be connected either with pegs or stainless-steel bolts [10, 19].

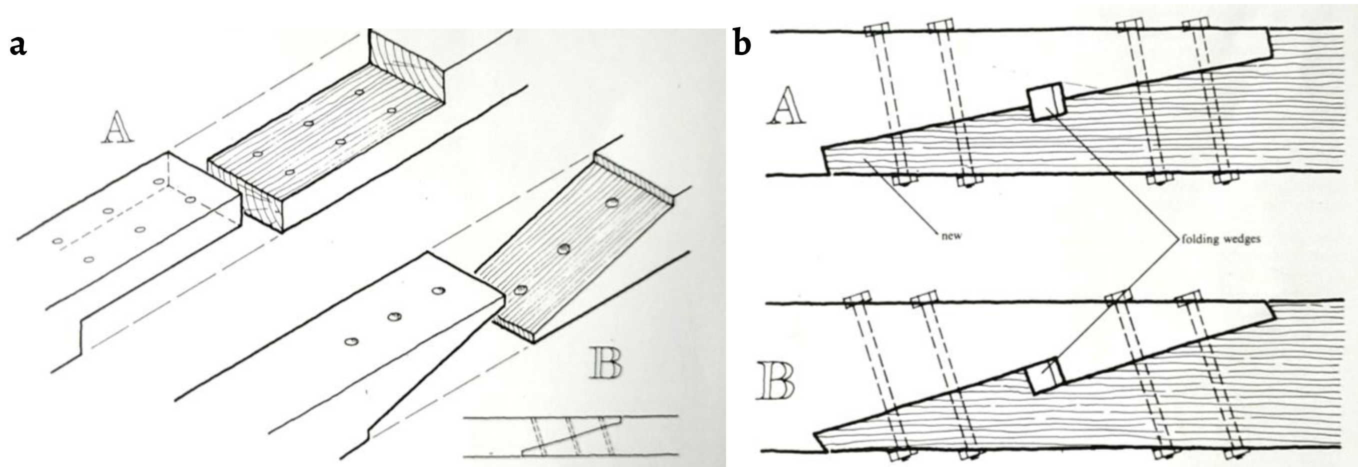

Figure 1. Typical scarf joints: *a)* two simple scarf joints for repairing horizontal elements, sill plates or wall plates, the size of joints should be 2.5 to 3 times the depth of the plate; *b)* the most common scarf used in tie beams, this type of joint is strong against curving upwards or downwards in the middle and sideways movements [19].

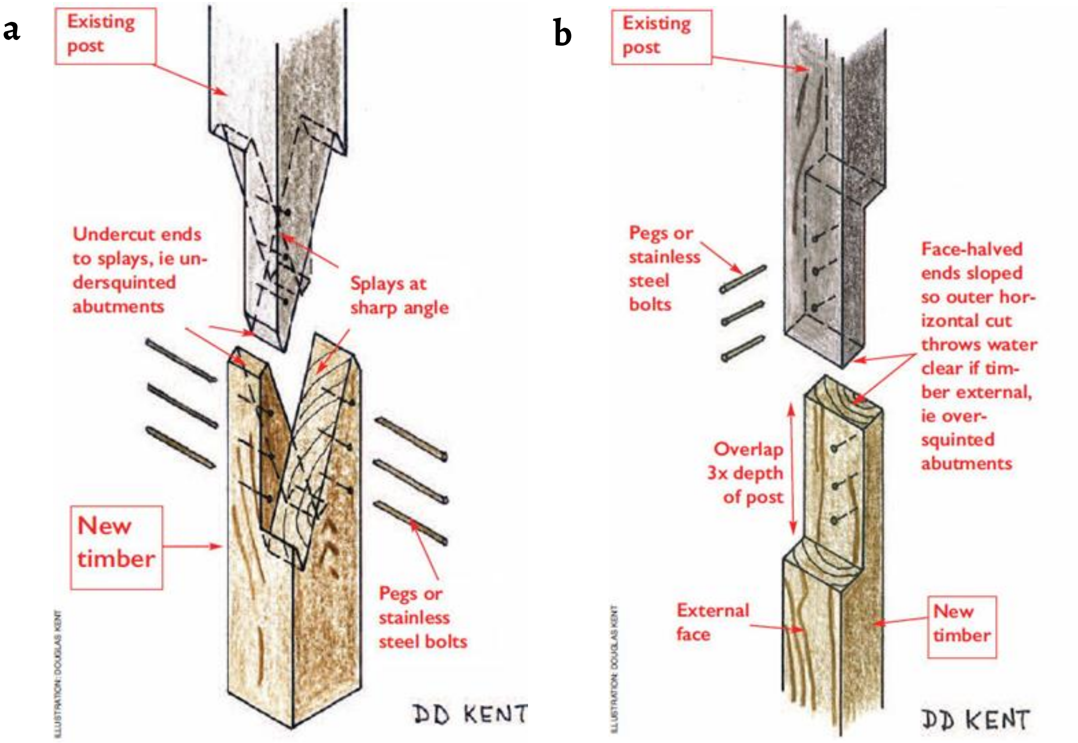

Figure 2. Drawings of: *a)*: scissors scarf repair to a post and *b)*: face halved scarf repair to a stud [1].

Figure 2 depicts repair to vertical members or in compression. The main difference from the horizontal scarfs is that the cuts are designed to guarantee that water is not guided into the direction of the joint.

Repairs using resins

Resin-based repair techniques face criticism due to their disadvantages, despite some companies promoting its use. While resin repairs offer advantages, such as minimal loss of historic fabric and gap-filling capabilities, their drawbacks may outweigh these benefits. Resins are not reversible and may fail when exposed to moisture, leading to potential issues. Figure 3 below depicts: in situ epoxy resin repair to the base of a post. A crack had occurred between the resin filling and the timber due to movement at the joint between the post and sill, besides, mould surrounding resin because of moisture.

Figure 3. The white arrow points out the location of crack which indicates that the bond between resin and the decaying end grain of the timber was not strong, failure because of poor design [2, p. 318].

Use of metal in repair work

Metal to repair timber has been used for centuries. Generally, they are reversible, it can be used to strengthen (Figure 4) a member that has insufficient load carrying capacity, supplementing it, and acting independently to provide support or acting together, even though it alters the frame structural behaviour. Besides, repairs can be at decayed or damaged joints or decayed end or face to be replaced. One advantage of using metal is that less historic material is lost, although the appearance of the repair may be noticeable. Despite its higher cost, steel is often a suitable choice due to its high strength-to-size ratio and resistance to corrosion when in contact with oak [21].

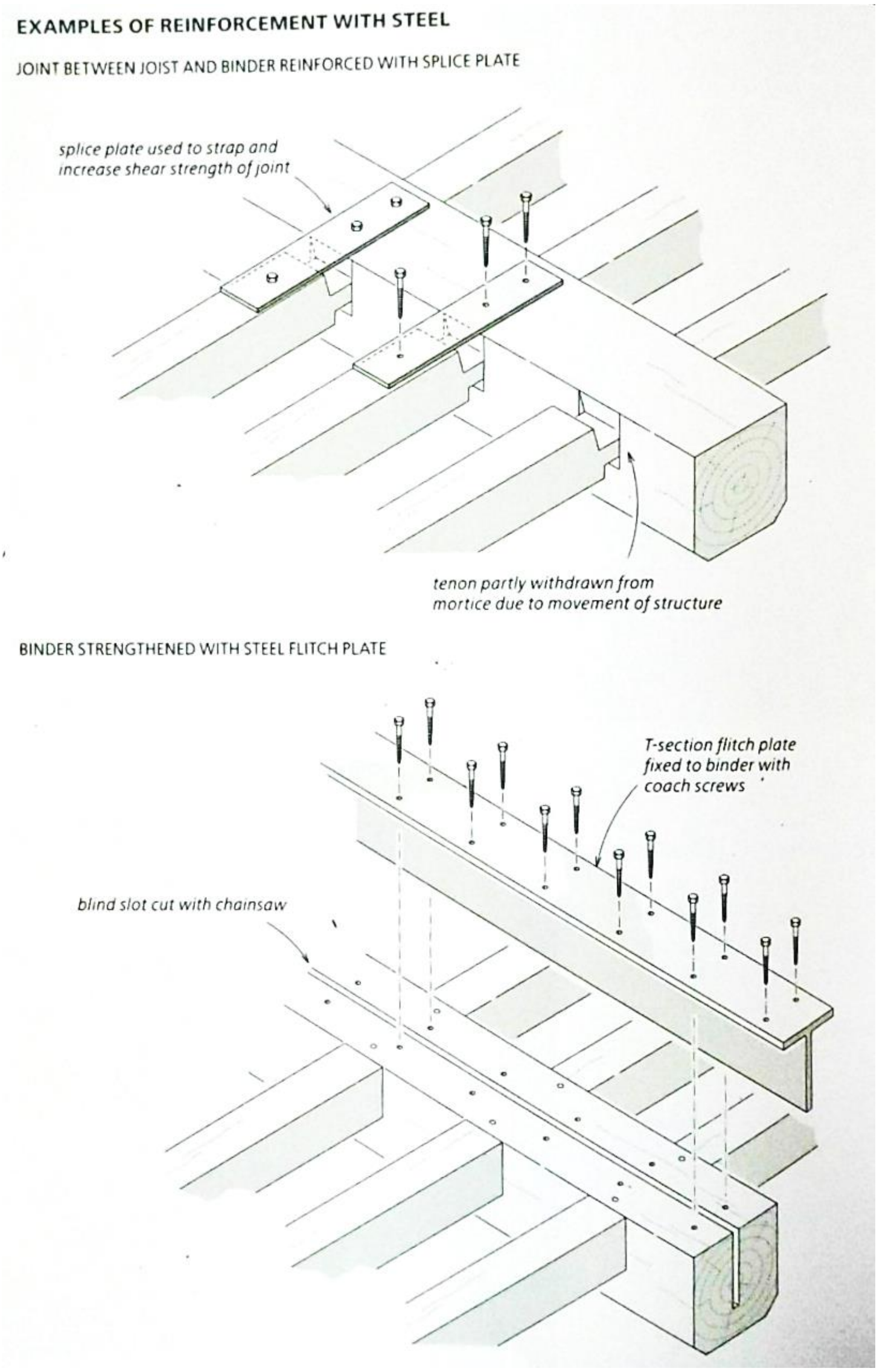

Figure 4. Timber strengthened with steel plates [2, p. 386].

Repair of sill plates

Sill plates are horizontal elements of a timber frame at the bottom that typically rest on masonry bases and are therefore susceptible to high moisture levels and decay. Therefore, it requires more attention, as partial or total renewal of the plate may be necessary. If replacement is needed, the supporting brick or stone plinth can be rebuilt, with an option to raise the plinth height to prevent future decay. If the masonry base is not being rebuilt, a solution is to create a new sill plate by cutting two halves and bolting them together with stainless-steel bolts [1]. Figure 5 illustrates different situations of repair techniques. The first (Figure 5a), if a sill beam has decayed and the supporting plinth must be redone, the new plate can be introduced from underneath with the mortices already cut to have the tenons on the studs as shown in A. "B" shows simple method of replacing in two sections so that the masonry is untouched. One half of the plate is cut to receive the tenons from the studs and the bolts must be located to avoid them. If tenons on the studs must be substituted, this can be done by cutting in a false tenon as shown in "C". [19, p. 11]. As regards the second situation Figure 5b shows in "A" how a new sill plate can be positioned horizontally and then held with infill parts, part "X" being put in from the front and "Y", then, from above. It requires a lot of time to be executed and is expensive. This repair can be used to putting new sections to plate in situ. "B" illustrates how infill pieces can repair a timber in situ [19, p. 11].

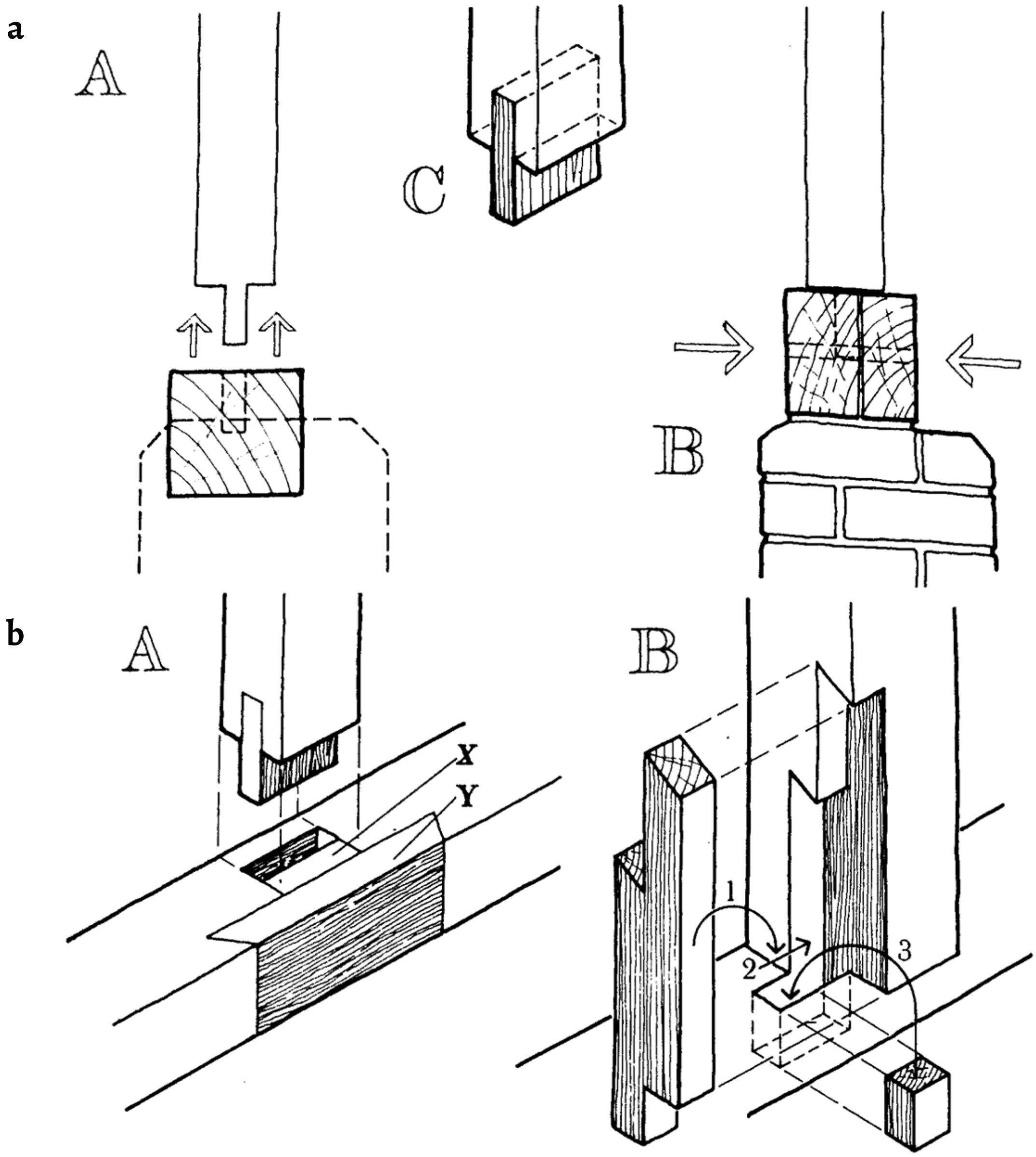

Figure 5. Repair of sill plates: *a)* Situation #1, *b)* Situation #2 [19, p. 11].

Repairing holes and shakes in historic timbers

There is no perfect method for dealing with holes or shakes, but it is possible to fill in shakes (splits) or holes in timbers. Splits are hardly of structural concern, even though might let rainwater penetrates from outside. A solution is to fill it with lime putty. The same concept is used for empty mortices or peg holes, they can either be filled with timber inserts or well-haired lime mortar and lime washed. Timber inserts can also be pieced in when part of a timber face has rotted away [1, 19].

The case study of Gunns Mill

Background history and significance

The Gunns Mill site in Gloucestershire is home to a historically significant former charcoal blast furnace, considered to be one of the most well-preserved in England. This place has a long history of iron making, during the medieval ages it was the leading iron-making district in the United Kingdom, with more blast furnaces in the country [22]. Gunns Mill dates from the seventeenth century, the main structure was built in 1625 and the furnace's timber frame was re-constructed in the 1680s using oak beams for its superstructure. In 1625 the ironworker John Winter built a blast furnace close to a mill and the name was transferred to the iron works. A dendrochronology study dated the oak trees used for the beams of the superstructure attached to the furnace were chopped in 1681-1682 [23].

Cast iron was produced in the furnace until 1736, when it changed to producing paper. A timber structure was built on top of the furnace area to dry it. Production of paper was continued by Lloyd's family for over three generations until 1840. By the end of the nineteenth century, the building changed ownerships many times for agricultural purposes and eventually fell into neglect [9]. In 1955, the site was listed as Grade II* and Scheduled monument [22]. In 1968, a preservation order was made [24-25]. The closure of Gunn's Mill as a Blast Furnace is possibly linked to the depletion of woodland and its rising cost, as well as mid-eighteenth-century wars and foreign competition, leading to a general decline in the industry [26]. Abraham Darby's development of a coke-fired blast furnace in 1709 became the dominant method of iron production, further diminishing the significance of the charcoal blast furnace at Gunn's Mill as a rare historical survivor.

In 1986, the site was scheduled by English Heritage. William Parker saved the blast furnace from demolition in 1994 when he purchased the site with an Ancient Monument and Listed Building Consent for conversion to a two-bedroomed dwelling. The building was already in poor condition and internal and external scaffolding was erected to prevent collapse. The dating of the oak timbers has increased the historic value of the site from important to unique, but unfortunately, Gunns Mill Furnace has remained covered in scaffolding (Figure 6b) [9, 27]. In 2000, English Heritage increased the structural support and weatherproofed the building. In 2013, William Parker donated Gunn's Mill to the Forest of Dean Buildings Preservation Trust (FODBPT) due to funding concerns for its restoration.

The FODBPT is a charity established in 1996 to restore and preserve historic buildings in the Forest of Dean area. They have conducted extensive repair and restoration work on the site, including repairing the roof, stabilizing the walls, and restoring the millpond. The paper drying house, however, remains in a state of disrepair and requires significant attention. The FODBPT conducted investigations to determine the building's condition and is seeking Heritage Lottery Funding for preservation works. The original building is made of coursed, squared rubble walling with eighteenth-century timber-framed additions on the first floor. This case study will focus on the timber structure of the paper drying house, highlighting concerns and areas in need of attention, followed by a brief analysis of the defects and proposals for intervention. Due to years of neglect and alterations, the building is listed as "High Risk" on the *Buildings at Risk Register*.

