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AI-DRIVEN COST ESTIMATION FOR MARINE STEEL IN TUGBOAT CONSTRUCTION

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ABSTRACT

Accurate cost estimation for new tugboat construction is a critical challenge in the shipbuilding industry, where conventional methods based on historical data fail to account for the real price at real time because of volatility of key materials. The paper addresses this gap by developing a data-driven framework for marine steel, a primary cost driver, which leverages a specialized Artificial Intelligence (AI) model. The research aims to enhance the application of advanced digital technologies in shipbuilding to support design, assembly, and logistical planning processes within shipyards. The framework, built using Python, features a Graphical User Interface (GUI). Through this interface, the system accepts internal project data from the shipyard and integrates it with live market data synthesized from the real-time web aggregation capabilities. This combined dataset, including steel plate specifications, supplier origin, certification, and logistics, is processed to calculate the true landed cost and automatically generate detailed cost reports. The model was applied to a tugboat construction case study in the Middle East. The AI-driven framework demonstrated a significant improvement in estimation accuracy compared to conventional methods, where the program can save about 20% for steel plates and 13% for steel stiffeners compared with the actual case study. It successfully enabled dynamic cost benchmarking of suppliers all over the world, while substantially reducing the time required to generate detailed steel cost breakdowns. The findings confirm that AI-enabled integration with e-marketplace data provides a practical solution for enhancing budgetary reliability, strengthening procurement strategies. Integrating these technologies contributes to more efficient review processes and reducing rework rates and achieving time and cost savings.

1. INTRODUCTION

The ongoing increase in global competition in the shipbuilding industry is leading to declining profit margins and increased pressure on costs in this sector. Ship designers and shipbuilders are active players in this global market. Shipyards have long been known for delivering high-quality products on time, but these high-quality products may eventually be replaced by less expensive solutions.

With such intense competition in the shipbuilding industry, it becomes essential to respond quickly to market changes, and this directly impacts on the way cost estimation is prepared.

When a shipyard submits a quotation, the available information is limited, and there is a high degree of uncertainty in the estimation and supply chain, including the equipment the shipowner supplies itself. Continuously increasing global competition in the ship building industry leads to decreasing margins and cost pressure in the industry. The ship designers and shipbuilders are active players in this globalized game. Shipyards have been known for delivering high quality products on time. However, high quality products will at some point be outcompeted by less expensive solutions (Shetelig 2013).

Traditional quotation procedures, which often rely on manual communication, multiple correspondences, and sequential approvals, slow decision-making and reduce shipyards' ability to compete in a rapidly changing market (Wahidi et al. 2021). Therefore, the adoption of a digital platform that enables buyers and suppliers to interact and conduct sales and purchases online is a significant improvement over traditional method. Known as an electronic marketplace, this platform provides instant access to global suppliers, automates the quotation comparison process, and enhances cost data transparency, enabling faster and more reliable decisions under volatile market conditions (Salian et al. 2025) that enables buyers and sellers to interact with and trade goods or services online is a best solution to overcome the limited time for shipyards to provide a quote to respond quickly to a changing market considering uncertainties estimation, that is electronic marketplaces. In the highly competitive shipbuilding industry, it is essential to respond quickly to a changing market. This has consequences for the way cost estimation are completed. The information available at the time a shipyard must provide a quote is limited, and uncertainties within estimation and the supply chain, including owner-furnished equipment (Jiang et al. 2013).

In general shipbuilding industry classified as an Engineering TO Order (ETO) because of the variance of design and the difference between the systems used on board from the point of view of the quantity and quality for the material and equipment which required for the building considering the shipping expenses as well (Bruce 2020).

In this paper, we will focus on the steel building material based on the general arrangement drawing and technical specification. Shipbuilders consider how the ship must be constructed to extract the required steel material and listed in order to be entered in the program.

