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EVALUATION OF GLOBAL AND LOCAL SHIP DESIGNING SOFTWARE
TREND AND WAY FORWARD

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Abstract: Choosing the right ship dimensions, speed, and capacity is one of the most important considerations for ship owners. This decision often depends on figuring out what type of ship best meets a specific need. Since there are many factors that may vary depending on the class or regulatory body, such as its technical specifications, construction methods, and operational needs, final design decisions usually come from a compromise between those competing requirements. To address such opposing requirements, naval architects currently employ multiple types of purpose-oriented parametric software that are interconnected. As a result, this article looks to depict the global evolution of employing CAD-based software for ship design, as well as general information regarding CAD/CAM/CAE tools for improving performance, structural integrity, stability, and enhancing ship maneuverability and seakeeping capability. Furthermore, this article represents Bangladesh's ship design capabilities as well as the accessible software used for ship design purposes locally. This article also aims to recommend some measures to improve Bangladesh's overall indigenous ship design ability.

Key Words: Ship modeling, CAD systems, hydrodynamics, seakeeping, Stability, etc.

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Introduction

Design is a synthesis process of combining together various disciplines and analytical techniques. In past examples, changes were made to an existing ship type as the basis for developing a modern design. This makes ship construction a complex process. “Ship design is not an exact science but embraces a mixture of theoretical analysis and empirical data accumulated from previous successful designs.”[1] Since the technical requirements of ship design, ship construction, and ship operation tend to have complex relationships, the final design of a ship is typically the result of compromise between those opposing technical requirements. Similarly, “warship construction is always a compromise between achieving perfection and sticking to intended purpose and cost. If higher speed is to be achieved, the cost will go up exorbitantly. Thus, to suit requirements, ‘must,’ ‘required’ and ‘nice to have’ parameters are to be sorted out meticulously; and these need to be fitted in the design platform methodically. This is a very time-consuming, demanding, and difficult job.”[2]

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[1] Anthony E Molland, ‘’The Maritime Engineering Reference Book”, A Guide to Ship Design, Construction and Operation, 9, 638-724, USA (2008)
[2] Abedin, C. A. "Warship Building in Bangladesh, Problems and Prospectus: Analysis and Recommendations", NDC E-JOURNAL, 6(1), 91-111, Bangladesh (2007)

CAD (Computer Aided Design) based modeling of ship construction began with the historical origins of documentation and drawings for constructing a ship. Presently Naval architects use several types of purpose-oriented parametric design interlinked computer-aided software to design and model a ship's structure; define construction material, and thereafter analyze its strength, stability, seaworthiness, etc. in compliance with the class or regulatory bodies' standards. First, data transferring and changing between these applications can be inefficient. Secondly, the conventional CAD/CAM system for shipbuilding relies on a procedural method which means that it is not able to properly express design requirements in production[3].

Ship modeling functions are distributed across various applications in order to take into account the constraints mentioned. Each application is used separately and repeatedly throughout the concept design stage, as well as during basic design, detailed design, production design, etc. This way, from ordering to delivery there is a distinct "design stage" followed by a separate ‘’manufacturing stage.’ The design stage can be further divided into contract design performed for the negotiation with the ship owner, basic design to meet the requirements of the ship owner, and detailed design performed from a functional aspect. On the other hand, the manufacturing process includes pre-processing, fabrication, assembly, precedence outfitting, painting, block erection, out-fitting, etc., and these processes occur in a very complex pattern over a long period of time.[4] Figure 1, shows the process of shipbuilding, which may vary and can create complexity due to the owner's requirements. This makes the manufacturing process different from other common processes.

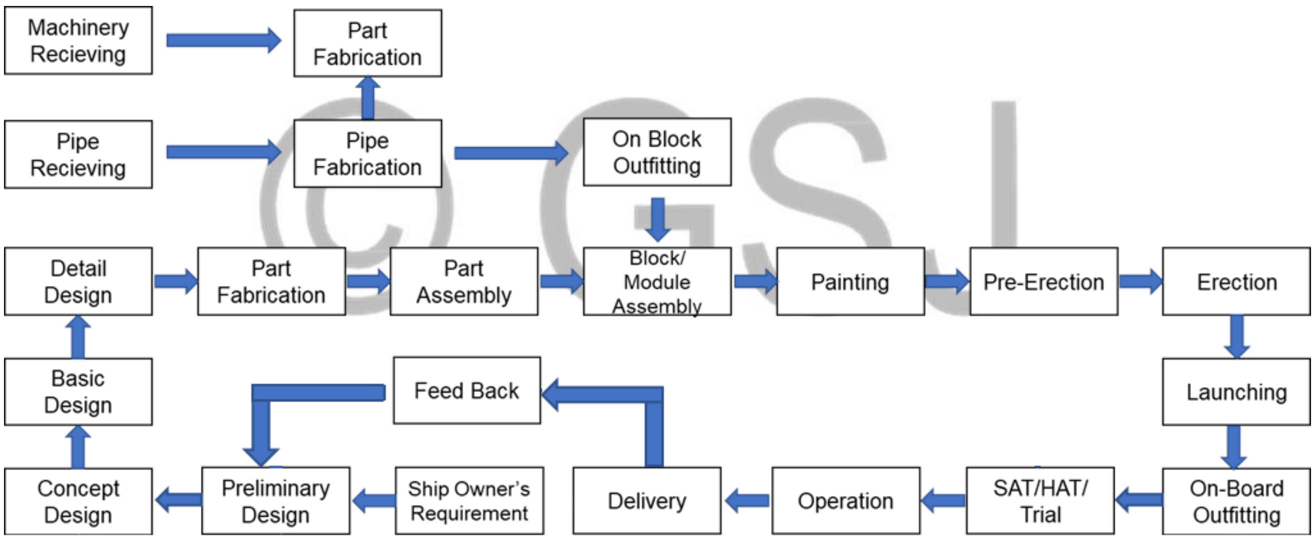

Figure 1: Flow of Ship Building Process

This article covers the evolution of using CAD-based software for ship design globally and locally based on both primary and secondary data gathered from various sources. Naval architects around the world usually rely on this type of software. There is a wealth of information and literature on it available online and in libraries. However, there is a lack of literature, research, reports, and articles on local ship design.

[3] Ryumin, S.; Tryaskin, V., Computer-Aided System for Parametric Design of Ship Hull Structures—CADS-Hull, Machines 2022, 10, 262, Switzerland (2022).
[4] Hongtae Kim, “Applying Digital Manufacturing Technology to Ship Production and The Maritime Environment,” Integrated Manufacturing Systems,13(5), 295-305

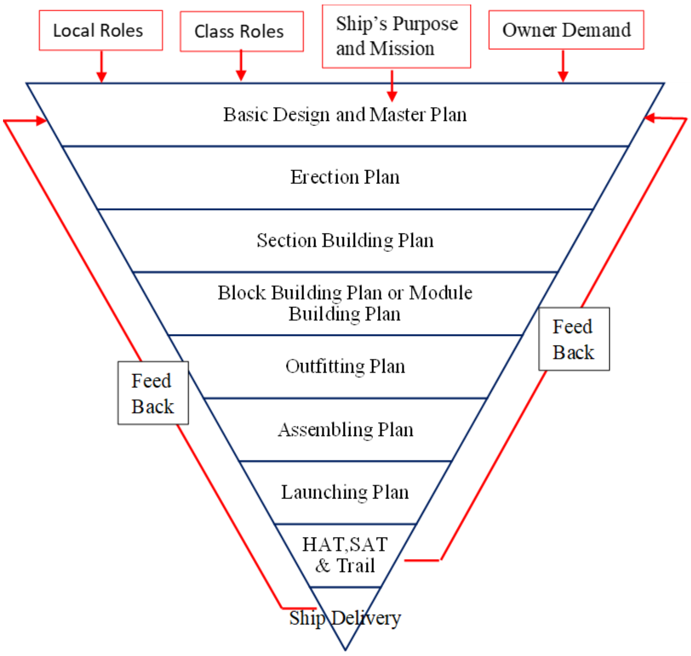

Figure 2: Stages of Ship Building

Overview of CAD Based Software Evolution in Ship Designing

Invention of CAD Systems. History says that the mathematician Euclid of Alexandria was responsible for the development of these CAD/CAM/CAE systems around 350 BC. However, many believe that the work of Pierre Bezier, a French engineer at Arts et Métiers Paris Tech, heralded the invention of 3D CAD more than 2000 years later. In response to his surface-related mathematical work, he created UNISURF between 1966 and 1968 to simplify the design of tools and parts for the automotive sector. Then, UNISURF served as the foundation for the subsequent CAD software generations. CAD systems were only introduced in academic courses a decade later. In the preliminary stages of the development of CAD Systems, running the software on mainframe computers constrained the use of CAD tools for production. However, the use of CAD systems scattered in numerous engineering fields when this software became usable into workstations and Personal Computers (PCs).

