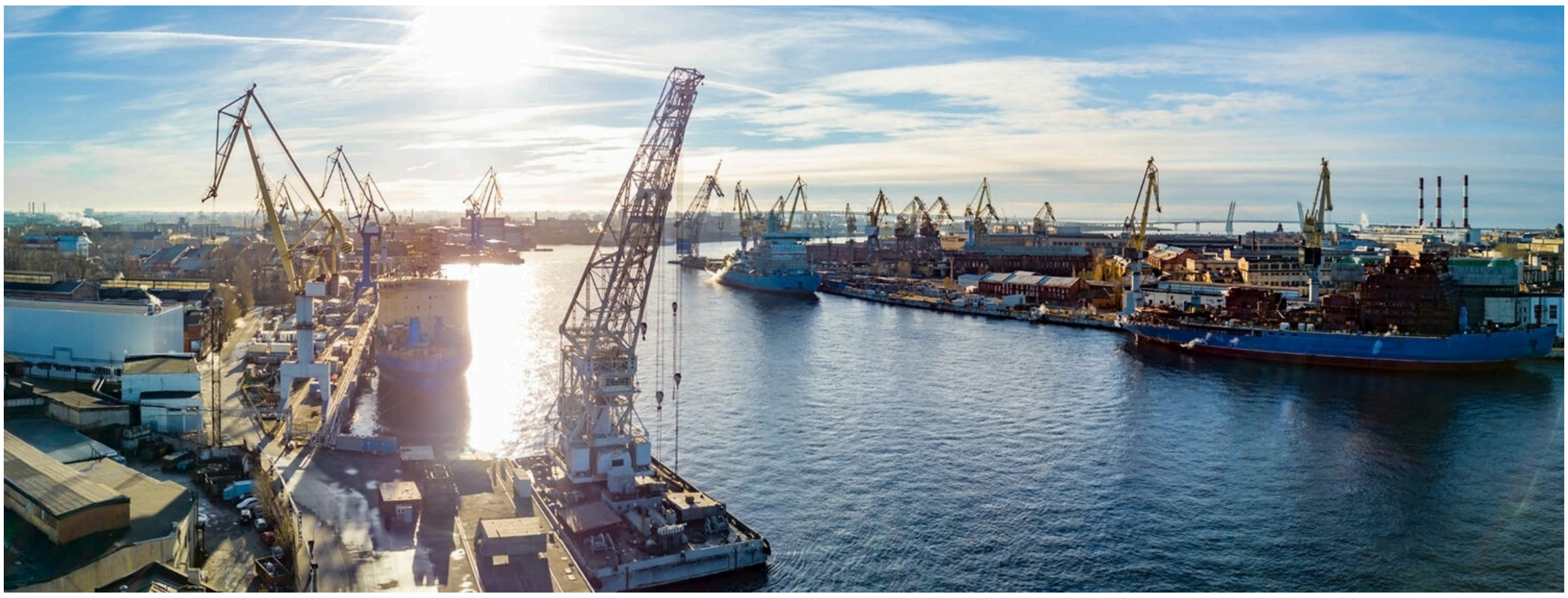

Can European Shipyards be Smarter? A Proposal from the SEUS Project

Posted on **September 13, 2023**

> *This paper was presented for the first time at the annual Conference on Computer Applications and Information Technology in the Maritime Industries (COMPIT) held in Drübeck. Germany, from 23-25 May 2023. The abstract has been redacted.*

Authors: Ludmila Seppälä, Cadmatic; Henrique Gaspar, NTNU; Herbert Koelman, SARC; and José Jorge Garcia Agis, Ulstein Group

1. European Shipbuilding and the Need for a Digital Thread

The European shipbuilding industry faces many challenges, including increased competition from Asia, economic uncertainty, and a growing demand for more sustainable vessels. However, despite these obstacles, the industry remains an essential player in the global maritime sector.

A white paper published by the European Maritime Safety Agency (EMSA) in 2021 emphasized the importance of investing in new technologies and innovation to maintain the competitiveness of European shipyards. One of the most notable trends in the industry is the increasing importance of digitalization and automation in the shipbuilding industry. Digital technologies such as artificial intelligence, the Internet of Things (IoT), and blockchain have the potential to improve efficiency, reduce costs, and enhance safety in the industry, *EMSA (2021).*

Diverse commercial, societal and academic actors emphasized the need for European shipyards to focus on innovation and sustainability to remain competitive in the global market, *Ulstein and Brett (2012).* The main argument is that adopting digital technologies is a key factor that will determine the future success of European shipyards. As the industry continues to evolve, the collaboration between stakeholders and the development of new technologies will be critical for success, *Diaz et al. (2023)*.

A vast and increasing amount of data is generated during the shipbuilding life cycle, *Seppälä (2019).* There is considerable scope to use this data more effectively across the shipbuilding network value chain, *Gaspar (2018).* Digitalization and computational tools have great potential to generate value for stakeholders in the form of cyber-physical systems or digital twins. It requires a significant reshaping of existing tools and practices to be exploited successfully by the European shipbuilding industry. The gains come in the form of increased quality and reduced time required for design, virtual prototyping, estimations of impacts for the use of greening innovative technologies, modularization, flexible data management, interoperability across proprietary tools, cyber security, efficient support for modern robotized fabrication and openness for integration with operational platforms.