In the context of this study, which aims to improve the accuracy of cost estimation and the efficiency of procurement processes in shipbuilding, the integration of an electronic marketplace represents an effective solution to overcome the limited time available to shipyards in obtaining and reviewing quotations. By linking real-time pricing data, supplier credentials, transportation and freight factors into a unified digital framework, the proposed platform contributes to a more dynamic, data-driven approach to material cost estimation and rapid response to steel price fluctuations in global markets.

The estimation construction costs of traditional methods are indirectly linked to the construction strategy and implementation schedule. The ship's construction method leads to the preparation of a Block Division Plan, where the ship is divided into large blocks that represent the main structural units consisting of several subassemblies.

In parallel with the Block Division Plan, an Assembly Plan is prepared, which determines the sequence and methods for assembling these constructed blocks together to form the entire ship. The construction costs estimated traditionally are, therefore, implicitly related to the construction strategy and construction schedule. How the ship is going to be constructed results in a block division plan, where blocks are large construction elements weighing and composed of several sub-assemblies. Alongside the block division plan, an erection plan is defined, outlining the sequence and methodology for assembling the constructed blocks to build the ship (Alblas and Pruyn 2024).

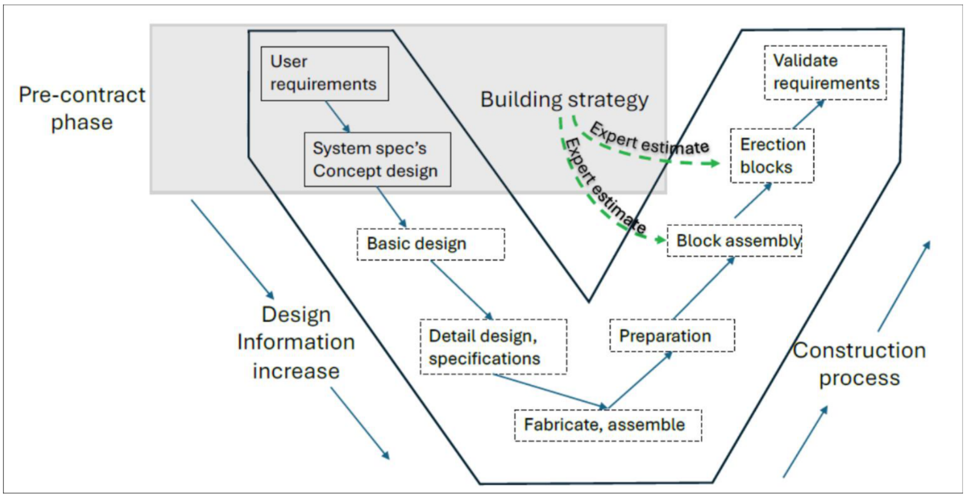

Figure 1: The evolution of design and construction information (Gerrit Alblas 2024).

In Figure 1, the left side of the figure depicts the progression of design information until it reaches a stage suitable for part production. Conversely, the right side illustrates the development of the construction process, which begins with the fabrication of parts and their preparation for assembly into blocks (Gerrit Alblas 2024).

The integrating digital technologies into design and production processes has become essential for achieving higher levels of efficiency, precision, and automation. A digital framework for automatically defining ship module assembly procedures based on structural information pre-read from hull blocks. The process begins with digital data entry for the hull block, which includes precise details of various components such as plates, stiffeners, brackets, and weld lines. The integration of information and automation of processes leads to improved production planning, reduced manufacturing errors, and better integration with cost and scheduling systems.

A hull block is an important intermediate product in the process of shipbuilding, which refers to the assembly of a number of steel plates and sections on the molding bed or platform through welding operation (Eong et al. 2020). The block construction is the most important process, the hours and costs of which respectively account for 40~60% and 30~50% of the total hours and costs of hull building (Qu et al. 2013).