Incorporating CAD Systems in Ship Building Industry. Certain ship design offices could not use computing equipment until the 1960s to increase the productivity of various projects. However, the concept of expressing, fairing, and producing new hull forms from a set of primary ship dimensions and coefficients using mathematical descriptions of ship hull forms was quickly realized to a significant extent. Beginning in the 1960s, using the basic data of the primary ship design, the designer used to produce intrinsically faired ship hull forms. The goal of this kind of software/module was to produce a preliminary hull form suitable for hydrostatics and qualitative appearance. Another module defined as earlier as the generation of hull forms was the fairing one, used to fit (and optionally fair) an existing hull form defined by a table of offsets or using line drawing, bi-arc, and splines techniques. Naval Architects used this type of module to change previously constructed locally fair forms, in which case only the local modification described by point coordinates needs fairing after fitting. Fitting and fairing are necessary for the entire hull form for non-fair forms designed using alternative approaches. As a result, the earlier CAD Systems were designed with all ship design disciplines (hull form generation, hull fairing, naval architecture calculations, design, and production of structure) coordinated, with the ultimate goal of obtaining ship production most shortly and cost-effectively possible.

Figure 3: Primitive Ship Building

Since then, the Marine CAD tools have been continuously updated and used as an internal tool at many ship design offices and shipyards, enabling high-quality projects to be completed in unusually short time frames. In 1969, the Spanish company, Bazan (now known as Navantia) was one of the first shipyards to use shipbuilding CAD Systems. Since then, it is not understandable the ship production and design without the use of CAD.

Adopting Outfitting Tools in Ship Building Industry along with CAD Systems. Since the 1970s, the capabilities of CAD systems in other shipbuilding disciplines like pipeline, equipment, heating ventilation and air conditioning (HVAC), electrical, and beyond have been increased. This evolution happened because of new shipbuilding challenges that required greater coordination between hull construction and outfitting and also compelled maritime software developers to pay special attention to this issue. Some marine CAD programs began to add outfitting tools, while others concentrated on finding a more direct interface with existing plant design-oriented systems. The actual requirements for the outfitting design are not restricted to close integration with the structural design and were responsible for the evolution of the one-of-a-kind outfitting design tool. In ship design, problem-solving methods, regulations, working procedures, manufacturing information, and so on are so particular to ship design that has a specific tool for outfitting purposes is preferable to attempting to adapt an existing one. Furthermore, this evolution ran parallel to the course of computers, from large computers operated with punching cards to modules running on mainframes only available to the largest shipyards, to minicomputers like PRIME or VAX with monochrome graphical screens, then the UNIX Operating System, and finally working on PCs with amazing graphics and great computing capabilities.

Presently tools for piping, HVAC ducts routing and definition of auxiliary structures such as foundations, gratings, ladders, electrical and accommodation, etc usually include particular environments for equipment modeling and layout. Outfitting design requires to work in a pure 3D environment and with a friendly and suitable user interface. Again, always new developments in outfitting tools have been handicapped by the available technology (hardware, graphic possibilities). Now-a-days it is commonly assumed that outfitting tools should be able to work in a solid visualization method, with enormous amounts of information on the scene by handling dynamically.

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Present Evolution of Simulation Based Design Concept using CAD/CAM/CAE Systems

Simulation Based Design (SBD) Concept. The industrial environments of shipbuilding are evolving fast due to technological advancement in the field of latest information and communication technologies. In response to this transforming environment, new concepts have emerged such as simulation-based design (SBD), which is based on a 3D ship CAD system. Such ideas aim to automate every step of the ship-building process, find mistakes early on by using simulation and virtual reality, and make effective decisions. Also, since ship building process from contract through design to building happens concurrently according to owner's requirement, design/manufacturing/maintenance cycle repeats frequently, and information becomes more detailed and complex in each stage. As a result, early information extraction from each stage can be challenging because many processes rely heavily on labor and require qualitative data. Applying simulation-based design through using Computer is the only method to get around these restrictions and shorten the time it takes for the process to progress from design to manufacturing. Also using simulation-based approaches in the early design stages makes it easier to change designs, resulting in huge savings in cost and performance. At present Computers are used in design, manufacturing, and production management. In the near future, simulation-based shipbuilding will also incorporate information technology like as modeling and simulation. Figure 2 shows how simulation-based ship building will incorporate in near future through the entire transition of shipbuilding process mentioned in figure 1.

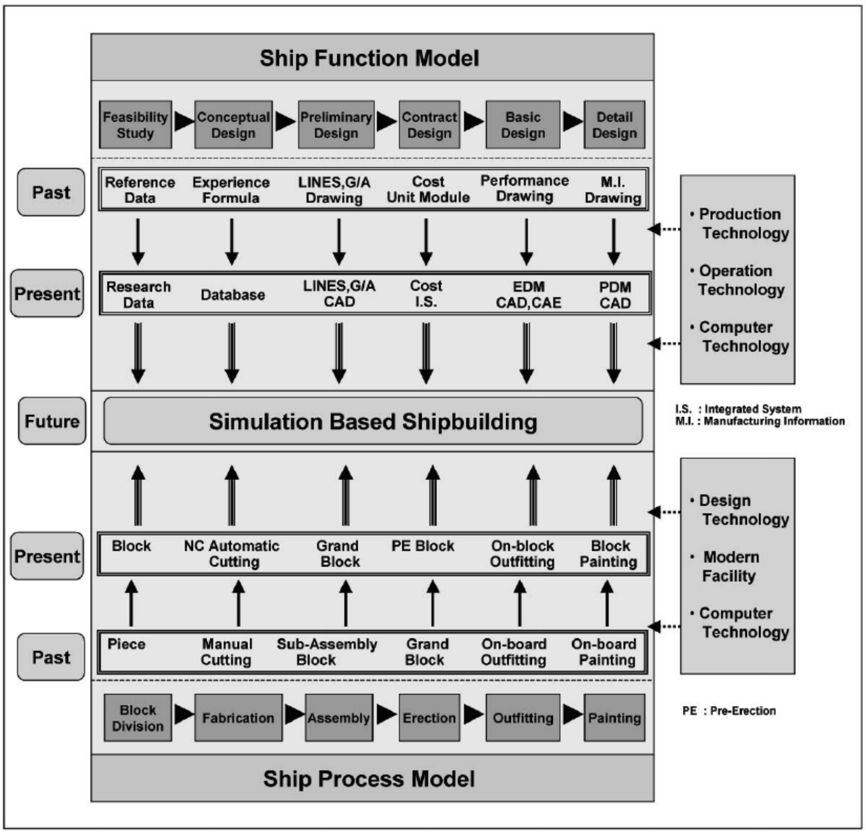

Figure-4: Transition of Simulation Based Shipbuilding Process.[5]

Global Trend of Adopting SBD Concept. To transform the historically labor-intensive and experience-driven shipbuilding industry into a knowledge-based and technology-driven industry through the advancement of information technology based on computer technology, in recent years, many government-funded research has been conducted so far.