To achieve these gains, a digital thread needs to be facilitated to enable data use and management to support the life cycle of complex engineering systems effectively, focusing on the shipyard as the core of the value chain as it converges the tasks of design, engineering, construction, and maintenance. By establishing a single source of truth for ship data, the digital thread facilitates data fusion for CAE/CAD/CAM/PDM systems, which can improve the organizing, managing, and contextualizing of shipbuilding data. It has the potential to provide virtual prototypes, enhance consistency and compliance with technical standards, use AI and ML, and NLP technology to assist and evaluate technological innovations, enable iterative learning, and significantly enhance communication and access to data for all stakeholders.

However, much of the productivity gain to be achieved during the early stages of ship design is constrained by the many different CAE/CAD/PLM/PDM/ERP tools and models used to create, combine, and evaluate each of the modules that a ship consists of. Consequently, the design of a modularized and standardized work system (enabling reuse of design models and drawings), or even a new design approach configuration, lacks an effective and agile common evaluation framework that can combine standard (traditional) and customized (innovative) solutions through the ship design, engineering, and fabrication processes. A successful smart framework should consider the detailed balance of these elements, especially regarding effective documentation towards clients and third-party partners, including activities beyond the design/delivery process, such as maintenance and repair, retrofit, operation, and scrapping

2. Being Smart: Challenges and Opportunities in Digitalization

The current situation in the shipbuilding industry is characterized by high competition, low-profit margins, high complexity and scale of products, conservative processes, limited use of data and disconnected data streams, and the scattered priorities of a variety of stakeholders in the life cycle, *ECORYS (2009)*. As a result, the European shipbuilding industry has experienced a major capacity reduction in the past 5 years. Over 15 shipyards have ceased operations in this period due to bankruptcy - miscalculated project risks or lack of contracts – in other words, lack of competitiveness.

Typically, ship design, engineering, and fabrication in Europe follow fairly traditional approaches, not keeping the same pace of development observed in the automotive, discrete manufacturing, and aerospace industry. Current shipbuilding approaches are partly fragmented, discontinuous, time-consuming, and laborious. The rationalization of business and work processes (e.g., PLM, PDM, modularization, parameterization, and other data-based techniques) have so far only been tested and implemented successfully in the daily tasks of yards to a limited extent. The marine industry is a traditional and conservative business when it comes to changing its value chain, which is complex and comprised of many globally distributed actors. Ship fabrication methods vary from shipyard to shipyard and the standard by which ship design drawing packages are prepared and communicated varies greatly. Novel and state-of-the-art knowledge and technology (smart) are used only to a limited extent to streamline and improve the efficiency of such work processes and collaboration. The high-cost levels in Europe compared to emerging and gradually more competitive low-cost firms and partly large and fully integrated yards in Asia dictates that high effectiveness yields need to be achieved at European shipyards.

Moreover, ship design, class approval, and maintenance include many documents managed over extended life cycles. The digital downstream to operations phase is challenging as 2D, 3D, and simulation models contain a vast amount of model elements. A typical vessel model of only one design project may contain up to 2-3 million model elements or parts. The approach is significantly different from a mechanical CAD model, as shipbuilding uses high levels of topological connections between parts to make it possible for fast modifications, such as the rearrangement of equipment and piping or changes to hull structures. Another element specific to the industry is the use of materials such as steel plates of pipes that require fabrication into panels or pipe spools before the construction process. This pre-fabrication can be done by external subcontractors or workshops where access to design and procurement data as well as the construction particularities, plays a critical role and can significantly impact the quality and schedule of the project. Based on data from Ulstein shipyard, up to 8% of total production time is used for coordination activities by foremen and up to 3% on project management. These are primary areas targeted for improving the process where digital data and information access can significantly impact the total costs and time used for production, *Agis (2020).*

Discrete manufacturing industries maintain so-called maturity management for all used parts. This highly demanded approach, which supports functional safety, traceability, and compliance, is not practiced in the shipbuilding industry. This is because the check and approval processes would get stuck due to the vast number of parts, limited design speed, and rise in complexity. However, one of the main reasons lie in the lack of computational tools that can support the digital tread and the life cycle process of shipbuilding. Staged maturity management and traceability are desirable for the shipbuilding industry and should derive from the life cycle approach to data usage. Literature suggests that the application of AI will benefit ship design, although few working systems are yet available.

The SEUS project aims to address these topics, making a step in this direction for a data-assisted method to support early ship design. While each of the pitfalls listed above can significantly slow down or improve the overall process, having a holistic view of shipbuilding is a prerequisite. This views, with suggested room for improvements via process innovation, is illustrated in Fig.1.