By using software program to analysis, the hull block though the flow assembly procedure we can get the accurate quantity for steel plate and stiffeners as the figures below (Bertram et al. 2005):

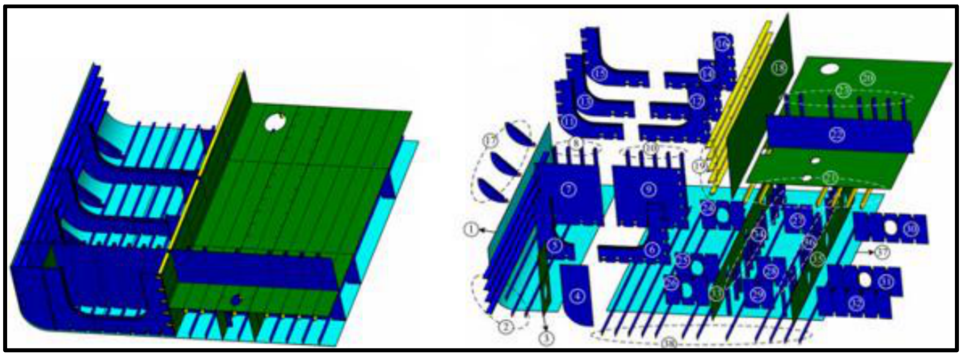

Figure 2: Hull block (Bertram et al. 2005).

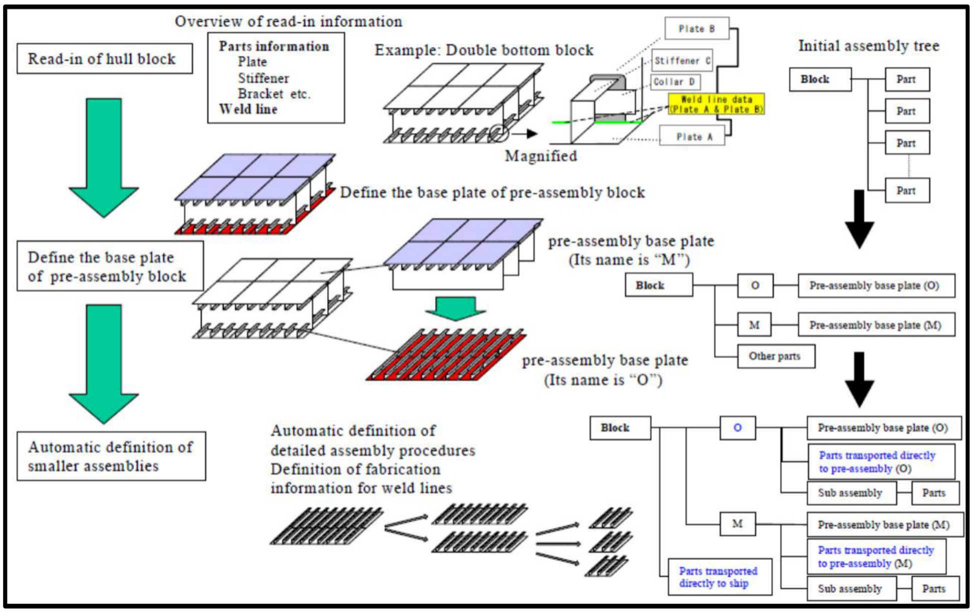

Figure 3: Flow Assembly procedure definition function (Bertram et al. 2005).

In figure 2, first the pre-assembly base plate of hull block is selected, then in figure 3, an assembly tree of the block is defined automatically, using production rules accumulated in the knowledge base (Bertram et al. 2005).

In the shipbuilding industry, material cost estimation plays a central role in project planning, bid preparation, and financial forecasting. For steel-hulled tugboats, steel represents the most substantial portion of material cost, particularly during the early design and tendering phases. The ability to accurately estimate these costs - before supplier agreement is in place - is a significant competitive advantage for shipyards and project owners.

Historically, cost engineers have relied on benchmark data, past project records, or cost-per-ton averages to estimate steel requirements. However, such methods do not reflect the fluctuating nature of the global steel market, which is influenced by complex variables such as raw material availability, transportation costs, geopolitical factors, and demand-supply dynamics. Moreover, increasing global access to steel suppliers through e-marketplaces has introduced a vast.