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[5] H. Kim, S.-S. Lee, J. H. Park, and J.-G. Lee, 'A model for a simulation-based shipbuilding system in a shipyard manufacturing process,' International Journal of Computer Integrated Manufacturing, Vol. 18, No. 6, 427 – 441, Korea (2005).

In United States. In order to create a design system/environment that can decrease the cost of system design and development, shorten development time, and verify and eliminate risks, the Defense Advanced Research Projects Agency (DARPA) of the United States Navy runs an SBD program. Starting in 1996, phase I of the SBD programmed established an environment for the implementation of SBD, and in phase II, SBD architecture that supports verification of phase I concepts are being developed. [6 & 7] DARPA has made an effort to create a few prototypes to use the SBD concept in follow-up research and feasibility studies. Good examples are the operation simulation of LPD-17, a next generation carrier, NSSN submarine development of General Dynamics Electric Boat Division, and Mobile Offshore Base of the Gulf Coast Region Marine Technology Center (GCRMTC). The technology used in these development processes is being commercialized. In addition, Bath Iron Works (BIW) performed a simulation of crane usage, floating dry-dock usage, dock and pier usage, installation and removal of production equipment, emergency vehicle movement and routes through yards, and personnel emergency evacuation routes from ships[8]. The Virtual Reality Laboratory (VRL) in the University of Michigan is doing research on the application of virtual reality, such as immersive virtual reality and augmented reality, to industry.[9] Structural walk-through modeling, accident simulation, and training simulation are all included in this study. Ship motion simulation and virtual simulations of the shipbuilding process are projects connected to virtual prototyping and virtual reality.

3D Model Generation

Designing Piping System

Block/Module Assembly

Painting and Pre-Erection

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[6] Cardner, J., Simulation of Mobile Offshore Base, Project Report, 1993, GCRMTC.
[7] Fast, K., EVS at electric boat, in Proceedings of Deneb's User Group Meeting, October 1996, Troy, MI
[8] Hugan, J.C., Using simulation to evaluate cargo ship design on the LPD17 program, in Proceedings of the Winter Simulation Conference, Orlando, FL, December 2000, pp. 1407–1410.
[9] Beier, K., Web-based virtual reality in design and manufacturing applications, in Proceedings of Computer Applications and Information Technology in the Maritime Industries, 2000, Hamburg, Germany. Figure 16. Comparison of total idle time (goliath crane) of erection methods.

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Launching HAT/SAT/Trail

Figure 5: Construction of Aircraft Carrier adopting Simulation Based Ship Designing Concept (Gerald Ford Nuclear Power aircraft carrier of US Navy)[10]

In Europe. Historically, Europe has been the leader in naval/marine-related organizations, shipbuilding systems technology, and inter- or international projects carried out by the European Community under the Competitive and Sustainable Growth (GROWTH) Program. The University of Strathclyde's VRSHIPS-ROPAX 2000 initiative is an example of such a program. The university, in partnership with other European naval-related institutions, runs the program as a part of the Thematic Network (TN) SAFER EURORO II on "Design for Safety." The goal of VRSHIPSROPAX 2000 is to create a complete virtual environment for a life-cycle ship design. Creating a virtual model of a passenger ferry called Safer EURORO II 2001 satisfies the requirement for testing various design components. Also, the Ship Stability Research Centre (SSRC) at the University of Strathclyde is conducting research on computer technology applications and interfaces between human factors as a means of achieving the objective of shipyards such as user requirements, competitiveness of ships, cost efficiency, and safety, under the rapidly changing environment of the shipbuilding industry[11]. The main project includes Sub- Sea Navigation of Remotely Operated Vehicles (ROV) and Evacuation Simulation of Ro-Ro Ferry Ships. Also renowned shipbuilding company named Damen Naval has research and technology team which is now giving focus on simulation technologies like Virtual Reality (VR), Augmented Reality (AR), Digital Twinning, modelling, and simulation to add value across the four stages of platform development such as concept, design, build, and in-service maintenance and operator training.

In Asia. Japan's government is working to make the shipbuilding sector an innovative business while attempting to preserve its current technological advancement and competitiveness. Under the direction of the Ship and Ocean Foundation (SOF), the Computer Integrated Manufacturing for Shipbuilding (CIMS) project was begun in the mid-1980s and was succeeded by the General Product Model Environment (GPME) project in 1996 to acquire technology for putting ship CIM models to practical use[12]. Recently, the GPME-based advanced CIM related to knowledge sharing technology, and

[10] https://www.cnet.com/pictures/meet-the-navys-new-13-billion-aircraft-carrier/11/

[11] Vassalos, D., Kim, H., Christiansen, G. and Majumder, J., A mesoscopic model for passenger evacuation simulation in a virtual ship environment and performance-based evaluation, in Proceedings of Conference on Pedestrian and Evacuation Dynamics, April 2001, Duisburg, Germany.

[12] Nagase, Y., Amemiya, T., Ito, K. and Sasaki, Y., GPME modeling methodology and applications, in Proceedings of the 9th International Conference on Computer Applications in Shipbuilding, 1997, Yokohama,

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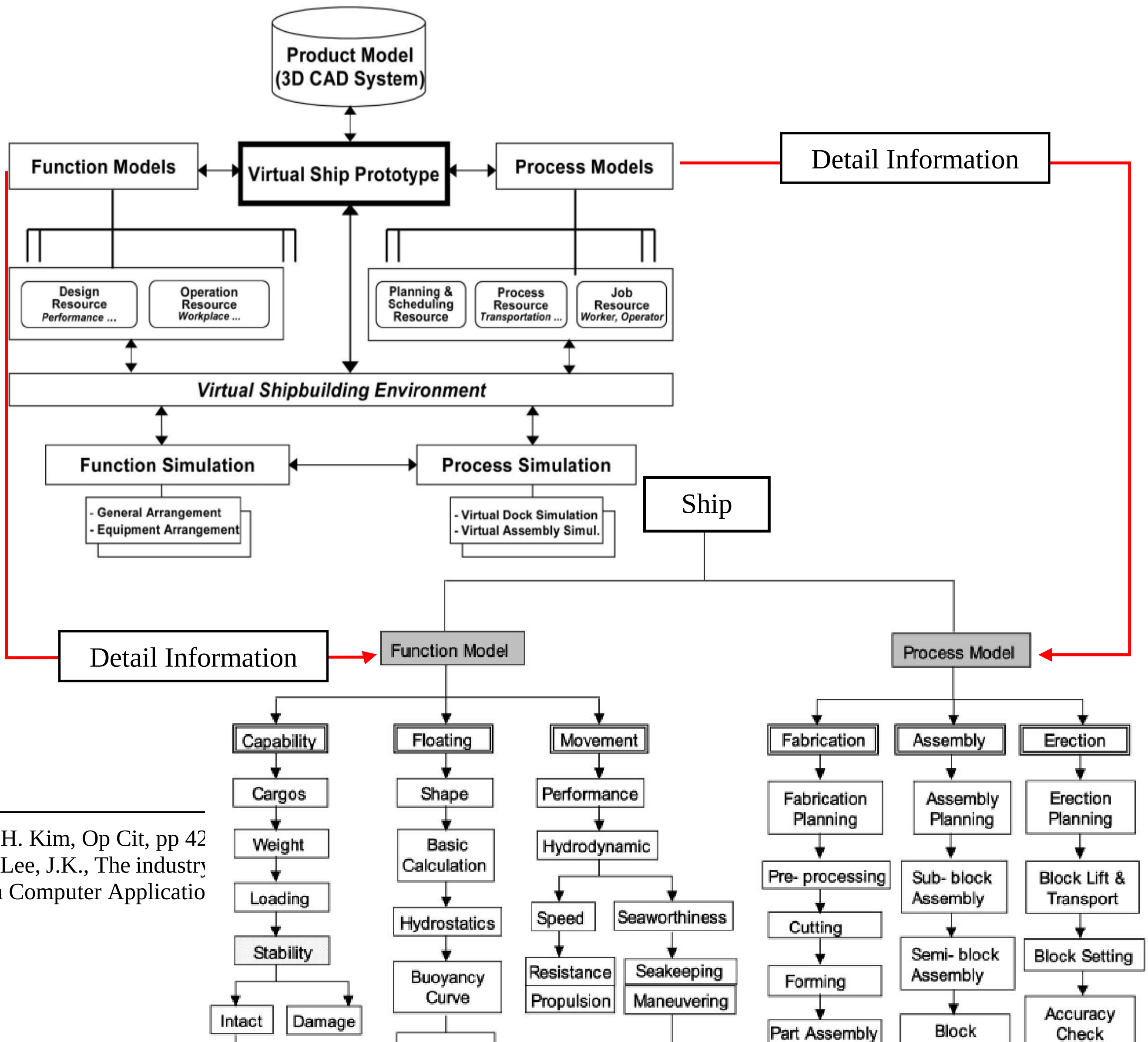
the LINKS project for implementing a virtual shipyard under the CALS concept were completed[13]. On the other side, although leading the globe in construction volume, Korea's shipbuilding sector still lags other nations in terms of technology quality. In Korea the Computerized Ship Design and Production System (CSDP) project led by the Korea Research Institute of Ships and Ocean Engineering (KRISO) was initiated to acquire ship CIM-based technology and the ship manufacturing system integration technology development project for acquiring application technology was completed and, recently, preparations have been made for ship CALS/EC development[14].

