Traditional shipyards: transition from the past to the future in the light of sustainable development

Vaseilios Vasileiadis[1], Thomas P. Mazarakos[2][0000-0001-5317-2656], Dimitrios Lyridis[3][0000-0003-0812-0560], Dimitrios Pappas[4], Sarantos Sarantidis[2][0009-0005-5446-7073], Costas Triandafyllos[5] and Antonia Moropoulou[6][0000-0002-5704-4368]

[1]Naval Architect and Marine Engineer,
President of Panhellenic Association of Traditional Shipyards
[2]Department of Naval Architecture, School of Engineering, University of West Attica,
Campus 1, Ag. Spyridonos 28, 12241 Egaleo, Attica, Greece
[3]School of Naval Architect and Marine Engineering, NTUA
[4]President of Panhellenic Association of Naval Architects and Marine Engineers
[5]Naval Architect and Marine Engineer
[6]School of Chemical Engineering, NTUA
amoropul@central.ntua.gr

Abstract. Arsenals are acting as traditional shipyards not only for the production of the wooden ships required today but also for ship repairing industrial activity which is very intense in the Eastern Mediterranean with emphasis in Greece. In Greece, 300 arsenals were developed and functioned in the last 200 years. From these, only 60 to 70 survive today even though the demand for industrial activities is augmenting. On the contrary, in international competition, arsenals producing new wooden ships for tourism, sailing, and fishing uses are emerging, and becoming significantly competitive. Institutional challenges, like the licensing of land use in the seashore, and short-term contracts at high prices are dramatically testing the viability of arsenals all around Greece and mainly in the Aegean. Arsenals, which were proven resilient through the centuries and under threats like environmental stresses, wars, and enemy' attacks, are today deteriorating. This manuscript addresses not only environmental concerns but also positions the traditional ship repair industry as a key player for sustainability and responsible tourism, sailing, fishing and trade practices.

Keywords: Shipbuilding Evolution, Traditional Shipbuilding, Naval Heritage

1 Introduction

Along the Greek coasts, in distinct sections of the shoreline and beach that present suitable conditions, shipbuilding and repair activities have been carried out continuously for thousands of years. These areas, where this activity takes place, have been traditionally called "karnagia" or "tarsanades" for centuries. The karnagia are scattered across the country. At the beginning of the 20th century, there were over 300 tarsanades, whereas today, only 70 remain. In Samos, Lesvos, Thassos, Kavala, Chalkida, Spetses,

Koilada Argolidos, Crete, Rhodes, Symi, and Kalymnos, our karnagia and their craftsmen strive to support coastal navigation [1-7].

It is worth noting that Greece has the largest fleet in the European Union in terms of the number of vessels engaged in coastal navigation. The islanders of the central Aegean rely exclusively on wooden boats due to their seaworthiness in rough conditions. The size of these vessels ranges from 8 to 30 meters, with 90% of them not exceeding 24 meters. These boats cannot be built or maintained in the country's large shipyards, as this would be entirely unprofitable for their owners. Therefore, it is evident that coastal navigation is entirely dependent on karnagia, and its survival is directly linked to them [8-12].

2 Karnağio/Tarsanas

A karnagio/tarsanas is defined as a small, private shipbuilding and repair business, including the coastal area, along with the minimal required equipment, facilities, buildings, and shelters. The following distinct traditional activities take place there:

a) Hauling, launching, repairing, maintaining, drying, and inspecting vessels on land to certify their seaworthiness, regardless of hull material
b) Constructing and modifying wooden hull boats
c) Producing and shaping shipbuilding timber from tree trunks
d) Providing oral and hands-on apprenticeship in the traditional shipbuilding craft of Greek-style wooden boats