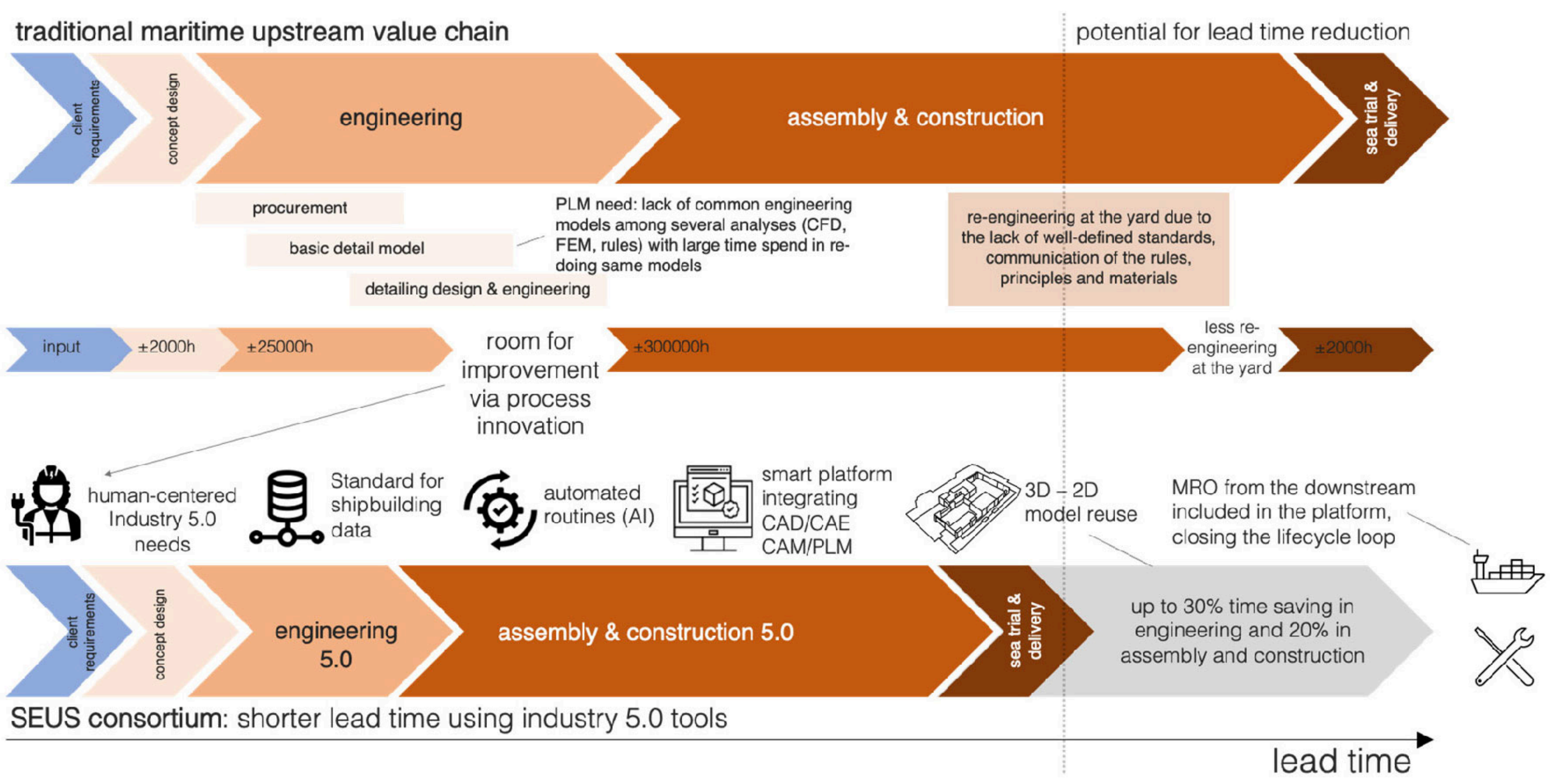

Fig.1: Potential for lead time reduction in the upstream maritime value chain

In this context, we summarize seven challenges for enhancing the current status of European Shipbuilding:

- Facilitate rapid early-stage design to support lower-risk bid development, particularly when integrating innovative new technologies

- Provide better capital cost estimations and performance predictions, particularly showing the improvements expected from the inclusion of new technologies
- Tools to be integrated with ship construction and production and consider supply chain management and future maintenance and repair of vessels.
- Address and quantify the competitiveness gains provided by the tool(s) in the context of the wider European shipbuilding sector.
- Ensure that the tool is robust and resilient against cyber threats.
- Identify and address the development of the necessary skills needed to achieve the maximum benefit from innovative advanced computational shipbuilding tools.
- Develop business cases to quantify the added value from the developed tool to the shipbuilder concerned and within the context of the wider European shipbuilding sector.

3. Smart European Shipbuilding (SEUS) Proposal

The main ambition of the Smart European Shipbuilding project (SEUS) is to tackle the mentioned challenges, by developing a smart platform dedicated to shipbuilding and its downstream and upstream lifecycle phases. This will be achieved by architecting an integrated platform for a combined and open solution incorporating CAE, CAD, CAM, and PDM software and testing it at shipyards. The new platform solution will be built with state-of-the-art European shipbuilding expertise provided by academic and industrial consortium participants. It intends to develop novel practices for human-centric knowledge management in shipbuilding, the use of NLP, and data-driven AI design elements in the current consensus or intelligent technologies and Industry 5.0, *EU (2021)*.

