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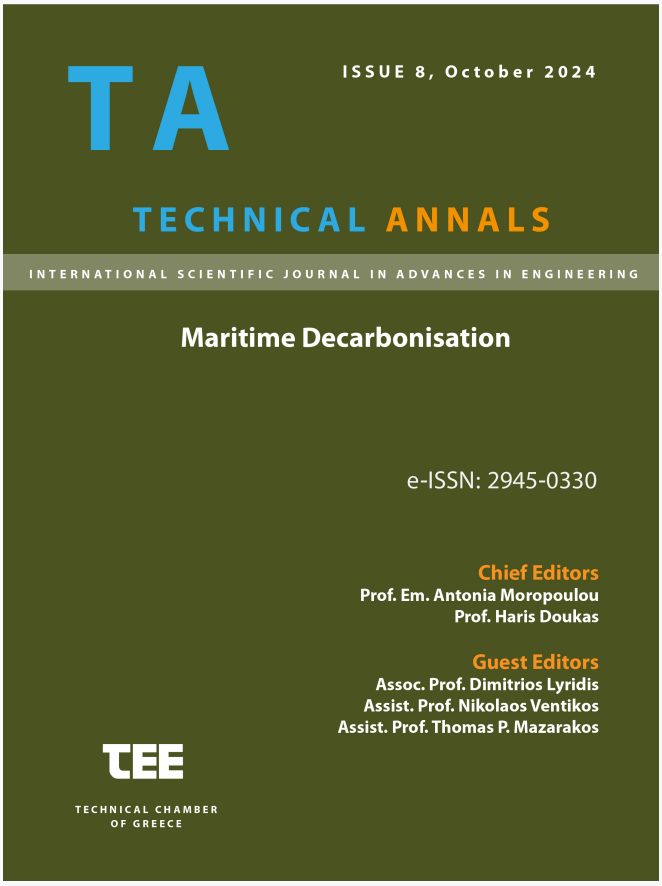

A convergence between cultural heritage and shipbuilding science

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A convergence between cultural heritage and shipbuilding science

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Abstract. In the contemporary context, the demand for wooden vessels remains prevalent in the domains of fisheries, tourism and contemporary sailing. This necessitates a convergence of traditional shipbuilding techniques and contemporary naval architecture. In this regard, there is a growing imperative for the scientific documentation of traditional shipbuilding practices, utilising modern techniques such as three-dimensional documentation and representation. Concurrently, contemporary naval architecture contributes to the design of lines plan. This advanced documentation facilitates the estimation of hydrodynamic resistance through the utilisation of modern calculation methodologies. The integration of contemporary naval architecture, material science and engineering optimisation of materials' interventions and maintenance with traditional shipbuilding art in an arsenal has modernised, reproduced and made viable the construction of a traditional boat. To this end, there is an imperative for the adoption of innovative practices to ensure the revival of the arsenals. The fusion of traditional shipbuilding and naval architecture could lead to the wooden ships that Aegean, Mediterranean, and the world need. The aim of this paper is to present a comprehensive action plan for the cultural, digital and scientific documentation of traditional wooden shipbuilding art. The complete, comprehensive and multidimensional documentation constitutes the basic foundation of the sustainable development and promotion of the Greek shipbuilding tradition. The proposed plan is not confined to the collection, recording and study of the traditional vessels currently being preserved; rather, it employs a comprehensive and multifaceted approach, with targeted actions, seeking the recognition of traditional shipbuilding as an integral part of the cultural heritage and its preservation and transmission to future generations.

Keywords: Traditional Shipyards, Shipbuilding Science, Naval Heritage

1 Introduction

Traditional wooden shipbuilding is one of the most emblematic elements of Greece's cultural heritage. It belongs to the arts with a very long history and has had a decisive contribution to the economic development of our country, throughout its history. It presents very special technical and cultural characteristics that are based on the application of empirical knowledge concerning materials, the method of cutting and processing, static and dynamic stresses, the aging of shipbuilding timber and practical geometric applications for the construction of a vessel.

Wooden shipbuilding and its empirical techniques have been the generative knowledge of modern shipbuilding science; however, it is in danger of being lost. In the last 25 years, an incalculable number of Greek traditional vessels have been lost [1, 2], many of which were monuments of traditional shipbuilding art [3, 4, 5]. The preservation of the art and tradition of wooden shipbuilding and its revival within a modernizing context is directly intertwined with the cultural identity of a maritime nation, such as the Greek one. This assumption makes the documentation of traditional shipbuilding more imperative than ever.