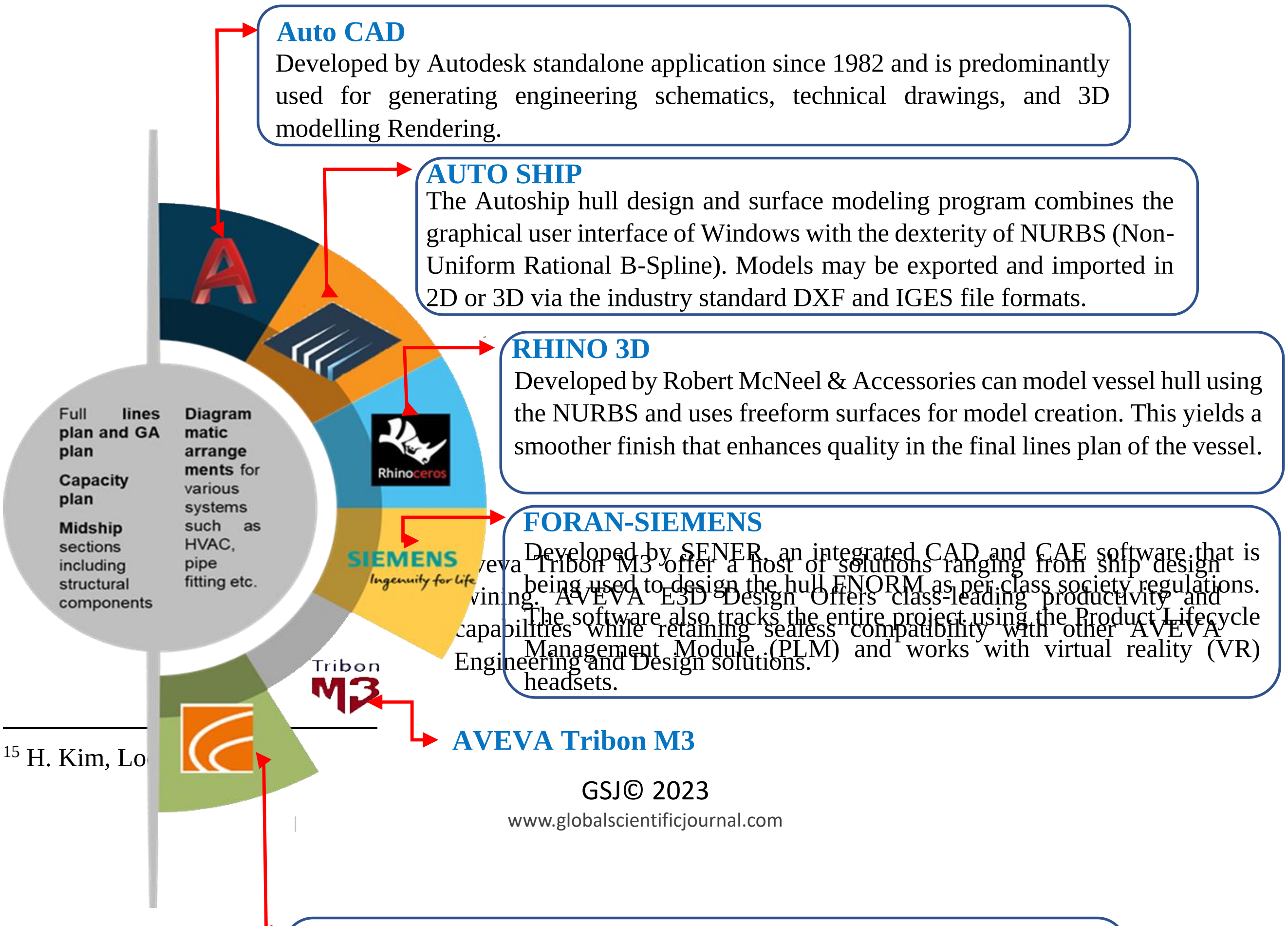
Overview of CAD Tools for Implementing SBD in Worldwide The shipbuilding model is composed of a function model and a process model. The function model represents design and operational resources related to the functions on ships, such as capacity, floating, movement, etc. based on a virtual 3D prototype. The process model represents the manufacturing process including fabrication, assembly, and erection. Figure 6 shows the framework of the simulation-based shipbuilding model. In order to realize simulation-based shipbuilding, it is important to represent both function modelling of the design and the operational resources related to ship functions and process modelling of the manufacturing processes, associated plans, and manufacturing resources. Shipyards, ship registration offices, engineering companies, ship owners, and marine transportation corporations should exchange information about the results of such modelling and inform ation of virtual ship prototypes. Figure 6 also shows the planning-level information about these models including the function model and the process model of ships for simulation-based shipbuilding. Naval architects and engineers use function models to satisfy the owner's requirements. They make sure that the final product meets all of its intended functions by working from reports and drawings. Different CAD/CAM/CAE tools are used around the world to optimize workflow and ensure accuracy in design processes.



[13] H. Kim, Op Cit, pp 42
[14] Lee, J.K., The industry
on Computer Applicatio

Figure 6: Framework and Associated Planning Level Information for Simulation-Based Shipbuilding[15]

For Determining Ship Dimension and Optimizing Capability of Ship. Naval architects and engineers use various CAD-based 2D and 3D software, such as Auto Ship, Auto CAD, Rhino 3D, FORAN and Auto Ship, to generate a full Lines Plan and General Arrangement Plan throughout all design phases to maximize the ship's capability. Engineers used these to develop the capacity plan, top-down sketch, mechanical layout, and systems installed on board. With the help of this software, architects generate midship sections and include structural components like stiffeners, girders, beams, etc. Again, in conjunction with the owner, architects produce 3D designs from 2D designs for further visualization and analysis. With this 3D software, architects can also prepare diagrammatic arrangements for HVAC systems, pipe fitting systems, fire control systems, navigation systems, combat systems, etc. Engineers further evaluate structural strength, hydrostatic stability, dynamic stability, damage load condition, seakeeping, maneuvering, etc. from the 3D drawings in detail throughout the whole design process. In figure 4 the software used in the aforementioned purpose and their special purpose are illustrated.



[15] H. Kim, Lo

Figure 7: Software Used for Determining Ship Dimension and Capability

For Determining Structural Analysis. After designing the 3D external hull form the final general arrangement plan in accordance with safety and comfort standards, architects can use various techniques to design internal structural parts. Midship and other frame-wise sections comprising structural parts like beams, girders, stiffeners, etc. require the use of these instruments. These include programs that analyze stress on a ship using a finite element approach and beam theory. Some of the most commonly used software for this purpose are Ansys Structural, MARS 2000, Siemens FEMAP and Nastran, STAAD PRO, MATLAB, etc.