The SEUS project will develop, implement, test, and qualify software solutions with an Industry 5.0 mindset for the European shipbuilding market. Smart technology, in terms of digitalization and cyber-physical systems, including humans, are concepts that have never been built from a shipbuilding perspective. Current solutions used by shipyards include significant parts of manual data handling and are prone to a high level of human error or a fragmented adaptation of PLM from other industries, such as aerospace, automotive, or other discrete manufacturing. The shipbuilding industry uses many computational tools to plan, design, simulate, and build vessels and other marine products, such as offshore platforms or other floating constructions. Consequently, the digital information chains of shipbuilding are more weakly integrated than in discrete manufacturing industries and thus lack support for a digital thread: digital continuity, digital lifecycle management, and digital ship operation support. This is an obstacle to gaining efficiency and to implementing new business models based on digital innovations and the development of IT technology. We have set up seven objectives towards a stepwise progress over 4 years:

- Create workflow activity map and use cases applying smart technology and Industry 5.0 concept, specific to European shipbuilding
- Enhance the human-centric competitiveness of shipbuilding and reflect diverse values of stakeholders, including shipyard workers, shipowners, operators, users/passengers, and shipbuilders in general
- Build a shipbuilding-specific PLM platform comprising defined data models and the selected elements of CAE/CAD/CAM and PDM solutions
- Develop a flexible platform that supports multiple instances of workflows to facilitate rapid early designs, and is fit to support AI tools and virtual prototyping
- Ensure openness and interoperability of the platform while keeping it cyber secure
- Test and implement in an industrial environment – developing the concept of the digital shipyard.
- Quantify added value gains provided by the developed platform, creating a business model of exploitation, and dissemination of project results

The technology readiness level (TRL) targeted by the project is 8-9, corresponding to the maturity level of a completed and qualified (tested in a large-scale pilot installation) platform, ready for a commercially competitive operational environment. The aimed shipbuilding platform will integrate existing computational tools with TRL 9, commercially exploited in shipbuilding. It will incorporate Industry 5.0 concepts (human-centricity, sustainability, and circular economy) and progress through the process of maturing TRL from level 4 (initial technology validated by combining existing software parts, including AI and ML) to level 7-9 (integrated platform with developed use cases, tested in shipyards).

4. Methodology and Expected Impact

4.1 SEUS Methodology Overview

The overall platform developed by the SEUS project aims to connect existing high-end solutions, specialized in selected areas of the shipbuilding life cycle, and unite data handling for the shipbuilding projects through life stages and disciplines based on expertise in shipbuilding use scenarios. This approach challenges both the prevailing CAD-centric approach in shipbuilding (historically CAD model is used in most shipyards for generating production data) and the PDM-centric approach, where data as such is managed, with an interface connected to the CAD model and focuses on project and change management.

Fundamental to the SEUS approach is that the current toolbox for shipbuilding can be more efficient if properly integrated into a human-centered environment, including Industry 5.0 aspects. The SEUS methodology is focused on developing a smart platform for CAD/CAE/CAM in shipbuilding based on the industrial and academic experience of its consortium members.

The SEUS approach revolves around the fulfillment of the seven mentioned objectives. It consists of four main steps, represented in Fig.2, namely:

- Shipbuilding Best Practices;
- Smart Shipbuilding PLM Platform;
- Shipyard Implementation;
- Business and Innovation.

Each main step contains the sub-process itemized below and is described as follows.