The complete, comprehensive and multidimensional documentation of traditional wooden shipbuilding is an imperative requirement for the preservation of an essential element of cultural heritage and at the same time a strong incentive for the sustainable technological and economic development of traditional shipyards. The adoption of a global approach seeks to recognize traditional shipbuilding as an integral part of cultural heritage. Key components of this approach are cultural, digital and scientific documentation which can be achieved through the convergence of modern shipbuilding science and cultural heritage.

In this paper, a plan of targeted interventions is formulated and presented as a result of the synergy of culture, science and technology for a common goal: the preservation of traditional shipbuilding and the sustainable development of Greek shipyards, which will incorporate new knowledge and innovation into their products and services and achieve increased competitiveness and strengthening of their profile in the context of international competition.

2 Cultural Documentation

The cultural documentation of traditional shipbuilding concerns the process of collecting, recording and analyzing information, both from written sources and from oral tradition. Historical sources (Special Bibliography, Traveler Reports, General State Archives, Registers, Maritime Museums) will be collected and used with the aim of recording the types of traditional vessels, traditional shipbuilding techniques, tools and materials, their construction, maintenance and restoration processes and, finally, the geographical distribution and historical development of traditional shipyards will be captured.

All this knowledge that exists in primitive form will be gathered and reformed in a structured manner in digital form so that, on the one hand, it will be accessible and

understandable, and on the other hand, it will be the source of production of educational material for shipbuilding training schools, who will preserve and develop traditional shipbuilding techniques and promote the intergenerational transfer of knowledge.

Within the framework of cultural documentation, particular emphasis will be placed on the collection of all existing National and European Legislation, which regulates the characterization, operation and commercial movement of traditional vessels, with the aim of a thorough critical analysis and the identification of weaknesses and deficiencies, which make it difficult to identify traditional vessels and consequently to take appropriate measures for their protection and commercial exploitation. A necessary condition for the preservation of the long-standing maritime tradition of our country and the survival of what we vaguely call "traditional vessels" today is, in principle, their institutional identification and subsequently the adoption of favorable measures by the State that will support the construction and operation of these vessels. At the European level, such an effort was made with the Community Directive 2013/53/EU [6] on recreational craft and personal watercraft, which replaced Directive 94/25/EC. In this legislation, in order to support the non-alteration of the identity of traditional vessels due to the requirements of the Directive but also to facilitate their circulation on the market, "original historic vessels and individual replicas of historic vessels designed before 1950 which were built, mainly, with the original materials and are marked as replicas by their manufacturer" are excluded from the scope of the Directive (Article 2, Paragraph (v)). This provision obliges Member States that are required to implement the Directive to clearly define the historical types of vessels that fall within their tradition. In this context, Greece issued the Decree No. 4200/08/15 [7] "Specification of the required supporting documents, as well as the more specific technical and detailed criteria for the classification of a professional or private pleasure boat as traditional and any other related matter". Article 1 of the said Decree attempts to establish criteria for the identification of a traditional vessel. According to this Article, for a vessel to be classified as traditional, the following must be complied with:

- It must have been built according to the characteristic elements of one of the documented, in Greek and international bibliography, types of Greek and European traditional vessels [8, 9, 10]
- The hull, bulkheads, deck, masts and superstructures must have been constructed with materials used in Greek and European traditional shipbuilding, with the exception of the materials of the internal linings and configurations that do not alter the appearance of the vessel, which are allowed to be different
- If it carries sails, it must be documented from Greek and international bibliography [8, 9, 10] that the sails it carries correspond to the types of sails that the specific type of vessel carried, according to Greek and European shipbuilding tradition

Finally, in the same article, various types of traditional vessels are mentioned by name, without specifying their characteristics. The above criteria are largely unclear and insufficient as they refer to and are based on Greek and international bibliography [8, 9, 10], and do not present technical self-sufficiency for the characterization of the traditional vessel. Also, the mixing of Greek and European traditional vessels entails the risk of hybridization and falsification of the traditional Greek vessel. Therefore, the

need to modernize the relevant legislation regarding the definition of the "traditional" vessel in a more consistent manner is highlighted. The legislative definition of the traditional vessel should be based on a thorough study, recording and detailed technical description of all types of vessels and their specific characteristics. The remarkable efforts of Greek researchers [8, 9, 10] in the field of recording will be utilized in the framework of the proposed intervention plan.