Figure 6. Gunns Mill: *a)* in the 1990s [24]; *b)* current state, view from Southeast (2017).

Current condition and brief survey on timberwork

Caroe & Partners Architects [22] has thoroughly described the situation of the building for the last ten years, Gunns Mill stands at a height of 8 m, rising to 14.5 m when including the later added timber structure. Additionally, the building spans a length of 8 m (17.5 m with the roofed structure) and has a width of 10 m. The building was constructed into a slope, with the furnace being loaded at the upper ground level and the iron and slag being discharged at the lower level. Above the furnace is a half-timbered drying loft, which was used to dry materials, and its roof is slated. The southern gable end of the drying loft is made of wattle and daub, while its west and east sides have windows. Adjacent to the drying loft is the Charge House, which was used to store and prepare materials in the dry prior to being fed into the furnace. The Charge House has a slightly higher floor level than the drying loft. The construction of the Charge House can be dated back to 1681-1682, based on the felling dates of its timber trusses. Even though the furnace is largely structurally sound, the drying loft has become unstable due to the partial collapse of the east wall of the Charge House, which has accelerated the decay of the timber frame, particularly the trusses. The lack of support above the staircase holes has also caused local instability in the furnace.

In summary, the east wall of the Charge House is leant because of many issues: failure of masonry underneath, movement of decayed roof, possible lateral force below floor level in the anticipated destabilized fill, also as an effect in the east drying loft wall is leant too. The roof structure and east wall of drying loft decayed severely because of lack of covering. It requires complex in situ repairs (Figure 7) [22].

The focus is the east and west walls of the drying loft, Figure 8 represent the survey carried out. The floor plan was drawn based on-site visits, photos taken and through analysis of drawings included in Cotswold Archaeology [27]. Additionally, the elevations were taken from the same source [27] and adapted by the author to aid in surveying the current condition of the loft to recommend methods of repair (Figure 9 and Figure 10).

Figure 7. Drying loft: *a)* East wall; *b)* West wall (2017).

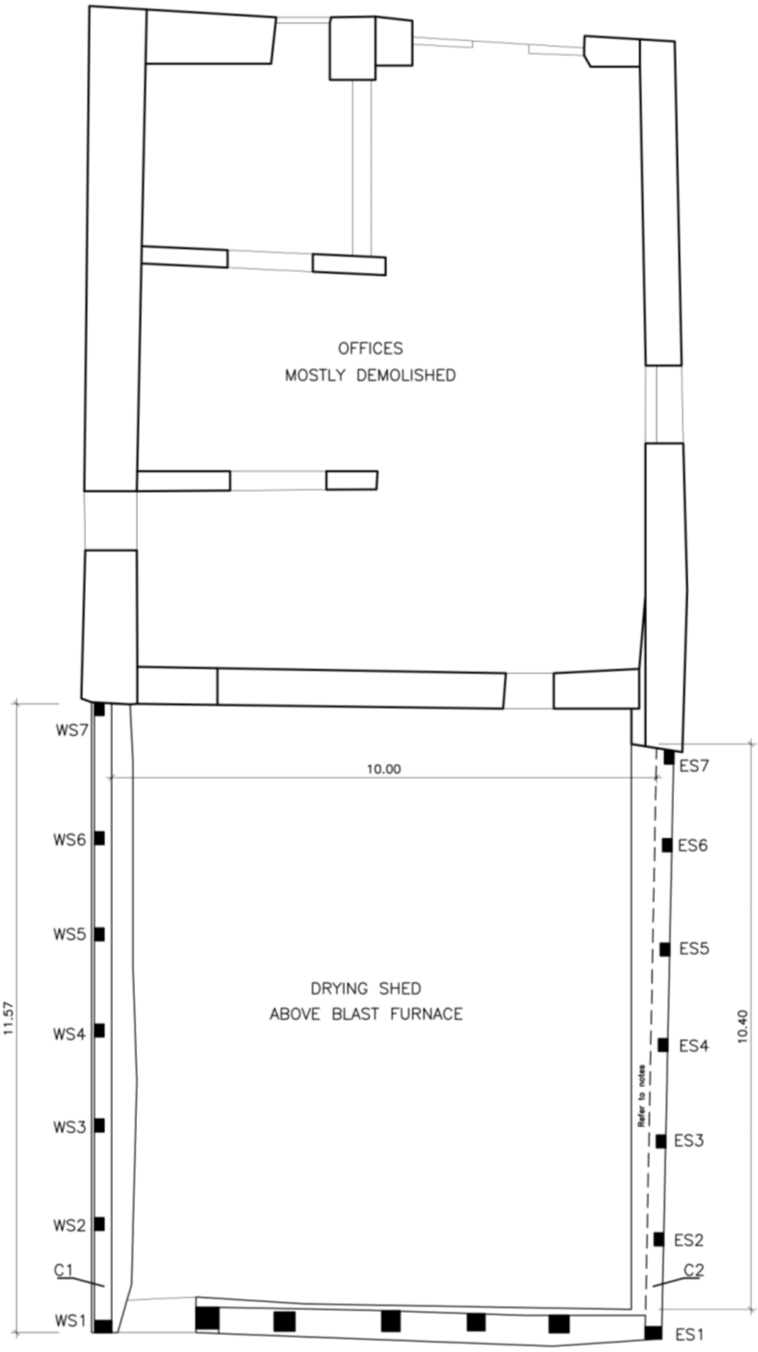

Figure 8. This is the construction of the timber frame over the blast furnace in c.1740 [27]. The sill plate on the east side has almost disappeared because of decay. ESY stands for East Wall Stud "Y"; WSX stand for west wall Stud "X", C1 West sill plate and C2 East sill plate.

Figure 9. Detailed survey of the East elevation: *a)* Localization scheme of the East wall studs, and *b)* Individual stud details (2017).

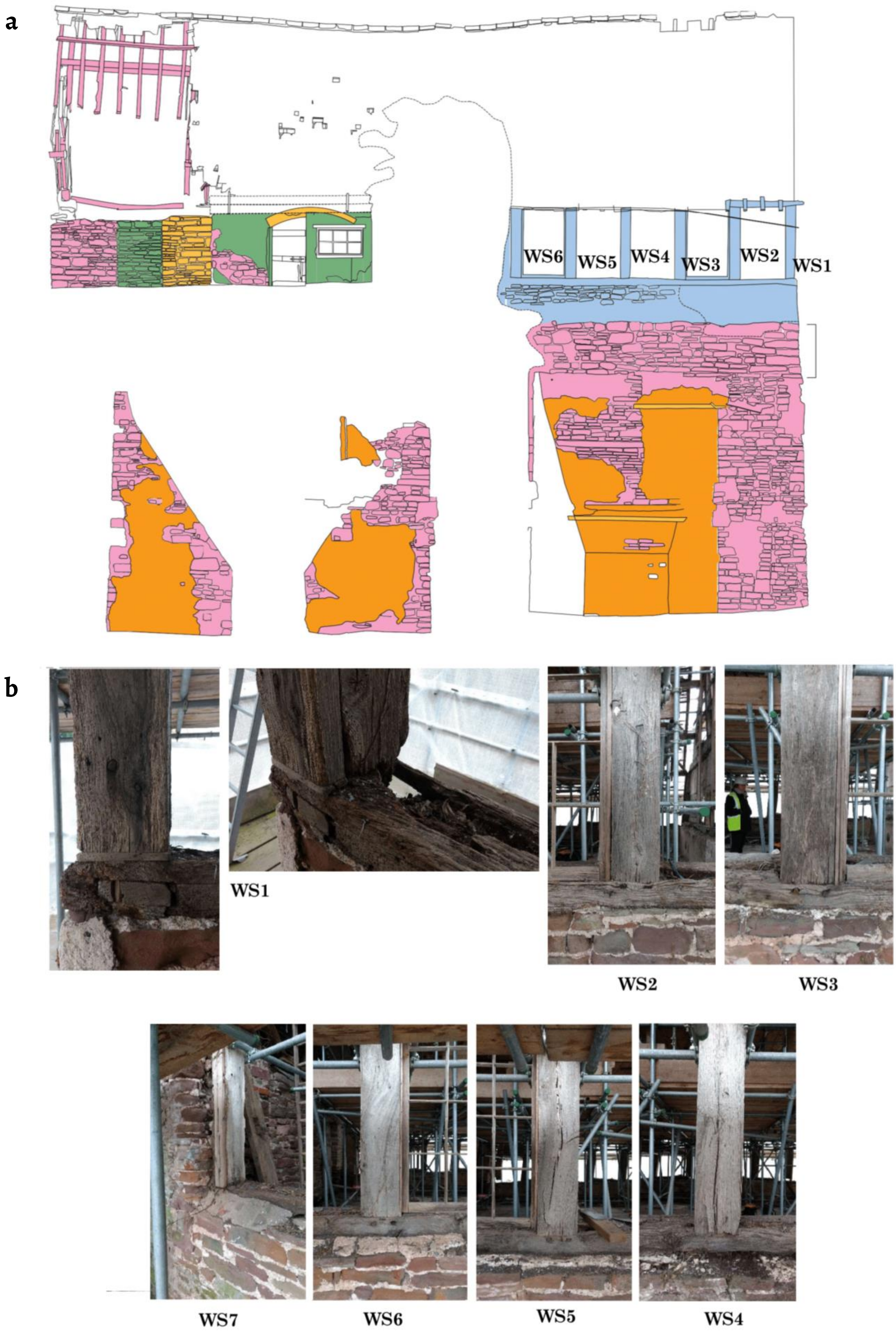

Figure 10. Detailed survey of the West elevation: *a)* Localization scheme of the West wall studs, and *b)* Individual stud details (2017).

Recommended method of repair

The recommended approach to the implementation of these techniques involves a comprehensive examination of the issues at hand by knowledgeable professionals in the field. This examination would then be followed by the conduct of repair trials in limited areas to test the viability of the methods being proposed. In order to ensure that the repairs are in harmony with the original materials and structure, it is crucial to use materials that are compatible with those of the historic joinery. Finally, the repair process must be completed in accordance with established guidelines such as the Building Regulations and recommendations from the Building Research Establishment. Possible strategies for the east and west walls of the Drying Loft are:

- Sill plates: The complete replacement of the east sill plate is necessary as it is nearly non-existent. Additionally, repairs to the plinth wall are required. These repairs should be performed according to the scheme outlined on page 10. On the west side, partial replacement is necessary, as some parts of the timber are sound. The repairs should follow the scheme on page 10. On the west wall, traditional methods, such as re-pegging, should be used to regenerate joints where necessary. On the east wall, new scarfs joints should be re-joined to the new sill plate.
- Studs: On the east wall, new scarfed joints will be added to the bottom part of all seven studs.
- Decay and infestation: The west wall shows signs of beetle attack and woodworm, for instance, refer to west stud 01. However, these attacks are likely to be historic, as they are dark and dirty and there are many spider webs nearby. The beetles are likely to have been killed by predators, so there is no cause for concern as they are inactive.

Conclusion

The aim of this report is not to delve into the intricacies of conserving historic timber frames, but to briefly highlight some of the key principles that are widely accepted in the field and that inform the various repair methods and techniques used. Timber is one of the oldest building materials used by humans. Prior to the fifteenth century, it was the most widely used material, until brick and later iron gained popularity. During the Victorian era, the high demand for wood in shipbuilding led to widespread use of timber frames in the United Kingdom. It is believed that oak was a popular choice for construction until the seventeenth century, and many traditional buildings made from this durable material are still standing today.

Then, Gunns Mills was analysed as a case study for repairs techniques of timber framed buildings. In the first part of the text the main repair techniques were described to use it as reference for the second part, which aimed to recommend an approach to the repair of east and west walls of the Drying loft. The first section of the report evaluated the advantages and disadvantages of various repair methods. The case study also highlighted several important factors to consider, such as appreciating the historical significance of the site and recognizing that repairs should not only be based on structural requirements, but also consider the building's historic value and visual appearance, as well as the conservation philosophy being adopted.

At Gunns Mill, the required work goes beyond simply repairing the timber. The building is comprised of various materials, including stone, wattle and daub, and brick walls, which must be studied in order to understand their interrelatedness. However, this comprehensive analysis of the building's construction falls outside the scope of this article, however great for future investigations. The future of Gunns Mill remains uncertain, but it is hoped that with ongoing support and funding, this important piece of industrial heritage can be preserved for future generations.

REFERENCES

1. The Society for the Protection of Ancient Buildings, SPAB, 'Knowledge Base', in *SPAB* (2009), https://www.spab.org.uk/advice/knowledge-base (accessed 2023-06-18).
2. Historic England, *Practical building conservation: timber*, Ashgate Publishing Ltd, Surrey (2012).
3. ICOMOS, 'Principles for the preservation of historic timber structures (1999)', in *ICOMOS.org* (1999) https://www.icomos.org/images/DOCUMENTS/Charters/wood_e.pdf (accessed 2023-01-31).
4. ICOMOS, 'The Burra Charter: the Australia ICOMOS Charter for places of cultural significance', in *IPHAN*, ICOMOS Australia (2013) http://portal.iphan.gov.br/uploads/ckfinder/arquivos/The-Burra-Charter-2013-Adopted-31_10_2013.pdf (accessed 2023-01-31).
5. Brereton, C., *The repair of historic buildings: advice on principles and methods*, 2nd ed., English Heritage, London (1995).
6. Pickard, R. D., *Conservation in the built environment*, Addison Wesley Longman Ltd, London (1996).
7. McCaig, I.; Ridout, B., *English heritage practical building conservation: timber*, Ashgate Publishing Ltd, Surrey (2012).
8. Forest of Dean Buildings Preservation Trust, 'Gunns Mill Furnace.' (2014), in *FODPT.org*, https://www.fodbpt.org/gunns-mill---home.html (accessed 2023-06-18).
9. Demidowicz, G & T. '*Gunns Mill, Abenhall, Gloucestershire*'. A history for English Heritage. Unpublished (2001), https://www.fodbpt.org/assets/demidowicz.pdf (accessed 2023-06-18).
10. Brentnall, C., 'Timber.', in *Materials & skills for historic building conservation*, ed. M. Forsyth, Blackwell Publishing Ltd, West Sussex (2008) 167-77.
11. Russell, R., 'Structural timber repairs', in *Building Conservation* (2013), http://www.buildingconservation.com/articles/structural-timber-repairs/structural-timber-repairs.htm (accessed 2017-02-15).
12. Singh, J., 'Timber decay', in *Building Conservation* (1996), http://www.buildingconservation.com/articles/envmon/timber_decay.htm (accessed 2017-02-23).
13. Ridout, B., 'Insect damage to timber, rethinking control mechanisms', in *Building Conservation* (2005), http://www.buildingconservation.com/articles/insectdamage/insectdamage.htm (accessed 2017-02-23).
14. Hunt, R.; Suhr, M., 'Old house handbook: A practical guide to care and repair.' in Frances Lincoln Publishers, London (2008) 95-111.
15. 'BS 7913: 2013. Guide to the conservation of historic buildings', in *Heritage-house.org* (2013), https://www.heritage-house.org/documents/BS-7913.pdf (accessed 2023-01-31).
16. Bravery, A. F.; Berry, R. W.; Carey, J. K.; Cooper, D. E., *Recognising wood rot and insect damage in buildings*, BRE Bookshop, London (2003).
17. Hutton, T., 'Woodworm, *Anobium Punctatum*', in *Building Conservation* (2008) http://www.buildingconservation.com/articles/woodworm/woodworm.htm (accessed 2017-02-20).
18. Orbasli, A., *Architectural conservation: principles and practice*, Wiley-Blackwell, Oxford (2007).
19. Boutwood, J., *The repair of timber frame and roofs - Technical Pamphlet 12*. SPAB Society for the Protection of Ancient Buildings, London (1991).
20. Wilson, P., 'Timber for repairs', in *Building Conservation* (2014), http://www.buildingconservation.com/articles/repair-timber/repair-timber.htm (accessed 2017-02-23).
21. Yeomans, D., *The repair of historic timber structures*, Thomas Telford, London (2003).
22. Caroe & Partners Architects, *GUNNS MILL, Feasibility Study / Draft*, ms. (2016).
23. Howard, R. E; Laxton, R. R; Litton, C. D., 'Tree ring analysis of timbers from Gunns Mills, Spout Lane, Abenhall, near Mitcheldean, Gloucestershire - Centre for Archaeology report 25/2001', in *Historic England* (2001), TREE-RING ANALYSIS OF TIMBERS FROM GUNNS MILLS, SPOUT LANE, ABENHALL, NEAR MITCHELDEAN, GLOUCESTERSHIRE | Historic England (accessed 2023-6-15).
24. Forest of Dean Buildings Preservation Trust, 'Gunns Mills Furnace', in *FODBPT.org* (2014), https://www.fodbpt.org/gunns-mill---home.html (accessed 2017-01-16).
25. Cotswold Archaeology, 'Gunns Mills,' Flaxley, Forest of Dean, Gloucestershire: Historic Building Recording CA Typescript Report 16097 (2016). Unpublished. https://www.fodbpt.org/assets/gunns-mill-flaxley-gloucs---hbr.pdf (accessed 2023-06-18).
26. Cotswold Archaeology, *Charge House (internal): structural engineer review. Gunns Mill flaxley, Gloucestershire: Archaeological Evaluation*, ms., CA Typescript Report 16297 (2016).
27. 'Timber framing history – a timeline', in *Carpenter Oak*, https://carpenteroak.com/timber_framing_history_timeline (accessed 2023-01-31).

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CONSERVAR PATRIMÓNIO

Conservation of industrial and technological heritage
Conservação de património tecnológico e industrial
INTERVENTION / INTERVENÇÃO

Return of the space hoppers: more measures on dH Comet G-BDIX

O regresso das bolas saltitonas: mais ações no avião dH Comet G-BDIX

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Abstract

De Havilland Comet 4C "G-BDIX" arrived at the National Museum of Flight (NMoF) in Scotland in September 1981 and has been displayed outdoors and fully exposed to the environmental conditions ever since. In 2018, National Museums Scotland (NMS) set a development in motion at its NMoF site with the aim to display the dH Comet, amongst other aircraft, in a new, environmentally controlled hangar. Due to planning permission issues the project was cancelled, and the museum is now scoping out alternative options. This led to focus on the outside of the aircraft and provided the opportunity to revisit the work carried out during a project in 2012/13, at the time making the passenger cabin watertight and rectify interior damage.