Fig. 1. Shipbuilding timber treatment

Fig. 2. Frames placement

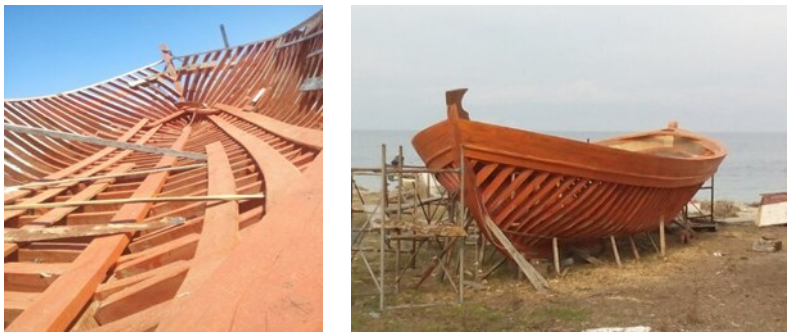

Fig. 3. Ship hull lining

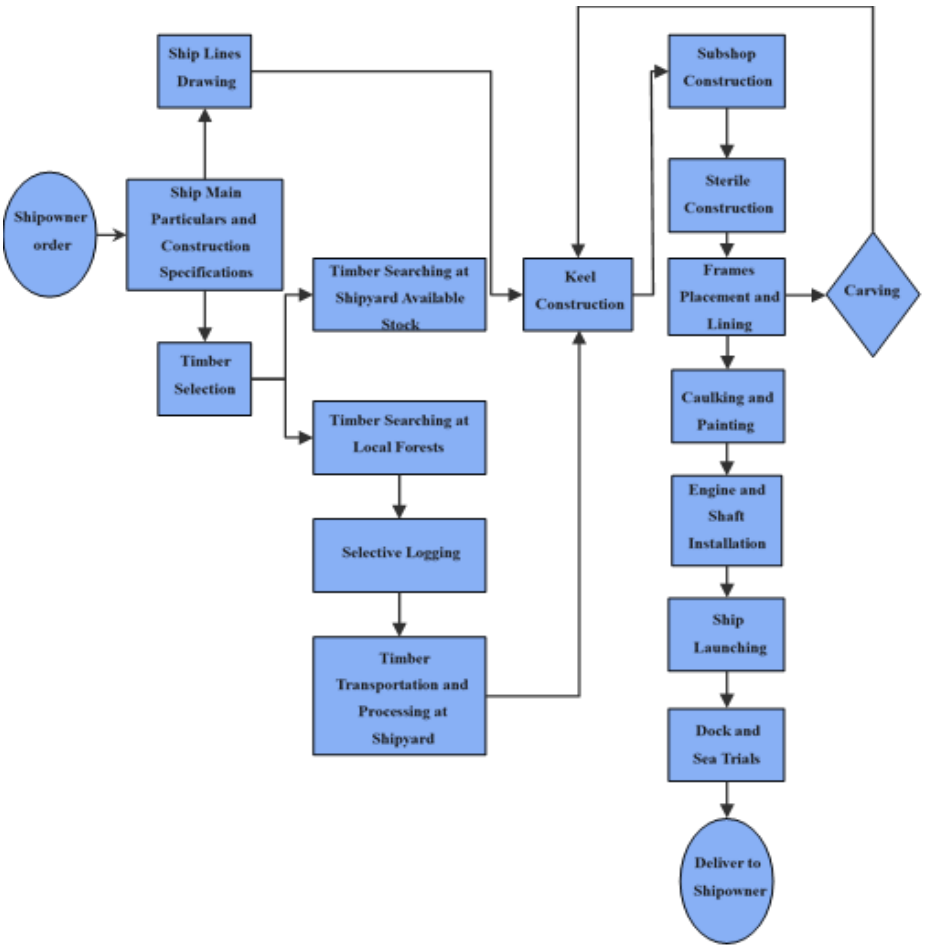

Fig. 4. Typical flow chart of karnagio processes

The size of the vessels built or serviced is limited by the available space, equipment, and the primary material—wood. Most of these are small-capacity vessels, as wood, as a shipbuilding material, does not allow for the construction of boats longer than 40 meters due to technical and economic constraints. The length of vessels that rely on karnagia services ranges from 6 to 18 meters, with very few exceeding 24 meters [8, 13-16].

Following an order from the Ministry of Shipping and Island Policy, port authorities recorded the existence and operation of approximately 70 karnagia/tarsanades across the country. These facilities occupy less than one-thousandth of the total length of the Greek coastline [2, 3, 17, 18].

Each karnagio/tarsanas employs two to five permanent workers. Additionally, when needed, external teams of two to three people work on-site for electromechanical and electronic installations, painting, specialized interior constructions, and other tasks. Furthermore, certified naval architects, mechanical engineers, and architects supervise projects that require study and design [4, 6, 11, 12].

The Ministry of Shipping and Island Policy is also responsible for conducting the legally required land inspections for the issuance of General Inspection Certificates (GIC) for ships and boats. These inspections are carried out by inspectors from the Ship Control Branch, the Coast Guard, or authorized classification societies [17, 19].

There is no production line. The processes remain predominantly traditional and handcrafted, ensuring that each construction is unique. Essentially, a karnagio/tarsanas functions as a permanent open-air construction site, accompanied by a small professional workshop for producing and shaping shipbuilding timber from tree trunks for in-house use. Additionally, a small sheltered area houses and protects the hauling/launching winch [1, 4, 14, 16].

The workshop is equipped with three or four woodworking machines with a total driving power of 20 to 30 KW and also serves as an office, design area, and tool and wood storage space. The hauling/launching winch, with a power of around 100 KW, does not participate in the production process and operates only during hauling and launching, causing minimal disturbance [3, 7, 15].

When the traditional method of hauling/launching with "vaza" (wooden cradles) is maintained, allowing for the servicing of larger boats, there is no alteration to the coastal geomorphology, ensuring the shoreline remains intact for the application of traditional methods. Constructing a ramp (slipway) simplifies and significantly facilitates the hauling and launching process, especially for very small boats. Modern global hauling/launching methods use the "travel lift" system, which requires the construction of port infrastructure [2, 6, 8].

There has never been significant environmental damage caused by the operation of shipyards (carnagia/tarsanades). Their facilities blend harmoniously with the environment, and both these structures and the products of their productive activities—wooden vessels of traditional Greek types and designs—constitute a distinctive element of the human-made environment. As such, they are an integral part of the unique landscape of the Greek coasts and seas [9, 10, 18].

Fig. 5. Typical karnagia through the ages as an integral part of the graphic landscapes and local societies

Scientists from foreign countries frequently visit these shipyards to document their timeless activities scientifically, while painters and photographers seek inspiration, capturing the beauty of the space, the traditional Greek wooden boats, and scenes from everyday life at the shipyard through artistic expression. Additionally, tourists approach these shipyards with great enthusiasm, expressing admiration for a unique craft that has been practiced in nearly the same way for thousands of years, producing exceptionally seaworthy vessels with a lifespan of up to one hundred (100) years—each one a distinct work of art [5, 11, 12, 13].