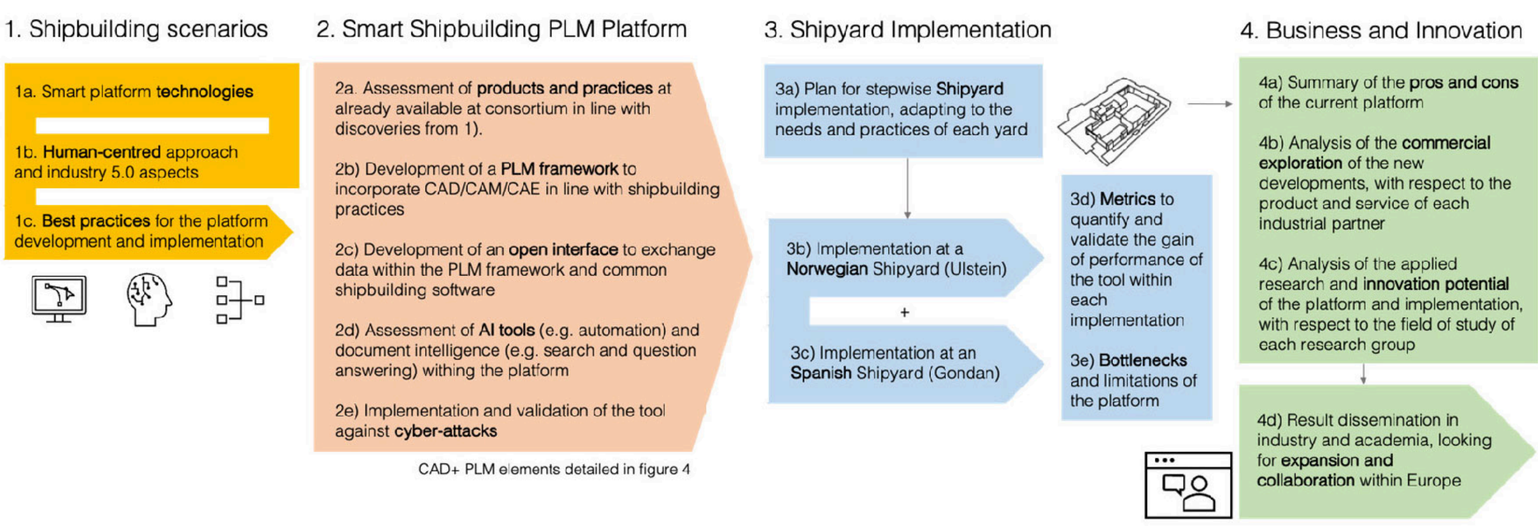

Fig.2: SEUS Methodology Overview

SEUS approach starts with the evaluation of the European shipbuilding scenario concerning the current state of digital tools and the potential to incorporate smart technologies. Parallel to it a deep study of what means a human-centered approach in shipbuilding will be developed, in line with the needs and aspects of Industry 5.0, aiming at the balance between cyber-physical systems and societal challenges. its technologies, potential for human-centered, and Industry 5.0 technologies. As a result, a body of knowledge with best practices for the implementation of the smart platform will be developed, feeding the next step.

The second part of the methodology converges the core of the project, with the development of a smart PLM platform incorporating CAD/CAM/CAE elements in line with shipbuilding practices. It consists of the assessment of products and practices already available in the consortium about the needs and standards compiled in the previous phase. Extensive software development will enhance existing toolsets and implement digital support for the use cases and scenarios, representing the computational tools for shipbuilding development stressed in the call. A detail of the desired elements in this development is observed in Fig.3.

The SEUS Smart CAD+PLM platform integrates the following main elements: CAE modules, CAD/CAM modules, PDM/PLM selected applications and features, and embedded shipbuilding expertise.

CAE modules address functionality related to initial and early design stages, such as hull shape form calculations, stability, weight estimations, and interfaces for CFD and FEM calculations, incorporating AI and a data-driven approach to design.

CAD/CAM modules include specialized applications for functional ship design (P&IDs, Electrical schematics), 3D detailed, and production design. It incorporates the reuse of initial design models, 3D modeling, and arrangement (Hull, Piping, Outfitting, HVAC, Cable 3D design, and other outfitting elements) and provides an automated output of fabrication data in a traditional format of 2D documentation along with the direct output for CNC-controlled equipment and robotized manufacturing, all ready for an integrated virtual prototype environment.

