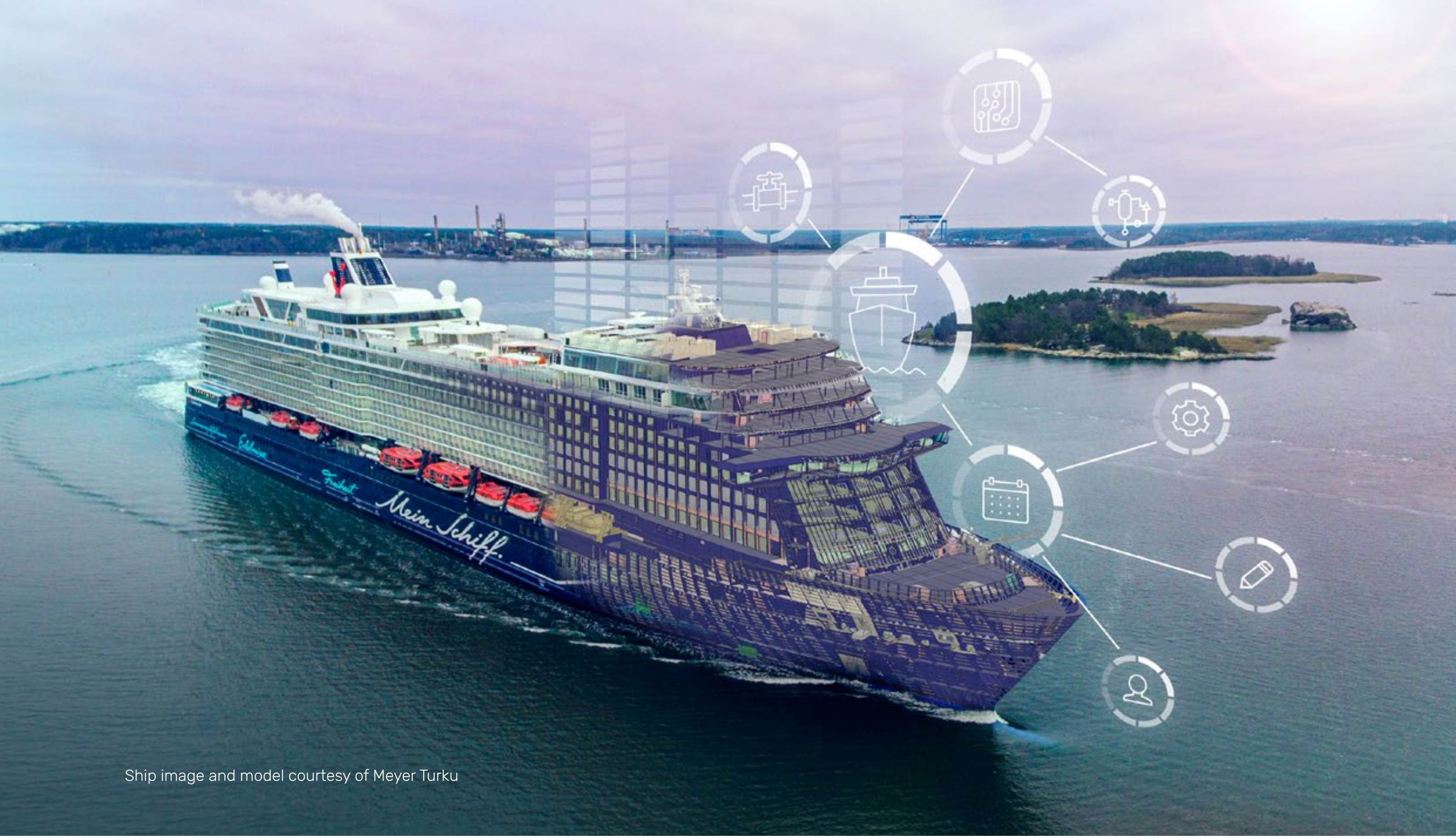
WHITE PAPER

Information management in shipbuilding projects

– Information flow from 3D design to production data

L Seppälä, Cadmatic, Finland

Ship model courtesy of Wärtsilä Ship Design Norway AS



Ship image and model courtesy of Meyer Turku

Summary

The complexity of modern shipbuilding, alongside changes in a business environment and growing capabilities of digital solutions, challenges work processes and offer the possibility to gain efficiency by eliminating gaps in the information flows. The paper discusses the changes in modern ship design and production and the interconnections between these two phases of the shipbuilding lifecycle from the information management point of view. It offers several examples of shipyard practices and outlines the direction of the development for digital transformation in this area.