3 The Role of Traditional Shipyards in Greek Maritime Activity

In Greece, coastal navigation consists of fishing, support vessels for aquaculture and shellfish farming, boats for maritime tourism and private leisure (both Greek and foreign-owned), port service vessels, and, at times, vessels of the Greek Coast Guard and auxiliary/light vessels of the Navy. These activities facilitate the development of key economic sectors such as maritime tourism and fisheries while simultaneously preserving the socio-economic fabric of coastal communities, particularly in the islands. Additionally, they contribute to national maritime security and defense [1, 17, 19].

To maintain their seaworthiness and safety, these vessels are hauled ashore annually for necessary repairs, maintenance, and legally mandated dry inspections, which are required for the issuance of the General Inspection Certificate (GIC). This certificate is essential for the lawful and safe operation of these vessels. Due to their small size or the considerable sea distances from their areas of operation, these vessels cannot be serviced at large shipyards, which are concentrated in metropolitan port cities. Unlike large and medium-sized shipyards, small shipbuilding and repair units (carnayia/tarsanades) are scattered along the coasts of both island and mainland Greece. Their widespread presence ensures the continuous availability of repair and maintenance services for these vessels and allows for the construction of new ones, fostering maritime activity across the country [2, 14, 15, 16].

Fig. 6. Typical shape of sxara (left) which serves for launching and berthing (right) procedures

4 The Importance and Necessity of Maintaining Traditional Shipyards

The preservation of seaworthiness for fishing fleet vessels, professional maritime tourism boats, recreational craft, port service vessels, and, at times, Coast Guard and auxiliary Navy vessels—as well as the ability to conduct mandatory dry inspections—are crucial for protecting property and human lives at sea. The uninterrupted operation of these shipyards directly affects maritime connectivity, particularly between the Greek islands and the mainland. The reliable and high-quality services they provide support the continued relationship of Greeks with the sea while sustaining a broad network of maritime trades and material supplies [6, 8, 13].

Furthermore, the operation of these shipyards is essential for:

1. The gradual and necessary replacement of aging wooden fishing boats with new, domestically produced vessels. The Greek fishing fleet, comprising 14.123 vessels, is the largest in the European Union in terms of numbers, despite its relatively low total capacity. Of these vessels, only 175 exceed 24 meters in length, with wooden boats making up the majority [3, 4, 7]
2. Meeting the increasing demand for professional tourist day boats by building new traditional Greek-style wooden vessels or converting wooden fishing boats into tourist boats. The number of professional and recreational maritime leisure vessels exceeds 7.000, with significant potential for further growth. A key factor in the development of maritime tourism is the presence of at least a minimum number of shipyards in each region, capable of covering immediate maintenance, repair, and winterization needs, as well as the construction of new vessels [9, 10, 18]
3. Reducing the import of wooden boats from the neighboring country, which has recently dominated the market—even in cases involving vessels of traditional Greek designs. Our neighbors, despite lacking a long-standing shipbuilding tradition and having had no shipbuilding activity from 1922 to 1990, have managed over the past three decades to develop a full range of shipbuilding capabilities. Utilizing knowledge acquired from Greek shipwrights and engineers from other countries, it has positioned itself as a competitive player in the international market, leading to concerns about the erosion of traditional Greek shipbuilding [5, 11, 12]
4. The preservation of the art of wooden boat building in Greece, a craft practiced continuously for thousands of years, drawing worldwide interest and admiration from scientists, artists, and tourists alike. This craft is recognized as an intangible cultural heritage of global significance
5. The continuity of the socio-economic fabric of island and coastal communities, especially those in remote areas
6. The preservation of the cultural, historical, and natural landscape, as well as the visual identity of shipyards (karnagia/tarsanades) and their products—namely, wooden vessels of traditional Greek types and forms—is of great significance

These vessels and shipyards constitute a rich naval, maritime, and architectural heritage, forming an integral part of the seascape along Greek coasts and waters. They

serve as tangible proof of the centuries-old continuity of Greek civilization and its deep-rooted relationship with the sea. The professionals operating these shipyards/tarsanades—who remain skilled shipbuilders, whether they hold formal shipbuilding diplomas/degrees or, preferably, have gained expertise through years of hands-on experience—are the sole bearers of knowledge regarding the traditional Greek art of wooden shipbuilding. As such, they are the only ones with the capability and expertise to construct new wooden vessels [3, 6, 7, 12, 18, 19].

5 Current Situation

The continued operation of approximately 70 small ship repair businesses (karnagia/tarsanades) remains highly precarious. The ongoing wealth and economic crises have dangerously increased the risk of further reductions in the number of operational facilities. This situation arises at a time when the preservation of the remaining shipyards/tarsanades is crucial, as they represent the minimum required number of small ship repair units necessary to meet urgent needs and serve the public interest.

Since the mid-1990s, the number of operational shipyards/tarsanades has been in continuous decline, mirroring the broader contraction of Greece's once-thriving shipbuilding and repair industry. Over the past decade, new shipbuilding projects have nearly ceased, and most facilities have either shut down entirely or restricted their operations solely to maintenance and repairs. Consequently, this has led to income losses, job cuts, and the disappearance of valuable expertise and skilled technical personnel [2, 3, 8, 11, 12, 20].