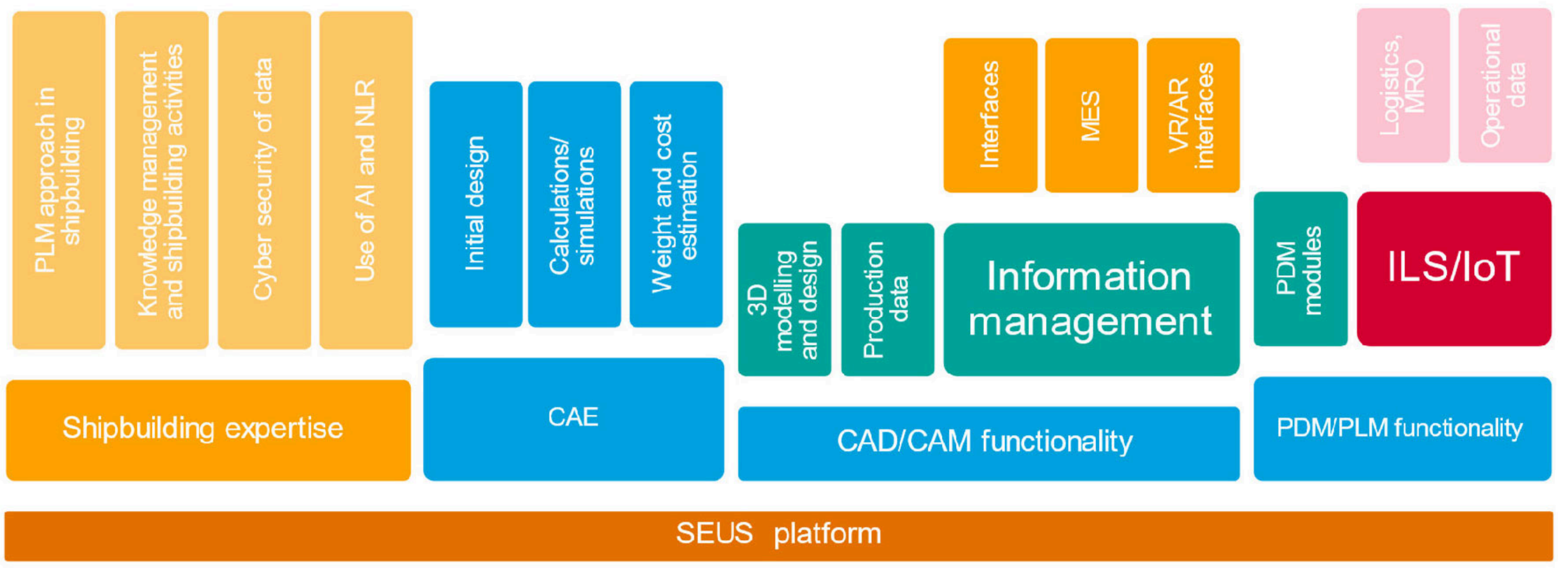

Fig.3: SEUS Smart Platform Desired Elements

PDM/PLM elements consist of selected modules for data management and product life cycle support, including project and change management, document management, Bill of Materials management, IoT integration, and ILS support. This sets a solid basis for the maturity management-based PLM concept that would enable support for functional safety, traceability, and compliance for the shipbuilding industry.

Shipbuilding expertise embraces knowledge of the PLM approach in shipbuilding and other industries' best practices, developed shipbuilding human-centric activity map and knowledge management, embedded cyber security practices, and the use of AI and NLP for ship project data. Added to all the elements, an open interface will connect the software toward efficient data flow, aiming at a common standard that can be used by different shipyards.

As part of the broader cyber security solution for the project, a series of cyber security workshops will be conducted with project team members and support teams. Those workshops will address issues of cyber threat awareness (including threats to AI apps), secure programming practices, active cyber security countermeasures, cyber security hygiene, and the development of the project's Information Security Management System (ISMS).

A dedicated challenge is the standardization of domain knowledge to speed-up design tasks, especially in early design phases when many new items need to be born quickly and when master data maintenance is typically hindering the ease of designs although needed for efficient downstream work. Attempts to realize PDM-based master data management by so-called orthogonal classification were successful. An analysis of given standards such as ISO 10303, SFI, and German Marine/Ship Assembly Register indicated that such kind of domain knowledge applies to PDM-based MDM and classification schemata, covering technical properties, property values, etc. to classify design documents, work tasks, ship items, equipment or any other PDM information object.

Mechanical CAD systems are used in the marine industry for outfitting and detailed designs of ship components and equipment, *Fonseca and Gaspar (2022)*. These systems are well integrated with PLM elements and approved conversion pipelines. The way of modelling vessels (e.g. steel and parametric hulls, equipment and piping materials) down to production differs for shipbuilding intent-driven CAD systems. This typically leads to a mismatch of the level of details in the 3D model and manageable ship product structures. A concept to interlink and inter-visualize CAD content from both worlds is targeted including the implementation of an integrated conversion pipeline, product structure management, and interactive visualization augmented with master data.

Integration between the PLM elements platform and CAD/CAE authoring application includes several layers of data management, data model alignment, 3D visualization technology, and the development of the user interface to cover various use cases. it will be executed by architectural the integrated platform solution, user stories, and iterative system design process. Various applications: Hull 3D design, Piping and Outfitting 3D design, HVAC, Electrical, etc, need to share data with data management shell and ensure transfer and synchronization with defined accuracy, 3D visualization, and embedded workflows to assist users in everyday design, project management, and production tasks.

4.2 Expected Impact

The impact of SEUS is based on primarily increasing the level of digitalization in European Shipyards, facilitating the transformation of this industry towards competitiveness with a human-centric mindset. A compilation of seven key impacts is presented in Fig.4 and explained as follows.