MAXSURF MULTIFRAME

Multiframe Structural Engineering Software provides linear and non-linear analysis, static and dynamic options and buckling calculations. It allows an architect to prepare design calculations in Excel and link them directly with Multiframe model. With this module, 3D frames, truss and plate analysis, Linear and Second Order analysis, Section properties calculation, Design check and optimization for steel frames can be achieved. Moreover, Multiframe Advanced can further compute Modal and Time History dynamic analysis considering all design codes such as ASD, AIJ, LRFD, BS5950, AS4100, NZS3404, AS4600, AISI, EC/3 & User defined code. Moreover, deflection, stresses, plate formulation compatible with the beam elements can be evaluated with this software.

ANSYS STRUCTURAL

Is used to study the strength and response characteristics of complex geometries. Naval Architects use Ansys Structural to analysis structural response under loading conditions such as hydro statistics and hydron dynamic pressures, slamming and green water loading, failure state loads, and extreme conditions. Using acceptable limits from techniques such as the Load and Resistance Factor Design (LRFD) and Working Stress Design (WSD) methods, naval architects can ensure that the structural response does not exceed permissible deformations, stresses, and strains.

MARS 2000

It is the main Bureau Veritas suite for application of Structural Rules for Classification of Steel Ships. Naval Architect use the software for the calculation of geomatric properties, hull Girder strength and ultimate strength criteria, Local strength

MATLAB

MATLAB, developed by MathWorks,

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Figure 8: Software Widely Used for Analyzing Ship Structural Strength

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For Analyzing Hydrostatics, Hydrodynamics, and Stability. The designs that have undergone structural analysis are then integrated into static stability tools to check for stability. Tools for hydrodynamics guarantee the building is also stable in wind and wave conditions. A few apps can also calculate the resistance, suggest modifications, create add-ons, and calculate the design's sailing speed. Maxsurf Hydrodynamics, MOSES, Ansys Fluent, Auto Hydro are the widely used software for hydrostatics analysis.

MATLAB

MATLAB, developed by MathWorks, is a heavy-duty mathematical and engineering software extensively used by naval architects, marine engineers, offshore researchers, and other maritime professionals to handle and

FEMAP NX NASTRAN

It is a sophisticated simulation application that allows a naval

MARS 2000

It is the main Bureau Veritas suite for application of Structural Rules for Classification of Steel Ships. Naval Architect use the software for the calculation of geometric properties, hull Girder strength and ultimate strength criteria, Local strength criteria of plates and ordinary stiffeners yielding buckling fatigue

MAXSURF STABILITY

Maxsurf Stability module can assess the stability and strength characteristics of a design generated by Maxsurf Modeler. Stability provides the Maxsurf user with a wide range of powerful analysis capabilities to handle all types of stability and strength calculations. Precise calculations are performed directly from the trimmed Maxsurf NURB Surface model without the need for offsets or batch file preparation. The wide range of analysis, data entry and data display options within stability make it an indispensable tool for designers of all types of all vessels. For designers with a limited budget, the basic Stability suite contains only the intact hydro statistics , and large angle stability analysis method. Stability enterprise adds probabilistic damage stability.

ANSYS FLUENT

Is an industry-standard module developed by Ansys that deals with CFD or studying fluid responses around a body. Fluent can be used for a single phase of poly-phase flows to simulate conditions for the superstructure, submerged part of the hull, and the portion of the hull that operates in both the submerged and surfaced condition. Naval architects prefer Fluent for determining drag coefficients, resistance, contributions from the hull, and study the fluid flow around the hull using poly-phase flows, the wave-making effect at the ship's bow and providing an initial estimate of the characteristics for designing a ship's bulbous bow.

AUTO HYDRO

Autohydro is the state-of-the-art hydrostatics and stability program. It performs intact and damaged analyses and produces customizable stability reports which are accepted by all major approval bodies. Autohydro is a complete hydrostatics and stability calculations program for naval architects, ship designers and marine engineers. A true 'floating simulator', Autohydro reports the reaction of the model to various conditions such as a loading configuration, a damage situation, conditions involving outside forces, wind or high-speed turning momentum or some combination of these. Autohydro can also be used to obtain hull form characteristics and capacities. Vessel attitude is displayed graphically and in text on the screen. Report information, text, and graphs, can be shown on the screen, printed, saved, or exported to other Windows applications.

MOSES

Moses is another software from Bentley System and part of its overall naval architecture and marine engineering suite. Unlike Maxsurf that primarily focuses on ships and other ocean-going vessels. Moses uses several features to determine model hydro statistics, hydrodynamics, mooring, anchoring, and overall stability. It can also run simulations to test for different states off the offshore structure including transportation, launching, lifting and lifetime performance. Running simulations cuts down on operational time and also predicts possible fault or flaws in the intended operation.

VERISTER

Veristar Stability is a program intended to calculate intact and damage stability together with longitudinal strength in line with IACS unified requirements. It includes a user-friendly interface and the most advanced graphic interactive methods. Veristar Stability includes data input for the creation of 3D models and intact stability processing. The module can provide Hydrostatics Particulars, Down-flooding Curves & Tables, Righting Levers KN, Calculation of GZ Curves, etc. It has additional modules for Damage Stability (including longitudinal strength distribution for damaged condition), Subdivision and Damage Stability of Passenger Vessels and Dry Cargo Ships and also Grain Shifting Moment calculation.

Figure 9: Software Used for Analyzing Ship's Stability

For Determining Ship Resistance, Required Power and Analyzing Seakeeping & Maneuvering. The resistance force acting on a hull are caused by the characteristics of both water and the hull. To

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reduce the wave resistance and optimize the requirement of Engine power, resistance and power calculation is very important in naval architecture field. There are different approaches to predict the resistance in the design phase. Well known methods are Computational Fluid Dynamics (CFD), Model Test, the Savitsky Method, the Holtrop & Menen Method and the slender body method. On the other hand, maneuvering and seakeeping are another two important naval architecture research areas. There are several methods to determine a vessel's behavior, but most of them are time-consuming, apply linear techniques or introduce several simplifications. After conducting Hydrostatics, Hydrodynamics, and Stability analysis of the CAD design, resistance, power, seakeeping & Maneuvering performance of the newly designed ship is evaluated using the below mentioned wide known software.

ANSYS AQWA

Ansys Aqwa is used to study hydrodynamic response and performance of vessels, offshore structures, and renewable energy convertors. It has application in modelling the responses of diverse structures ranging from ships and research vessels to FPSOs and semi-submersibles. Aqwa can model structure behavior in different operating conditions including sheltered harbors or the open ocean. Using the native CAD tools or imported models, Aqwa can study hydrodynamic parameters, resistance, power, motions, and RAO analysis. Aqwa diffraction is also able to analyses moored or connected structures in different wave conditions. It is used in studying complex motions during dynamic positioning (DP) or tethering operations.

MAXSURF RESISTANCE AND MOTION

With this module, Maxsurf provides tools for quickly predicting the resistance of a ship hull using a choice of tank testing regression methods or an analytical Slender Body method. The user is given many options and instant feedback indicating which method is best suited for the hull type being analyzed. With Maxsurf Resistance, the Naval Architect has a powerful tool for getting quick answers using proven methods without manual calculations. Again, Maxsurf Motions program enables designers to quickly predict the seakeeping performance of MAXSURF designs which once has been loaded into Motions. The user specifies the wave spectrum and heading, vessel speed and several other analysis parameters. Seakeeping Characteristics such as Response Amplitude Operators (RAOs), added resistance, significant , absolute, and relative motions, velocities, and accelerations of the vessel in the specified sea spectrum can be computed. Motion, velocity and acceleration and Motion Sickness Incidence (MSI) may also be computed for any position on the vessel. All data is displayed simultaneously in graphical and tabular form for further analysis.