KEYWORDS
Aeroplane
Aviation
Industrial heritage
In situ
Outdoors

Resumo

O avião De Havilland Comet 4C "G-BDIX" chegou ao Museu Nacional do Voo (*National Museum of Flight*, NMoF), Escócia, em Setembro de 1981 e, desde então, está exposto ao ar livre, sujeito às condições ambientais exteriores. Em 2018, os Museus Nacionais da Escócia (*National Museums of Sctoland*, NMS) desenvolveram um projeto com o objetivo de expor no espaço do NMoF o dH Comet, entre outras aeronaves, num novo hangar com controlo ambiental. Devido a problemas de autorização, o projeto foi cancelado e o museu está agora a estudar soluções alternativas para a conservação do avião. Esta situação levou a que a atenção se centrasse na conservação do exterior da aeronave e proporcionou a oportunidade de revisitar o trabalho realizado durante um projeto desenvolvido em 2012/13 que tinha como principais objetivos tornar a cabina de passageiros estanque e retificar os danos interiores do avião.

PALAVRAS-CHAVE
Avião
Aeronáutica
Património industrial
In situ
Exterior

Introduction

The dH Comet has an important place in aviation history. The Comet 1 was the first commercial jet-powered airliner in the world, entering service in 1952 [1, p. 25]. Only seven complete airframes of different marks are preserved in museums [2-3].

The dH Comet presented in this article was delivered to the Royal Air Force in April 1962 as XR399 [4]. From 1975 until 1980 it was operated as G-BDIX by Dan Air London [5]. Dan Air was the largest operator of the aircraft type and the last one to retire it [6, p. 146]. The Comet landed at the museum in September 1981 (Figure 1). The flight to the museum was the last of a civil dH Comet.

In the 1990s, the exterior of the aircraft was completely repainted by a group of volunteers. At the same time, gaps between panels and around access hatches on top of the wings were covered with sheet aluminium alloy, bitumen based flashing tape and aluminium foil adhesive tape to stop water ingress into the structures beneath.

With some exceptions, the materials used for the long-term preservation of the airframe while being displayed outdoors are not selected by their reversibility, as common practice in conservation [7]. Instead, materials for the measures described in this article are primarily chosen which have been tested and are being used in the aviation industry because of their suitability, durability and compatibility with aluminium alloys and acrylic glass under harsh environmental conditions [8].

Figure 1. dH Comet 4C G-BDIX at the National Museum of Flight.

Emergency measures

Between 2005 and 2012, no major work was carried out on the Comet because other projects had to be prioritised.

In 2011, the Comet was closed to the public because of water ingress into the passenger cabin and an unstable cabin floor.

From September 2012 to March 2013 the conservation team (Mike Loftus and myself) and volunteers carried out short-term emergency measures to enable a reopening of the aircraft to the public. The cabin interior, the over-wing emergency exit hatches and all 36 passenger windows were removed. After removal of the interior, it transpired that the water ingress was caused by failing rubber seals of the emergency exit hatches.

The exit hatches, made of a magnesium alloy, had their paint removed to bare metal with Langlow Strip Away Pro and 320 grit sandpaper to identify even the smallest areas of corrosion. The corrosion was ground away with Dremel aluminium oxide grinding stones and affected areas coated with LAS 4853/ 4854 zinc chromate 2 Pack etch primer. The holes and cavities were filled with Fixtpro J032 aluminium epoxy putty. The hatches received a complete coat of zinc chromate 2 Pack etch primer and two coats of aviation grade two-pack polyurethane paint (PPG Aerospace CA8000-707).

The pressure seals of the emergency exits were badly deteriorated and needed replacing. Because off-the-shelf rubber seals were not available, PPG Aerospace PR1422B2-1150 fuel tank sealant, a two-part, manganese dioxide cured polysulfide compound, was used instead to create bespoke seals. The recess for the original seal was filled with the fuel tank sealant. Upon installation of the emergency exits, another bead of fuel tank sealant was added between hatch and aperture.

Most of the passenger windows, each made of an outer and inner pane of acrylic glass with a vulcanised rubber spacer in between, were starting to separate along the spacer. The panes were joined back together with silicone-free No Nonsense Anti Crack acrylic sealant. Upon re-installation, a bead of PPG Aerospace PR1425B1/2-1001 windshield and canopy sealant, a dichromate cured polysulfide compound, was applied between window and window aperture.

Figure 2. John and the Retro Space Hoppers: *a)* partly inflate; *b)* insert; *c)* completely inflate; *d)* check.

While exit hatches and windows were treated in the workshop, the apertures in the fuselage needed to be protected. The over-wing emergency exits were covered with blanks out of wooden frames, covered with Irish linen, cellulose nitrate dope and Plastazote foam padding. These blanks formed a good seal, even in high winds and heavy rain. For unknown reasons, that same system did not work for the passenger windows. Instead, our volunteer John suggested retro space hoppers to fill the window apertures. Ten adult-sized retro space hoppers were purchased and inserted into the open window apertures, which kept most of the rain out of the passenger cabin. As most of the interior has been removed during the project, a small leakage was acceptable. When sufficiently inflated, the space hoppers took on the shape of the oval windows, and bulges formed on the in- and outside, which prevented the space hoppers from falling out (Figure 2). Only occasionally, a space hopper was dislodged by very high winds.

The floor panels in the cabin aisle were also damaged. They were made of sheet aluminium with strengthening ribs riveted to the underside. Many of the ribs were broken and rivets had failed because they were constantly walked upon by visitors. In the galley areas the floor also had corroded. Repairing the floor panels could not have been achieved within the restricted deadline of the project. Instead, all floor panels in the aisle and galleys were replaced with 13.9 mm aluminium honeycomb centred, glass fibre skinned panels, also known as Aerolam, a material used in modern airliners as flooring. The original floor panels were placed in storage.

Water, which was standing in the aileron servodyne and hydraulic equipment bay under the cabin floor, was not coming from the windows but from other areas we were not able to access. To prevent water accumulating in the lower fuselage, two 10mm drain holes were drilled through the skin in each bay. This will prevent corrosion and the possible development of legionella bacteria.

At the end of the project, an annual outside clean of the Comet resumed by the Preventive Conservation Team of National Museums Scotland.

Aim of the current measures

In 2018, National Museums Scotland (NMS) started the development of a new hangar to move de Havilland Comet "G-BDIX" and two other aircraft inside. The opening of the new hangar was planned for April 2022 but was delayed indefinitely because the museum did not get the required planning permission.

With the prospect of the Comet moving indoors, and two other capital projects, no major work has been carried out on the exterior of the Comet between 2012 and 2021. When it became unclear how much longer the Comet and the other two outdoor aircraft must remain outside, funding was made available to carry out thorough condition assessments and some urgently required work until 2025.

The aim of the current project is to reduce the rate of degradation and stabilise the condition of the aircraft until they can be moved indoors and fully restored by:

- Determining the condition of the more inaccessible but structurally important areas of the aircraft.
- Making the wings watertight.
- Treating corrosion in areas of the upper wing surfaces, on the undercarriages and undercarriage the attachment points (Figure 3).
- Revisiting the measures undertaken in 2012/13 on the outside of the fuselage.

Figure 3. Corroded main undercarriage attachment point.

Current measures

By 2020, leaks had developed in the flight deck of the Comet, originating from the sextant aperture in the ceiling and the windows. A mobile elevated platform (MEWP) was hired to enable us to seal the leaks with non-corrosive, neutral silicone sealant and 3M Aluminium Foil Adhesive Tape 425. The MEWP was also used to inspect and preventively apply sealant to other areas of potential leaks on top of the Comet, as well the other two outdoor aircraft at the National Museum of Flight.

In November 2020, new bird spikes were attached to the top of the fin and two antennas to slow down the degradation of coatings and fuselage skin by acidic bird droppings. The old spikes, which have been applied in 2007, had failed over the years.

In the years 2021 and 2022, drain holes were inspected to ensure they are free, and no water is collecting inside the aircraft and corrode skins from the inside.

Furthermore, ten out of the 36 passenger cabin windows started to take in water again. Five of those were removed, dismantled, re-sealed and reinstalled. The acrylic sealant used during the 2012/13 project did not prove to be durable enough for this application and was therefore replaced with neutral silicone sealant Soudal Silirub LMN. Retro space hoppers were taken out of retirement to protect window apertures again while the windows were resealed (Figure 4). The procedure for the use of space hoppers, when used first time, was successful and has not been changed, please see previous section "Emergency measures". As described, a small amount of water ingress into the passenger cabin was acceptable in 2012/13 because most of the cabin interior had been removed. Within the last two years, windows were only removed when the weather forecast did not predict any rain as the cabin interior remained in situ. Covering the openings was still essential to prevent birds, dust and direct sunlight entering the cabin, especially because of textile covered seats and carpets beneath the windows.

Figure 4. Retro Space Hoppers in window apertures.

Figure 5. Failed bitumen based flashing tape from the 1990s.

Tape, which had been applied during the 1990s over gaps and openings on the wings, started to fail in many areas, partially by peeling off and partially by developing holes (Figure 5). The tape on the right-hand wing was replaced in most areas with new 3M Aluminium Foil Adhesive Tape 425. Tre Emme SPA Geko bitumen based flashing tape was applied where larger areas needed to be covered (Figure 6).

Figure 6. New bitumen based flashing and aluminium foil adhesive tape covering openings and gaps on top of the right wing.

The wings of the Comet are more than two metres above ground. To safely access and work on the wing, a work platform and "Airdeck" inflatable fall arrest bags come into use. For safety, work on the wings can only be carried out in dry weather and with winds below 18 miles per hour (29 km/h).

A different programme of work was carried out in unfavourable weather conditions. Due to the previous leaks in the cockpit, mould had developed on the leather seats and corrosion had built up on light alloy components, with the lower rails of the opening windows being particularly affected. The mould was removed with a soft brush, Numatic HZQ370 HEPA filter vacuum and 10 % isopropanol in deionised water, applied with damp cloths, and with a toothbrush in seams and other crevices. A low concentration of isopropanol has proved effective during previous other projects in similar circumstances and reduced the accumulation of harmful fumes. The limited space in the cockpit did not allow the use of an extraction unit in the required location and the windows could not be opened for ventilation, but a Sundström half mask with SR 217 A1 gas filter was donned for additional safety. Corrosion was reduced with steel wire wool, lubricated with Kremer Pigments 70400 special boiling point spirit 100-140 °C and a Dremel rotary tool with brass and steel wire brush attachments. Since the treatments in the cockpit have been completed, a dehumidifier has been placed inside to reduce the possibility of mould and corrosion reappearing. Inside the passenger cabin, many rubber bungees at the top and bottom of each seat pocket had severed. These were replaced with new ones as the original ones could not be restored.

Paint samples were taken from the exterior of the Comet. There is no question that the aircraft will get fully repainted in the livery it is in, if a full restoration will get carried out, as this was the paint scheme it was in when it left active service. But from the results of the analysis and the condition of the paint and metal substrate it will depend on whether the existing layers of paint will be preserved or removed during the restoration.

In 2013, most of dH Comet C2 XK699, a Gateguard at the Royal Air Force base at Lyneham, had to be scrapped due to high levels of corrosion [9]. To determine whether the work that is being carried out on "our" Comet is worthwhile, more inaccessible areas of the aircraft were inspected. Hatches were opened which provide access to the main spars of the wings to ensure their structural integrity. The front main spars did not show any signs of corrosion (Figure 7). At a later stage, lining in the luggage holds was removed to inspect the structural integrity of the lower fuselage. Only a small amount of surface corrosion was found.

Figure 7. View of the right front main spar.

Areas of corrosion on the main undercarriage legs were treated by reducing the corrosion with brass wire brushes, 3M Flap Discs 769F, a coat of LAS-656 barium chromate primer and one coat of Akzonobel Aerospace Eclipse Topcoat, a two-pack polyurethane paint. Brass wire brushes reduce the risk of galvanic corrosion, as the elements copper and zinc are already existing in aluminium alloys. For the same reason 3M 769F discs were chosen, with a grain made of aluminium oxide and ceramic [10]. The use of barium chromate is essential because of its inhibitive characteristics.

Barium chromate is highly toxic and carcinogenic. During application and drying, half masks with gas filters were worn. During the removal of corrosion, Sundström half masks with SR 510 P3 particle filters were used. Dust and debris were removed with a Numatic HZQ370 HEPA filter vacuum because the undercarriage has been previously painted with a zinc chromate etch primer. Waste material is being collected and disposed of by the waste management company Veolia UK.

In 2018, the right main undercarriage bogie of the Comet collapsed. Presumably, a seal had failed. Therefore, a full set of spare undercarriages was acquired in 2021 to enable the aircraft to be moved into a new hangar one day. One of our volunteers, an active aircraft engineer, reinflated the leg with nitrogen, levelling the aircraft once more. The seal had not failed but only slowly released the nitrogen over the years. A replacement of the complete legs might not be necessary anymore, should the aircraft be moved in the future. Our volunteer determined the condition of the charging point on the aircraft and is experienced and trained in the use of nitrogen bottles and regulators. For safety, this work was carried out while the museum was closed to the public.

Plastic facia panels on the passenger seat's arm rests have degraded over time and broke, also due to visitors constantly brushing against them when walking through the narrow aisle of the aircraft. One of our other volunteers, a retired boat builder, is currently producing replica panels out of fibre glass. The original panels will be placed in storage without risk of further damage.

Planned future measures

This year, in 2023, it is planned to treat corrosion on the nose undercarriage in the same way as the main undercarriages. All tyres of the aircraft will receive a coating of Autotek AT00TWB250 black tyre wall paint for UV protection.

The remaining five passenger cabin windows, which started to take in water again, will be removed and resealed.

The left wing will have new bitumen based flashing tape and aluminium foil adhesive tape applied. When this task will be finished the tape on both wings will be coated with Upol Acid #8 Etch Primer and two coats of two-pack polyurethane paint to protect it from corroding and to reduce the possibility of peeling in high winds.

On top of the wings are reinforcing panels made of magnesium alloy. Those panels suffer from severe exfoliation corrosion (Figure 8). The corroded layers will be mechanically removed. The remaining panel will be inhibited with barium chromate primer and painted.

The over-wing emergency exit hatches started to corrode again (Figure 9). The corrosion will be ground out with a rotary tool and the holes filled with aluminium epoxy putty. In 2012/13 there was only grey aviation grade paint available. This time, the hatches will be repainted with Akzonobel Aerospace Eclipse Topcoat in their correct red and black colours.

From 2025 onwards, a rolling programme of routine checks and corrosion treatments will be implemented. Failing measures can be renewed or improved.

Whether the aircraft remain outside or move into a new hangar one day, a full exterior restoration is envisaged by National Museums Scotland at some point in the future.

Figure 8. Severe exfoliation corrosion on magnesium alloy panel.

Figure 9. Recurrent corrosion on emergency exit window.

Conclusion

The inspection of vital, structural components and areas proved that the resources spent on the aircraft are justified because the general condition of the Comet is not as poor as the corrosion of some external areas might suggest. BAC 1-11 G-AVMO (Figure 10a) and Avro Vulcan XM597 (Figure 10b), the other two aircraft on display outdoors at the National Museum of Flight, will undergo similar inspections before any treatment will be carried out.

Figure 10. Aircrafts on display outdoors at the National Museum of Flight: *a)* BAC 1-11 G-AVMO and *b)* Avro Vulcan XM597.

Replacing the tape on top of the wings is very effective to prevent water entering internal structures. In heavy rain, the undercarriage bay of the right-hand wing remains dry. The undercarriage bay in the left-hand wing, which currently awaits the replacement of its tape, still suffers from water ingress. This measure might also prevent water from entering the aileron servodyne and hydraulic equipment bay (section "Emergency measures").

Windows, which have been resealed during 2021/22, are still watertight. They will be closely monitored to ensure that the recently used sealants are more durable than the acrylic sealant from 2012/13.

Especially the leaking windows and recurrent corrosion on the emergency exits show clearly that outdoor aircraft are a constant, ongoing project which requires planning and resourcing on an annual basis.

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REFERENCES

1. Darling, K., *De Havilland Comet – Airliner Tech Series*, Vol. 7, Specialty Press Publishers and Wholesalers, North Branch (2001).
2. 'De Havilland DH106 Comet 1 &2', in *BAE Systems*, De Havilland DH106 Comet 1 & 2 | BAE Systems (accessed 2023-05-08).
3. 'De Havilland DH106 Comet 3 & 4', in *BAE Systems*, De Havilland DH106 Comet 3 & 4 | BAE Systems (accessed 2023-05-08).
4. 'UK military aircraft serial allocations', in *UK Serials Resource Centre*, www.ukserials.com (accessed 2023-05-08).
5. *UK Civil Aviation Authority*, ms., https://cwsprduksumbraco.blob.core.windows.net/g-info/HistoricalLedger/G-BDIX.pdf; (accessed 2023-05-08).
6. Rivas, B.; *De Havilland Comet, 1949-97 (all marks) – Owners' Workshop Manual*, Haynes Publishing, Sparkford, Yeovil (2016).
7. 'Icon ethical guidance', in *ICON – The Institute of Conservation*, https://www.icon.org.uk/resources/resources-for-conservation-professionals/standards-and-ethics/icon-ethical-guidance.html (accessed 2023-05-08).
8. 'Advisory circular', in U.S. Department of Transportation – Federal Aviation Administration (2018), https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_20-62E_CHG_1.pdf (accessed 2023-04-24).
9. 'Nose of RAF Lyneham's Comet Mk2 saved by volunteers', in *BBC News* (2013), https://www.bbc.co.uk/news/uk-england-wiltshire-24940615 (accessed 2023-01-20).
10. 'Flap disc 769F – product data sheet', in *3M* (2020), https://multimedia.3m.com/mws/media/1886915O/3m-flap-disc-769f-technical-data-sheet-0220-technical-data-sheet.pdf (accessed 2023-01-20).

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The conservative restoration brings the 1907 Fiat 130 HP back on the track

O restauro conservativo traz o Fiat 130 HP de 1907 de volta às pistas

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Abstract

The Fiat 130 HP, from the collection of the Museo Nazionale dell'Automobile of Torino, was the winner (driven by Turinese driver Felice Nazzaro) of the 1907 Grand Prix of the French Automobile Club, which took place on the Dieppe circuit. The car underwent a painstaking conservative and functional restoration from 2019 to 2021: this restoration has been essential for the museum to consolidate a new method, which considers historic cars as works of art and which follows the restoration guidelines of cultural heritage. Interventions were coordinated by MAUTO Restoration Center and carried out by craftsmen specialized in this sector. They included both the mechanics, which required thorough works, including the reconstruction of structural elements of the engine, and the bodywork, whose original color was rediscovered through scientific analyses. Other elements, which had been changed over the years and did not respect the original features of the vehicle, were corrected.