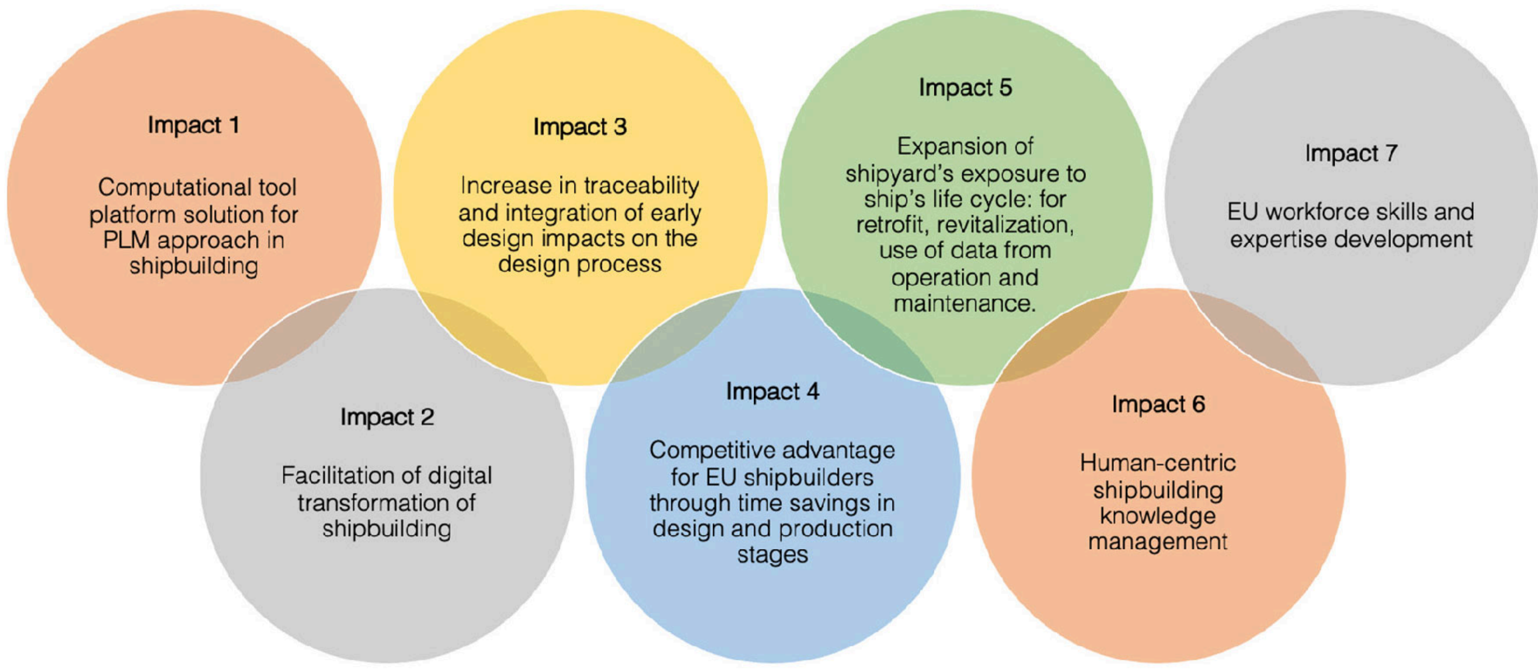

Fig.4: Expected Impacts

Impact 1: Computational platform solution for PLM in shipbuilding
The development of a platform with a PLM approach specific to shipbuilding would be a pioneering addition to the existing landscape of computational tools for shipbuilding in Europe and globally. Like CAD/CAM tools that provided a breakthrough by using computing and 3D modelling some 30 years ago, the PLM platform is a leap forward in digitalization. With interoperability, a standardized data model, and process management tools our initiative will impact European shipbuilding competitiveness with shorter lead times and the capability to adapt to design and production time changes. It will add to the currently unutilized potential for the end customer by reducing lifetime costs during ship maintenance. Since the data model and specialized application landscape during ship design are fragmented, the information disappears between the different design phases, from the initial design to the basic design to construction.

Impact 2: Facilitation of digital transformation of shipbuilding
Increasing the shipbuilding industry's digitalization levels dramatically will affect how the marine industry works and profits from information consistency and control. Industry 4.0 outlines the benefits of digitalization in the manufacturing industry, such as improved productivity, collaborative working ways, flexibility, agility, reduced costs, and innovation opportunities. Taking this concept further and augmenting it with knowledge and skills in management and circular production models would allow shipbuilding to catch up with other industries and pioneer the use of digital tools to serve society's goals. The expectations are to support resource-efficient designs and provide tools for the evaluation of design impacts at the virtual prototyping stage, develop a human-centric approach for digital shipbuilding processes, and up-skill European shipbuilders.

Impact 3: Traceability and integration of early design impact the design process
The EU targets for the decarbonization of shipbuilding require the possibility to integrate innovative technologies in the early stages of design to evaluate the effectiveness of alternatives and their impacts on the project. In shipbuilding practice, this means experimentation with hull shapes (Ulstein X-bow is an example of such innovation to significantly impact the stability of sea-going vessels), propulsion design, and power or fuelling alternatives (LPG/LNG, ammonia, or hydrogen, etc). The potential impact of these technical solutions on the project will be evaluated at the earliest possible design stages and will be linked with historical data (whenever possible) and downstream detailed design and construction data. The platform aims to integrate all these data streams into the interconnected digital thread to provide traceability of decisions and impacts and significantly simplify working processes for the early design stages for all participants – naval architects, designers, engineers, shipyards, and shipowners.

Impact 4: Competitive advantage for EU shipbuilders through time savings in design and production stages
Communication presents one of the biggest hurdles in shipbuilding projects. Inconsistent, incomplete, and unclear information generates uncertainty in projects that lowers the quality of project decisions resulting in delays, higher costs, and poorer project realization. The SEUS platform aims to provide the next level of communication and information transfer among participants in the shipbuilding project. By eliminating the need for manual data transfer and providing access control tools, it aims to provide information dynamically extracted on demand, as well as supplementing it with 3D data and other relevant information. The primary focus will be on the communication between ship designers and shipbuilders. The involvement of third parties such as equipment suppliers, subcontractors, classification societies and flag status, or shipping companies will, however, also be considered in the case studies. The use of such a platform will significantly reduce the time searching for information at all phases from different tools and sources and especially impact the design to production data transfer. Additional NLP-based conversational search models based on AI and neural networks are expected to provide additional support for information search and communication.

Impact 5: Expansion of shipyard's exposure to ship's life cycle: for retrofit, revitalization, use of data from operation and maintenance
The SEUS platform aims to enhance the exposure of shipyards and ship design offices to the life cycle of the vessels they designed and built to provide insights from the operation stage and historical data for comparisons and evaluation of the design solutions used. It also empowers shipyards by retaining communication with their customers and expanding service offerings toward the operational stage. Both sides can gain from this connection: shipyards can expand their service offering in the post-delivery stages, while operators can get accurate engineering and design models and avoid remodeling while using the digital twin approach.