However, in addition to the characterization of the traditional vessel, the legislation should also introduce a series of accompanying measures for the sustainability and development of the traditional vessel. Measures such as:

- The creation of public schools with free access for teaching the art of shipbuilding
- The favorable tax treatment of the traditional vessel in the phases of construction, purchase and operation
- The promotion of traditional Greek vessels in the international market
- The strengthening of the modernization/renewal of the equipment of existing carnages

The encouragement of the creation of new businesses that will be active in the field of construction, marketing and operation of the traditional vessel. The technical and economic analysis of these measures will be part of the proposed intervention plan.

In combination with the aforementioned Legislation, the Development of Technical Specifications for the construction, maintenance, inspection and certification of traditional vessels, in the form of Classification Regulations, will also provide a special impetus to the construction sector. These Regulations should be written in the Greek language, using traditional terminology and technically understandable by the average expert manufacturer. Particular emphasis during the development of the Regulations will be given to the preservation of the traditional morphology of the vessels, their construction style and construction materials, while utilizing new technologies for printing, drawing, cutting and assembly. The publication of these Regulations in electronic form and their free circulation will favor the dissemination of relevant know-how.

3 Digital Documentation

The comprehensive three-dimensional digital documentation of traditional vessels requires the use of modern cutting-edge technology, which can capture all the necessary information to be used at the stage of scientific documentation. For the digital capture and digitization through 3D scanning technology of traditional vessels and shipyards, mixed methods can be used that combine three-dimensional scanning with laser scanners and photogrammetry [11].

Three-dimensional digital documentation aims to digitally preserve the know-how and geometric principles of traditional shipbuilding art in very high resolution and accuracy. In addition, a 3D model archive will be created so that these traditional practices can be studied in detail and the diachronic motivations that shaped traditional vessels

as we know them today can be explored, without the need for the presence of a specialist scientist (naval architect and marine engineer, historical scholar, archaeologist, etc.) in the field, i.e. the object will be studied by its digital twin.

The model solutions are implemented in specialized software that integrates the data from laser scanners and photographic images captured through the photogrammetric method. The software then assimilates the coordinates of photostabilized points, leveraging the method of least squares to solve for the parameters and construct the desired model. Additionally, it performs statistical analysis of the outcomes and estimates their precision and reliability.

4 Scientific Documentation

The scientific documentation of traditional shipbuilding art is the key point in the preparation of an innovative plan for the sustainable development of traditional shipyards. It includes the development of 3D hull representation methodologies, virtual reality (VR) technology of traditional ship models, their redesign and structural strength and, finally, the durability testing of wood and its treatments in different wetting conditions.

The development of a process for the 3D representation of a ship is a complex process that uses advanced technologies and techniques. The methodology that preceded the 3D digital imaging stage allows for the precise but discrete recording of the surface geometry. The scanning creates a detailed point cloud, consisting of hundreds of millions of points representing the surface of the ship. The position of each point is described by coordinates (x,y,z) with respect to a given Cartesian reference system and, often, additional information is included such as, for example, the color of each point which is usually represented as a 3D vector (r,g,b) with respect to the RGB color model.

It is a fact that modern three-dimensional information recording devices produce very dense point clouds, the processing of which is time-consuming and requires the use of extremely powerful and expensive computing systems. Consequently, the processing of the produced point cloud constitutes an important stage in the entire process, as well as its introduction into a three-dimensional design environment for the creation of the final model of each vessel.

Initially, the cloud size will be reduced through simplification/decimation algorithms. The simplification algorithms aim to drastically reduce the density of points, while preserving the characteristics of the geometry shape. This is achieved by preserving points in areas with high curvature and/or tangent plane discontinuities (edges) that are considered critical for maintaining the geometry shape. Once the point cloud is processed, it will be imported into a three-dimensional design environment (3D CAD), such as Rhinoceros 3D [12] or Autodesk Inventor [13]. At this stage, the simplified point cloud will be used as a basis for creating the individual elements of the vessel geometry, utilizing analytical representations of curves and surface sections using Non-Uniform Rational B Splines - NURBS (Fig. 1, 2, 3).