KEYWORDS
Conservation
Historic car
Engine
Grand Prix
Felice Nazzaro
Functionality

Resumo

O Fiat 130 HP, da colecção do Museo Nazionale dell'Automobile de Turim, foi o vencedor (conduzido pelo piloto turinês Felice Nazzaro) do *Grand Prix*, do Automóvel Clube Francês, de 1907, que teve lugar no circuito de Dieppe. O carro foi submetido a um restauro conservativo e funcional de 2019 a 2021. Este restauro foi essencial para o museu consolidar um novo método, que considera os carros históricos como obras de arte e que segue as orientações de restauro do património cultural. As intervenções foram coordenadas pelo Centro de Restauro MAUTO e realizadas por artesãos especializados neste sector. Incluíram tanto a mecânica, que exigiu trabalhos profundos, incluindo a reconstrução de elementos estruturais do motor, como a carroçaria, cuja cor original foi redescoberta através de análises científicas. Outros elementos, que tinham sido alterados ao longo dos anos e que não respeitavam as características originais do veículo, foram corrigidos.

PALAVRAS-CHAVE
Conservação
Carro histórico
Motor
Grand Prix
Felice Nazzaro
Funcionalidade

Introduction

The Fiat 130 HP (Figure 1) was the protagonist of an extraordinary feat with its victory in the 1907 French Grand Prix. The car was driven by Felice Nazzaro, a Torino-born driver and test driver, who proved his skills by taming a racing car with unique technical features. The car is powered by a 4-cylinder twin block vertical engine with a capacity of over 16,000 cc, featuring innovative V90° overhead valves, 130 HP power, and a weight of 1025 kg. With a four-speed gear change, it reaches 160 km/h, topping 200 km/h. The cooling system consists of a huge radiator with over 8000 small brass tubes, in which water flows under the thrust of a centrifugal pump located in the bottom right side of the engine crankcase. The engine features a mixed splash and total loss lubrication system; oil drops onto the several bearing brasses from a mechanical pump, located on the dashboard, which consists of several pumping elements placed in a tank [1-2].

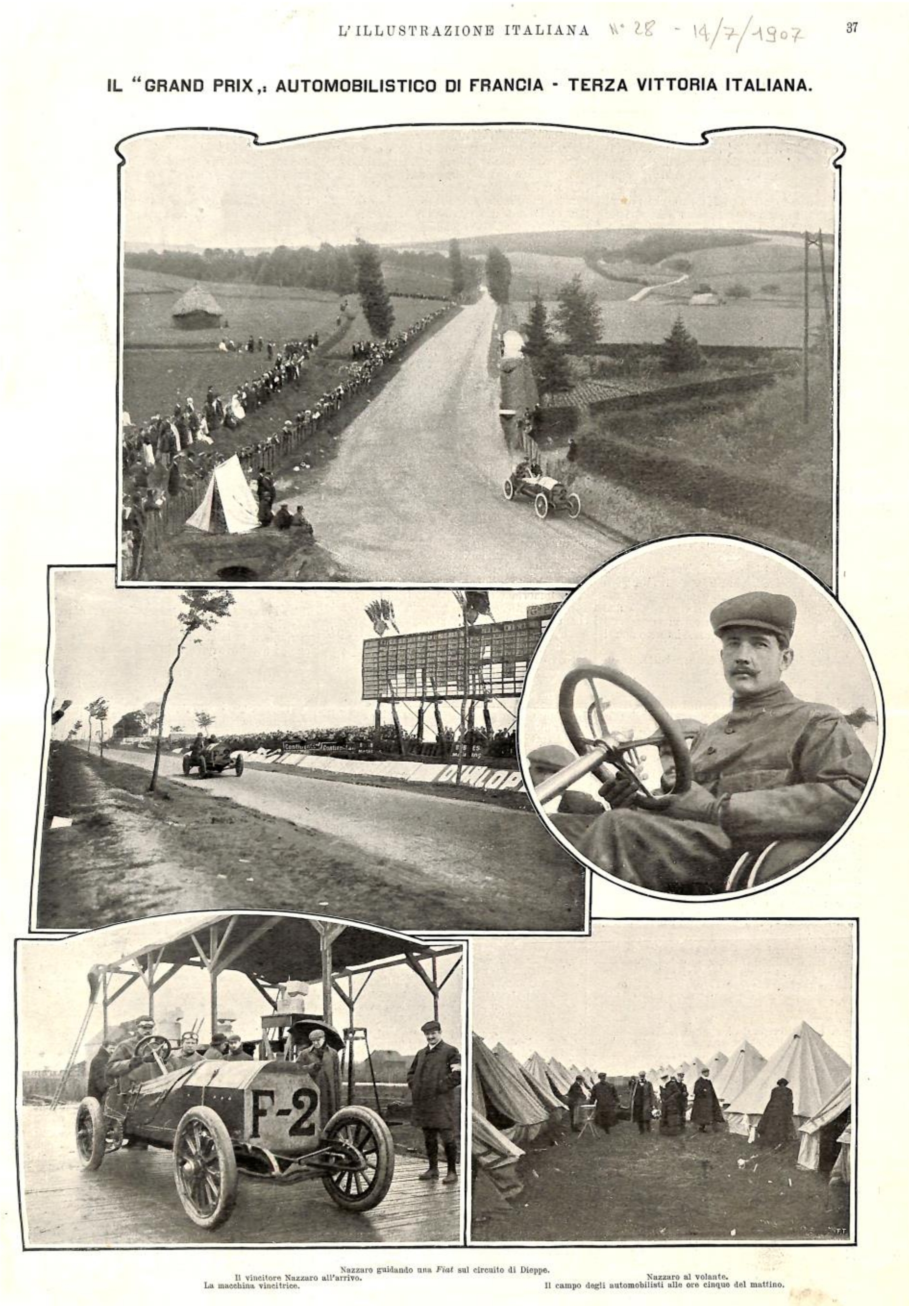
Many original mechanical parts remained, as proven by the "FN" punches (the initial letters of Felice Nazzaro): this feature proves the unbelievable authenticity and originality of this unit.

In recent years, this incredible car, which now belongs to the MAUTO – Museo Nazionale dell'Automobile in Torino, underwent a painstaking restoration aimed at solving a serious problem with its engine, which broke after a dynamic demonstration in the late 90s. The engine had such serious gaps in both the cylinder blocks and the crankcase that its look and functionality had changed. The complex works, which have given new life to one of the cornerstones of Italian racing cars at the dawning of sports races, has become a key case study on the dynamic conservative restoration method.

Figure 1. The fiat 130 HP 1907 after the restoration work.

The history of the Fiat 130 HP

The year of 1907 marked a symbolic moment for the history of automobile: besides the triumphal victory of Itala in the Beijing-Paris race, that was a year of sports wins for Fiat and of great mechanical development in all sectors. Back then, the international sports season was dominated by three races: the Targa Florio along the Madonie circuit, the Emperor Cup on the Taunus circuit, and the French Grand Prix at Dieppe, each one with its own rules. Car manufacturers were obliged to have different types of cars, whose features satisfied each specific type of race formula. Fiat focused on racing and committed to design three very different engines, which were entrusted to a team of drivers headed by Felice Nazzaro. The three cars became famous as the Fiat 28/40 HP "Targa Florio", the "Fiat Taunus" and the Fiat 130 HP "Grand Prix de France": all three of them featured a 4-cylinder twin block vertical engine, four-speed gear change, chain transmission, pedal break on the differential gear, wooden wheels, and ignition system with a LV (low voltage) magneto. Nazzaro made a clean sweep in all three competitions, earning Fiat an outstanding status (Figure 2) [3].


L'ILLUSTRAZIONE ITALIANA N° 28 - 14/7/1907 37

IL "GRAND PRIX" AUTOMOBILISTICO DI FRANCIA - TERZA VITTORIA ITALIANA.

Nazzaro guidando una *Fiat* sul circuito di Dieppe.

Il vincitore Nazzaro all'arrivo.
La macchina vincitrice.

Nazzaro al volante.
Il campo degli automobilisti alle ore cinque del mattino.

Figure 2. An article on the Fiat F2's victory at the French Grand Prix [4, p. 37].

The design and the Grand Prix

The Fiat 130 HP derived from the 100/110 HP, whose design had been entrusted to Giovanni Enrico, an engineer: a mechanical behemoth with a capacity of over 16,000 cc, featuring innovative V90° overhead valves, 130 HP power, and a weight of 1025 kg, capable to achieve the speed of 160 km/h, topping 200 km/h. Three units were made for the Grand Prix of France: at the wheel were Vincenzo Lancia (under the name of F1); Felice Nazzaro (F2) and Louis Wagner (F3) [5]. Nazzaro's sports masterpiece took place on the Dieppe circuit. After a very prudent start to save fuel, the driver, who had already won the Taunus and the Targa Florio, slowly increased its pace according to a time scheme, using up all resources of his car in a grand finale [6]. The overall average speed of over 113 km/h was achieved by Nazzaro by carefully rationing consumption: when the tank was checked after his victory, it appeared that he had been able to save 12 L out of the 230 L allowed (the consumption admitted was up to 30 L per 100 km, for a 770 km distance) [7].

From the Grand Prix to the arrival at the museum

A few years after its incredible victory, the mechanical project of the Fiat 130 HP was already obsolete, but the prize record of this car won it a place in the French branch of Fiat, which was run by E. Loste; as it often happened with car manufacturers that achieved outstanding victories in sports races, Fiat used its successful car to advertise the brand.

The trail of the Fiat "F2" was lost in the 1910s, until Auguste Antony, a famous mechanic and manufacturer of cyclecars, became its owner: in order to drive it on the road, he made technical improvement to the mechanics, added headlamps, indicators and the number-plate; some recently discovered pictures witness these changes [8].

After the end of World War II, Francis Mortarini, a famous French trader of historic cars, rediscovered the relics of the Fiat 130 HP in Antony's garden: so, he decided to buy it and get it restored, during which he eliminated some of the additions made by Antony, and subsequently proposed it for sale to Carlo Biscaretti di Ruffia for the Museo Nazionale dell'Automobile [9]. The museum had no funds available for the purchase, and he asked Fiat for help: Fiat tried to exchange it for a new 1100, but the price asked was much higher. Fiat, however, provided the funds required for the purchase and, before donating the car to the museum in 1956, carried out a second restoration to correct the previous restoration mistakes made by Mortarini [10].

The car has been on display at the museum since 1956, and is rarely started. Only in the 70s it takes part in some important events in Italy and abroad, such as the 1974 "Semaine Internazionale Automobile", held on the occasion of the eightieth anniversary of the Automobile Club of France. The last one was at the end of the 90s, when during an event it suffered the breakdown of the carter and cylinder block.

The restoration

As mentioned in the introduction, the engine of the Fiat 130 HP was seriously damaged, which made it impossible to admire, both statically and dynamically, one of the racer engines characteristic of the early twentieth century. A painstaking conservative functional restoration was carried out from 2019 to 2021. The works, coordinated by the Restoration Center of the MAUTO, and carried out by artisans specialized in this sector, included: the mechanical section, which required thorough interventions, because of a break in the front cylinder block after the engine packed up in the late 90s, including the reconstruction of structural parts of the engine; the bodywork, which had been modified several times over the years without respecting the original features of the car. Through studies and scientific analyses, the materials of the car have been examined to correct elements not in keeping with the original historical period were corrected.

The bodywork

Though the original project only included works on the mechanical part, it soon seemed clear that also the bodywork required restoration. In fact, previous restoration works had greatly changed the look of the car, even if its bodywork had always been painted various shades of red.

After the car was disassembled, the frame, without the mechanical part, underwent several studies and analyses, which led to the identification of its original color under several elements that had never been disassembled. The original color was analyzed through a spectrophotometer and resulted of a definitely darker shade; unfortunately, a very little quantity of the original paint was left and therefore the decision was made to fully repaint it. However, the Italian legislation does not allow the use of paints in use at the beginning of the 1900s, therefore a modern paint has been used, with RAL similar to the original, and applied by brush. Additionally, during the paint stripping stages several brass elements were identified that had been wrongly painted: they were cleaned, and oxides were removed [11].

The radiator

One of the most demanding works was the reconstruction of the radiator. In order to preserve the original features of the piece, the decision was taken to rescue the external brass shell of the radiator and fully reconstruct the radiating mass. About 90 % of the original mass was clogged with scale and dirt, and several spots had been repaired, which cut off some areas. The cooling water no longer flowed properly and overheating, breaks or damages to the mechanical parts of the engine could likely occur.

So, it was necessary to carefully unsolder the brass shell of the radiating mass and then, after counting the number of brass tubes forming the radiator, cut each tube in the predetermined length. The most painstaking work was creating a template for the craftsman to insert each tube, leaving a 1-mm space between each other in order to let water flow properly and obtain the best cooling power. Once the pre-assembly work was carried out, the radiating mass was soft-soldered and subsequently joined to the external shell in a single body (Figure 3) [12].

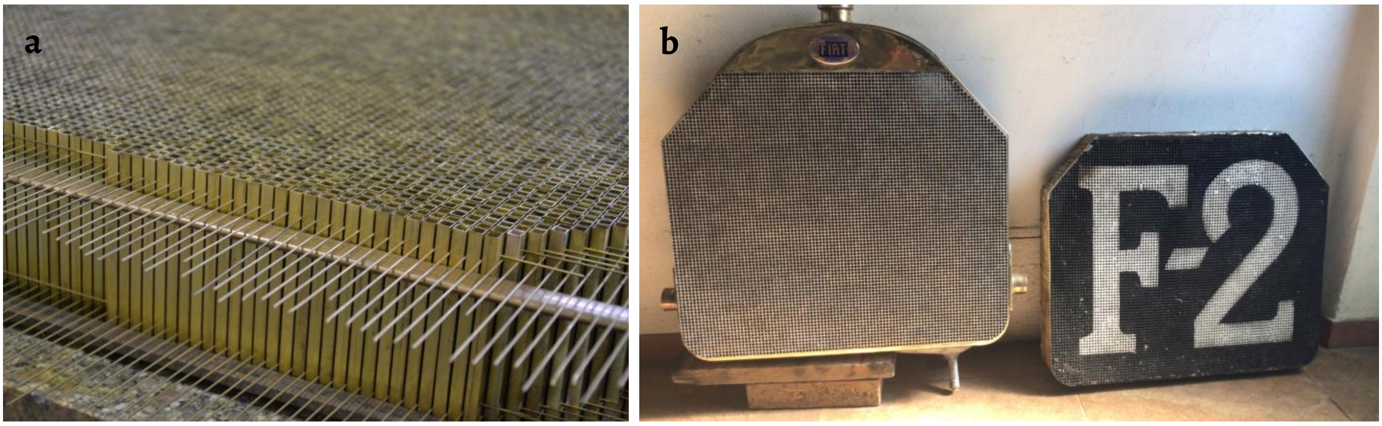


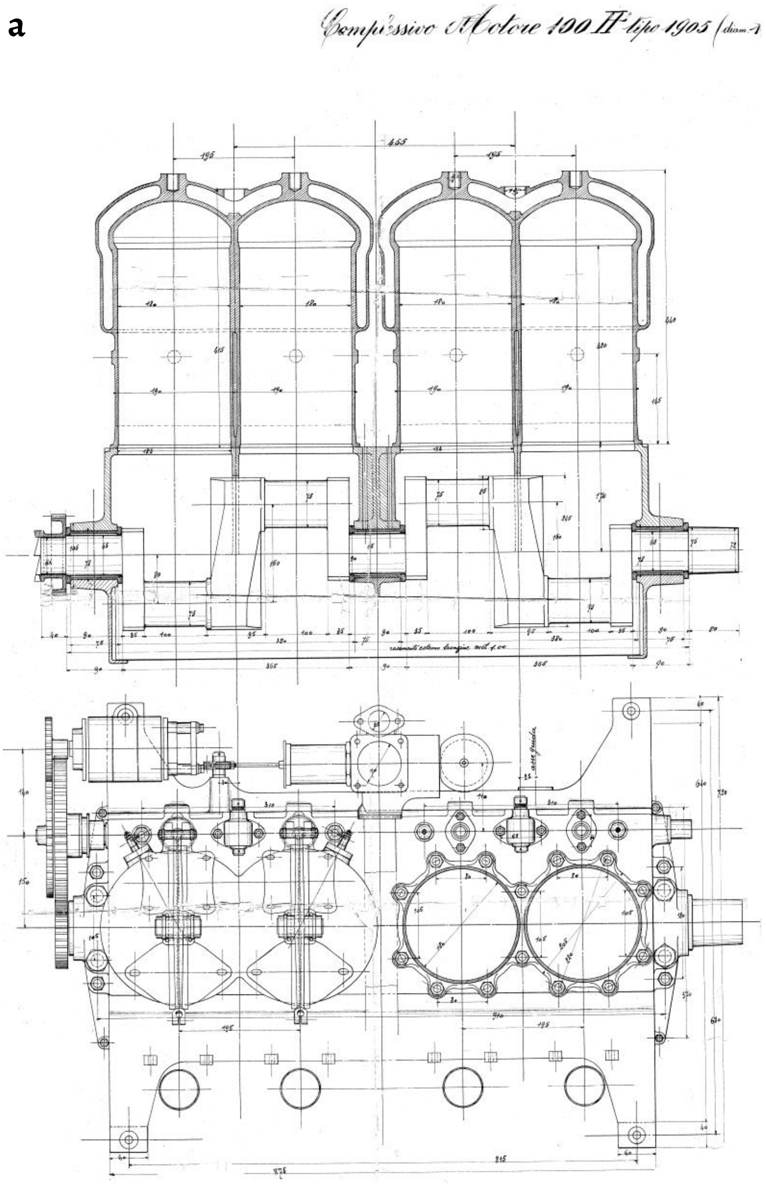
Figure 3. Radiating mass: *a)* the construction; *b)* on the left the completed radiator and on the right the original radiating mass (now preserved in the museum depots).