Despite the ongoing need and potential for constructing specialized vessels—such as submarines, naval ships, Coast Guard boats, research vessels, rescue ships, passenger ferries, fishing boats, and traditional Greek wooden day-cruise vessels—the sector remains underutilized. More critically, Greece must not reach a point where it cannot meet urgent repair and maintenance needs simply because fundamental yet essential industry sustainability issues remain unaddressed. This is particularly unacceptable given that Greece has many highly skilled shipbuilders, suffers from high unemployment, and maintains relatively low labor costs. Unlike large and medium-sized shipyards, the development trajectory of small shipyards primarily depends on internal factors. A key internal determinant is an appropriate regulatory framework that ensures the sector's survival and growth. The shortcomings of the current regulatory framework governing shipbuilding and repair highlight the pressing need for its reform.

6 Regulatory Framework for Operation and Development

Greek shipyards (karnagia/tarsanades) have long engaged in ship maintenance and repair, as well as in the construction of wooden boats, caiques, and larger vessels. This tradition represents one of the most historically significant and defining activities of the Greek nation, contributing to its livelihood, struggles, and cultural development since its earliest days. This craft is deeply ingrained in the collective consciousness of the Greek people and continues to hold immense value and relevance in modern Greece.

Nevertheless, numerous fundamental issues affecting the karnagia/tarsanades sector remain unregulated by the contemporary Greek State. There is no specialized legal framework fully safeguarding this activity within its natural and historically designated space—namely, the shoreline and coastal zones. Consequently, the continuity of this activity, as it has been practiced for centuries, is not legally secured, and it often clashes with legislative interpretations and administrative decisions. This regulatory gap has led to severe restrictions on professional practice, bureaucratic obstacles, and friction between industry professionals and authorities, which hinder sectoral growth and, more alarmingly, threaten its survival.

Key issues requiring urgent institutional recognition and regulatory action include:

- Incorporating the sector into spatial, urban, and maritime planning strategies
- Integrating it within a comprehensive island and maritime policy framework
- Fully legalizing the use of coastal zones for shipbuilding and repair activities
- Approving the installation of essential operational equipment
- Issuing official approvals and lease agreements for the use of shoreline and port land
- Establishing clear terms for lease duration and financial obligations
- Streamlining classification and licensing procedures for businesses
- Securing access to raw materials from Greek forests while ensuring sustainable forestry practices
- Promoting education, research, certification, and overall recognition of the sector
- Actively supporting and showcasing the industry's significance within national policy

The most pressing issue is securing the necessary space for the sector's operations, which must meet specific geomorphological and environmental conditions. This includes access to shoreline areas, port lands, and marine zones while aligning with national maritime and urban planning policies. However, decisions affecting these matters are fragmented among various ministries, local port authorities, and other governmental bodies.

The existing regulatory frameworks governing industrial parks and informal industrial zones inland cannot address the needs of the ship repair sector. The absence of a dedicated legal framework for karnagia/tarsanades and the inconsistencies in the interpretation of Law 2971/2001 have led to a reluctance among land management authorities to assume responsibility for approving coastal usage rights for these businesses. As a result, for decades, shipbuilding professionals have been left in a state of legal uncertainty, vulnerable to administrative constraints and lacking the necessary institutional support to sustain and grow their industry [1, 2, 3, 8, 11, 12, 20, 21].

7 Efforts To Preserve The Activity

In recent years, both citizens and the state (i.e. Greek Ministry of Shipping and Island Policy, workers' unions, labor unions) have been making a strong and continuous effort to preserve the shipbuilding and repair activities of traditional shipyards (karnagia/tarsanades).

To ensure their survival, the following measures are necessary:

1. Financial Support: The shipbuilding and repair sector should receive financial aid
2. Tax Reductions: Lowering VAT and income tax rates for businesses in the sector
3. Reduction of Concession Fees: Lowering the fees for the use of port land zones and canceling any recent decisions to increase these costs for existing shipyards operating in port areas
4. Long-Term Concessions: Establishing long-term (up to 50 years) leasing agreements for port land zones, with renewal rights and reasonable fees (1.5 euros/m² with five-year adjustments) for both existing and new shipyard businesses
5. Coastal Land Concessions: Facilitating access to necessary shoreline areas for existing and new shipyards
6. Fair Usage Fees: Setting a standardized fee of 1.5 euros/m² for the use of shoreline areas, with periodic adjustments
7. Lease Terms Linked to Licensing: Ensuring that land leases remain valid as long as the business has an active operating permit, up to 50 years, with renewal rights
8. Securing Necessary Space: Guaranteeing adequate space for shipyard operations
9. Incorporation in Planning: Including shipbuilding and repair activities in maritime spatial planning and urban development frameworks
10. Strategic Development Integration: Recognizing shipbuilding and repair as a key sector in national maritime and regional development policies
11. National Development Program: Implementing a national program for the growth of the shipbuilding sector, with at least five years of financial incentives
12. Legislative and Economic Safeguards: Adopting five-year legislative and financial measures to ensure the continued operation of shipyards, similar to measures taken for aquaculture businesses
13. Industry Synergies: Integrating shipbuilding activities with related maritime sectors such as tourism, coastal fishing, and aquaculture to support sustainable development
14. Designation of Suitable Areas: Ensuring compatibility between shipyard locations and designated aquaculture development zones
15. Financial Incentives for Wooden Boats: Providing additional subsidies for the maintenance of traditional wooden boats used in maritime tourism and cultural heritage
16. Reduction of Tax Burdens: Lowering tax assessments for owning and maintaining traditional Greek wooden vessels
17. Updating Traditional Boat Designation: Revising legislation (e.g., Decision 4200/08/15) to properly define traditional fishing and wooden vessels
18. Recognition of Wooden Shipbuilding as a Traditional Art: Enacting legal provisions to officially recognize wooden shipbuilding as an intangible cultural heritage
19. Increased EU Funding: Boosting financial aid through EU programs (such as ESPA) for building and restoring traditional wooden boats