Contents

Authors biography

Ludmila Seppälä holds the position of Business Development Director, Marine Industry at CADMATIC. She is responsible for the long-term development of design, information, and data management solutions in the global shipbuilding and marine industry. Her previous experience includes design projects, production follow-up in shipyards, and numerous implementations of CAD/CAM systems in ship design companies and shipyards around the globe.


Ship model courtesy of Wärtsilä Ship Design Norway AS

Introduction

The shipbuilding projects require a particular approach to the ship design process, extensive information for manufacturing, and a carefully designed information flow of data between these phases. In an ideal situation, the complete shipbuilding lifecycle solutions would support incremental creation and the use of data from one phase to another. Data refers to the 3D CAD model of a complete vessel and all of its parts: hull, structure, equipment, piping, outfitting, electrical cables, and linked engineering data from results of a simulation, electrical load calculations, as well as engineering bill of materials and production data to facilitate manufacturing, pre-outfitting, and assembly. In reality, this process in the modern shipbuilding environment is highly fragmented regarding stakeholders, work processes, and supporting IT systems. These include organization and network structures, used digital solutions systems and preferences for data formats, collaboration mode, and the scale of digitalization. Existing academic research mainly focuses on the theoretical implications of ship design as a product – highlighting its functional characteristics and partially economic profitability. The practicalities of shipbuilding process design and implications of workflows, management, and information flow design are often guarded as internal information, as they significantly impact shipyards' competitiveness.

This paper looks at information flow between two phases of the shipbuilding lifecycle – design and production - and highlights practical possibilities to gain efficiency by eliminating information flow gaps and placing data in the context.

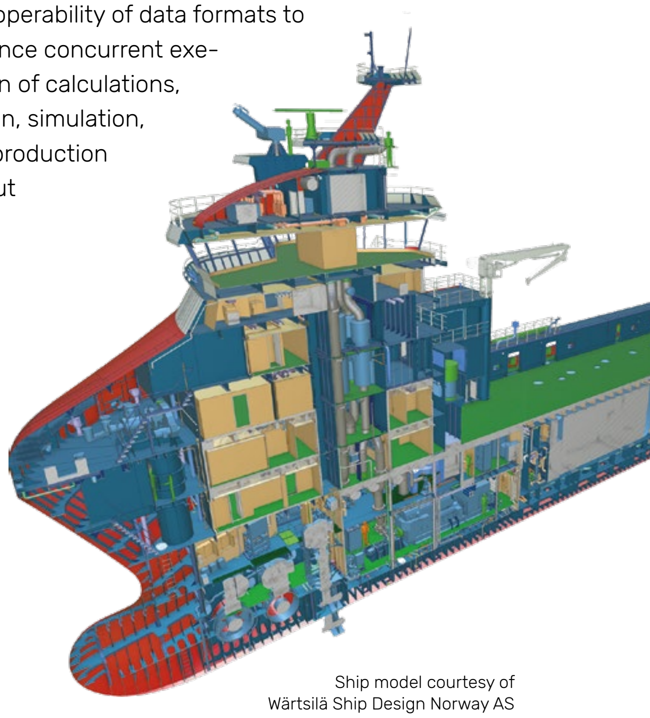
3D design in shipbuilding

The ship design stage focuses on creating the 3D model to comply with a vessel's functional requirements. Often it is assumed that CAD data includes only "a diagram or model of the final product" [1]. Typically, modern shipbuilding CAD software offers users to enrich the 3D data with production information already in the early stages of design. A safety net of settings and pre-defined values surround the designer's actions to assist with regulations of the classification society and prepare the use of design data for production. Multiple locations in the work process ensure that the design complies with the possibilities of production. For example, using settings of bending machine parameters for pipes – curves will automatically get the radius corresponding to bending machine settings, facilitating the correct space allocation for piping and providing embedded production data for later stages. Another example is using material sizes from the stock of steel plates to ensure maximum available sizes and minimization of the cutting. Embedding production data, such as templates for shell plate bending, ensures that the material needed for the templates can be visible in the procurement system, and profile cutting information is according to the automated CNC machinery format. These are just some of the thousands of automatic functions assisting ship designers in creating 3D data and setting the stage for production data output.