The engine and the mechanical parts

Analysis of the projects

Research carried out on historical documents kept at the Documentation Center of the MAUTO and the Fiat Historical Center before starting the restoration works showed the existence of a number of original designs (Figure 4). In particular, they were essential to thoroughly study the several structural elements of the engine, gear and clutch. And they were valuable in reconstructing mechanical parts and missing or non-original elements [13].

a



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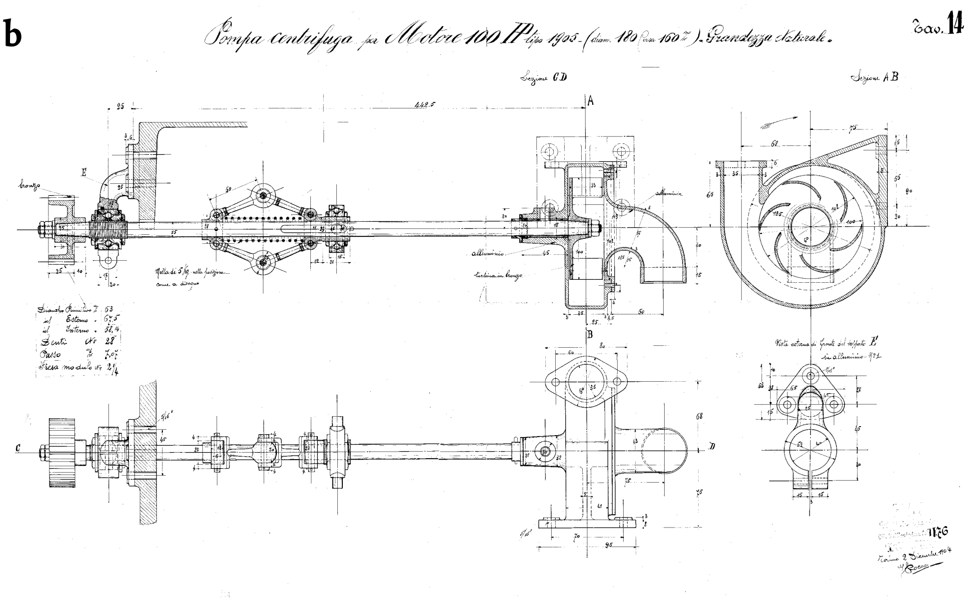

Figure 4. The original technical drawings from Centro Storico Fiat [14]: *a)* cylinder blocks and carter; *b)* water pump and watt regulator.

Disassembly

The restoration work started by disassembling all parts of the car in order to evaluate in detail all works to be carried out. For a proper analysis, also the engine was disassembled in order to check the size of the damage occurred when the engine packed up [15-16].

A careful restoration project was made only after accurately studying the historical documents and fully disassembling the car: with a view to restore the vehicle to its operational condition, the project kept in mind the originality and the incredible history of this unit [17].

Reconstruction of the crankcase and the sump

As the results of the engine breakdown, the crankcase and the sump were heavily damaged and twisted, and brakes and gaps could be no longer rescued. The material itself, aluminum, could be no longer repaired and, consequently, the decision was taken to replace those parts; the original elements are currently kept in the museum storage areas.

In order to manufacture these elements properly, the metal alloy was analyzed with a quantometer, Optical Emission Spectrometer for the analysis of solid metals with ferrous and non-ferrous matrices (Bruker Q4 Tasman), a non-destructive analytical instrument, which revealed a 9 % aluminum and silicon alloy. Then, a 3-D scanning was made, which made it possible to digitally reconstruct the elements. Thanks to these new technologies, the original technical drawings were compared with the digital reconstruction and small adjustments could be made, so that the crankcase and the sump could be properly re-created. Starting from the digital reconstruction, the sand casting mold was made through quick prototyping, then the melting with Al-Si (9 %) alloy was carried out. One new piece only can be made with this methodology, since, once the casting is finished and cooled, the sand mold must be destroyed to take out the raw finished product. Finally, the cast was finished by sanding, smoothing and polishing (Figure 5).

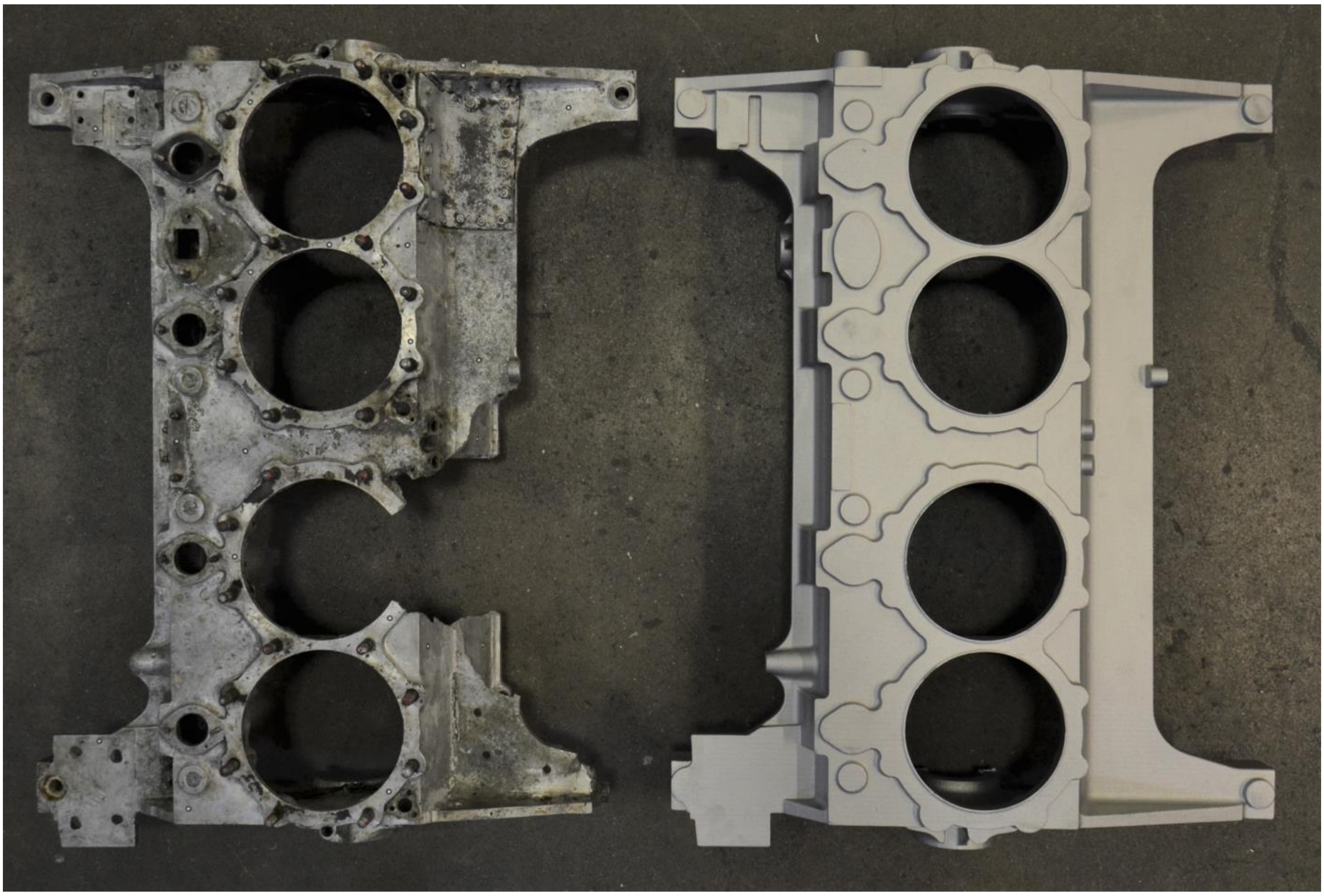

Figure 5. The original carter and the rebuilt one.

Then, the oil drains in the crankcase were reconstructed with a fully handmade work, which was carried out by copying the drains and the relevant inclinations of the original crankcase. These drains serve to collect oil, which is poured onto the engine walls by splashing when the engine is running. Oil is collected in these drains and, when it drops, lubricates the main bearing brasses [18].

Restoration of the cylinder block

Also the front cylinder block showed strong damages and gaps caused by the breakdown and, after a deep analysis, the decision was taken to repair it with a cast iron inset. In order to make this piece, it was necessary to start from a cast iron cylinder that reproduced the end part of the cylinder block leaning onto the basement, and then to cut a section of this ring to insert it in the missing part of the cylinder block. The new inset and the cylinder were joined by a welding process (Figure 6) that included heating the entire cylinder block. Then it was slowly cooled for 24 hours by dipping the entire block into a container filled with vermiculite, a mineral with excellent insulating properties. The original block was preserved thanks to this very complex work. During the cylinder block repair process, also the inlet valve, which was broken and showed several cracks on the cylinder head, was repaired [19].

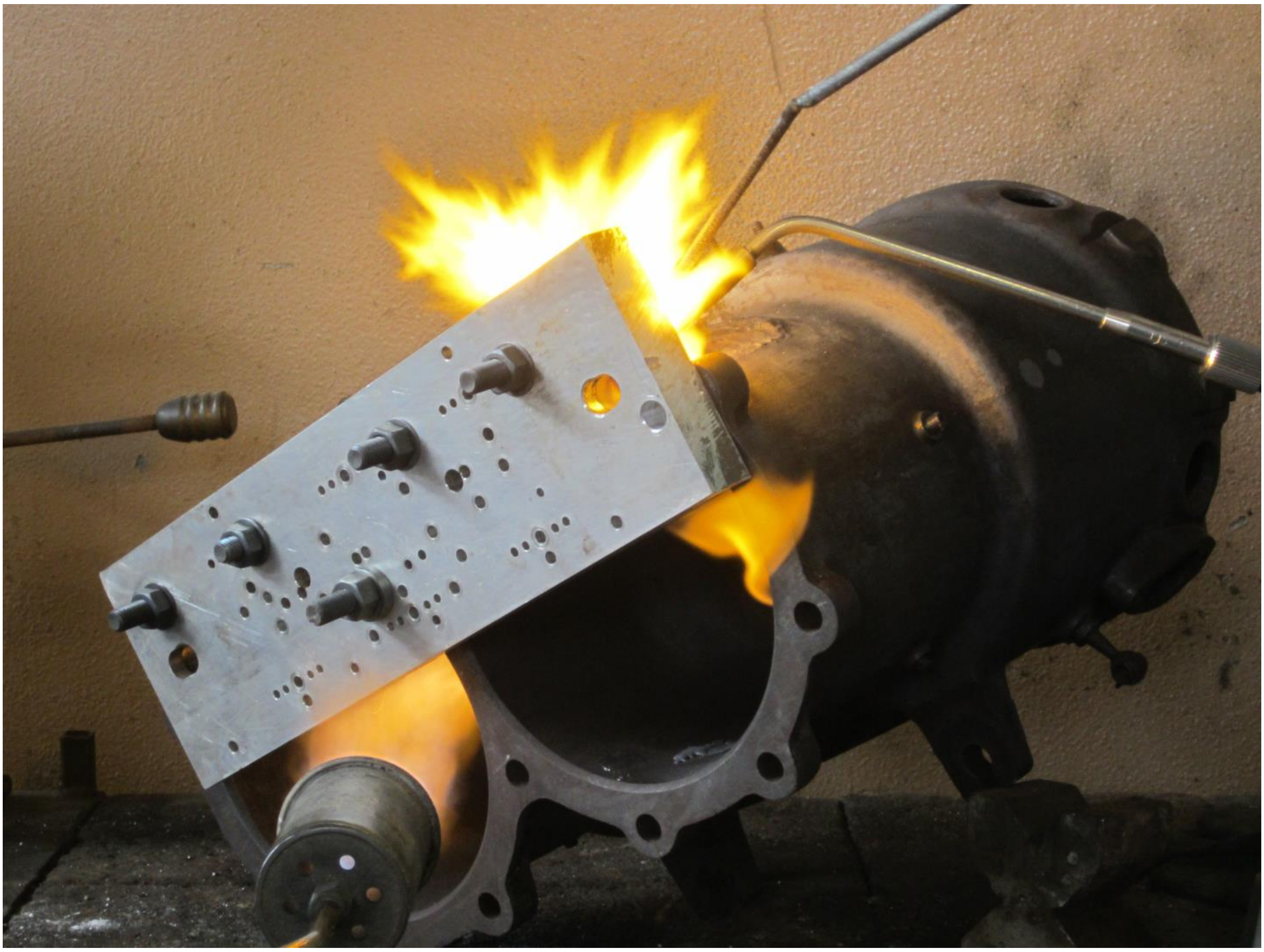

Figure 6. The welding of the cylinder block.

Revolution control and magneto

In the 1910s, Antony removed the revolution control of the car, which is a key element for the proper engine operation. The control designed by engineer Enrico, similar to a centrifugal governor, was originally linked to the FIAT carburetor. Due to the modernization of the car ignition and carburetion system, the Fiat carburetor had been replaced with a more reliable Claudel carburetor in the 1910s. On that occasion, the revolution control was eliminated, and a mechanical revolution counter was added. The decision was taken to restore the revolution control and connect it with the high voltage magneto ignition system for electricity to be disconnected when the revolutions established for the engine were exceeded [20-21].

The Bosch magneto in the car was in good conditions and only had to be magnetized again and the lightning conductor had to be reconstructed. The museum purchased a second magneto, which will be used as spare part in case of emergency [22].

Reconstruction of mechanical parts

Some mechanical parts had to be reconstructed, because they did not properly perform their function. They included pistons and segments, piston-rods (Figure 7), inlet and exhaust valves, camshaft, water pump and runner, and main bearing brasses. The latter ones were made of white metal, as they appear in the original drawings, and the inner grooves, which distribute oil onto the surface, were handmade as in the original unit. Specific patterns and tools often had to be made for complex operations like these [23].

In previous restoration works, original bolts and nuts had been replaced with commercial bolts and nuts. 90 % of the bolts were reconstructed as they appear in the original drawings. As a matter of fact, since this was a racer, engineer Enrico designed special low nuts and hollow-head bolts to reduce their weight.

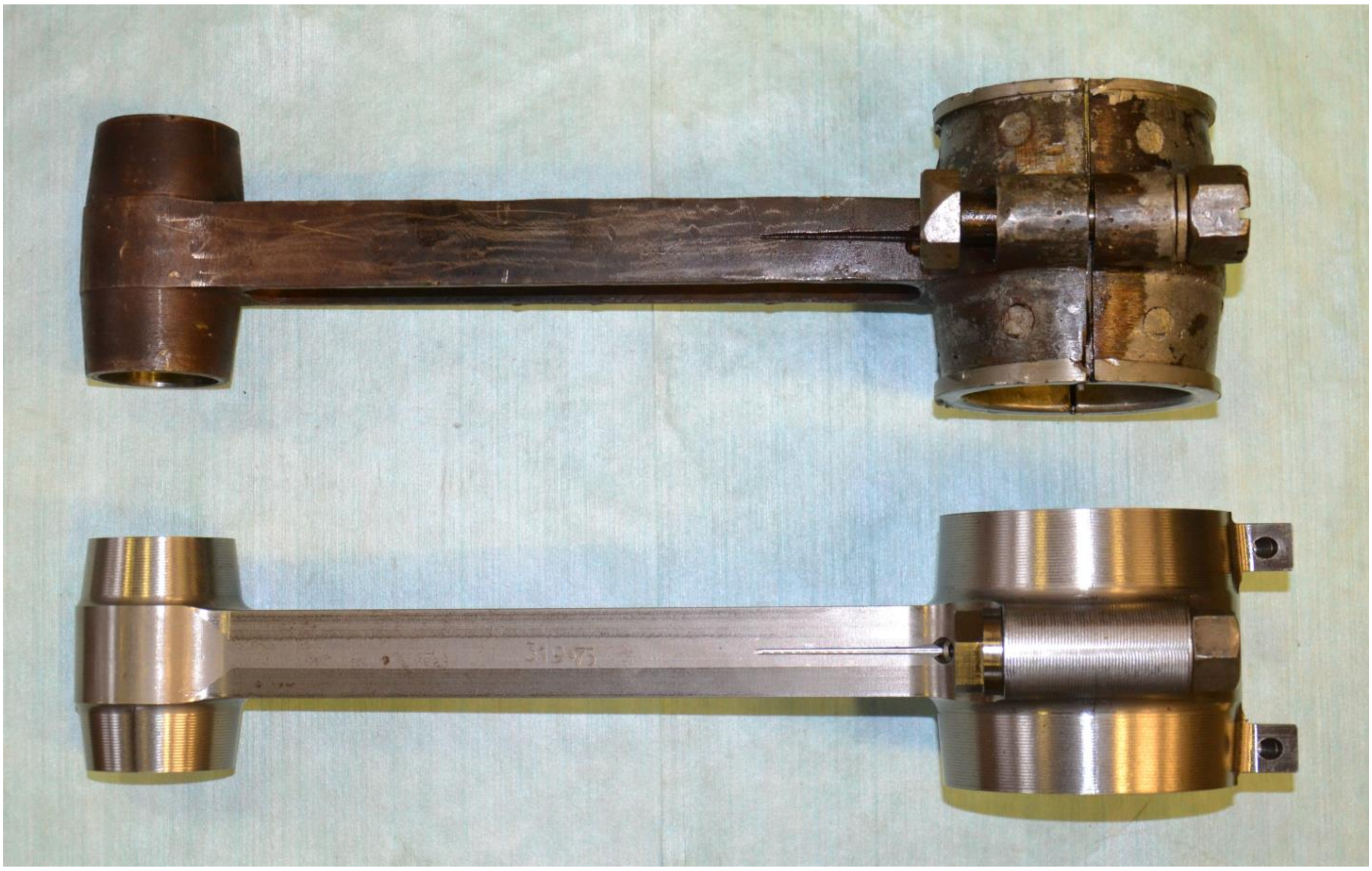

Figure 7. The original piston-rods and the rebuilt one.

Crankshaft restoration and balancing

The crankshaft has been straightened, rectified and strengthened in the rear main bearing, where a previous strengthening work had been carried out as the result of the breakdown of piston no. 4. This old repair has been strengthened for safety in order to avoid future cracks in that area. Additionally, brass closing cups, which collected oil to lubricate the bearing brass of the piston-rods, have been made. The flywheel was in good conditions and was balanced with the crankshaft (Figure 8) [24].

Figure 8. Crankshaft balancing.

Brench tests and circuit tests

After the full restoration of the mechanical parts, the engine was reassembled and tested on the bench for dynamic stability tests, fine-tuning and final adjustment. The engine was tested for over 40 hours of actual running (Figure 9).