This paper addresses this challenge by developing an AI-enhanced Python application that estimates marine-grade steel costs for a new tugboat project in the Middle East. The application is designed to interpret steel weight and component breakdown from general arrangement drawings and structural assumptions. It then uses real-time pricing APIs from international e-marketplaces to estimate accurate and up-to-date costs for steel plates and stiffeners based on specification inputs such as thickness, dimensions, grade, and certification requirements.

Steel is one of the most critical and cost-sensitive materials in the shipbuilding process, accounting for a significant portion of the total material cost. Price volatility in the global steel market, influenced by supply-demand dynamics, international trade policies, and logistical constraints, poses a major challenge for cost engineers. Therefore, real-time and intelligent estimation of steel prices becomes essential in minimizing estimation errors and improving bid competitiveness.

In the past, cost engineer was waiting the designer to share with him the steel list to get the quantity and dimension for plates and stiffeners which will be using for the hull construction, then request to many of suppliers of steel for quotation, after that arrange a comparison sheet to select the cheapest price complying with the specifications. This process was taking many days until getting the steel cost, in this paper will show how this process could be closed in one day.

2. LITERATURE REVIEW

This literature review examines the evolution of cost estimation methods in the shipbuilding industry, the emergence of modern digital technologies and their role in developing design and production processes, and the growing importance of electronic marketplaces in supporting purchasing and decision-making processes within shipyards. The study aims to identify research gaps in current models and propose ways to leverage digital platforms to improve cost estimation accuracy and responsiveness in the face of ongoing changes in material prices and market challenges, thereby enhancing planning and production efficiency and the competitiveness of shipyards (Chou 2011).

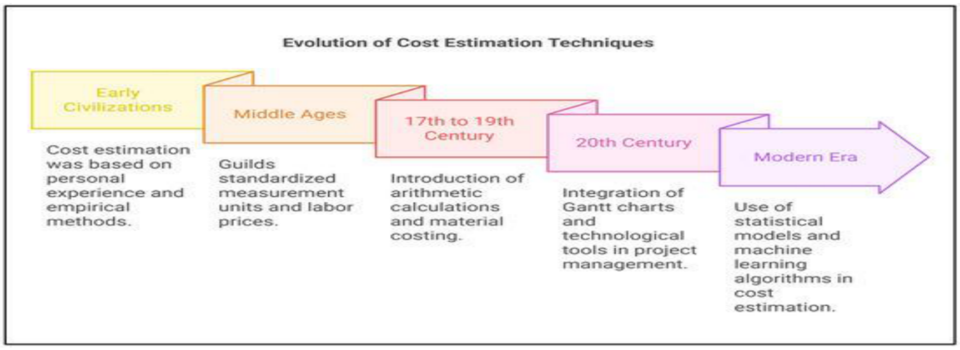

Figure 4: Evolution of cost estimation techniques data (Shamim et al. 2025).

In figure 4, the use of machine learning algorithms, such as regression models, decision trees, and support vector machines, is growing for estimating project costs from historical data (Shamim et al. 2025).

Real-world evidence shows that cost overruns in tugboat construction are a recurring problem across the sector, not isolated incidents. Cases such as the delayed purchase of a tugboat for the Taiwanese navy due to insufficient approved budgets, unrealistic pricing assumptions in the Indian Ports Authority's tenders for modern, environmentally friendly tugboats, and the financial losses reported by major shipbuilders like Damen Shipyard all point to a systematic underestimation of costs in a competitive and volatile market. These challenges are further exacerbated by global market trends showing rapidly rising tugboat prices and persistent delivery delays due to supply chain disruptions. Overall, these examples highlight the need for more realistic, market-oriented costing methods during the early stages of tendering and procurement to reduce budget uncertainty and mitigate the risk of cost overruns in tugboat projects.

The integration of AI and machine learning into cost estimation processes allows engineers to build estimative models that adapt to changing market inputs. (Zhang and Zhang 2025) applied regression models to forecast the cost of construction materials based on live data, demonstrating that AI outperforms traditional models in responsiveness and extended this work by developing machine learning algorithms specifically for construction cost estimation, confirming that Python's robust libraries make it ideal for implementing real-time cost systems.