20. Retirement Compensation for Aging Fishing Boats: Introducing financial compensation for retiring old fishing vessels, allowing for renewal of the fishing fleet and new shipbuilding opportunities
21. EU Negotiations on Fleet Reduction Programs: Advocating for policy changes in EU fishing fleet reduction programs to allow repurposing of decommissioned vessels instead of mandatory destruction
22. Lifting Restrictions on Fishing Licenses: Allowing the issuance of new fishing licenses within EU-approved limits
23. Subsidizing New Wooden Fishing Vessels: Supporting the construction of new traditional wooden fishing boats
24. Support for Floating Maritime Museums: Funding municipalities and institutions for acquiring and maintaining traditional wooden boats to establish floating museums of shipbuilding and maritime heritage
25. Sustainable Use of Timber Resources: Managing forestry resources to ensure a steady supply of quality shipbuilding timber, especially from island forests such as those in Samos, Thassos, and the Sporades
26. Simplification of Regulations: Streamlining and reducing bureaucracy for establishing and operating shipyards, in line with national efforts for regulatory simplification
27. Eliminating Unnecessary Legal Restrictions: Removing contradictions and inefficiencies in existing legislation that hinder shipyard operations
28. Clear Operational Framework: Establishing clear terms and conditions for shipyard activities
29. Creation of a National Shipyard Registry: Establishing a national registry of shipbuilding and repair businesses
30. Standardization of Environmental Criteria: Rationalizing environmental classification criteria for shipyard activities as outlined in existing law
31. Improvement of Legal Framework: Amending Law 2971/2001 to properly regulate coastal zones used for shipbuilding and repair.
32. Public Awareness and Education: Introducing maritime and shipbuilding heritage topics into primary education curricula
33. Technical Education and Apprenticeships: Expanding post-secondary education and training programs for shipbuilding-related professions
34. Vocational Training for Shipbuilders: Providing financial support for apprenticeships in shipbuilding and repair
35. Employment Programs: Creating targeted apprenticeship and employment programs for young workers
36. University-Level Training: Establishing and launching the two-year vocational training program “Wooden Boat Technician (Shipwright)” at the University of West Attica
37. Expansion of Training Programs: Setting up similar training schools at the University of the Aegean and the International Hellenic University

Traditional shipyards (karnagia/tarsanades) are an integral part of Greece’s shipbuilding heritage, having supported coastal navigation for centuries. Despite declining numbers and increasing challenges, they remain essential for the maintenance, repair,

and construction of wooden vessels, which are vital to fishing, maritime tourism, and other key industries. Their preservation is not only a matter of cultural heritage but also an economic and social necessity, contributing to the sustainable development of coastal communities and maintaining Greece's deep-rooted connection with the sea [1, 2, 3, 5, 6, 8, 11, 12, 20, 21, 22].

8 The role of parametric design in the adaptive development of traditional vessels

However, traditional shipyards themselves, for their sustainable development, should be modernized. Tradition should not be an obstacle to their transition to the modern era and the adoption of innovation and a modern business model. Computational methods, such as the parametric analysis presented in this paper, could give an impetus to their evolution so that a new generation of shipyards can emerge, in which ships can be built that will combine the beauty and simplicity of tradition with the computational documentation of science.

In recent years, the evolution of computational engineering (Computer-Aided Design, (CAD), Computer-Aided Manufacturing (CAM), and Computer-Aided Engineering (CAE) systems) favored the virtual design, where engineering objects (or parts) can be created in 3D view and evaluated in real-time. 3D design based on CAD, CAM, and CAE systems gradually replaced the traditional drawing which, despite its great level of artistic expression, portability, low-cost equipment and intuitive workflow, couldn't compete with the computing precision, realistic virtualization and modification flexibility of 3D design. The extended use of computing systems enhanced the object geometry representation with the aim of parametric curves and surfaces.

The concept of parametric design is not something new in ship design. The first application of this concept was spotted in 1950 and since then, many researchers have developed their work not only exclusively related to this matter but also in combination with the concept of optimization according to each design expectations and ship vessel functionality [23-30]. It is crucial to mention that an application of parametric design in traditional ship drawing is still not recorded. It is a strong belief that parametric design (in combination with the appropriate computing programs) could renew the valuable data of traditional ship drawings and technical information with new possible alternative drawings for specific design concepts and optimize according to certain requirements (for example, ship resistance elimination). Traditional designers will be able to acquire the new data information and as a result, the drawing procedure will occur in much less time and the main interest will be swift to the stage of construction.

