Integrated Design, Production Planning and Construction in Ship Building

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Abstract

In today’s increasingly challenging environment, shipbuilders are seeking to secure a competitive advantage by leveraging the power of innovative technology to streamline work processes and achieve life cycle efficiencies. A technology-driven data-centric multi-discipline integrated system ensures data integrity and cross-discipline collaboration throughout ship design, production, build and maintenance. Accurate digital records enable effective production planning and supply chain management for optimum ‘on tool’ time, whilst shared project workbenches eliminate costly and time-consuming duplicated efforts. This paper discusses the benefits of digital execution of all shipbuilding work processes, with particular focus on information integrity and associated life cycle efficiencies; the most advanced approach ensuring accurate definition of physical asset at all times, and key success factor in driving delivery to standard, schedule and budget.

1. Introduction

It seems that “Nothing is new under the sun”. As it was since centuries ago already, shipbuilding is yet the business - sometimes the art - of bringing heavy materials, each heavier than water, and turning them into floating manufacturing products, often amazing in their sizes, their power, or their beauty. In the meantime, despite technology is all around our lives, computers in the shipyard:

• are not helping a worker in increasing his productivity;
• are not relieving his supervisor from the risk of working with obsolete and superseded versions of design information;
• are not making construction planners confident about reducing contingencies in their estimations or validating execution plans against materials availability;
• are not providing management with accurate status information enabling fast and proactive decision-making.

Of course, a lot of software is available in shipyard offices supporting single function, single department work processes, and sometime supporting high-end business information. However, despite sometimes significant IT investment have been undertaken, a deep and integrated coverage of all operational tasks is definitely missing. In addition, maintenance suffers a lack of accurate and ready-to-use as-built information, which makes operations even more challenging and potentially heavily affecting the time when ship will go to back service and/or to market. All that brings three important opportunities:

1. A lot of room is yet available to deploy digital execution technology at shipyards.
2. Effective benefits are achievable by addressing work processes integration and enabling different departments and shipyard functions to share and work the same digital information and reuse them in real time.
3. Long-term improvements come from shifting focus to embrace the whole ship life cycle while including single production project only.

In other words, a big chance is available to shipyards of any size for taking benefits of pioneers’ experiences, and adopting proven systems that can support today’s competition.
2. Digital data-centric execution revolution

It is about 20 years already since data-centric approach has applied in supporting all phases of asset definition and management\(^1\), but many benefits to design and execution practices are yet ahead of current traditional execution.

The easiest consequence to understand is that designers can finally give up from managing CAD files, since relevant CAD drawings are no longer main scope of design tasks, to become just automatic output, automatic deliverables, which result from smart design execution. In addition, designers can also relief from relevant boring and time-consuming drawings revision and storage management.

It sounds like a revolution; however, it becomes a real everyday practise as soon as all design data, including graphics for either 2D or 3D modelling go into reliable, leading, commercially available database. It then implies that both CAD file based drawings as well as proprietary CAD/3D data format and storage technologies are actually superseded practices. However, beyond those improvements, smart technology and digital data centric approach to ship design and execution deploys even more benefits.

Fig.1: Benefits of Smart digital data centric technology

2.1. Objects Correlation

Object correlation is the ability to digitally recognize design objects in the system and automatically understanding how they work together. It has two important implications, both bringing value and efficiency to project stakeholders:

1. Multi-discipline coordinated consistency
2. Multiple objects design change implication

Multi-discipline coordinated consistency implies that as soon as all the data describing given objects

\(^1\) All work processes and phases in are considered here, going through engineering and design, procurement, fabrication, construction, maintenance, and decommission.
are in standard databases, the system can recognize whether a component\textsuperscript{2} in the project is the same among several tools, which is a key feature in maintaining and reusing consistent information across different disciplines and functions.

Multiple objects design change implication allows automatic propagation of a change among correlated components in 3D, so that as soon as a design change has to be executed on a given component, the system realizes and points out which further objects are going to be impacted, therefore supporting the 3D designer accordingly. Hence, a better, more accurate design solution can be achieved with just a few clicks.