This type of embedded data and verification of the design model distinguishes shipbuilding-specific CAD from a general mechanical CAD, as it deals with an extreme amount of data – typically thousands of equipment and millions of piping components and steel parts, and a high degree of interconnections between the parts and topology of relations. It differentiates shipbuilding from a typical manufacturing industry approach where the CAD model produces engineering BOM, later converted to manufacturing BOM and further split according to tasks, teams, or assembly lines for production. The requirement for interconnections and scale of shipbuilding projects call for significantly more elaborated tools for product and work breakdown structures and planning tools, and at the same time, it makes data transfer between the design and production critically important for shipbuilding.

Besides the primary functional considerations, the main trends shaping the modern ship design by digitalization and sustainability goals include the following directions:

- Increased demand for flexibility and speed in the early design stages to evaluate variants of the design and estimate the economic feasibility of different powering options
- Automation of routine design tasks and high level of embedded rules and settings, based on requirements or best practices, to assist the designer
- Interoperability of data formats to enhance concurrent execution of calculations, design, simulation, and production output



Ship model courtesy of
Wärtsilä Ship Design Norway AS

Modern shipbuilding production

The primary goal of the shipbuilding process is to manufacture the vessel according to the defined specifications and deliver it on time and without defects. Therefore the engineering and design process has to provide needed data for the production process and not only focus on fulfilling the design and functional goals. Historically, technical departments were concerned primarily with the vessel function, and production information was developed later by draftsmen in the production departments, such as the steel or piping production department [2]. Information needed from the design stage in the production process in the traditional shipbuilding process was represented by a set of drawings and listings – for ordering needed materials and for instructions on how these materials should be assembled.

This process changes in modern shipbuilding. The impact of productivity requirements, economic returns, and IT systems development change the landscape of shipbuilding production in the following directions:

- Production flow became the basis for the shipyard's layout and served as a main productivity improvement area for modernization in the late decade [3].
- Production strategy, dictated by economic reasoning, disconnected the design and production processes. It might be a "design from stock" or modular engineering process when the design is created before the production site is selected and production requirements are known. It can be an "offshoring" strategy for using a remote construction site for steel construction due to cheaper labor costs and lower requirements for quality while keeping outfitting production at the yard, like in the case of Norwegian shipyards [4]. Initiatives, such as shared production facilities in North Netherlands, require specific production data output to support high volumes of production that will be assembled in micro panels and later used in the construction of different projects and shipyards [5].
- Machinery and automation equipment of production lines - advanced robotics and computational tools applications leaped forward in the last decade resulting in more connected manufacturing and automated assembly lines in shipyard's production processes [6].

Due to these changes, production needs for data can not be satisfied with a set of 2D documents and material take-offs from the design stage. In most cases, needed data would be adaptable output for the design stage, with a high degree of flexibility in the definition of work breakdown structure and data presentation and a possibility to take into account required machinery output. Besides design data, production needs consolidation with planning and project management to facilitate the whole process. At the methodology level, there are existing models for shipyard production simulation models [7] and the use of discrete event simulation for shipbuilding production modeling [8]. However, these discussions mostly fail to account for the 3D CAD data quality and its influence on the production process.