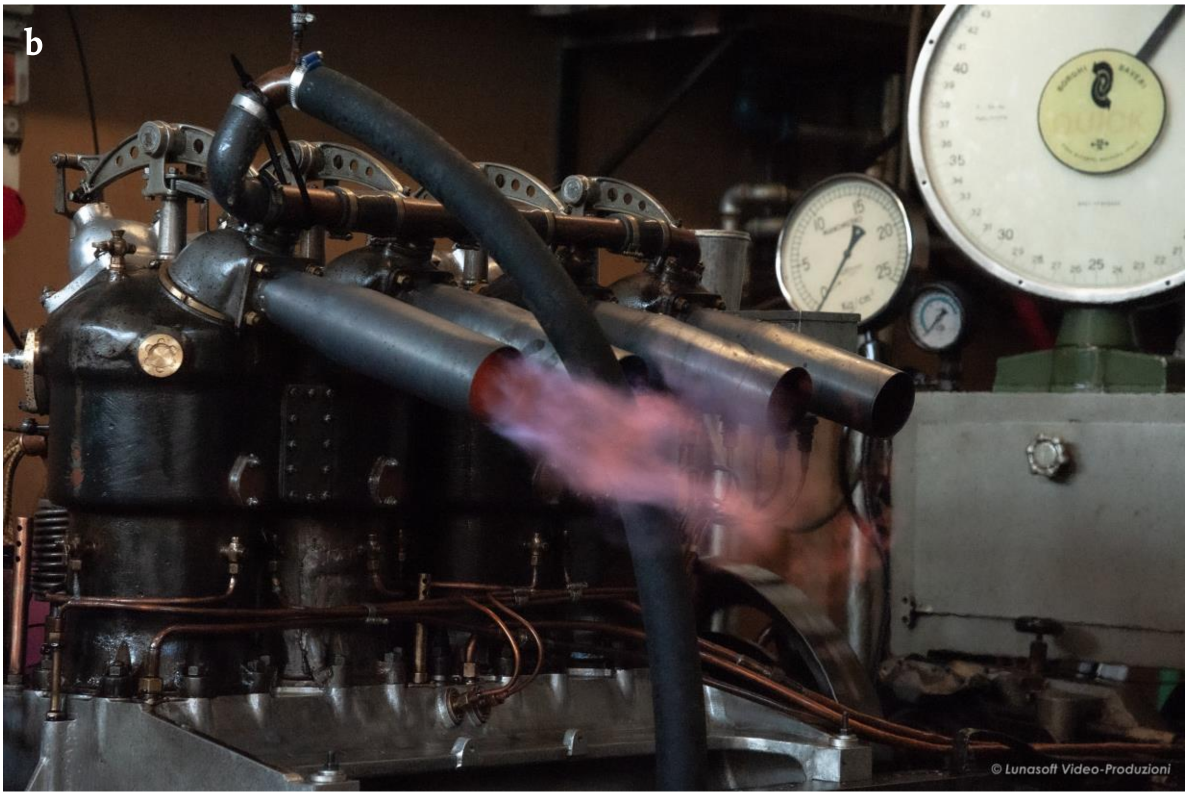

Figure 9. *a)* The engine on the test bench; *b)* engine tested on the test bench with free exhaust.

Figure 10. The positioning of the engine on the chassis.

After the initial tests, when the engine was connected with the original silencer, the decision was taken to use the open exhaust. Even if the silencer unit was strongly bolted to the bench and the engine, the strong stress and vibrations made it rock, which caused small cracks around the valve seat of cylinder number 4. In order to avoid further problems with the engine's original casts, then, four funnels were assembled that functioned as open exhaust. These funnels were also planned in the original project of the car, which could be used with either this system or the low silencer if the regulations of a specific race so required (as in the French Grand Prix).

Once the tests were over, the engine was positioned on the frame with the relevant alignment with the change gear and leveled on its supports, and the car was reassembled (Figure 10).

Finally, the Fiat 130 HP was tested several times on both unpaved roads, which were most common back in time, and on a circuit, where, on the contrary, top speed, acceleration, braking times and operation at different numbers of revolutions with the adjustment of advancement and delay were tested [24].

Conclusion

The restoration of this unbelievable unit has led the Restoration Center of the MAUTO to consolidate a new working method on historic cars, which follows the restoration principles and guidelines of cultural heritage and applies the foundations set out in the Charter of Turin. Cars are studied, starting from the materials kept at the Documentation Center of the Museum, analyzed and restored with scientific methods, but are mechanically functional at the same time: this requires an accurate study of each element, which considers their originality, proper functionality and safety.

Setting in motion such important vehicles from the historical and technological point of view is key to pass on to new generations technical, scientific and mechanical aspects that currently are no longer found in cars, yet are the evidence of car evolution. Additionally, hearing, listening, and observing these engines take visitors back in time and let them feel the same thrill and feelings of the audience attending races in the early 20th century, when these cars were ignited before the start-line.

Acknowledgements

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REFERENCES

1. Pergher, C., 'Fiat 130 HP (F2) - 1907. Un successo venuto da lontano', *Notiziario Modellistico* **1.90** (1990) 4-16.
2. Filson Young, A. B., *The complete motorist*, Methuen & co., London (1905).
3. *Motor racing*, Seeley Service & co., London (1939).
4. Morasso, M., 'Il "Grand Prix" Automobilistico di Francia – La terza vittoria italiana', *L'Illustrazione italiana* **28** (1907).
5. Bernabò, F., 'L'imbattibile Fiat di Felice Nazzaro', in *Enciclopedia dell'automobile*, Fratelli Fabbri Editori, Milano (1967) 397-411.
6. 'Il Grand Prix dell'A.C.F.', *L'Automobile* **14** (10 Luglio 1907) 2-9.
7. 'Il nuovo grande trionfo italiano nel Grand Prix dell'A.C. di Francia', *L'auto d'Italia* **27** (7 Luglio 1907).
8. Lambert, P. E., 'Antony. Le pilot -constructeur douaisien', *L'Authentique* **11** (2021) 32-40.
9. Mortarini, F., '1700 heures pour ressusciter la Fiat G.P. 1907', *L'Automobile* **179** (1961) 63-66.
10. Rogliatti, G., 'Fiat "Grand Prix 130 HP" 1907', in *Le più belle vetture d'epoca*, Automobile club d'Italia; L'editrice dell'Automobile, Roma (1970) 152-153.
11. Pareto, R.; Sacheri, G., 'Vernici', in *Enciclopedia delle arti e industrie*, vol. 6, Unione Tipografico Editrice, Torino (1898) 908-920.
12. Pagé, V. W., *The modern gasoline automobile*, Norman W. Henley publishing c., New York (1928).
13. Puttini, S., 'Fiat 130 HP Grand Prix', in *Le favolose rosse. Le grandi auto da corsa italiane.*, Istituto Geografico De Agostini, Novara (1986) 22-26.
14. Fiat 100 HP, technical drawings, Fiat Historical Archive (1905).
15. Pedretti, G., Manuale dell'automobilista e guida del meccanico conduttore d'automobili, Ulrico Hoepli Editore, Milano (1899).
16. Robotti, I., *La tecnica del motorista*, Lattes, Torino (1930).
17. Marchesi, E., L'Automobile. Come funziona e come è costruito., Lattes, Torino (1906).
18. Pagé, V. W., *The modern gasoline automobile*, Hodder and Stoughton, London (1917).
19. Pedretti, G., *Guida pratica del meccanico "chauffeur"*, Ulrico Hoepli Editore, Milano (1913).
20. Pedretti, G., *Il Meccanico "cauffeur"*, Ulrico Hoepli Editore, Milano (1916).
21. Poincaré, L., *Carburation et carburateurs*, Masson & Cie, Gauthier Villars & Cie, Paris (1925).
22. Chiodi, A., Magneti d'accensione. Manuale teorico pratico del magnetista., Ulrico Hoepli Editore, Milano (1930).
23. Timperi, L., *Il libro dell'automobile moderna*, Ulrico Hoepli Editore, Milano (1927).
24. Pedretti, G., *Chauffeur di se stesso*, Ulrico Hoepli Editore, Milano (1915).

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Conservation of a WWII Supermarine Spitfire section wing

Conservação de uma secção de asa de um avião *Supermarine Spitfire* da II Guerra Mundial

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Abstract

This study focuses on a WWII Supermarine Spitfire aircraft section wing conservation, salvaged from the seabed in 1988 and stored in a private garden. The object was in poor condition so decisions on the conservation, preservation or removal of parts of the original elements were needed. Firstly, the wing fragment was studied to determine its heritage interest and to assess its historical, industrial, technical and scientific values. This object will become a memorial to the pilot who died during the mission, in his hometown. The conservation project aims to find the best solution to both conservation priorities and exhibition needs. Based on cleaning tests on corroded, painted aluminium alloys carried out within the PROCRAFT Project, a treatment was determined. This case serves as an example of how the results of a European project can be implemented in a conservation-restoration process and how industrial conservation theory can be applied to archaeological artefacts.

KEYWORDS
WWII cultural heritage
Aluminium alloys
Supermarine Spitfire
Cleaning treatment
Conservation-restoration
Archaeological artefact

Resumo

Este estudo considera a conservação de uma secção de asa de um caça *Supermarine Spitfire* da Segunda Guerra Mundial, resgatada do fundo do mar em 1988 e armazenada num jardim privado. O objeto encontrava-se em mau estado de conservação, sendo necessário decidir sobre a preservação de partes dos elementos originais. A asa foi estudada para determinar o interesse patrimonial e avaliar os seus valores histórico, industrial, técnico e científico. O objeto tornar-se-á um memorial ao piloto que morreu durante a missão na sua cidade natal. O projeto de conservação visa encontrar a melhor solução para as prioridades de conservação e as necessidades de exposição. Com base em testes de limpeza de ligas de alumínio pintadas e corroídas, realizados no âmbito do projeto PROCRAFT, determinou-se um tratamento. Este caso ilustra a aplicação de um projeto europeu num processo de conservação e como a teoria da conservação industrial pode ser aplicada a artefactos arqueológicos.

PALAVRAS-CHAVE
II Guerra Mundial
Ligas de alumínio
Supermarine Spitfire
Limpeza
Conservação e restauro
Artefacto arqueológico

Introduction – the PROCRAFT project

The Second World War (WWII) is often considered to be the golden age of military aviation, with aircraft symbolizing modernity and power. They played an important role in legendary battles, such as the Battle of Britain and D-Day, which involved around 14,000 planes (fighters, bombers and transport aircraft). During this period, the USA built over 250,000 aircraft, while the other countries produced no fewer than 500,000 planes. Most of these aircraft were either lost in combat or disappeared during war missions. Many remains can be found across Europe, both on land and at sea. At the end of WWII, some of the remaining aircraft were used in other conflicts, but the majority of the machines were scrapped, melted down, or left to corrode. Thus, for example, out of the 12,731 specimens of "B17 Flying Fortress" only 20 have survived to the present day. This represents 0.15 % of one of the most widespread models, while other types of aircraft were practically all destroyed [1]. In France, not a single example of the two most produced French WWII aircraft, the Morane-Saulnier 406 and the Potez 63, has been preserved [2].

WWII aircraft heritage has an undeniable historical and emotional value for Europeans, but these archaelogicals remains have only recently officially entered the field of archaeology and cultural heritage conservation. Their presence in national museums is limited. They are often cared for by volunteers and volunteer-led associations.

The discovery of an airplane wreck is challenging from several points of view: its composition and materials, its history, its legal statutes and its size and condition.

To meet these challenges, Arc'Antique laboratory has collaborated since 2020 with four main partners: CEMES – Center for Material Elaboration and Structural Studies, University of Bologna, University of Ferrara and Czech Technical University in Prague, and 21 associated partners in the PROCRAFT project (PROtection and Conservation-Restauration of Heritage aircrAFT). The last ones include scientists, State representatives, conservators, academics, museums, associations, from Canada, Greece, Sweden, Italy, Czech Republic and France. They represent all the various actors in this heritage chain benefiting from their joint expertise and capabilities.

The goal of the PROCRAFT is to create innovative procedures and solutions for each key step in aircraft conservation:

- Tailored conservation-restoration techniques;
- Smart coatings for outdoor protection respecting the requirements for safeguarding cultural heritage;
- Innovative solutions for preventive conservation in confined or semi-confined environments;
- Guidelines for aluminium (Al) alloys conservation for volunteer groups.

The results of this project will:

- Enhance and share knowledge about the conservation of WWII aircraft, focusing particularly on the conservation of Al alloy components;
- Contribute to the preservation of aircraft heritage;
- Promote dissemination and presentation of our work to the public.

Project phases (WorkPackage –WP) (Figure 1) within the PROCRAFT aim to:

- Document constituent materials and related alterations to aircraft wrecks from six nations involved in WWII (WP 2).
- Carry out chemical and mechanical cleaning tests depending on the corrosion layer and composition (WP 3).
- Deliver surface protection studies for Al alloys (WP 4).
- Understand the sensitivity of alloys according to their composition and state of degradation, characterize galvanic corrosion and active corrosion processes to implement suitable treatment (WP5).

- Define guidelines for preventive conservation of aircraft wrecks (WP 6).
- Ensure public awareness and dissemination of information gained from the project (WP 7).

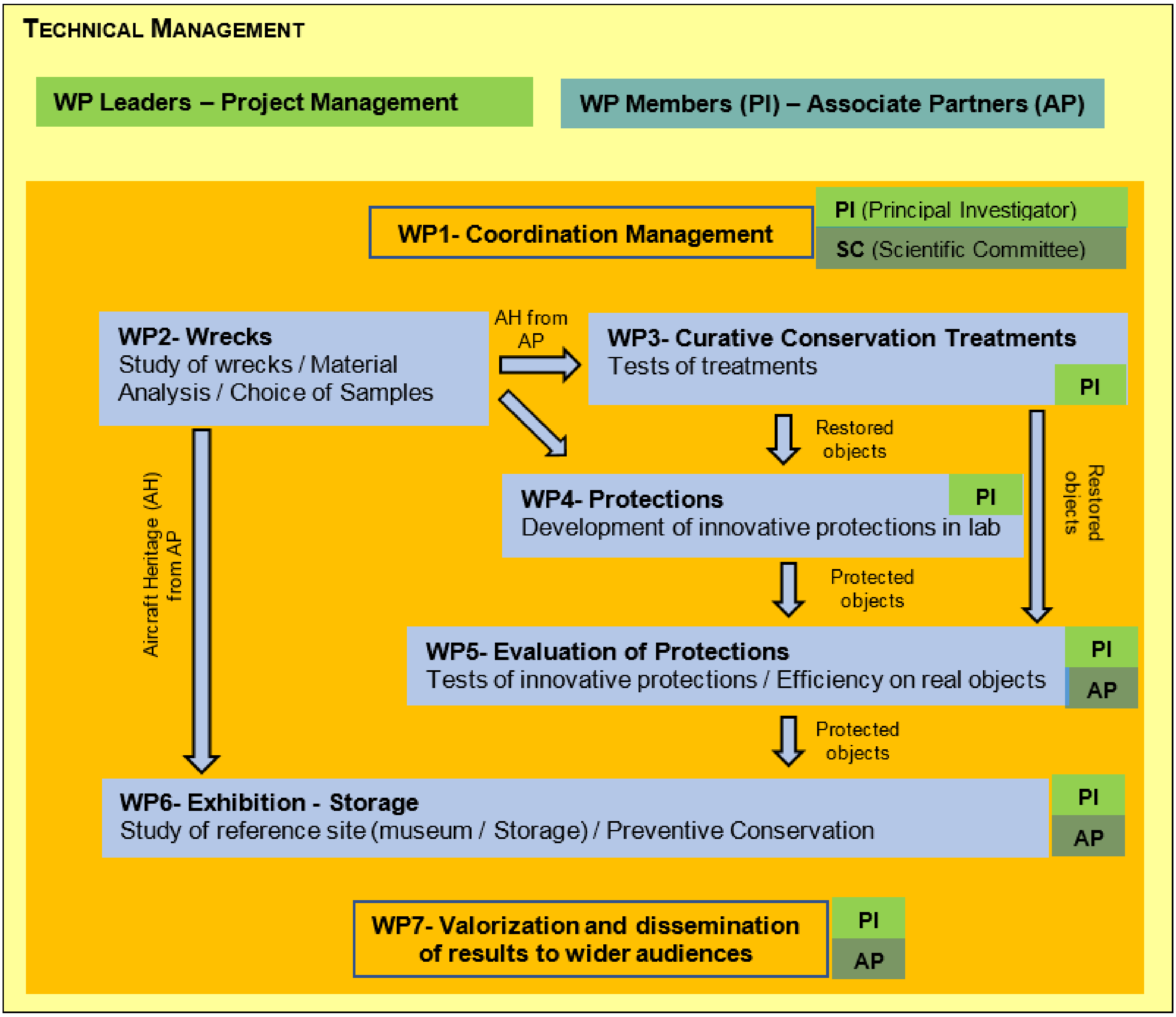


Figure 1. Organization of project phases within PROCRAFT.

Within the framework of the PROCRAFT, one of our associate partners, the Department of Underwater Archaeological Research in France (DRASSM), entrusted us with a wing fragment from a Spitfire Mk VII MB887 to carry out tests for WP purposes. The Spitfire wing fragment encompasses the whole range of challenges involved in conservation and long-term preservation of aircraft heritage wrecks: 1) large surface with remnants of original paint, 2) varying states of degradation and corrosion aspects, 3) inaccessible parts, 4) no climate-controlled storage environment.

Due to its historical and technical value, we decided to use the results of WPs 3 and 5 to manage a global conservation project centred on the Spitfire fragment. This paper focuses on the direct application of the first PROCRAFT results for the conservation-restoration of this WWII Supermarine Spitfire aircraft wing fragment. The broad outlines of WP 3 results are presented but details outcomes are not shared.

Firstly, this study set out to assess the aircraft's heritage value and to adapt our archaeological conservation-restoration processes accordingly. After a complete diagnostic, parts that could be saved were selected. Stabilization treatments were assessed, and cleaning tests were performed to determine suitable treatment conditions for a damaged, painted Al alloy. This paper presents the different actions carried out to ensure the conservation of the Spitfire wing as an example of collaboration and joint decision-making process between various stakeholders including volunteers, conservators, and state representatives.