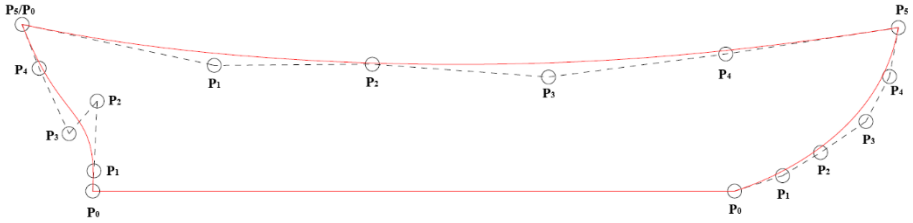

Fig. 1. Control points of a "trexantiri" profile (side view) [9]

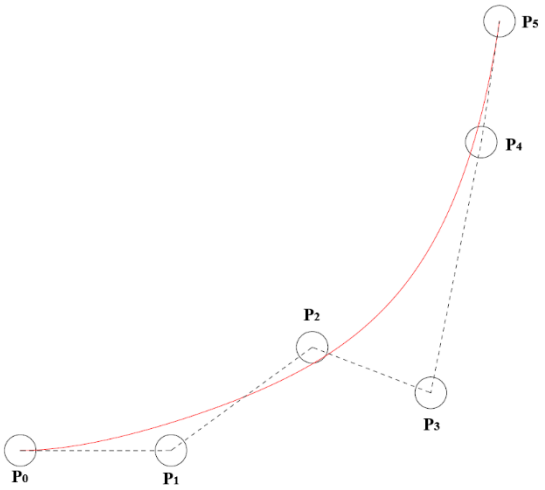

Fig. 2. Control points of a "trexantiri" midship section [9]

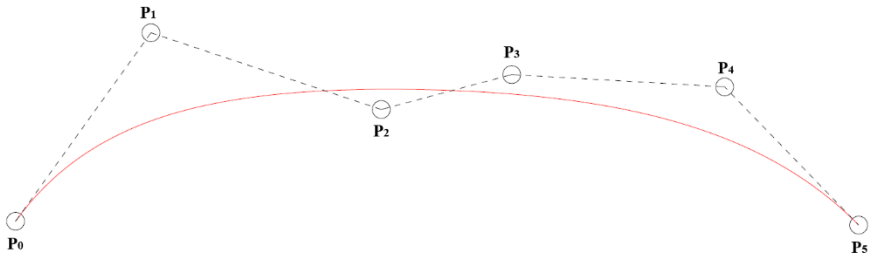

Fig. 3. Control points of a "trexantiri" deck (top view) [9]

Initially, the hull area will be selected from the points of the cloud for the initial approximation of the shipbuilding lines plan and the production of longitudinal and transverse section and waterline drawings. The process of designing the lines plan includes an iterative process of checking and smoothing. In addition, a geometric model will be created representing the hull and internal structural elements and reinforcements, as well as the hull planks, deck, superstructures, rudder and propeller of the vessel (Fig. 4).

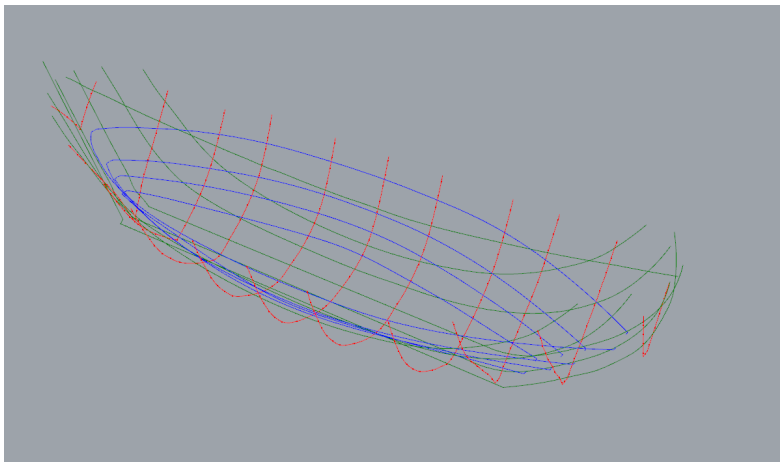

Fig. 4. Stations (red lines), water lines (blue lines) and buttocks (green lines) of a "voutixtadiko" traditional vessel [9]

The produced three-dimensional ship models will be checked and improved based on existing data in the literature. In addition, for the smoothed lines of the vessels under

study, basic hydrostatic and hydrodynamic quantities will be calculated using specialized software, such as MaatHydro [14], Maxsurf [15] and Shipflow [16]. The produced digital material of the 3D models of traditional vessels will be used for the development of VR applications (Fig. 5).