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Table 1: AI Integration (Zhang and Zhang 2025).

Without AI	With AI Integration
Wait days for vendor steel/equipment price	Get price in seconds from online database
Manually check 10 websites	Automated price comparison from suppliers
Estimate shipping, taxes by guesswork	Real-time estimates using logistics AIs
Update Excel files manually	Auto-update prices inside your Python/Excel tool
Risk quoting outdated costs	Use live, up-to-date pricing

Electronic marketplaces have emerged as powerful digital tools that connect buyers and suppliers within an integrated online environment, enabling transparent pricing, and access to a global network of suppliers. However, the application of these platforms in shipbuilding remains limited, despite their significant potential. Given the specific nature of marine materials - such as classification society certification requirements, complex transportation and shipping processes, and long lead times - the creation of dedicated e-marketplaces for the shipbuilding sector could significantly improve cost estimation accuracy and supplier selection efficiency, supporting the transition to an integrated digital maritime supply chain management system (Chen et al. 2025).

The shipbuilding industry has made significant progress in digital design and production management using modern systems (Eyres and Bruce 2012). However, the integration of real-time market data into cost estimation systems remains limited and underdeveloped. Traditional estimation methods cannot adapt to rapid price fluctuations or address supply chain uncertainties, especially in global steel markets, which are affected by changing economic and logistical factors (Čajka and Koteš 2020). Furthermore, many shipyards still rely on manual procurement procedures, which result in poor data consistency and slow response times to quotations and market changes. Therefore, the research gap lies in the absence of an integrated digital platform that links cost estimation models, online marketplaces, and supplier databases into a single framework (Gunasekaran et al. 2017; Tunca and Wu 2019). Bridging this gap through the development of an integrated digital platform could contribute to increasing the accuracy of financial estimations, accelerating the quotation process, and improving shipyards' ability to adapt to global market fluctuations.

3. METHODOLOGY

Ordering steel material from the e-market using artificial intelligence (AI) is an advanced approach that streamlines the procurement of essential materials for shipbuilding and construction projects. The system categorizes different types of steel based on thickness, grade, certification, and country of origin, and compares prices from multiple suppliers to ensure the selection of the most cost-effective and high-quality option. It also allows real-time monitoring of market fluctuations and estimates shipping, customs, taxes, and other fees, providing full transparency in decision-making. Using AI reduces risks associated with sudden price changes and enables engineers and procurement managers to plan more effectively, securing materials on time at optimal prices, thereby enhancing supply chain efficiency and minimizing financial and time losses.

The process begins with collecting live pricing and supplier data from online platforms such as Alibaba, Steel Orbis, or Made-in-China, either through APIs, while including critical parameters like steel grade, thickness, dimensions, certification, country of origin, and delivery options, where the cheapest price complying to the requirements and specifications, incorporating total cost estimations that account for shipping, customs, taxes, and insurance. The procurement workflow ensures timely and cost-effective purchasing of marine steel, reduces supply chain risks, and enhances overall efficiency in managing materials for shipbuilding projects (Princz et al. 2025).

3.1 Steel Grade

The shipbuilding steel plate is typically classified into different grades based on its strength and characteristics. The commonly used grades are A, B, D, or E. This grade has a similar yield strength (not less than 235N/mm^2) and tensile strength (400-520N/mm^2), with variations in its impact toughness at different temperatures. It is primarily utilized in the fabrication of ship hulls, decks, and other vital parts of vessels that navigate oceans, coasts, and inland waterways (Marine n.d.).

Table 2: Steel strength and characteristics.