Supermarine Spitfire aircraft: Historical and technical studies

The WWII Supermarine Spitfire aircraft wing was salvaged in 1988 from the seabed less than three miles off the French coast in the English Channel. The fragment represents the leading edge, the front part of a "universal type" (or Type C) starboard wing. The machine guns are missing but some landing gear parts were still attached. The object was saved from destruction by a volunteer who kept it for over 30 years in his garden. Local authorities, supported by the "Association Bretonne du Souvenir Aérien 39-45" (ABSA 39-45 association) and the DRASSM, responsible for the object's conservation, decided to restore the wing fragment and exhibit it as a memorial in honour of the pilot who gave his life to liberate France.

The Spitfire is an iconic WWII fighter aircraft which played a pivotal role in the war in the United Kingdom air defense. It was also used as a fighter-bomber to attack targets in Europe, as well as in North Africa, the Mediterranean and the Middle East. On 1st June 1944, during Operation Rhubarb to neutralize a cargo train in France, Officer James Atkinson, a 22 year-old Australian pilot, was reported missing at sea with his plane, the MB887. Forty-four years later, off the coast of Saint Brieuc, a French fisherman recovered the wing fragment, which was authenticated by its identification plate.

The Spitfire was continuously produced in large quantities throughout WWII and underwent many modifications to improve its performance [3]. The Spitfire Mk VII was developed specifically for high altitude flying, and only 140 were produced. One of its innovations was the presence of two symmetrical radiators under the wings for the supercharger and oil cooler. This Spitfire model also had an internal fuel tank in the wings for high-altitude climbs. The tank is still present on the recovered wing fragment (Figure 2) and comes from a relatively uncommon Spitfire model. A complete example is exhibited at the Smithsonian's National Air and Space Museum, but this particular plane never took part in active combat, being used only as an evaluation aircraft. The wing fragment has great authentic historical value and symbolizes the memory of the fallen Australian pilot. It is of significant value from several points of view:

- Historical value: representative of an iconic WWII aircraft, the object is a poignant symbol of the deadly air battles of the time.
- Scientific and technical value: the object is one of a series of only 140 and features a major fuel tank innovation.
- Social value and authenticity: the object is directly linked to the death of the young Australian pilot James Atkinson (bullet impact marks are visible on the wing), and could be a fitting memorial to him, highlighted with explanations on the historical context.
- Aesthetic value: despite deterioration due to its long exposure to seawater, the object can be easily interpreted and its function understood.

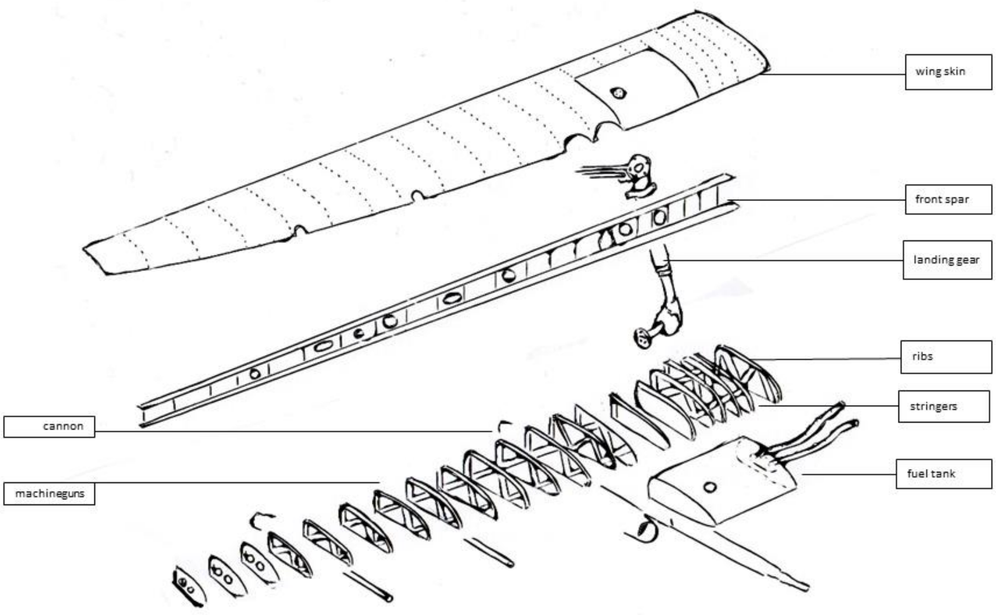


Figure 2. Exploded view of the Spitfire Mk VII wing fragment.

Materials and methods

SEM-EDS analysis

To determine elemental composition, small-sized samples were cut from the object, and were embedded in epoxy resin, polished with 800-000 SiC grade paper and finally polished by cloth with diamond paste from 3 µm down to 1 µm. Scanning electron microscopy (SEM) JEOL JSM 5800LV, operated at 20 kV and coupled with Energy Dispersive X-Ray Spectroscopy (EDS), was used to analyze the elemental composition. EDS acquisition was performed on six areas of 500 × 500 µm² with a minimum of 100,000 counts on each spectrum.

Gel preparation

Agar gel

This is a gelatinous agent consisting of polysaccharides that come from a species of red algae. It is compatible for use in solutions with a pH between 5-8. AgarArt (supplied by CTS) was used as 3 wt % AgarArt. The treatment solution was heated to 50 °C before slowly stirring in the Agar Art powder. It was then heated to 90 °C until the mixture became homogeneous and translucent. After cooling for 24 hours, the gel was heated a second time to 90 °C. For spray application, the gel was inserted into a spray gun tank at 70 °C. The gun used was a Wagner W450 wall sprayer model.

Xanthan gum

This is a gelatinous agent consisting of polysaccharides, obtained by the fermentation of simple sugars using bacteria. Both products are basically Xanthan gum but Vanzan (supplied by CTS) is industrially modified. It is compatible for use in solutions with extreme pH. Xanthan Gum (supplied by Kremer) was used as a 2 wt % whilst Vanzan was used as a 5 wt %. The treatment solution was mixed with Xanthan powder at room temperature and the gel was used 24 hours after preparation.

Examination and diagnosis

The object is fabricated from: Al alloys, ferrous alloys, elastomers, synthetic materials, paint (remains).

The wing is mainly fabricated from Al alloy (Al-Cu) that is highly sensitive to corrosion. SEM-EDS analysis determined that most parts are made of Duralumin with an elemental composition of Al (93.3 %), copper – Cu (4.2 %), magnesium – Mg (0.9 %), manganese – Mn (0.65 %), silicon – Si (0.5 %), iron – Fe (0.4 %) and traces (nickel – Ni, zinc – Zn, titanium – Ti, chromium – Cr). Records [3] show that Duralumin parts were protected by Al cladding (pure Al hot-rolled on both sides of the alloy, to provide more resistance to corrosion) and painting. However, SEM analysis of samples taken from different areas of the wing did reveal cladding only on the stringers. Residues of the original paint are still visible on the upper skin with an average thickness of 20 µm.

After 44 years on the seabed, the wing fragment was stored for a further 34 years in a private garden (Figure 3). The plane's history has resulted in a wide range of visible deterioration; mechanical degradation caused by the combat and crash (Figure 4a), deterioration due to seawater (Figure 4b-c), and the presence of undergrowth during the period of outdoor storage in the garden (Figure 4d). In our conservation process we undertook a full condition assessment including of the mechanical and electro-chemical deterioration. The main observations are summarized in Table 1.

Figure 3. The Spitfire Mk VII wing fragment stored in the garden.

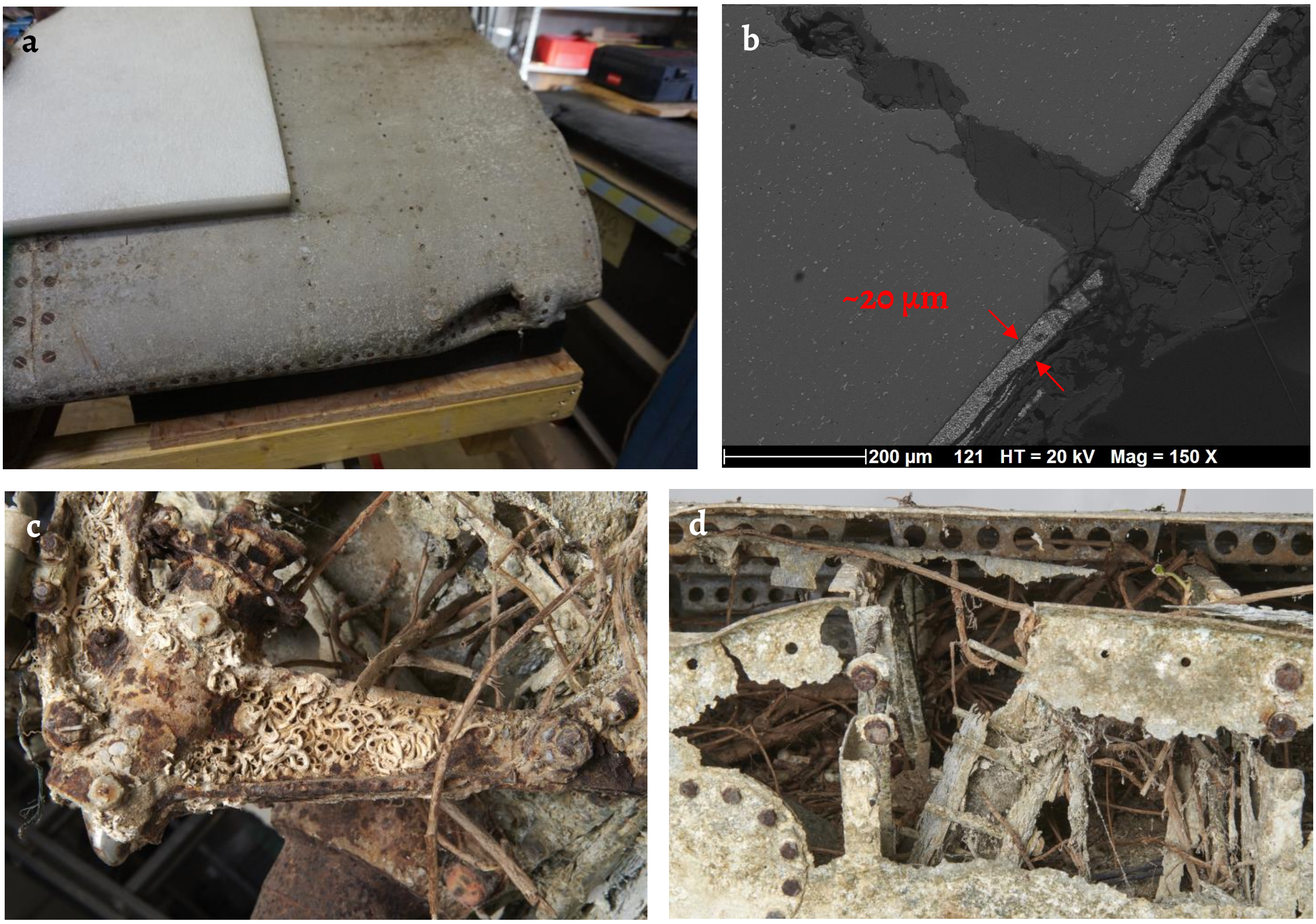
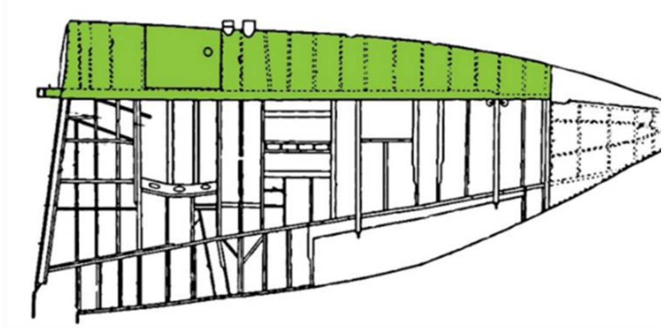
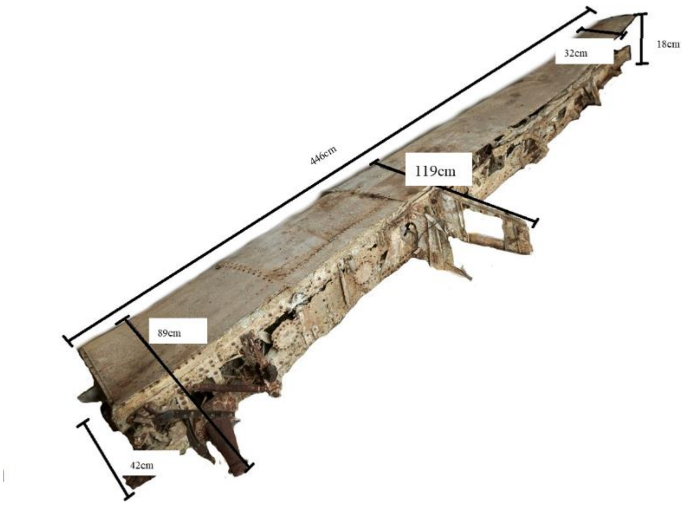
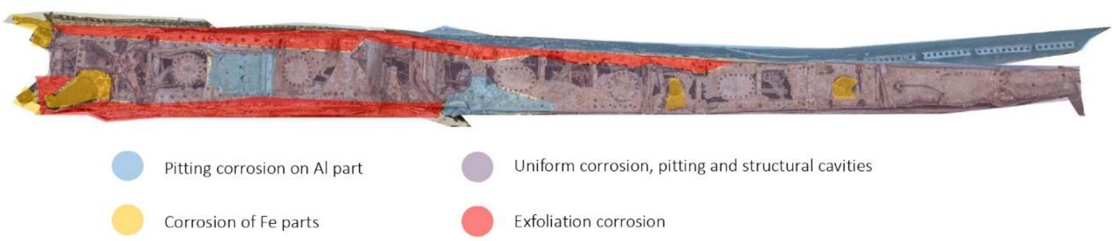


Figure 4. Examples of deterioration observed on the wing fragment of the Spitfire Mk VII: *a)* bullet impact; *b)* SEM photo of a sample (cross-section) from the wing showing generalized corrosion with inter- and intragranular corrosion in relation to micrometric intermetallic precipitates; *c)* development of marine microorganisms, called "concretions"; *d)* presence of undergrowth inside the wing.

The most severe mechanical degradation of the aircraft probably dates from the time of the crash. The fisherman recovered only the front part of the starboard wing which accounts for no more than 30 % of the total area of a Spitfire wing. Significant degradation also took place during the period it was in the sea and stored outdoors. The internal structure had undergone extensive damage. There are major differences of state between the interior and exterior parts. The internal wing structure was in poor condition; the front spar, stringers and ribs no longer provided adequate mechanical strength due to major exfoliation and pitting corrosion. The corrosion had buckled and lifted the Al sheet (Figure 5). The ribs near the tank were in good condition, while others were in very heterogeneous condition (poor to very poor). All of the ribs displayed localized corrosion, some of which had deteriorated into exfoliation. The location of the different degradations, which were classified into four categories: localized corrosion with pitting, original paint residues, rust stains and missing rivets (Figure 6). The skin (top and bottom) was in good condition overall with traces of paint still visible (Figure 3). Paint remains were abraded and poorly preserved. Localized mechanical surface alterations were visible but did not impact overall legibility.

Table 1. Summary of the main damage identified on the Supermarine Spitfire aircraft wing fragment.

Description	Scheme
Fragment location scheme The recovered fragment is colored in green on this diagram which shows a Spitfire wing in its entirety	
Size Recovered dimensions: Length: 446 cm High: 18 to 42 cm Width: 32 to 119 cm	
Main alterations caused by corrosion	 
Main mechanical alterations	- Adherent and non adherent deposits (marine concretions/remains of vegetation) - Severe deformations, gaps, uncoupling, cracks, breaks, missing structural elements mostly (95 %) on the internal structure - Mild deformations, gaps, cracks, stains and missing structural elements on the skin structure (30 %)

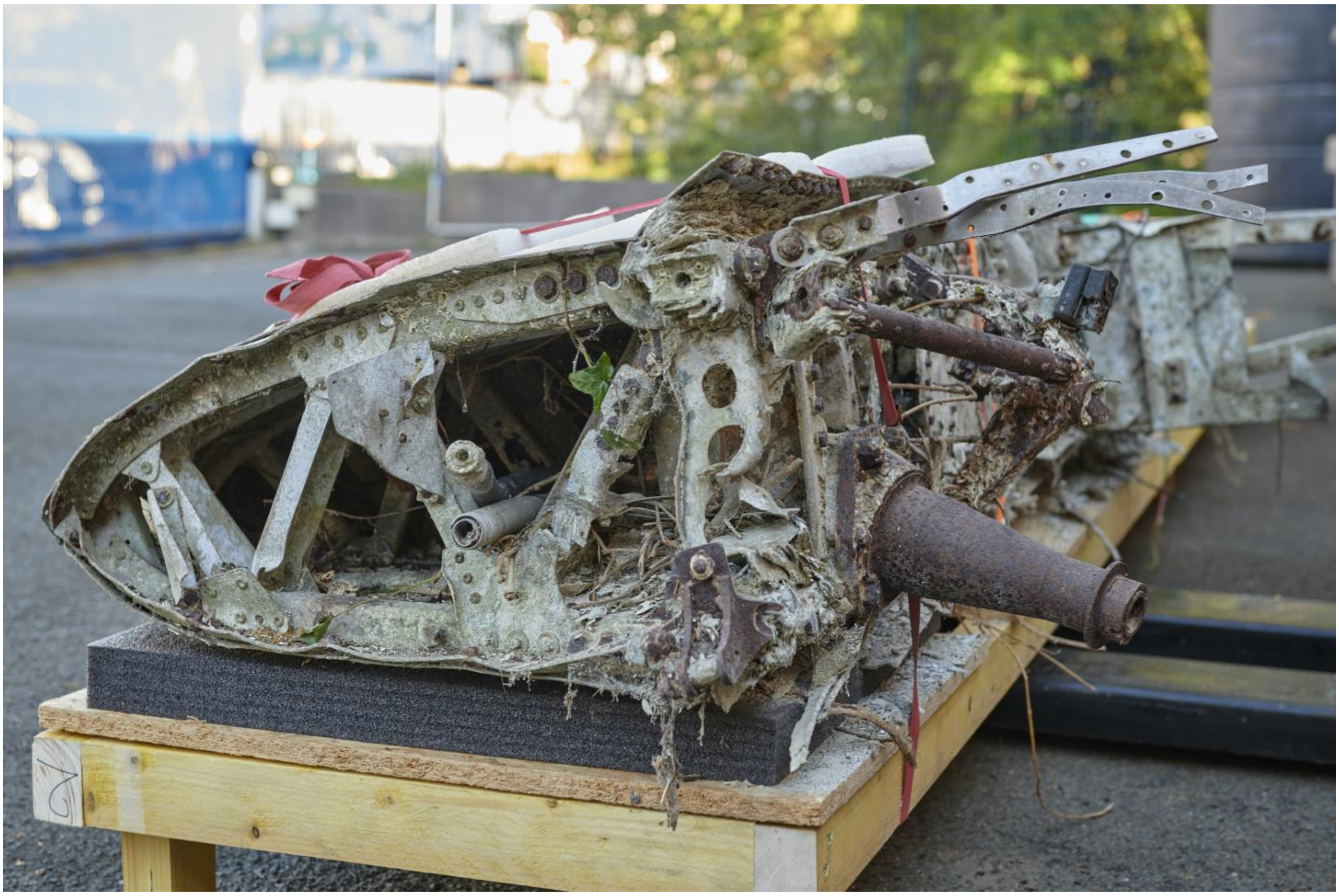


Figure 5. Exfoliation of the spar which caused the Al sheet to buckle.