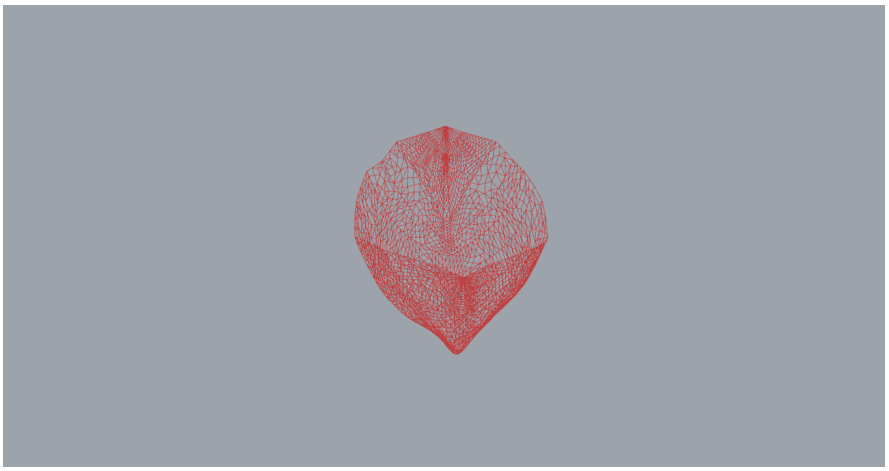

Fig. 5. Discretization of a "voutixtadiko" traditional vessel for resistance calculations [9]

The development of a realistic VR experience includes, in addition to the geometric representation model of the vessel, the application of textures, the simulation of physical properties, the addition of lighting and sound, as well as the development of interactions with the user. Specifically, textures add visual realism to the materials of the model, such as wood, metal or glass. These will be created with software tools such as Substance Painter [17] or Adobe Photoshop [18] and will be applied to the model through tools such as Blender [19]. Their correct application highlights details and gives depth to the model, enhancing its visual verisimilitude.

The simulation of physical properties is also crucial for the realistic representation of the vessel in VR. Elements such as gravity and inertia give realistic movement to the ship, while objects react naturally to the forces they receive. Lighting provides a sense of space and atmosphere, enhancing the experience. Techniques such as global illumination and dynamic shadowing simulate sunlight or lights, providing a dynamic feel based on time and weather conditions. Good lighting enhances image quality and adds realism to the environment. Sound is essential to complete the VR experience.

Sounds such as waves or machines contribute to the sense of presence and immerse the user. 3D sound systems place sounds in space, adding depth and realism. These sounds can come from real recordings or be synthetically created. The user's interaction with the environment enhances the interactivity of the experience. Various interaction scenarios can be created, such as navigating, grabbing objects or performing functions, with the aim of enriching the experience. For example, users can navigate the vessel, interact with objects and perform navigation-related functions, creating a fully immersive experience.

The necessary simulations of physical properties, lighting, sound, as well as the development of user interactions will be implemented using virtual world development environments such as Unity and/or Unreal Engine. Where required, in addition to the point cloud, photographic material will be used to fully record the details of the outer surface of the hull as well as the interior of the vessel. The photographic material will be further exploited through the Gaussian Splatting technique [20] to create a 3D navigation and overview application of the vessel with very high quality photorealism. The Gaussian splatting technique is an innovative approach to the visualization of high quality 3D scenes, offering excellent realism and real-time performance. Objects in a scene are not represented as collections of their boundary surfaces, but as collections of Gaussian spheres, i.e. spheres that have a density distribution that follows a Gaussian curve. The characteristics of the spheres (position, size, color and other material properties) are variables in an optimization problem given the photographic material (photographs in various positions and orientations) and the criterion is the optimal reproduction of the images (at the pixel level) through rendering of the spheres by virtual cameras located at the positions and having the orientation corresponding to the real cameras that created the original images. The correlation of the position-orientation of the real camera with the original images is done using photogrammetry techniques.