Ship Structural Member	Function / Location	Typical Thickness (mm)	Steel Grade Commonly Used
Shell Plating (Bottom & Side Shell)	Main hull plating; resists hydrostatic and wave loads	10 - 30 mm	A, B, D, AH36, DH36
Deck Plating (Main & Upper Decks)	Horizontal load-bearing surface	8 - 25 mm	A, B, AH36
Bulkhead Plating (Watertight & Non-Watertight)	Separates compartments and provides strength	6 - 20 mm	A, D, AH36
Keel Plate (Centre Girder Area)	Primary longitudinal strength member	20 - 50 mm	AH36, DH36, EH36
Frames and Longitudinal	Provide stiffness to shell and decks	6 - 16 mm	A, B, AH36
Stringers and Girders	Reinforcement of hull and deck structure	10 - 25 mm	A, AH36
Deckhouse and Superstructure Plating	Upper structure above main deck	4 - 10 mm	A, B
Tank Top Plating (Double Bottom)	Forms top of double bottom tanks	10 - 20 mm	AH36, DH36

3.2 Steel Size and Weight

In addition to knowing the steel grade required for a project, knowing the dimensions and quantities of steel plates is one of the most important pieces of information suppliers need to accurately quote any purchase order. the weight of a steel plate is usually similar across grades, with density not significantly different from one type to another.

- To calculate the estimated weight of a steel plate order, the following equation is used:

$$W\ (ton) = (l \times w \times t) \times (7.85 \times 10^{-9}) \times Q$$

Equation 1: Steel weight calculation.

Where:
W: total steel weight (Ton)
$(l \times w \times t)$: Length x Width x Thickness (mm)
(7.85×10^{-9}): density of marine steel (ton/mm^3) (Čajka and Koteš 2020).
Q: Number of plates

Figure 5: Steel Dimensions

In figure 5, volume is calculated from the slab dimensions (length x width x thickness), and the standard density for marine carbon steel is approximately 7.8 tons/m^3. this calculation helps more accurately estimate material and shipping costs before placing an actual order and is a crucial step in the pricing and planning process for shipbuilding.

3.3 Steel Standard and Certification

In ship design, material selection is a critical element in ensuring a vessel's structural integrity and economic efficiency throughout its service life (Eyres and Bruce 2012). Several interrelated factors must be carefully considered when selecting steel grades for shipbuilding.

According to books of classes, Weldability is also a vital characteristic, as modern shipbuilding relies heavily on welding to join massive steel components. Good weldable steel reduces the likelihood of defects and residual stresses that could negatively impact the integrity of the vessel's structure (ABS 2021 and LR 2022). Toughness, especially at low temperatures, is also essential to avoid brittle fracture, which is common in ships operating in cold or polar regions (DNV 2023). Corrosion resistance also plays an important role in material selection, as ships are constantly exposed to seawater and harsh environmental conditions. This makes it essential to use steel with protective coatings or corrosion-resistant alloys in critical areas such as ballast tanks and hull outer shell (Čajka 2020). In addition, the availability and cost of materials impact the economic feasibility of construction. Shipyards tend to choose locally available steel grades certified by recognized classification societies ((IACS) 2022). Finally, all materials used in shipbuilding must comply with the certification requirements of international classification societies such as ABS, DNV, and LR, ensuring that their mechanical and chemical properties meet globally recognized safety and durability standards (International 2019). These factors collectively guide naval design engineers in selecting the most appropriate steel grade for each structural component of a vessel, ensuring optimal performance and longevity.

Figure 6: Steel Marking for plates and stiffeners

Table 3: Steel Standard

Standard	Organization	Description / Application	Reference
ABS	American Bureau of Shipping	Defines grades such as ABS A, AH36, DH36, and EH36 used for hull and structural components in ship construction.	(Shipping 2021)
LR	Lloyd's Register (United Kingdom)	Publishes LR A, LR AH36, and similar grades with material and welding requirements for marine structures.	(Limited 2022)
DNV	Det Norske Veritas (Norway)	Specifies DNV A, AH36, and EH36 for hull and offshore structures, emphasizing toughness and weldability.	(DNV 2023)
BV	Bureau Veritas (France)	Issues BV A, BV AH36, BV DH36; widely used in European shipyards.	(Veritas 2022)
KR	Korean Register (South Korea)	Applies KR A, KR AH36, and KR DH36 for hull structures in Korean-built ships.	((KR) 2022)
CCS	China Classification Society (China)	Specifies CCS A, AH36, and DH36 grades; the main standard for Chinese shipbuilding.	((CCS) 2023)
RINA	Registro Italiano Navale (Italy)	Publishes RINA A, AH36, and DH36 standards for marine hull applications in the Mediterranean region.	((RINA) 2021)
NK (ClassNK)	Nippon Kaiji Kyokai (Japan)	Defines NK A, NK AH36, and DH36 steel grades widely applied in Japanese and Asian shipyards.	((ClassNK) 2023)
IACS	International Association of Classification Societies	Harmonizes standards across all classification societies under UR W11-W17, ensuring global material equivalence.	((IACS) 2022)