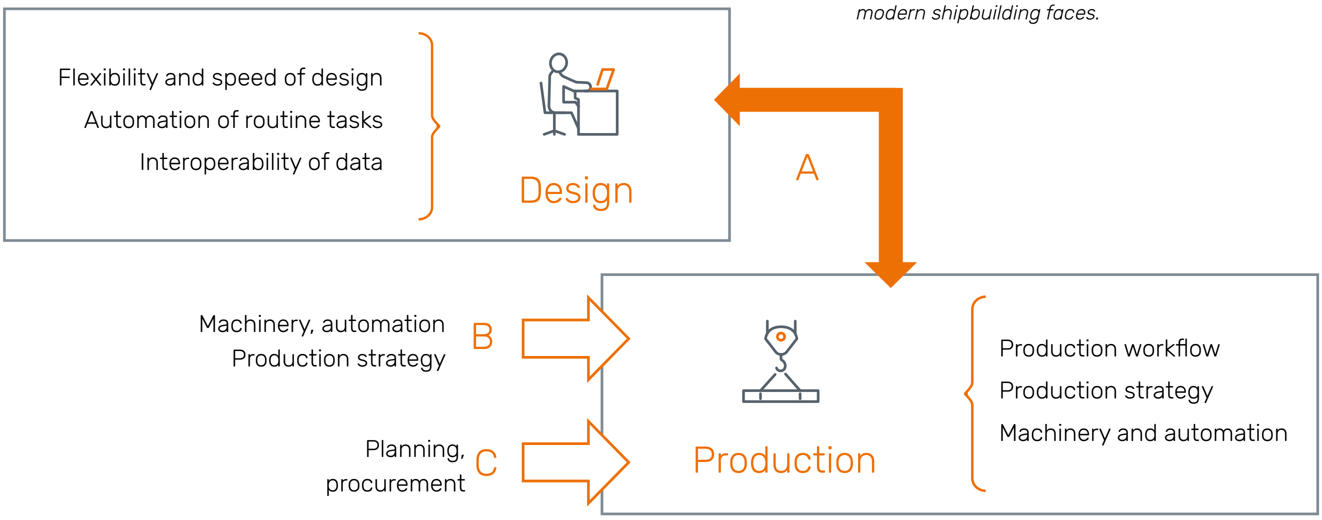
Information flow from 3D design to production

Schematically, the transfer between design and production phases can be presented in a simplified Figure 1. The primary connections for the production process are with design (A), production methods (B) (such as production strategy, location, subcontracts, machinery, automation level, and similar), and planning and procurement systems (C).

While in previous decades, it was expected that connection from design to production is one way, in modern shipbuilding, these processes are often concurrent and tightly interconnected by information flows. It can be considered from a perspective of the Industry 4.0 paradigm – blurring the borders between design and manufacturing or hybridization of digital-industrial manufacturing. There are visions and expectations for shipbuilding to embrace the opportunities from digitalization [9] and the product lifecycle approach already in daily use in other industries, such as automotive or aerospace [10]. However, shipbuilding requires a specific approach and acknowledgment of the design data's role and impact.

Increased interconnection between design and production (A) is bi-directional and can be considered as design output adaptivity requirement. Ship design in detailed stages should provide a flexible standards output considering machinery and automation requirements and production strategy, achieving efficiency in the production goals also consolidating data with planning and procurement. Both processes are essential and simultaneous, and therefore besides continuous improvement of production data origins in ship design, modern solutions should offer users a platform approach to consolidate data from different sources and provide data in the context of user requests.

Figure 1. Simplified schematical connection of production process in shipbuilding from an information flow point of view and changes that modern shipbuilding faces.



Examples of data flow gaps mitigation between engineering and production

The following examples originate from shipyards' experience optimizing their work processes by implementing modern shipbuilding technology, such as Cadmatic ship design applications and the Information Management platform. While end-to-end digitalization is an attractive vision, in most cases, it is impossible to execute a significant overhaul of IT systems at once. Addressing and improving information and data flows between the existing systems provides tangible gains in productivity and a gradual increase in digitalization gains.

Placing data in the context of production tasks using color coding

Access to the information does not guarantee that it can be used in time. For example, work package information might be available in a manufacturing system, but it is disconnected from the 3D model and provides an only textual status updates to production teams. Having the possibility to visualize this data in 3D and providing access to any other data in the required format, such as on a tablet or in VR/AR set, might be a game changer for the production process due to the possibility to visualize the data in digital format and thus enhance interactions. It also opens gates to industrial metaverse applications and provides applied use of 3D digital data residing in physical environments in the production process.

An advanced example from ship production practice concerns the weight of equipment information for installation teams. For the on-site teams, it is critical to have information about the weight of equipment scheduled for the installation before planning activities. Engineering data typically contain weight information, however, often, it is based on preliminary estimations without a specific modification of equipment items, and it might significantly vary from the procurement data. When equipment is ordered, the supplier provides exact information about the dry/wet weight and weight of the packaged item for every position. This information is typically available in the procurement system or ERP system, depending on what is used in the ICT landscape of the yard. This example is one of the typical challenges – information is available but not in the context of a needed task.