Impact 6: Human-centric shipbuilding knowledge management
Human-centric shipbuilding knowledge management can be presented as a customizable shipbuilding activity modeling framework for associating typical shipbuilding activities, shipbuilding expertise, and the data thread through the shipbuilding life cycle. The framework includes values, interaction, collaboration, and shipbuilding actors' skill development and training. Identifying these elements of the framework and devising evaluation methods that exploit the association between human subjectivity and context data would be a part of the novel research of the SEUS project. This will impact the effectiveness and productivity of a highly skilled workforce and sustainable knowledge management practices. An additional aspect presents lifecycle-integrated training and learning programs for diverse shipbuilding stakeholders.

Impact 7: EU workforce skills and expertise development
Historically, European shipbuilders lead the industry as the most innovative and technologically advanced. In the last decades, European shipbuilding has focused almost exclusively on high-value vessels that formed the core of the expertise. Executing projects of this complexity scale requires advanced project management skills, technological and industrial skills, procurement, building and construction, and many other areas of expertise. The platform aims to provide a single source of truth for almost all people involved in every shipbuilding project, with a UX designed for each target audience that reflects their characteristics and controlled access to data. It would provide a context for everyday tasks and boost creativity and workers' digital skills, keeping the EU leadership position in the area.

5. Concluding Remarks: A Call from Peers to Join the Smart Approach

A strong point of SEUS is its consortium, a balanced partnership composed of academics, software developers, and shipbuilding partners representing 5 countries from Europe, which is fully dedicated to bridging the knowledge in its communities and facilitating the uptake of the main results. SEUS's partners are experienced in customer implementation, dissemination, and communication activities in their home countries and internationally, and this experience will be enormously beneficial for achieving the objectives here proposed. Therefore, the consortium is committed to disseminating SEUS's approaches and outcomes, while simultaneously staying focused on the identified target groups and reaching the objectives of development, dissemination, and exploitation.

In this context, peer and stakeholder engagement support is an imperative set of activities to be integrated with the SEUS communication strategy. Besides sharing the results and findings of the project with a broad audience, the consortium welcomes external collaboration. With the ultimate target of supporting European shipbuilding, many projects can benefit from joining efforts and sharing findings in the industry's best interests.

We close this paper with call for peers to contribute and interact with the consortium. In a short term, to develop and publish their own understanding of the smart concepts here discussed, such as industry 5.0, digital thread, PDM/PLM incorporation. In a middle term, the evaluation of the pros and cons of their approaches with our proposal, and the investigation on how to combine features in a way that is beneficial to the majority of European partners. The project considers part of the development for an open standard to connect to the commercial tools, allowing other commercial partners to interact with the tools.

Acknowledgments

The SEUS project has received funding from the Horizon Europe Framework Programme (HORIZON) EU program under grant agreement No 101096224. Consortium members include the software companies Contact Software (Germany), Cadmatic Oy (Finland), SARC BV (The Netherlands), the two shipyards Ulstein Group (Norway) and Astilleros Gondan SA (Spain), and the research from Turku University (Finland), the Norwegian University of Science and Technology (Norway), and NHL Stenden University of Applied Sciences (The Netherlands). Info is updated at http://seus-project.eu/.

This article reflects only the authors' views, and the European Commission is not responsible for any use that may be made of the information it contains.

References

AGIS, J.J.G. (2020), *Effectiveness in decision-making in ship design under uncertainty,* PhD thesis, NTNU, Trondheim

BRETT, P.O.; ULSTEIN, T. (2012), *Critical Systems Thinking in Ship Design Approaches*, IMDC Conf., Glasgow

DIAZ, R.; SMITH, K.; BERTAGNA, S.; BUCCI, V. (2023), *Digital Transformation, Applications, and Vulnerabilities in Maritime and Shipbuilding Ecosystems,* Procedia Computer Science 217, pp. 1396-1405. https://doi.org/10.1016/j.procs.2022.12.338

ECORYS (2009), *Study on Competitiveness of the European Shipbuilding Industry*, ECORYS Research and Consulting, Rotterdam

EMSA (2021), *The EU Maritime Profile – the maritime cluster in the EU, Section 2*. European Maritime Safety Agency (EMSA) https://www.emsa.europa.eu/eumaritimeprofile.html

EU (2021), *Industry 5.0: A Transformative Vision for Europe – ESIR Policy Brief No.3,* European Commission, Brussels

FONSECA, I.A.; GASPAR, H.M. (2022). *A Standards-Based Digital Twin of an Experiment with a Scale Model Ship,* Computer-Aided Design 145

GASPAR, H.M. (2018) *Data-Driven Ship Design,* 17th COMPIT Conf., Pavone, pp.22-35, http://data.hiper-conf.info/compit2018_pavone.pdf

SEPPÄLÄ, L. (2019), Drawingless Production in Digital Data-Driven Shipbuilding, 18th COMPIT Conf.

Want to know more?

CONTACT US