2.2. Global Work Sharing

True and real work sharing on a global basis allows timely visual status updates are provided on what other disciplines, other operating centers and eventually engineering partners or subcontractors are doing, therefore maximizing cooperation and collaboration among all stakeholders. It works real time, and it enables a huge productivity increase of liaison engineers and it massively reduces coordination costs.

2.3. Automation

All project information is available in the standard databases, so it becomes possible to process it further and apply design rules and verification checks resulting in both a quality increase as well as an enhancement in efficiency. With such an approach, typical deliverables of engineering design tasks are all automatic outputs of system data processing: creating drawings, defining requisitions for purchasing materials, forecasting construction execution upon site materials availability, planning construction men-hours, etc.

The consequences are:

- No more error prone manual executions;
- Significant increase in design quality and consistency;
- A huge decrease in verification costs.

2.4. Change Tracking and Management

Real time Change Tracking and Management is key in developing detailed design, especially with today’s fast track projects. Smart data centric technology becomes a key in enabling features as the following:

- The ability to record each digital version of the same document and automatically compare them;
- The ability to highlighting differences in material requirements among various project statuses and phases;
- Receiving system notifications about deliverables reflecting a design change, which needs to be released with a higher revision number, which is fundamental information that needs to be available timely to the construction crews.

2.5. Digital Materials Management and Execution

Smart digital data centric approach to materials management allows so-called Surplus and Shortages

\textsuperscript{2} Component is any physical object having a virtual representation in 3D, e.g. either a long lead equipment, a valve, a piping line, any structural element, etc.
Free execution, meaning that ‘just in time’ delivery of materials at the fabrication shop or at construction site is possible.

The goal is to prevent shortages before a planned fabrication or installation will take place. Adopting Surplus and Shortages Free principles, shipyards can avoid expensive last minute purchases of missing components and prevent claims from subcontractors. At the same time, they can also avoid surplus and excess materials delivery and save relevant costs for purchasing, handling, and storing such excess materials.

This is driven by the digital execution of engineering and procurement work processes, including logistics and supply chain management that goes beyond typical IT barriers of different ecosystems, and allows any stakeholders, including sub-contractors, vendors, freight forwarders, and any third party to provide and receive accurate and timely information dealing with the task to execute.

2.6. Specify Check Asses

It ensures Tag Number consistency, which results from applying digital rule-based naming conventions that can be specified at the early days of ship design. It maximizes the reuse of equipment or instruments relevant properties and specifications across the engineering and supply chain, and down to fabrication, construction, and completion assessments. No more inconsistent designs and no more inefficient practices like either re-entering or re-typing the same data will be requested; this prevents risk of introducing errors, and relevant control requirement, and therefore reduces execution costs.

2.7. Reuse Simulate Look Ahead

Smart technology allows all ship design data in standard databases, and maximizes reuse of data across the whole life cycle; at the same time, it allows simulating changes by enabling “what if” and “look ahead” analysis. It means that both the output of engineering and design tasks, 3D model and relevant deliverables can be immediately reused to feed constructability analysis and construction design review sessions. Because such analysis and review are actually possible in smart data centric ship design, construction stakeholders may join the project earlier than ever.

Furthermore, enhanced visualization triggers additional benefits like preventing potential fabrication and construction issues in the yard, and enabling more accurate construction planning. In addition, the digital acknowledgement of the so-called Engineering Construction Quantity eliminates the need to long and costly document based engineering to construction handover process, providing increased value and efficiency to the whole shipbuilding process.

2.8. Capturing Real Assets

Smart digital technology allows capturing real assets with real dimensions, so that a complete digital model can be created reusing existing elements as a source for defining new virtual assets. At the same time, it enables new digitally based certifications and quality control / quality assurance work processes for comparing fabricated assemblies, manufacturing parts, modules, etc. Shipyards can use a relevant digital view from the 3D model to digitally determined deviations and matching tolerances.

2.9. Retrieve and Operate

Last but not least, smart technology based on a standard database allows an easy handover of this huge and valuable set of engineering and design data to the Owners, which therefore ensures that plant lifecycle management is based on accurate information.