Figure 10: Software Used for Analyzing Seakeeping and Maneuvering

For Project Planning and Management.

To keep track of these varied processes, project planning software manages and budget the entire operation before a single dollar is even spent. Certain firms specialize in designing integrated suites that have many of the above software and tools integrated into a single workstation. By installing various plug-ins or features, an entire structure can be designed from scratch.

MAXSURF STABILITY

Developed by Bentley Systems, MaxSurf is a part of a suite of programs intended to cover the lifecycle of ship design and construction. The integrated suite includes a 3D surface Modeler allowing more control over hull splines than NURBS-based model, the Stability Module for determining static stability based on latest stability criterion , the Resistance Module for powering and performance estimation, the Motions Module for seakeeping, and the Structure Module for initial structural design. By imposing different wave conditions, the user can also test the ship's intended response and make necessary alterations to the design with minimal effort.

AUTO SHIP

Auto Ship System of marine engineering software offers a truly integrated approach for every step of the CAD/CAM process from generating hull lines through to nesting of parts. In Autoship, the model that is created is used throughout the entire CAD/CAM process. And if any changes are done to the Autoship model, all the other programs can easily adapt to the revision. The Autoship System was developed by naval architects for naval architects and continues to offer you the best integrated approach from start to finish. Output from Auto*hydro* has been accepted by all major governing bodies such as Lloyds, Det Norske Veritas, ABS, the U.S. Coast Guard, and the Canadian Coast Guard.

EXCELL

In the realm of complicated software that model complex phenomena, MS Excel is an easy means to simplify the data, break it down into manageable processes, and visualize various aspects of the construction life cycle. MS Excel is mainly used in the fields of marine production and planning and is an excellent tool to present data in a non-SS technical fashion to clients and end-users. Common uses of this tool include forecasting timelines, initial cost estimates, inventories of parts and requirements, recording technical parameters, and analyzing structural scantling.

NAPA

NAPA is a marine engineering software firm that specializes in the integration of CAD with data analysis and other software solutions. The main software solutions provided by NAPA include the Hydrostatics & Stability Module, the Hydrodynamics Module, Hull Form Design, and Structural Design Module. Besides naval architecture, the firm also specializes in software for determining real-time ship stability and safety, data monitoring and logging, performance optimization, and real-time performance analysis of a fleet.

AVIVA Marine

Is a leading engineering software organization that specializes in the maritime and marine sectors. They offer a host of solutions ranging from ship design to digital twinning and remote maintenance tools . Some of the top Aveva Marine software include E3D for designing, Aveva Outfitting, Aveva Hull Design, Point Cloud Manager for workflow design & optimization, Aveva ERM for project management, and Unified Operations Centre for operation simulations. Aveva also specializes in integrating software, ensuring scalability of solutions, ensuring connectivity of the hundreds of assets projects may require, and even integrating IoT into designs to ensure state-of-the-art vessels.

NUPAS CADMATIC

NUPAS Cadmatic is an engineering solutions provider in different fields, including the marine and offshore sectors. Their marine design software solutions ensure standardized quality of design and engineering during the project lifecycle. Their diverse solutions cover a range of features naval architects require, and most functionalities are data-driven. Some of the top software solutions provided by Cadmatic marine include Hull & Structural Design, Outfitting & Piping Design, Electrical & Automation, and Information Management. Cadmatic has also worked with NAPA to integrate many features and ensure cross-platform functionality. As an integrated maritime solution, all aspects of the project can be tracked, and project phases can be recorded right from the design stage till eventual hand-over to the client.

Figure 11: Software Used for Project Planning Software, Integrated Suites, and Workstations

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Comparison among Ship Designing Software at A Glance.

Accredited by The Classification Society. International Association of Classification Society or IACS accredited a large variety of ship building software solutions. These software enables the architectures and engineers to comply with rules, statutory requirements and optimize the performance of the ship. Table 1 shows the software which are approved by the classification societies so far:

Table 1: Common ship design software which are approved by the classification societies or IACS

Technical Features	**Approval From Class**								**Remark**
	ABS	**DNV**	**LRS**	**BV**	**IRS**	**GL**	**NKK**	**RINA**	
AUTO SHIP	NO	YES	YES	NO	NO	YES	NO	NO	Delta Marin for 3D modeling is accredited by classification society DNV
MAXSURF	NO	NO	NO	NO	NO	NO	NO	NO	
AVEVA	YES	NO	NO	YES	NO	NO	NO	YES	
RHINO 3D	NO	NO	NO	NO	NO	NO	NO	NO	
FORAN NX NASTRAN	YES	YES	YES	YES	YES	YES	YES	NO	
AUTO CAD	YES	YES	YES	YES	YES	YES	YES	NO	
SOLID WORKS	NO	NO	NO	NO	NO	NO	NO	NO	
NAPA	NO	NO	NO	YES	NO	NO	YES	NO	

From the Perspective of Line Fairing and Parametric 2D/3D Hull Generation. Among the 3D CAD software Auto Cad , Solid Works and Rhino 3D cannot generate parametric hull based on length Breadth, and Depth, draft, LCB, etc. Also, these software cannot generate hull from by line distortion approach from table of offsets. On the contrary, **Auto Ship, Maxsurf, Aveva, Foran NX NASTRAN and Napa** have extensive library of predefined hull forms and Autoship has a built-in foil library for generating Parametric Hull. In addition, for generating hull of a ship **AVEVA, NAPA** and **FORAN** automatically uses stored design intent information for each design object, rather than specifying 'numeric' geometry or moving the control points. On the contrary, designer **generates hull by moving control points located in Hull NURBS in Maxsurf.** Again**, Autoship** prefers to rely more on command-based interface for this purpose. Fairing of hull lines to full scale and Generating table of Offsets from the lines developed and merging Bulbous Bow and appendages are also possible in **Maxsurf, AVEVA, FORAN, NAPA** and **Auto Ship.**

From the Perspective of Structural Strength Analysis. Ship Structure, NX NASTRAN, AVEVA, ANSYS, MARS 2000, MAXSURF have interfaced with major FEM packages**.** In this regard**, Mars 2000** has incorporated **BV Rules and Maxsurf** will incorporate **LRS** rules in future**. Auto ship** can create structural design based on classification society's rules and regulation. Construction Module to fix compartments, structural members, and equipment to check accessibility and exporting structural data to CNC cutting machines are possible using **Ship Constructor, NAPA, FORAN NX NASTRAN, AVEVA.** For this purpose, **Maxsurf** is not useful and thereby **Ship Constructor** is being used for the additional supplement. Section modules, Shear Force & Bending Moment computations of the Hull Girder can be calculated using **Maxusrf, NX NASTRAN**. On the contrary **Autohydro** cannot perform section modulus or moment of inertia calculation.

From the Perspective of Stability Analysis. **Maxsurf, Aveva, NAPA, Auto Hydro and Hydro Max** can analyze the Hydrostatic particulars from the lines for even keel as well as inclined plane, Bonjean Curves (areas, moments), Cross Curves of stability, Capacity computations, Hull/Structural weight, and CG calculations for floodable length Calculations. However, **Maxsurf** indicates that Bonjean curves are no longer used due to being superseded by more modern calculation. All this software can generate complete Stability Booklet without need to collate external data which includes Intact & Damage Stability, probabilistic damage calculations as per SOLAS requirements (Chapter II-1) (except **Maxsurf**). This software can analyze the stability of designed ship based on predefined Stability Criteria for diff. vessel types and Class rules.