Parametric curves point coordinates are determined with the aim of simple numerical equations based on an independent parameter that either takes values from the real number set or a more restricted number set. Each value of the parameter in question corresponds to a specific parameter curve point. Parametric curves are used exclusively in the field of modeling and among their advantages, the ability to display closed curves, the ease of their extension to three-dimensional space and their independence from the respective coordinate system are included.

Traditional ship geometry representation and evaluation in CAD, CAM, and CAE environments is also able to be carried out with the aim of parametric curves and surfaces. Firstly, critical information about the hull geometry of a traditional ship type of our interest is collected from a sufficient sample of existing geometries. At this stage, traditional designer know-how and old traditional ship drawings and geometry limitations recordings might able to be valuable allies. Secondly, the appropriate parameters are defined in a manner consistent with not only the efficient ship geometry representation but also the production of possible reliable alternative designs according to parameter value modification. Therefore, a series of geometry limitations must be determined. Moreover, ship parametric curves are developed and, based on them, ship parametric surface is implemented, with the best possible surface quality to be set as a main goal, in every possible alternative design solution. Finally, the parametric model is evaluated according to the above criteria.

The selection of the appropriate parameters for the traditional ship hull description is a crucial element for an effective parametric design and requires a thorough understanding of the model geometry and the model operating conditions. Each designer must aim for the least number of parameters needed for the traditional ship hull representation, considering the fact that a proportionless large number of parameters increases the parametric design complexity and prevents the use of optimization computing programs.

Parameters used in ship parametric design are mainly categorized into the following groups: main parameters, ship bow part parameters, ship middle part parameters and ship stern parameters. The main parameters are related to the ship's main dimensions (length overall, moulded breadth, moulded depth and designed draft). Ship bow parameters are related to the parameters that affect the geometry of the ship bow part. Ship middle part parameters are related to the parameters that affect the midship section and generally the geometry of the ship middle part. Ship stern parameters are related to the parameters that affect the ship stern part. At this point, it’s crucial to be mentioned that parametric values might not only be numerical but also logical (for example, the selection of ship stern type).

The range of parameter values directly affects the number of possible alternative design solutions and its determination is at the discretion of the designer. It is obvious that the greater the range, the larger the number of possible design solutions and also the greater the chances of convergence to an ideal optimal solution in case of an optimization problem. However, the range of parameter values must correspond to the respective geometry limitations, which are either imposed by the designer himself or arise as logical and necessary conditions for a correct design (e.g. the height of the designed draft cannot be larger than the height of depth).

Traditional ship parametric curves that are firstly designed are those that consist of the ship's basic geometry (ship profile, midship section, main deck line, draft waterline, etc.). The majority of the defined parameters are used in the numerical expression of those curves, as well as the majority of geometry limitations set on the primary stage. In Fig. 7-9 a set of basic parametric curves for the traditional ship type “trexantiri” are presented. In Fig. 10-12 a set of basic parametric curves for the traditional ship type “skafi” [31] are also presented.