Subsequently, a redesign of traditional vessels will be carried out, which constitutes a comprehensive process of control and smoothing, with a cyclic alternation between transverse sections, waterline and longitudinal sections. A geometric model is created to represent the external and internal structural elements and reinforcements as well as the hull planks, deck, superstructures. Through specialized computational programs, hydrostatic and hydrodynamic quantities are calculated [12-16]. A structural analysis of basic representative types of traditional vessels is carried out with Classification Society Rules or modern methods (e.g. Finite Element Method [21]) in order to determine the level of safety from a structural point of view. This ensures reliable performance without failure or collapse under operational and extreme conditions (Fig. 6).

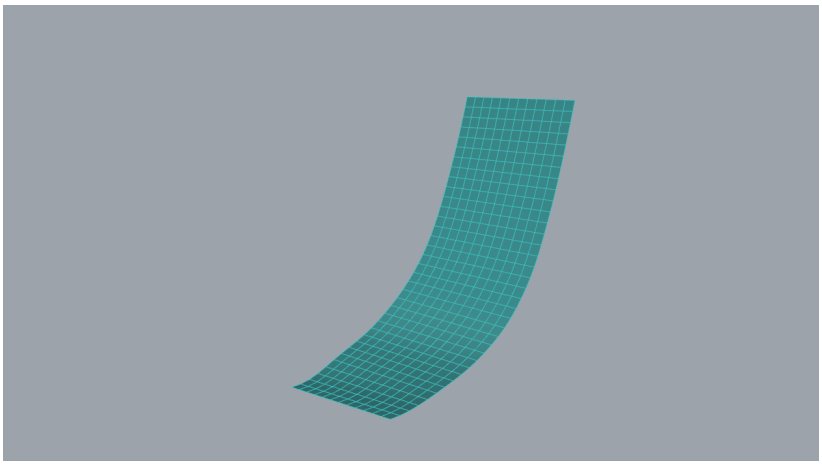

Fig. 6. Discretization of a midship section of a “voutixtadiko” traditional vessel for FEA analysis [9]

Also, again with the help of modern analysis methods, such as Finite Element Method (FEM) and Computational Fluid Dynamics (CFD), the design can be optimized, without violating the morphology of the vessel, the construction technique and the materials used can be enhanced, with the ultimate goal of reducing construction costs. Also, Guidelines will be developed for the control of the structural integrity of existing vessels, emphasizing the timely detection of damage and the need for their restoration.

The study of the state of conservation of tangible cultural heritage using non-destructive techniques has experienced great growth in the last decade. The rapid technological developments concerning the instrumentation of these techniques, as well as the new software for processing their data, have increased the reliability of the results obtained.

The above, combined with the particular requirements of research in the field of cultural heritage, where on-site study at the scale of the construction is usually necessary, as well as limited sampling, has led the scientific community to the widespread use of non-destructive techniques in the context of the study of material properties, corrosion mechanisms, the diagnosis of deterioration, as well as the evaluation of different conservation interventions. However, in the domain of safeguarding traditional vessels, the utilization and exploitation of the potential offered by Non-Destructive Testing (NDT) remains at a comparatively lower level in comparison to the domains of built cultural heritage and art objects. This presents a novel challenge.

In this context of innovation, one of the objectives of the proposed plan is to study in detail the capabilities of NDT, in terms of the characterization of the materials of construction of traditional vessels, the treatments, the types of wear, as well as their mechanisms. The NDT will be carried out on site at the scale of traditional vessels. In addition, NDT will be carried out in the laboratory, on appropriately shaped specimens of various types of wood, treated and untreated, before and after accelerated aging tests involving wetting conditions with clean water and seawater. Thus, the susceptibility to wear of the types of wood under consideration (e.g. iroko, pine, katrani) will be studied, as well as the durability and compatibility with each substrate of the treatments under consideration (e.g. epoxy, polyester putties, etc.), mainly in relation to their deposition method and changes in microstructure, wetting and drying time. From the above, it becomes clear that the application of NDT both on-site at the scale of the vessels and in the laboratory will yield sufficient data, which will be able to establish a sufficient knowledge base regarding the construction materials and the effective treatments that lead to the protection of traditional vessels. These data will be included in a manual for increasing the life cycle of the construction materials and treatments of traditional vessels, based on the maintenance processes.