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3 Animation can simulate different approaches to construction execution before they would actually be adopted.
Smart technology is the main mean to improve efficiency and eliminate waste in any discipline and relevant crossfunctional collaboration. The use of smart technology advances lean construction in any organization.

3. **Lean work process integration**

However, beyond being “Smart™”, digital data-centric execution has actually more to deliver to shipbuilding. That deals with the ability of implementing so-called “Lean” approach to both fabrication and construction. The word “Lean” has many meanings and uses; the first is to minimize and eliminate waste, which is a common definition of the word. Another use of the word “Lean” is to sway towards an opinion; so that this definition may be the most applicable for the industry use of “Lean”, as a common factor in all “lean thinking”, “lean ideas”, or principles, is that it requires adopters to embrace a new direction, and change their mindset, execution approach, or philosophy. At this purpose, “Lean construction” is a “way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value”.

![Fig.2: Lean Construction Principles](image-url)

**LENS CONSTRUCTION PRINCIPLES**

**VALUE IS ADDED BY**

- **DIGITAL COMMUNICATION & COLLABORATION**
  - Owner
  - Workforce
  - Project Stakeholder

- **ELIMINATING WASTE**
  - Materials
  - Effort
  - Design Errors
  - Idle waited Time

- **OPTIMIZING WORK PLANNING**
  - Early Planning
  - Distribution of Workload

- **MODULAR CONSTRUCTION ACTIVITIES AND OFF-SITE FABRICATION**
  - Reduce Site Congestion
  - Reduce Lock-Box Workload

- **LOOK AHEAD SCHEDULING**
  - Just-in-Time Deliveries
  - Engagement of all Parties

- **IMPROVE WORKING ENVIRONMENT**
  - Clean
  - Safe
  - Efficient
  - Productive
“Lean Construction, as defined by the non-profit Lean Construction Institute (LCI), is a production management-based project delivery system, emphasizing the reliable and speedy delivery of value. The goal is to build the project while maximizing value, minimizing waste, and pursuing perfection – for the benefit of all project stakeholders.” (Lauren Pinch, Construction Executive, November 2005)

Value in fabrication or construction is like value in any business: it is a return on your investment. Therefore, adopting lean principles is an investment in the future of the project, which will reap benefits and give a solid return on investment. In other words, Lean Construction is a new paradigm in fabrication and construction planning that uses lean concepts to approach value rather than cost, and efficiency rather than schedule.

Lean construction implies:

- Improve communication planning among stakeholders with visualization and open display of schedule, design, and workflow.
- Eliminate waste of materials, duplication of efforts, and design errors.
- Improve work planning by early planning, with a focus on improved workflow, achievable tasks, distribution of workload, and a clearly defined work scope.
- Look-ahead scheduling with just-in-time deliveries, engagement of all parties, availability of resources, access to site, and coordination of other dependencies.
- Plan and coordinate off-site fabrication and modular construction activities to reduce site congestion, distribute workload, minimize field work force, and improve just-in-time delivery.
- Create a clean, safe, and efficient working environment, and communicate safety.

So that, it is not only what has eliminated – the waste – that matters, but also what has added, that is the most defining denominator: value. And new value has such, definitely incorporates two contributions from data-centric / technology based execution: The first comes from digital execution of existing work processes; which is important aspect as technology allows data reuse, collaboration, and powerful work processes integration. The second comes from continuous improvements in business work processes re-engineering, which actually brings new digitally executed work processes into the evolving picture of Traditional Vs. Optimized industry execution.

4. Digital Planning and Manufacturing

Prior to the existence of parallel or concurrent engineering concepts, the shipbuilding industry formed unique processes which execute design, production planning, and production for hundreds of thousands of parts simultaneously.

4.1. Design for construction productivity

The basic unit for design, fabrication, and assembling tasks is the ship block, and these tasks and processes should be executed concurrently, to optimize total production time. Productivity of the shipyard depends on design and production data to be efficiently generated and properly utilized, to deliver data to the production department in a short period.