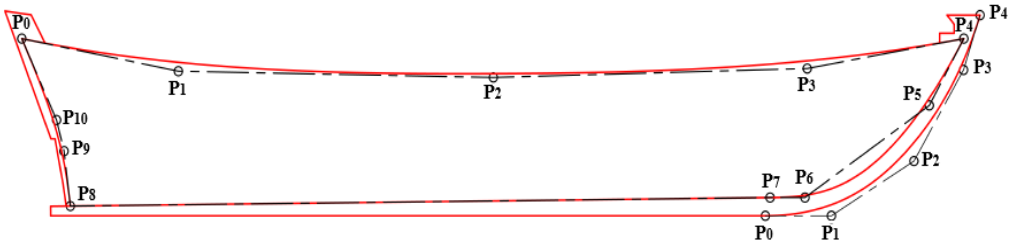

Fig. 7. Trexantiri profile curve

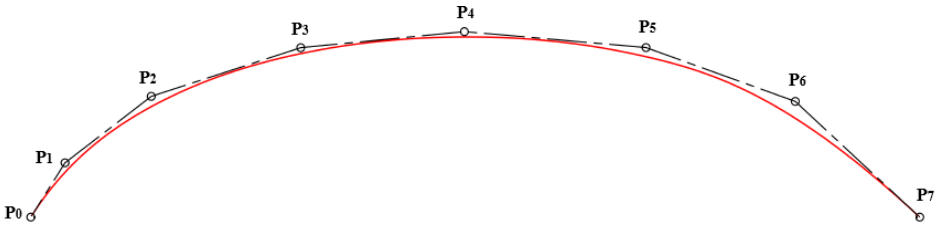

Fig. 8. Trexantiri deck curve

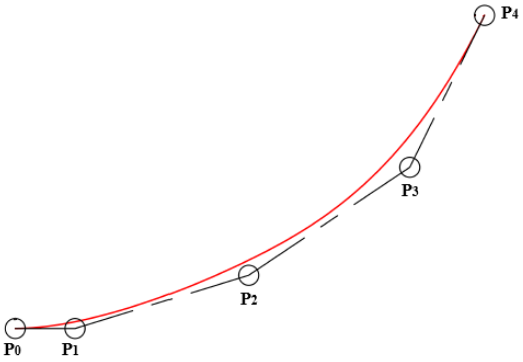

Fig. 9. Trexantiri midship curve

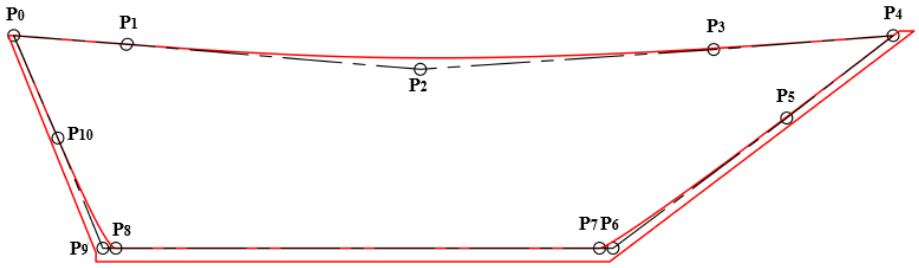

Fig. 10. Skafi profile curve

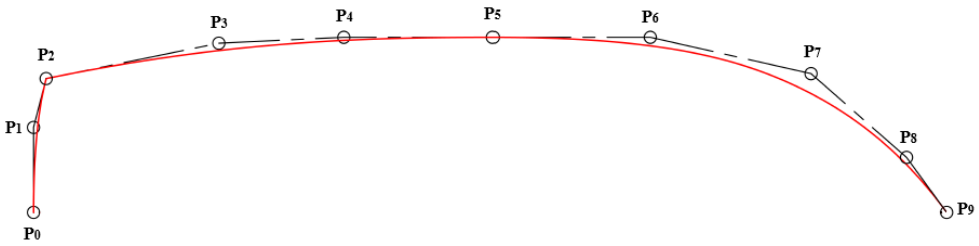

Fig. 11. Skafi deck profile

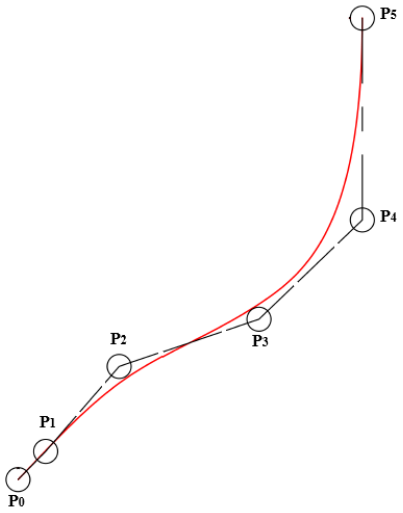

Fig. 12. Skafi midship curve

However, to ensure the precision of the traditional ship hull representation, several additional parametric curves must be drawn. The shape of those curves is determined by the basic geometry curves and the remaining parameters and geometry limitations.

Finally, a traditional ship hull surface is created with the aim of the above parametric curves. Ship hull surface must be smooth and with the appropriate continuity between its parts. During each stage of parametric design, additional parameters and geometry limitations may arise as a result of the detailed evaluation of the traditional ship hull and the necessity for design quality enhancement.

9 Conclusions

The Greek State must ensure, on the one hand, the uninterrupted operation of existing ship repair and maintenance facilities (karnagia/tarsanades) in their long-established locations and, on the other hand, to provide opportunities for the development of new facilities. This aims to guarantee the continuous availability of reliable and high-

quality maintenance and repair services for fishing fleet vessels, professional and recreational maritime tourism boats, port service vessels, and, at times, Coast Guard and auxiliary naval ships. These efforts serve the public interest rather than merely benefiting the approximately 70 small existing businesses in the sector.

Strengthening the industry and, above all, securing the necessary space for the operation of existing shipyards/tarsanades is a matter of immediate maritime concern and falls primarily under the jurisdiction of the Ministry of Shipping and Island Policy. Similar to port-related issues, this sector supports national economic areas that rely on seaworthy vessels, contributes to national defense, promotes maritime activities and excellence in Greece's territorial and international waters in the Eastern Mediterranean, and ensures the geographical and cultural cohesion of the Hellenic Republic. Furthermore, it enhances the prosperity and sustainable economic development of coastal and island communities by fostering communication and balanced interaction between communities, the sea, and the land.

Therefore, the issue of granting long-term usage rights for parts of the shoreline and port land zones to ship repair businesses (karnagia/tarsanades) must be promptly resolved. These rights should be allocated under fair and consistent financial terms nationwide to ensure the sustainable and balanced development of the industry while maintaining an optimal distribution of facilities across the regions. This approach will uphold the principle of non-discriminatory treatment of geographical areas and Greek citizens by the State, as well as healthy business competition among similar enterprises.

Comprehension of traditional ship geometry (and its complications) to be designed and assortment of the necessary data from identical existing geometries are critical elements for the parametric design process. Any peculiarities of hull geometry should be considered for the design to result in a reliable solution; at the same time, there should be flexibility in any simplifications to reduce the complexity of the design. The definition of parameters and geometry limitations must facilitate the process of parametric design or the process of dealing with a future optimization problem.

The combination of parametric design with an appropriate optimization model system could possibly expedite the drawing process of a traditional ship. Based on elements like ship resistance, total capacity, ship hydrodynamics, ship strength and the features of the available timber, new possible alternative designs should arise from the above procedure and be evaluated in real-time. New improved drawings will then be created, as well as with the appropriate geometry limitations and dimension-less ratio ranges and be accessed by the interested traditional designers for their purpose and evaluation. Traditional designers will also be welcomed to be trained in those parametric computational methods, as well as the designers who perform the parametric design should be trained in the traditional ship drawing methods because the accumulative recycling information will favor both sides in many ways but most importantly in the preserve and evolution of Greek traditional shipbuilding.