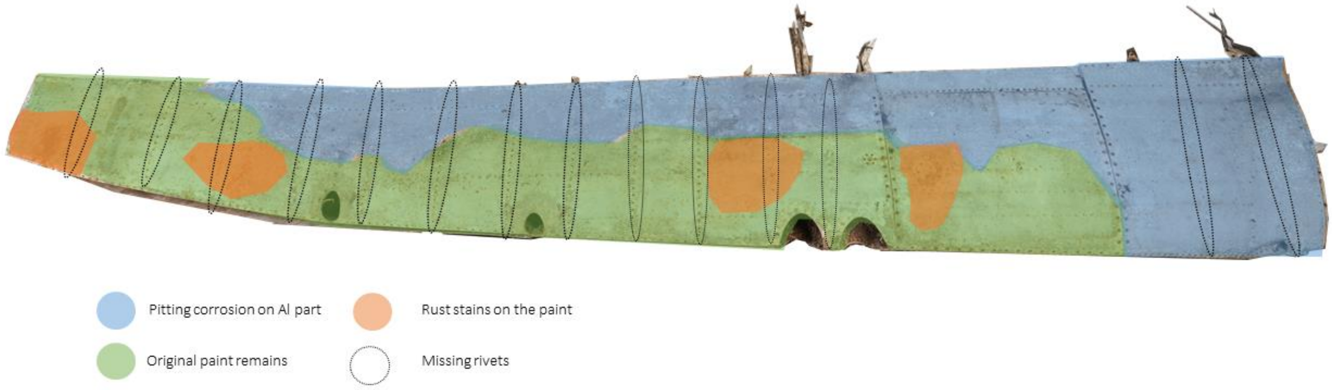


Figure 6. Location of various degradations on the wing fragment of the Spitfire Mk VII.

Mechanical damage due to bullet holes was visible on the side of the location of the machine guns. Most of the rivets that attached the ribs to the wing skin were missing. These Al-Cu alloy rivets are richer in Mg than Duralumin and are more susceptible to corrosion. The tank and elastomer parts do not seem to have deteriorated. The Fe bolts had resisted better and were still present. On the other hand, the presence of Fe elements had caused galvanic corrosion by accelerating the degradation of the Al alloys. The Fe elements were slightly corroded, and Fe corrosion products had caused rust stains on the surface of the wing.

Duralumin is highly sensitive [4] when in contact with chlorides, developing pitting and intergranular corrosion aggravated by the presence of intermetallic precipitates (Figure 4b).

Records [3] show that Duralumin parts of the Spitfire were usually protected by Al cladding (pure Al hot-rolled on both sides of the alloy, to provide more resistance to corrosion) and painting. However, SEM analysis of samples taken from different areas of the wing did not reveal any cladding. During the period of storage in the garden, the wing fragment was under a plastic tarp, surrounded by vegetation which generated humid conditions resulting in increased Al alloy corrosion. Localized corrosion had become generalized in some areas, especially at the level of the internal structure. Al alloys are highly sensitive to variations in relative humidity which produces mechanical stress and enhanced mechanical deterioration. The disappearance of the rivets due to corrosion had worsened the mechanical condition of various elements which were no longer physically held together.

Pitting and intergranular corrosion is common in archaeological Al alloy wrecks. In the case of a DC-3 aircraft wreck [5], variable degradations were observed: some parts were very degraded, while others looked as if they had just come out of the factory. For wrecks salvaged from the sea, the first treatments to be developed were inspired by the stabilization of ferrous materials [6-10] involving chemical or electrochemical rinsing to remove chlorides. However, a study on the effectiveness of these treatments showed that very few chlorides remained present in the Al alloys [11] when the object is no longer in contact with a chloride environment. In fact, the absence of compounds containing chlorine and aluminium is probably due to the high solubility of these compounds [12]. The chloride extraction treatment step is therefore not considered necessary, but additional conservation treatments remain essential to ensure the preservation of this type of Al alloy wreck.

The wing skin was in relatively good condition but required cleaning. Due to corrosion of the Duralumin, internal structure parts were in really poor condition, particularly the front spar and stringers (Figure 2). The front spar is the major structural element and this required urgent remedial conservation treatment (Figure 4d) as it had developed extensive exfoliation. Stringers needed consolidation, while some ribs that were too severely degraded had to be removed (about 10 %).

Conservation objectives

By taking into account the object's history and background, conservation state, diagnosis results and exhibition expectations, we determined the following conservation objectives:

- All elements that improve the overall understanding of the functional and technical characteristics must be preserved and consolidated, whereas corrosion products or parts that are not relevant to the object's original function should be removed.
- Because of its archaeological origin and the fact that remnants of paint subsist in some areas, the final surface appearance will be homogenized rather than standardized.
- Non-adherent exogenous deposits will be removed as well as marine concretions. Surface corrosion products, mostly hydrated aluminium oxide, will be cleaned or removed.
- An exhibition will take place in the town hall close to where the wreck was found. It is an indoor environment with unstable environmental conditions. Sufficient surface protection will be provided to ensure the stability of the metal and compounds.

Treatment has been carried out for a three-month period using the results of tests from the WP 3. The most suitable treatment for the Spitfire wing has been chosen to achieve conservation objectives.

PROCRAFT: results of previous cleaning tests

As the wing surface presented varying surface conditions, the specific treatment protocol had to be determined, and therefore the results of previous testing were considered. WP 3 research established cleaning protocols by carrying out tests on metal surfaces, corroded surfaces and painted surfaces from authentic WWII aircraft wrecks. The objects included a propeller blade from an unidentified aircraft found in the Bay of Brest, a stiffener fragment from a Dewoitine D338, abandoned after WWII near Marignane airport (France), and a plate fragment from a Messerschmitt Bf109, which crashed during WWII at Le Rheu (west of Rennes, France). Assessment and description of corrosion layers were carried out on the different objects before evaluating different cleaning methods.

In these cleaning tests, mechanical techniques and chemical treatments were compared. The mechanical techniques, most widely used by conservators, such as brushing with or without water, using a scalpel, micromotor and blasting were tested. Results are shown in Table 2.

Chemical treatments were applied using Agar or Xanthan gels. Many of the treatment solutions were selected based on previous studies on Al alloy treatments. All chemical treatment solutions are listed in Table 3. On this type of surface, rinsing only took place when all the other treatments had been carried out, and consisted of very light rubbing with a cotton swab soaked in deionised water, until no further residue was deposited on the swabs.

Table 2. Mechanical techniques used and the results obtained.

Mechanical Treatment	Impacts on clean metal surface	Impacts on corroded surface	Impacts on painted surface
Scalpel	- Unsuitable - Time-consuming for large surfaces - Risk of scratching	Suitable for local corrosion products	Suitable for local use
Micromotor with steel brush	- Unsuitable - Time-consuming for large surfaces - Risk of scratching	Unsuitable	Unsuitable
Blasting with a vegetal abrasive		Most effective in removing mild surface corrosion, resulted in a homogeneous surface.	
Soft brush with deionized water			Only effective if the paint adheres strongly to the surface

Table 3. Chemical treatments used and the results obtained.

Treatment Solution	pH	Gel	References	Results
Citric acid (0.055 M)	5.4	Agar	[13-14]	citric acid or tri ammonium citrate (TAC) solutions remove corrosion products, but it took at least 6 to 12 ten-minute applications of gel to achieve a clean surface with a shiny finish
Tri-Ammonium Citrate (TAC) (5 % w/v)	7.5	Agar	[15-16]	TAC cleaned off most of the surface deposits and removed corrosion products, but also removed the thinnest parts of the painted layer of the Messerschmitt object. TAC had limited effectiveness but did not modify the paint
EthyleneDiamineTetraAcetic Acid (EDTA) (0.5 M)	8	Agar or Xanthan	[6, 17]	EDTA cleaned off most of the surface deposits and removed corrosion products, the surface was clean after a minimum of 6 ten-minute gel applications. EDTA solution was the most effective but can slightly damage paint.
Sodium Metalicate (2 % w/v)	9	Xanthan	[17]	Sodium metasilicate had little effect on corrosion products even after 60 minutes of treatment. On the painted surface, sodium metasilicate yielded the best results so far as it removed exogenous deposits without inducing any discoloration of the painted surface
Ammonium sulphate (0.125 M) + Ammonia (NH_3) (0.25 M)	9.6	Xanthan	[9]	The ammonium sulphate and ammonia mixture worked well but yielded a matte finish Ammonium sulphate with aqueous ammonia dissolved paint remains and is not recommended for painted surfaces.
Cationic Resin by CTS (120H Cation)	2.9	Only with water	[18]	120H Cationic Resin also gave excellent results. However, there are limitations due to its fast reaction time and it is not suitable for larger surfaces

Finally, different cleaning techniques were tested: mechanical techniques and chemical treatments applied by gel. On corroded surfaces, the best results were obtained by blasting with vegetal abrasive, or by applying EDTA gel. On painted surfaces, the best results were obtained with chemical treatments. The choice of the active agent depended on which compounds were to be removed. When the paint strongly adhered, mechanical techniques, like blasting with vegetal abrasive or brushing with water, also gave very good results.

Because objects tested in WP 3 present similar materials and corrosion issues and that they could be directly relates to the choice of Spitfire treatment, the results of previous testing were employed on the Spitfire Mk VII MB887 wing fragments. Thus, for the parts of the Spitfire wing with residues of paint, the selected treatment solution was TAC.

Treatment choices for the Spitfire Mk VII MB887 wing fragment

The first step was to clean the internal area, removing any sediment, soil, sand, concretions and vegetation still present. Micro-suction enabled most of the various deposits to be extracted. After preliminary cleaning, the object gained considerably in terms of legibility. It was then necessary to consolidate the most severely damaged parts of the structure. For those parts that were exfoliating, an initial, in-depth consolidation was made with Paraloid B44 at 15 % w/v in acetone, then a second consolidation on the surface with Paraloid B44 at 30 % w/v in acetone. The front spar was lined with fiberglass using Paraloid B72 at 30 % or 60 % w/v in acetone. It was necessary to fill some of the internal parts to stabilize all the elements and restore the overall appearance of the object. Fills were made of Paraloid B72 (at 60 % or 70 % w/v in acetone) loaded with glass microspheres and pigments. Marine concretions were removed from ferrous parts by mechanical techniques, mainly with a rotation system, micro engraver or micro chisel. On structural Al alloy parts, mechanical techniques (sandblasting) were generally sufficient. The removal of concretions was finalized with a cotton compress impregnated with nitric acid at 10 % w (pH=1) for 30 seconds, then the surface was rinsed abundantly.

For the cleaning of the wing skin, which presented paint residue, aluminium corrosion products and rust stains, a first round of chemical cleaning was employed with a solution of TAC at 5 % w/v applied by Agar gel to 3 % w/v. Compared to other chemical agents, TAC was more efficient in removing dirt and was less aggressive. The gel was sprayed hot, in line with a protocol determined for application to large surfaces [19]. Three 20-minute applications were necessary to remove dirt and reduce rust stains (Figure 7). Cleaning of the wing skin was followed by blasting with vegetal abrasive to homogenize the surface.

The last part of the treatment which will focus on application of a protective coating and exhibition of the wing fragment is still in progress is scheduled for completion in early 2024.

In order to select the most suitable coating, we will use the results of WP5 which will specifically address coatings. The surface protection chosen for the wing will need to ensure treatment compatibility and reversibility.

The study of the exhibition system is also still in progress. The following specifications for display have been given to the stakeholders:

- The object must be mounted in such a way as to reinforce the structure and enable technical interpretation of the object;
- The interior surface must be accessible to enable long-term dusting and maintenance;
- The safety of the public must be ensured and clear information provided to help them understand the object;
- It must include a memorial to the pilot James Atkinson.

Figure 7. Mechanical cleaning: *a)* before; *b)* after treatment; *c)* consolidation; and chemical cleaning with TAC 5 % w/v applied with Agar gel to 3 % w/v by spray: *d)* removal of the gel; *e)* surface before cleaning; *f)* surface after cleaning.

Conclusions

This object epitomizes the wide range of issues related to technical and archaeological heritage. The historical and technical studies of the wing fragment highlight its considerable significance in terms of heritage and historical, emotional, aesthetic, scientific and technical value. The conservation project has also enabled the development of innovative cleaning techniques for Al alloys. Established mechanical cleaning techniques were coupled with chemical cleaning. The next conservation step for the preservation of the wing fragment is the surface protection of the aluminum alloy components. Tests will be carried out in the context of the PROCRAFT to select the most effective protection. The object will then be exhibited locally in Britanny (France) as a memorial to the pilot.

Acknowledgements
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REFERENCES

1. Berutti, S., *Cieli d'acqua – I relitti aeronautici del secondo conflitto mondiale nei mari del mondo*, online, http://www.wreckdiveliguria.com/newsite/archeoaeronautics.htm (accessed on 2022-07-26)
2. Fournier, L., 'La protection des aéronefs au titre des monuments historiques', *In Situ* **35** (2018), https://doi.org/10.4000/insitu.17047.
3. Jackson, R., *Spitfire, La légende.* Ed. Techniques pour l'Automobile et l'Industrie Paris (2011).
4. Vargel, C., *Corrosion of aluminum*, Elsevier, Oxford (2004).
5. Tengnér, C., 'The preservation of a marine archaeological DC-3 aircraft', in *Aluminum: history, technology and conservation, proceedings from the 2014 international conference*, eds. C. Chemello, M. Collum, P. Mardikian, J. Sembrat, and L. Young, Smithsonian Scholarly Press, Washington DC (2014) 97-102.
6. MacLeod, I., 'Conservation of aluminum alloys corroded under water: from in-situ conservation through storage to exhibition', in *Aluminum: history, technology and conservation, proceedings from the 2014 international conference*, eds. C. Chemello, M. Collum, P. Mardikian, J. Sembrat, and L. Young, Smithsonian Scholarly Press, Washington DC (2014) 39-45.
7. Degrigny, C., 'The conservation of historical marine, terrestrial and industrial aluminium objects: a review', in *Aluminum: history, technology and conservation, proceedings from the 2014 international conference*, eds. C. Chemello, M. Collum, P. Mardikian, J. Sembrat, and L. Young, Smithsonian Scholarly Press, Washington DC (2014) 87-95.
8. Bailey, G., 'A critical review of the 1996 conservation treatment of a World War II aircraft carried out at the Australian war memorial', in *Aluminum: history, technology and conservation, proceedings from the 2014 international conference*, eds. C. Chemello, M. Collum, P. Mardikian, J. Sembrat, and L. Young, Smithsonian Scholarly Press, Washington DC (2014) 103-106.
9. MacLeod, I., 'Stabilization of corroded aluminium', *Studies in Conservation* **28**(1) (1983) 1-7, https://doi.org/10.1179/sic.1983.28.1.1.
10. Degrigny, C., 'Stabilisation de moteurs d'avions immergés', *Studies in Conservation* **40**(1) (1995) 10-18, https://doi.org/10.1179/sic.1995.40.1.10.
11. Tissier, Y.; Guilminot, E.; Berges, S., 'Characterization of two propeller blades from submerged WWII-era wrecks', in *Aluminum: history, technology and conservation, proceedings from the 2014 international conference*, eds. C. Chemello, M. Collum, P. Mardikian, J. Sembrat, and L. Young, Smithsonian Scholarly Press, Washington DC (2014) 79-86.
12. Graedel, T. E., 'Corrosion mechanisms for aluminum exposed to the atmosphere', *Journal of Electrochemical Society* **136**(4) (1989) 204C-212C, https://doi.org/10.1149/1.2096869.
13. Dornier 17, in *Royal Air Force Museum*, https://www.rafmuseum.org.uk/dornier-17/ (accessed 2022-07-26).
14. Bailey, G. T., 'Stabilization of a wrecked and corroded aluminium aircraft', in *Metal 2004 Proceedings of the ICOM-CC Metals Working Group Interim Meeting*, Nacional Museum of Australia, Canberra (2004) 453-464, Microsoft Word - Section 1 Preventive conservation.doc (nma.gov.au) (accessed 2023-07-10).
15. Morrison, R.; Bagley-Young, A.; Burnstock, A.; Berg, K. J. van den, Van; Keulen H. van, 'An investigation of parameters for the use of citrate solutions for surface cleaning unvarnished paintings', *Studies in Conservation* **52**(4) (2007) 255-270, https://doi.org/10.1179/sic.2007.52.4.255.
16. Giraud, T.; Gomez, A.; Lemoine, S.; Pelé-Meziani, C.; Raimon, A.; Guilminot, E., 'Use of gels for the cleaning of archaeological metals. Case study of silver-plated copper alloy coins', *Journal of Cultural Heritage* **52** (2021) 73-83, https://doi.org/10.1016/j.culher.2021.08.014.

17. MacLeod, I.; Kelly, D., 'The effects of chloride ions on the corrosion aluminium alloys used in the construction of Australia II', *AICCM Bulletin* **26**(1) (2001) 10-19, https://doi.org/10.1179/bac.2001.26.1.003.
18. Carlino, M.; Guilminot, E., 'Utilisation des résines échangeuses d'ions pour le nettoyage d'objets métalliques archéologiques ou historiques', *CeROArt* **12** (2020), https://doi.org/10.4000/ceroart.8014.
19. Giordano, A.; Cremonesi, P., 'New methods of applying rigid agar gels: from tiny to large-scale surface areas, *Studies in Conservation* **66**(8) (2021) 437–448, https://doi.org/10.1080/00393630.2020.1848272.

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