From Perspective of Cost Purchase. Figure 12 shows that the software used for determining ship dimensions, fairing lines, and hull generation (2D and 3D) are comparatively cheaper than other special purpose-oriented software. Since these software are widely used not only in ship designing field but also in other industries like the civil industry, the aviation industry, the automotive industry, etc., they are relatively cheaper. On the contrary, purpose-oriented software, like that for analyzing structural strength and stability, have high purchase cost since these programs evaluate structural integrity and stability according to the IACS and IMO Rules. Apart from analyzing the structural strength and stability of marine and offshore structures, these software are also widely used in the aviation industry. But software for analyzing resistance, power, seakeeping, and maneuvering characteristics of newly designed ships and offshore structures have higher purchase cost, since they are integrated with CFD analysis and the ship's response against complex wave pattern analysis. These programs are used on a limited scale in the field of naval architectural research as well as by ship design firms when establishing a new design or pattern for a ship's hull. Furthermore, project planning software just keep track of the planning of various stages from ship design to ship construction, integrating the software for the above-mentioned purpose into a single workstation. As a result of the benefits that these types of software provide to naval architects, they are among the most affordable. Since purpose-oriented software like software for analyzing stability and structural strength and software for determining resistance, power, seakeeping, and maneuvering have high purchase cost, Bangladeshi Ship Designing Sections generally use the crack version of this software, which comes with significant project integrity, data security, financial, and legal risks.

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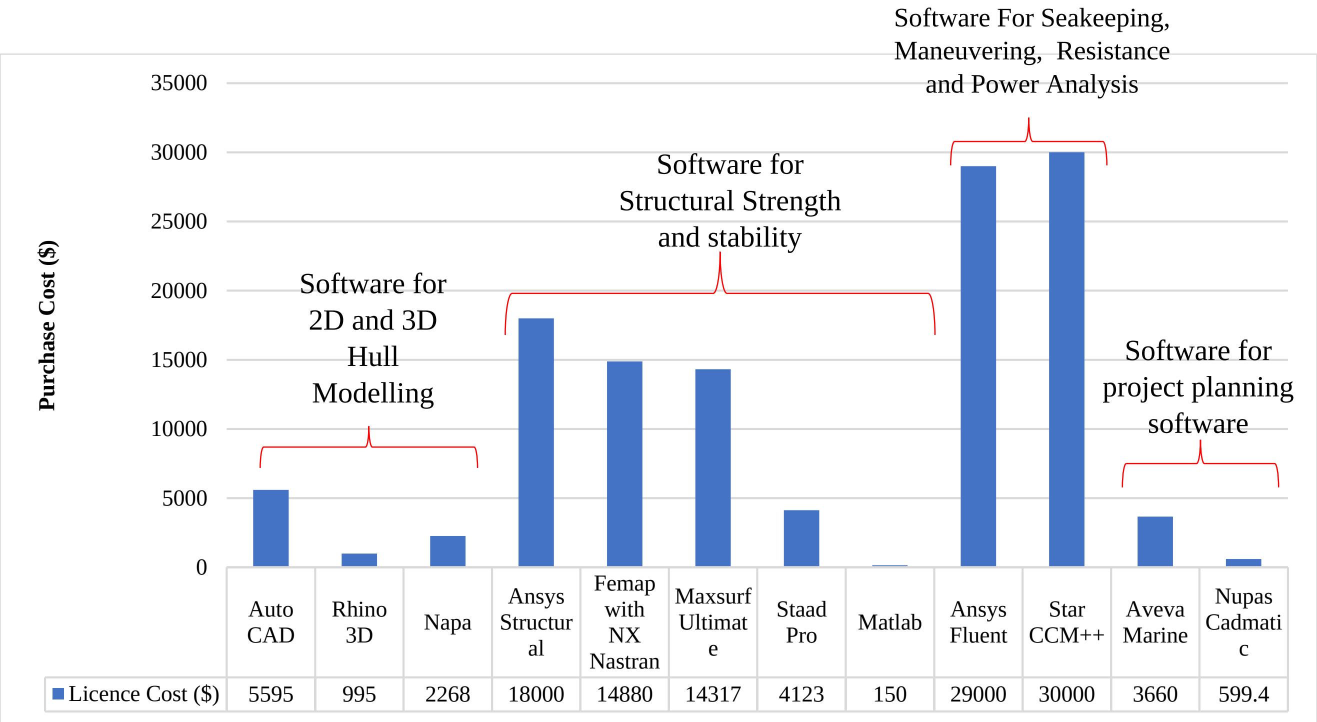

Figure 12: Cost Comparison between the Software used in Naval Architecture Field

State of Ship Designing Capability of Local Shipbuilding Industry

BN requires to sort out her weakness in constructing warships indigenously and to take remedial actions to enhance her capability. There are many weaknesses which require necessary actions to get addressed. Among those, the main weakness of our shipbuilding capability is the lack of design expertise and facilities. All private and public shipbuilding industries in Bangladesh procure designs from abroad and mostly make a copy ship from them. The main reason for our lacking design capability is the small market for building new ships in the country.[16] Designing a new ship requires a proper design cell dedicated for modern designs. Moreover, a full-fledged design set up includes precision matters like hydrodynamics of ships profile, hydrostatics, speed, and power requirements, depending on ship's resistance, appendages etc. To verify all these requirements, making of model and proper model testing is a prerequisite. But there is no Model Testing Towing Tank and other related facilities in Bangladesh to verify the required parameters of the designed ship before it is built. The whole gamut needs to be attended in a co-ordinate manner.

Tools Used by Naval Architects in Bangladesh. Over the last few years Bangladesh could not progress so much in indigenous ship designing sector. However, in this sector around a dozen of local ship designing house have progressed significantly in case of indigenous ship designing. Among those ship designing firm like Marine House, Meta Centre and Three Angle has achieved the capability to design small scale local ships indigenously for inland and coastal route under International Association of Classification Society (IACS). Recently some local ship design firm design 06 (six) in no Bangladesh Navy operated LCU and these are constructed by Khulna Shipyard, prior taking approval from International Classification Society. Currently these LCUs are being operated by Bangladesh Navy successfully. Among the software used by this Bangladeshi design firm, **Auto CAD** is widely used for generating 2D drawings like General Arrangement Plan, Lines Plan, Shell Expansion Drawing, Machinery Space Drawing, Propulsion Drawing etc. Then Rhino 3D is used to generate 3D hull and piping system. For structural analysis **Femap Nastran** and **Mars 2000** software are used in Bangladeshi Designing Firm to finalize midship and other frame wise sections to ensure that structural components comply the Class Rules. For hydrostatic stability, damage stability, hydro dynamic stability Maxsurf Stability is widely used. On the contrary, to meet up owner's requirement for CFD analysis, designing firms are yet too capable of using the CFD analyzing tools. However, with the help of **Ansys fluent**, from foreign designing firms this type of analysis is being conducted. For analyzing Motion and Sea Keeping of the ship structure, **Maxsurf Motion** is used in limited scale. For overall project Management and for cross checking of the parameters of the designed ship that complies Class Regulation, **NAPA – Integrated Maritime Solutions** is being widely used in those firm house.

Tools Used by Naval Architects in BN Owned Shipyards. Khulna Shipyard (KSY), Dockyard and Engineering Works Limited (DEW) and Chittagong Dry Dock Limited (CDDL) are the BN owned shipyards. So far, KSY and DEW has achieved the success of constructing warship like LPC. PC, Tug, Floating Crane with the help of foreign engineers. On the contrary, till now these shipyards could not produce any design of warships which they have already built. They have bought design from the ship manufacturing yard from foreign countries and with the help of foreign engineers, they could build warships indigenously. Again, CDDL still could not develop their capacity to build warships at all. According to 'Forces Goal 2030', CDDL will have to build five new frigates. But this project requires massive infrastructure development and capacity development of CDDL. At the same time,

[16] Abedin, C. A. "Warship Building in Bangladesh, Problems and Prospectus: Analysis and Recommendations", NDC E-JOURNAL, 6(1), 91-111, Bangladesh (2007)

CDDL needs to develop its design section capacity to establish as a full-fledged design section. Presently capability of design section situated at CDDL is of limited scale.