Furthermore, the 3D digital imaging of traditional vessels, which can determine the state of preservation of the vessel in terms of its geometry (e.g. any deviations, modifications to curved surfaces) and possible changes - variations in the surface texture, will be correlated with the data of the non-destructive diagnostic test that determines the state of preservation of the materials of the vessels under examination. Thus, the integrated three-dimensional digital documentation will bring and correlate geometric, spatial and descriptive information regarding the materials. Accordingly, a comparative

study of the physicochemical and physicomechanical NDT data obtained before and after accelerated aging tests of different types of wood and treatments can be correlated with the results concerning the strength of traditional boats. This will lead to interdisciplinary decision-making for the selection of the most suitable and compatible carrier and treatment materials. These materials will be used in the construction of the traditional boat that incorporates modern science [22-25].

In summary, the proposed action plan will develop a standard, innovative method for designing sustainable construction of traditional vessels. One of the types of vessels to be studied as described above will be formatted as a "blueprint" model that will include a standard 3D model of the vessel using computational tools, materials to be used for its construction, construction and maintenance instructions. This model will be able to be adapted to the specific requirements of a new vessel, within limits to be defined.

Based on this model, the construction of the traditional vessel will be carried out under the supervision of Naval Architects and Chemical Engineers to ensure the faithful adherence and application of the research results. The construction process of the traditional vessel will be videotaped to create a digital archive for educational purposes.

Essentially, a vessel will be created, which will retain the image, simplicity and lines of tradition, but will be scientifically fully entrenched by Naval Architects and Marine Engineers.

5 Strategic Planning

Finally, the proposed plan is completed with the development of strategic actions for the commercial exploitation of traditional shipbuilding, in the context of sustainable development. The strategic planning is based on two main pillars:

First, in education and training. Educational material will be produced in the form of manuals, an open access database and interactive multimedia applications. The manuals will be accompanied by audiovisual material with the aim of recording traditional shipbuilding techniques, in order to preserve the unique identity of this professional sector. The knowledge passed down from generation to generation embodies the collective wisdom, values and artistic expressions of a nation. Traditional shipbuilding techniques, perfected over the centuries, are not only a testament to the craftsmanship of shipwrights, but also a symbol of the resilience and creativity of this industry. The digital platform of the proposed plan will include a website, an open access database, an electronic file of traditional vessels, educational videos with the construction of the vessel, interviews and educational interactive multimedia applications.

Secondly, in the business planning, that is, in the drafting of a report within the framework of a holistic approach for the reform and sustainable development of shipyards. In this context, an assessment of the national importance of traditional shipbuilding activity will be made, the causes of its decline will be investigated and proposals will be developed for the revival of sustainable, innovative shipbuilding of traditional vessels. It will have as its main objective the commercial exploitation of traditional

shipbuilding within the framework of sustainable development in a five-year time horizon.

The potential products of the business activity and the corresponding market sectors to which they will be offered will be identified. The time and cost required to develop it as a commercial product will be estimated based on the results of the proposed action plan. This is the classic phase in which the results of research are formalized into a marketable object-product (development). The infrastructure and resources (including human) necessary to offer the products to the market will be determined. The principle of gradual development of the business activity will be followed, so that the initial requirements are limited, and increase in a controlled and economically viable manner.

Finally, the estimate of the sales volume will be formulated based on a plan to access the market sectors that the business activity will target, and its financial performance will be calculated over a five-year time horizon.

6 Conclusions

The proposed action plan will create a range of applications and ways of exploiting traditional shipbuilding; the partnership of scientists and industry will produce original, specialized and integrated know-how which will constitute a valuable tool for the scientific community and a legacy for the cultural heritage.

The construction of a traditional vessel, through the refinement of cultural, digital and scientific documentation, will be done in a way that harmonizes traditional technique with scientific analysis into an integrated whole. The expectation is that this vessel, which will be tangible proof of the excellent result that can be achieved with the convergence of science and traditional technique, will constitute a model for achieving social, commercial and economic sustainability of the shipbuilding industry. It will constitute an original product, as it has never been attempted before.

Through the methodology proposed in this plan, we will be able to take all the necessary information that comes to us from the past, enrich it and channel it to future generations. It will have significant positive consequences at a business and social level, as it is expected to strengthen the dynamics of businesses in the sector, both in human resources and in logistical infrastructure.

The innovation of the proposed plan is that it does not simply capture the knowledge that has been created over the centuries, but integrates and optimizes it, creating a common component, combining the beauty, grace and aesthetics of traditional shipbuilding, with the theoretical and computational documentation of science.

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