A solution for the challenge was found by merging available data from several sources and visualizing it for access to planning on-site activities. The first stage included the identification of the sources of data: the ERP system containing the weight information after the procurement and the 3D engineering model. Design of information flow included access to the ERP data, selection of equipment for which it is required (with weight over 25kg), and comparison criteria for engineering defined weight and data from the ERP system. Once the information flow design was clarified, it became a simple task to set up the information management tool. Results for the planning and installation included a pre-set visualization style in the information management platform with one-click colored 3D models according to weight data. This way, on-site work can be planned to take access to heavy lifting machines and cranes into account and avoid situations where installation teams have to make unplanned hull cuts or wait for heavy equipment lifting.

Achievement is a significantly improved planning process and elimination of waiting times on-site. In this example, a simple identification of information flow and placing data in the context – all part of seizing the power of digital tools, led to measurable improvements in the work process and cost savings.

Figure 2. Example of color coding and data visualization for production in Cadmatic eShare.

Planning of installation packages

A typical project in modern shipbuilding includes 500-1000 piping work packages for installation. The design phase for piping systems should include creating the 3D model with all related data and information for the work breakdown splitting. Depending on the workflow, the output of the design phase might be a basic 3D model, ready for a generation of production data, or a complete package of the documentation, including spool drawings, BOM, and detailed planning information.

Planning of manufacturing and installation for this process based exclusively on engineering data might result in delays and disruptions due to a lack of information about deliveries from pipe shops or suppliers. Including the data from ERP (or another type of system) provides possibilities for merging data: engineering and work break down, and delivery progress from the workshops or subcontractors and placing it in the context of the work process. Engineering and design data for piping is typically based on functional diagrams and include 3D model, component and material information, fittings and armature, joints and fittings, and additional materials, such as bolts, nuts, gaskets, insulation materials, and the like. A piping system is split into spools, and often spools from different systems are packages in a work breakdown structure for work packages installation in certain ship areas.

This example represents a case where consolidating data from engineering and installation planning using innovative technology can save significant time. It is a laborious task in case of only one project, while if a shipyard has several subcontractors delivering pipe packages and tens of simultaneous projects – it becomes essential for production planning and control.