Production planning aims to bridge design and production using 3D model data, production scheduling, and production-related knowledge after contracting. Optimizing the whole the production process actually implies assessing both: block and assembly management based on work location, and size, weight, and orientation. In today’s globalized scenario, design and building of ship might take place in different part of the globe. It is also possible fabricating blocks of the same ship at different shipyards, and those shipyards most likely have different production capabilities and schedules. It implies that advance definition of block and assembly size, and relevant weight is not possible, and therefore, rapid design revision must be easy.
Available technology allows large-scale modification, so that ship design and modeling may begin very early in the engineering process. Among other physical properties that can affect the way an assembly moves through the shipyard, size, weight, and orientation have the biggest impact on cost. For example, orienting a block to minimize the number of overhead welds will reduce the difficulty of welding, thereby reducing welding men-hours and optimizing cost. Rules based Smart™3D system allows implementing the shipyard’s knowledge and construction best practices into the system, and enables automatic selection of the best orientation and sequence for each assembly.

4.2. Controlling execution

Main goals of production process control are on-time delivery of the contracted ship, optimized resource allocation for the ship construction process, and maximized throughout shipyard facilities. The ship construction process faces ever-changing factors such as design changes, design errors, delay of upstream processes, late arrival of materials, and delay of current processes. The quality process control system has to cope with these kinds of challenges. To achieve an effective process control system, the work package definition, design delivery planning, BOM activity, and material acquisition date should be frozen. The execution of materials supply chain management process will ensure as much as possible just in time materials availability. Based on the BOM’s material information, detailed material amounts and unit costs of production can be used to make cost estimations. Finally, efficiency and productivity of the ship construction can be measured by the executed data per work package.

4.3. Work packaging

A work package is an optimized management unit for ship construction based on a Work Breakdown Structure (WBS) and is usually decomposed to zone, discipline, stage, and skill for ship construction workers. The work package contains not only the work amount, target men-hours, and work schedule information, but also drawings, material, machine, and workers in order to apply scheduling, design, material, and process monitoring tasks. A work package may roughly cover one month of work and can be divided into sub-packages of several work steps.

5. Maximizing “Time on tools”

Enhancing construction productivity and maximizing so-called “Time on tools” implies effective planning of both fabrication and construction operations. It starts with the ability to smoothly integrate all disparate data that construction planners and supervisors require in one single platform, like:

- Construction master schedule
- Intelligent drawings and documents
- 3D models
- Materials requirements and supply chain data

so that all information will be available from inside the construction planning package.

Among others, innovation brings several benefits in supporting both planning construction or fabrication operational tasks, such as:

1. Automation in detail work face planning or work package planning, which allows automatic identification of involved work steps, relevant man-hour estimation, validating construction planning against real time materials availability, and track progress
2. Animation facilitating planning review and “What if analysis”, which means enabling so-called 4D simulations, reviewing work package scheduling to modify sequences, and share animation, after has been recorded
3. Stay in synch with engineering, by means of accessing 3D models, reviewing all properties of
components shown in the 3D, review list of available engineering data and smart drawing, including the ability to track changes and get notified when engineering information addressing a given construction work package has revised.

4. Digitalizing manufacturing process by means of linking digital spool drawings management to cutting machine software, first, so that the same digital information from smart drawing will drive the machine, implying that errors will go down to Zero, and at the same time Fabricators with have huge savings and a great improve in the quality of fabrication process

All that implies that construction or fabrication planners will have the ability to take informative and therefore appropriate decision addressing the job that will be executed next, and, last but not least, will be able to provide the team who will do the real job with accurate information on the scope to execute.

6. Conclusion

The challenging time that shipbuilders are facing today, suggest that organizations of all sizes shall adopt innovative technology to streamline work processes and achieve life cycle efficiencies. Clients in any business are more and more looking for value, which implies the ability for shipbuilders to demonstrate that waste has reduced to minimum achievable, and relevant costs are not part of their bill.

Today, smart technology-driven ‘integrated system’ concept deploys digital support to the whole shipbuilding process, spanning across design, through production planning and down to construction, providing information integrity and associated life cycle efficiencies.

This approach ensures an accurate virtual record of the physical asset at all times, plays a key role in driving delivery to standard, schedule, and budget, and secure a competitive advantage to shipbuilders who adopt it.

References

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