Among these three shipyards, only design section of KSY has the capability to design up to production level. Moreover, KSY still does not have the capacity to design ships indigenously and get it approved by classification societies. However, it has achieved the ability to modify class approved ships drawings necessarily. KSY Design section uses tools like **Auto CAD** for correcting GA plan of previously built ships under supervision of classification society, **Rhino 3D** for generating Hull, **Maxsurf** stability for analyzing stability of newly modified design. To enhance the capability to analyze the structural strength, CFD analysis, sea Keeping and Maneuvering capability of warships etc KSY has a plan to purchase **Napa, GHS, Auto ship and Ships Con**.

DEW also cannot design indigenously. The shipyard procures ship class approved designs from foreign shipyard. However, they can modify the designs under class supervision using **Auto CAD** and analyze the stability using **Maxsurf**. The shipyard still cannot achieve the capability to analyze the structural strength, sea keeping, and other analyses related to ship designing. On the Contrary, since CDDL still did not build any warships yet, the capacity of the design section of the shipyard is not so much. CDDL design section uses only Auto Cad to design docking plan and design related to production.

Future Design Approach and Way Forward

Mission Focused Design. Let us talk about the armed forces platform design in general and naval ship design in particular. Future armed forces need to be more concentrated on mission-focused designs because "the synchronization, management, and coordination of concepts, activities, technologies, requirements programs, and budget plans will advise and guide key decisions making on the end-to-end mission." This idea is contrast with recent platform-centric designs concept as it failed to integrate the departments in broader warfare concepts.[17] The capabilities of future Navy systems will be measured not by the individual attributes of a single hull type, rather by the combination of the hull's combat capabilities, capacity, and ability to interact with off-hull systems. Modern Navy should have the tools and workforce to embrace this paradigm shift, as well as Navy acquisition leaders must take positive action to achieve this end state. Modern Navy must improve its development of digital models and simulations of planned systems and validate concepts of employment within live, virtual, and constructive (LVC) test environments. Decision makers' planners should be capable to integrate digital models and simulations to optimize concepts of operations and integrate mission-focused design[18].

Digital Model Approach. For programmatic, organizational, and technical reasons, the Navy's legacy approach to platform design is embodied in its use of physical prototypes. The Navy builds physical prototypes to test platform-centric operational concepts of operations, and integration with other systems appears to be of secondary importance. Physical prototyping is certainly required for effective material design, but, in isolation, it fails to deliver critical information such as that needed to fulfill the distributed maritime operations concept, for example, which requires the integration of sensors and shooters across time and space. Legacy document-based systems engineering generates static design artifacts, such as drawings, specification documents, and test plans. Any given Defense Acquisition System it requires around one hundred separate design documents to meet regulatory, statutory, or component requirements. These document libraries become rows bookshelves decision is made, creating serious challenges for integrated product teams.

[17] Government Accountability Officer, Littoral Combat Ship: Actions Needs to Address Significant Operational Challenges and Implement Planned Sustainment Approach, February 2022
[18] Proceedings: US Naval institute, Oct 2022

Digital engineering uses models and authoritative data to coordinate and integrate all disciplines and phases of work for the life cycle of a platform or system Having a central digital model ensures that any design team accessing the model always accesses what integrators all the "single source of truth." Digital models can simulate real-world physics and conditions or can be functional models designed to explore system configurations. This model-based approach allows engineers and acquisition professionals to evaluate designs in digital space with a high degree of fidelity before building costly physical prototypes. A key contribution to the success of the US Navy Virginia-class submarine program was its full rendering in digital computer-aided design (CAD) software[19]. CAD programs used to design Virginia excelled in creating geometric models that were useful for piping arrangement, maintenance task analysis, and design aspects involved in the arrangement of physical objects. However, CAD is only one tool in the digital transformation toolkit, and CAD typically only comes into use after system requirements have been codified and the system's rough form begins to take shape. CAD model is extremely useful, but it is not capable of allowing designers to consider trade-offs in the same way as an integrated digital model.

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[19] Congressional Research Service, Navy Virginal (SSN-774) Class Attack submarine Procurement: Background and Issue for Congress, 28 April 2022

Figure 13: Module Construction of Submarine (Virginia-class Nuclear Power submarine of the US Navy)[20]

A key benefit of examining many resource configurations for an integrated digital design is the ability to identify realistic performance capacities. The Congressional Research Service and the Government Accountability Office frequently assess whether the Navy meets its own internally set measures of performance such as reliability, availability, and maintainability (RAM). Another key advantage of digital models is the ability to seamlessly make changes across a system. Traditional program management practices require that the government develop detailed technical requirements

[20] https://bremolympicnlus.wordpress.com/2015/09/03/virginia-class-submarine-construction/

after evaluating potential concepts of operations those requirements are passed to industry, where the detailed design work takes place. Much of this work is done in CAD Significant technological challenges encountered during the design process can lead to cost overruns and delays because designers and the government must resolve the issue. Digital models allow for more-detailed design work earlier in the requirements development phase[21]. They also permit verification of concepts of operations models to be rerun once detailed models are completed.

Integrate War-Gaming with Technical Design. War-gaming provides a lower cost, easily repeatable process for testing concepts of operations and future system needs for any naval force. While war-games excel at parts of this, they often lack the detailed physical models necessary for developing system requirement documents. Thus, the war-game's value remains locked in the document-based deliverable the team produces. The Navy historically has relied on war-gaming develop future concepts of operations and engineering design to evaluate future system requirements, but these activities too often occur in silos. However, the attendant costs, long development timelines, and geographic limitations of physical test infrastructure mean only a few prototypes are affordable. In addition, test infrastructure is not collocated with war gaming centers limiting designers' ability to rapidly integrate war-gaming lessons into system design[22].

Digital models can merge the intensive efforts associated with prototyping and the flexibility of war-games in hybrid LVC environments, which include a mix of the natural world (live), a simulated environment virtual), and an operator interface through which role players may employ a mix of real and synthetic players (constructive), Integrating digital models into LVC environments allows for both detailed models of the physical world and repeated evaluation of these systems by war-gamers and engineers alike, at lower costs than physical prototypes. Testing in this environment means changes in technical requirements can be evaluated against a system's ability to meet concepts of operations requirements. Requirements created from digital systems can be handed to contractors for construction with increased confidence that the delivered system will meet fleet needs.

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Conclusion

Existing and usual design process requires an extensive collection of paper documents in binders that must be manually updated each time there is even a minor design change. Over time, the paperwork for a single class of ships might feel as if it could fill a warehouse. A digital model could exist on a single drive. Today's, digital models last for the lifetime of the system, not just a single phase of acquisition. As system matures, the models keep pace and allow for continued verification of designs and requirements a critical feature. As platform use-cases change or real-world data is gathered, that information is fed back into model. And each mature model contributes to the digital ecosystem for the benefit of future programs. Digital models can simulate real-world physics and conditions or can be functional models designed to explore system configurations.

Since the shipbuilding sector is vital for creating a strong maritime nation in the twenty-first century, the information-driven society of this sector requires continuous upgradation and development. For this, innovation in conventional design and manufacturing processes and information/automation technology should be supplemented. The shipbuilding industry today promotes CAD/CAM-based next-generation shipbuilding systems. Fundamentally, the goals of these systems include early error detection, effective decision-making, automation of traditional procedures, enhanced productivity and quality, and the quick manufacturing and production of ships. Hence, Bangladesh, should pay great

[21] Department of the Navy, Navy and Marine corps Digital Systems Engineering Transformation Strategy, June 2020
[22] International Council on systems Engineering, Systems Engineering Vision 2035, 2021

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attention to simulation-based manufacturing as like as the major shipbuilding nation to achieve indigenous ship design capabilities and enhance product quality. Also, apart from adopting it in various ship design stages only, simulation-based manufacturing should also be used for the block erection, assembly, processing, cutting, and testing processes in the local shipyards as per application and operational requirements. Because in the near future, by applying virtual simulation technology to the design, modeling, analysis, simulation, manufacturing, testing, and information systems under simulation-based manufacturing environments will build a foundation for concurrent engineering systems, which will be a significant driver of the competitiveness of the shipbuilding industry.[23]

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[23] H. Kim, Op Cit, pp 441.