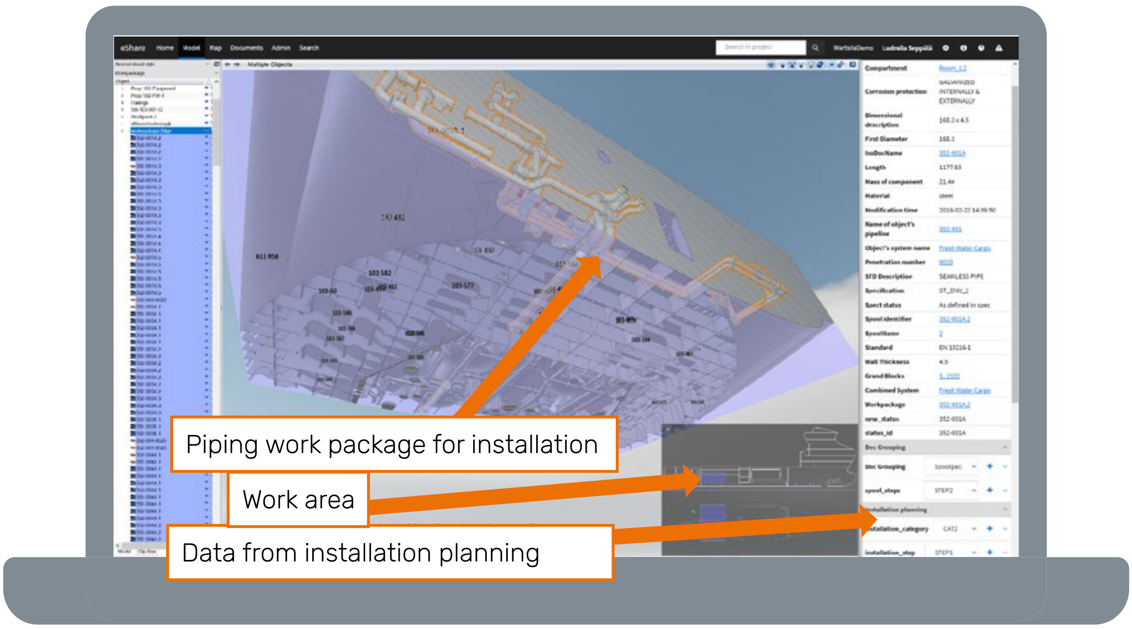


Figure 3. Example of 3D model and installation planning data in the context of work package visualization.

Communication between design and production in the shipbuilding network

Increasing production efficiency and the overall shipbuilding process requires more communication between the design departments and the shop floor. Providing information "on-demand" and within the context reduces the number of paper drawings and creates an interactive digital environment. It is crucial for the concurrent design and production processes when parts of the design model are released for production while yet might be affected by changes in design.

Having a "single source of truth" data can significantly increase the quality of decisions and reduce the time spent searching and verifying the information. At the same time, providing a context for production execution can increase the production quality and at least partially address the lack of skills or understanding of the overall process by production teams. Adding a link between the design model and nesting status provides a solution to track the hull building process accurately. It lets designers see in an instant what parts have been cut and welded, and the progress of building and inspection is visible, reducing the number of uncertainties and questions.

In the example presented in Figure 4, extending the usability of 3D design data and integrating it with the production tracking systems (such as nesting) enables concurrent processes and provides the needed visual context for project management.

There are many similar examples of the use of integrated information to benefit design-production communication. Powerful IT integration platforms and advanced user interfaces replace "codified" communication based on 2D static documents and open opportunities for a more interactive dynamic data exchange and use. While having an end-to-end digital thread is an important goal, eliminating the gaps while focusing on purposes is a practical strategy for digitalization in shipbuilding.

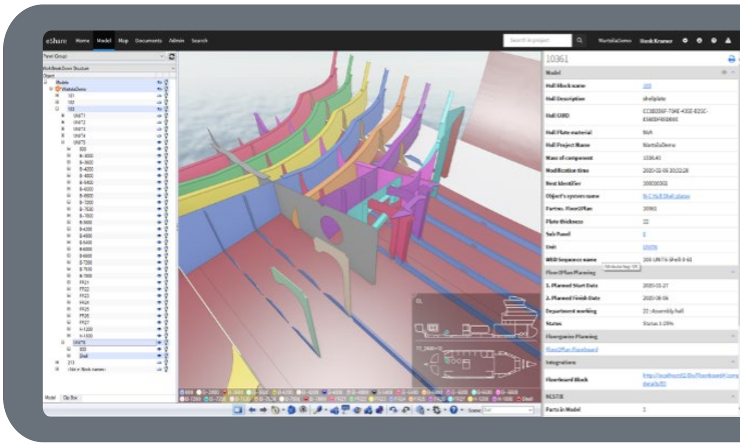


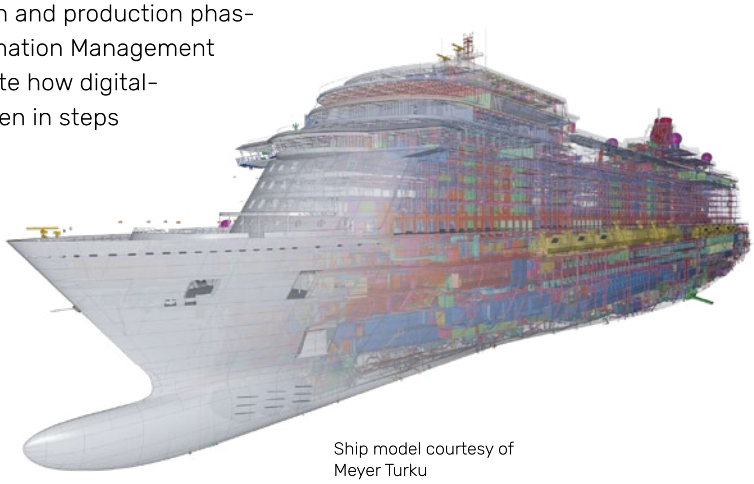
Figure 4. Example of 3D model of hull construction with coloring according to the hull material data and information about the readiness of micro panels for production from the shop floor planning.