References

1. Karavokyros, G. The Shipbuilders of Samos: History and Techniques of Wooden Shipbuilding. Samos Cultural Foundation, 2006, Samos
2. Vlassopoulos, N. Shipbuilding in Lesvos: The Legacy of the Tarsanades. University of the Aegean Press, 2014, Mytilene
3. Papadopoulos, E. The Shipyards of Chalkida: From Traditional Wooden Boats to Modern Repairs. Evia Nautical History Archives, 2013, Chalkida
4. Xanthakis, K.: The Art of Caulking: Preserving Traditional Boats in Greek Shipyards. Hellenic Maritime Museum, 2010, Piraeus
5. Georgopoulos, I.: From Axes to Planes: The Evolution of Traditional Ship Repair in Rhodes. Dodecanese Cultural Foundation, 2021, Rhodes
6. Ntounis, Ch.: Ithacan Captains: The Old and the New. Union of Ithacans Worldwide, 2001, Athens
7. Vavouranakis, G.: Seafaring and Shipbuilding in the Aegean Bronze Age. University of Crete Press, 2010, Heraklion
8. Katsikogiannis, A.: Tarsanades of Crete: Wooden Boats and Shipyards from Venetian to Modern Times. Crete Maritime Heritage Society, 2015, Heraklion
9. Michailidis, S.: Wooden Boat Restoration in Kalymnos: Techniques and Traditions. Kalymnos Maritime Research Institute, 2017, Kalymnos
10. Ziotis, G.: Broken Imprints. Pigi Publications, 2022, Thessaloniki
11. Koutsoumba, D.: Greek Traditional Shipbuilding: Techniques and Evolution. Hellenic Maritime Museum, 2008, Piraeus
12. Rigos, A.: The Shipyards of the Aegean: Wooden Shipbuilding and Its Legacy. Nefeli Publications, 2017, Athens
13. Xifaras, M.: The Art of Ship Carpentry in the Aegean: Shipyards and Techniques. Aegean Maritime Museum, 2011, Mykonos
14. Dimitriou, T.: The Wooden Boats of the Argolic Gulf: A Shipbuilding and Repair Tradition. Peloponnesian Folklore Foundation, 2018, Nafplio
15. Damiadis, K. & Siras, A.: The Trechantiri in Greek Shipbuilding Art. Aegean Maritime Museum, 1995, Athens
16. Kotsovillis, D.: On the Rigging of Ships. [Unknown Publisher], [Unknown Date], Athens
17. Delis, A.: Merchant Shipping and Trade in 19th Century Greece. Alexandria Publications, 2015, Athens
18. Mazarakis-Ainian, L.: Naval History of Greece: From Antiquity to the Present. Estia Publications, 2012, Athens
19. Kouloumpis, P.: The Last Master Shipbuilders of Spetses: Wooden Boat Construction and Restoration. Spetses Nautical Club, 2009, Spetses
20. Antoniou, K.: Research on the shipbuilding data of the Greek type of vessels. National Technical University, 1969, Athens
21. Papageorgiou, S.: The Greek Ship: History and Tradition. Melissa Publishing, 2003, Athens
22. Venetsanos, A., & Mantziou, L. (2024). Shipyards: Rise-Reuse. Kallipos, Open Academic Editions. https://hdl.handle.net/11419/12991
23. Murphy, R. D., Sabat, D. J., Taylor, R. J.: Least cost ship characteristics by computer techniques. Marine Technology 2(2), 174-202 (1963)
24. Mandel, P., Leopold, R.: Optimization Methods Applied to Ship Design, Trans. of SNAME 74 (1966)

25. Chryssostomidis, Ch.: Optimization Methods Applied to Containership Design, MSc Thesis, Massachusetts Institute of Technology, Massachusetts, United States of America (1967)
26. Lyon, T.D.: A Calculator – Based Preliminary Ship Design Procedure. Marine Technology 19(2), 140-158 (1982)
27. Papanikolaou, A., Nowacki, H., Zarafonitis, G., Kraus, A., Androulakis, M.: Concept design and optimization of a SWATH passenger/car ferry. In: Proceedings, IMAS 89, Marine Management (Holdings) Ltd., London (1989)
28. Ginnis, A. I., Kostas, K. V., Feurer, C., Belibassakis, K. A., Gerostathis, T. P., Politis, C. G., Kaklis, P. D.: A Catia ship-parametric model for isogeometric hull optimization with respect to wave resistance, ICCAS (2011)
29. Ginnis, A. I., Duvigneau, R., Politis, C., Kostas, K., Belibassakis, K., Gerostathis, T., Kaklis, P. D.: A multi-objective optimization environment for ship-hull design based on a bem-isogeometric solver. In: Proceedings, International Conference on Computational Methods in Marine Engineering (2013)
30. Yu, Y.-Y., Lin, Y., Chen, M., Kai, L.: A new method for ship inner shell optimization based on parametric technique. In: Proceedings, International Journal of Naval Architecture Ocean Engineering, 142-156 (2015)
31. Sarantidis, S., Mazarakos, T. P. (2024). Parametric design for hydrodynamic optimization purposes: The case of "Symiaki skafi". Technical Annals, 1(8). https://doi.org/10.12681/ta.40636