Information flow: Benefits from digitalization and flexibility for work processes

Digitalization is not just the use of digital technologies. It is a way of transforming the work processes, and new possibilities—the vision of seamless information flow and drawingless production [11] are already becoming a reality in modern shipbuilding. Besides robust functionality to support design and production phases, intelligent technology should support data integration with existing systems and allow companies to engage in a step-by-step digitalization process. Addressing the gaps in information flow grounds developing digital solutions following shipbuilders' needs. This approach embraces Industry 4.0 concepts and goes toward the Industry 5.0 concept of developing IT solutions – including sustainable goals and skills in the equation of digitalization [12]. This way, the digital solutions are not only developed in functionality according to possibilities of data handling by IT systems but follow and challenge the work patterns and serve the goals of the overall shipbuilding process.

Conclusions

The growth of complexity in shipbuilding projects and its distinctive differences in design and production processes from other industries call for specific solutions. Besides changes and shifts of focus in each phase, special attention is needed for the information flows between these phases. Business processes, such as offshoring production or pre-outfitting, put additional demands on IT solutions. Modern ship-building solutions must provide users with high-level integration possibilities and focus on innovation for use cases to support these data use and information management needs. Examples presented in this paper are based on cases where shipyards gained significant time savings and quality improvements by addressing the gaps in information flows between design and production phases and using the Cadmatic Information Management platform. These examples illustrate how digitalization transformation can be taken in steps as an evolution process, changing the way shipyards work under changes in a business environment and seizing the power IT solutions provide.



Ship model courtesy of Meyer Turku

Acknowledgements

Screenshots for the figures in this paper are taken from the Cadmatic Information Management platform using a demo environment project courtesy of Wärtsilä Ship Design Norway AS.

Numerous discussions with Cadmatic personnel, customers, and the shipbuilding industry peers contributed to the ideas presented in the paper.

References

1. OKUBO, Y., MITSUYUKI, T., 'Ship Production Planning Using Shipbuilding System Modelling And Discrete Time Process Simulation', Journal of Marine Science and Engineering, 2022

2. BRUCE, G., 'Shipbuilding Management', Springer, 2022.

3. MOLLAND, A., 'The Maritime Engineering Reference Book. A Guide to Ship Design, Construction and Operation', Butterworth-Heinemann, 2008

4. SEMINI, M. et al, 'Offshoring Strategies in Norwegian Ship Production', Journal of Ship Production and Design, Vol. 34, No. 1, 2018

5. CONOSHIP Inl., 'Robotization for a future-proof shipbuilding industry in the northern Netherlands', 2022

6. MONGADO-ESTAVEZ, A., et al, 'Towards Automated Welding in Big Shipbuilding Assisted by Programmed Robotic Arm Using a Measuring Arm', Springer, 2017

7. BACK, M-G., et al, 'A study for production simulation model generation system based on data model at a shipyard', International Journal of Naval Architecture and Ocean Engineering, Vol. 8, Iss. 5, 2016

8. GOO, B., CHUNG, H., HAN, S., 'Layered discrete event system specification for a ship production scheduling model', Simulation Modelling Practice and Theory, Vol. 96, Elsevier, 2019

9. MUNOZ, J., PEREZ-FERNANDEZ, R., 'Adopting Industry 4.0 Technologies in Shipbuilding Through CAD Systems', Trans RINA, Vol. 163, 2021

10. GRAU, M., etc al, 'Enabling the Digital Thread for Shipbuilding and Shipping', ICCAS, 2019

11. SEPPÄLÄ, L.' Drawingless Production in Digital Data-Driven Shipbuilding', COMPIT, 2019

12. EUROPEAN COMMISSION, 'Industry 5.0: A Transformative Vision for Europe', European Commission, 2021

Cadmatic is a leading 3D design and information management software developer and supplier for the marine, process, energy and construction industries.

Cadmatic
Linnankatu 52 A
20100 Turku, Finland
Tel. +358 2 412 4500
sales@cadmatic.com
www.cadmatic.com

For Cadmatic worldwide offices see
www.cadmatic.com/contactus