3.4 Intelligent Market-Based Cost Estimation System

According to follow actual challenges of supply chain for shipyard and interview data with procurement department other department managers affected by the supply chain across various departments, in order to address the following challenges (Strandhagen et al. 2022).

Table 4: Challenges in shipbuilding supply chains

Challenges	Impact on Competitiveness
Delay in cost estimation	Loss of tenders due to slow quotation response
Inaccurate cost estimation	Financial losses and uncompetitive pricing
Slow procurement processes	Extended project duration and reduced bidding speed
Lack of integration between departments	Higher actual costs compared to competitors
Poor cost visibility and forecasting	High risk in decision-making and pricing strategies

It is designed to support early-stage cost estimation and procurement decisions in tugboat construction and developed using Python and features a graphical user interface (GUI) that allows cost engineers of shipyards to input technical and commercial parameters and receive immediate real cost from electronic marketplaces.

An environment that integrates data collection, decision logic, and computational models within the proposed intelligent system. The AI component is implemented through rules-based reasoning, constraint-based filtering, and automated decision-making algorithms (Sarker 2021). Python acts as a coordination layer that evaluates engineering constraints, processes multi-source market data, and implements optimization logic to identify compatible and cost-effective purchasing options.

The program collects many quotations from multiple electronic marketplaces and online supplier platforms. After that, by using API Gemini Key, the program starts calling the web sites of electronic markets and supplier`s platform via google search engine in order to compare the getting quotations, then a filtration to be done in order to get the cheapest price complying with the supplier origin, class certification, steel grade, and dimension.

According to these inputs the program calculates the weight (see Equation 1), covert the price to USD for steel plate and steel stiffeners in separate applications as the following:

A: Steel Plate

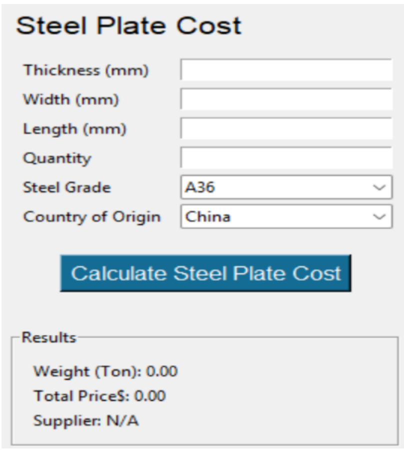

Figure 7: Interface of Ordering Steel Plates

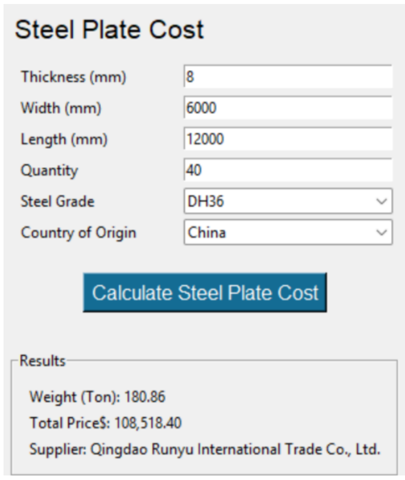

Figure 8: Result of Ordering Steel Plates

As shown in Figure 7, the steel grade and size, plus other parameters to be checked out like certification, priming, country of organ and shipping to be included during input the data to the program by user. In Figure 8, After input the data the output will be summarized to show the total price for all different requests with informing about the supplier who quotes the cheapest price on e-marketplace.

B: Steel Stiffeners

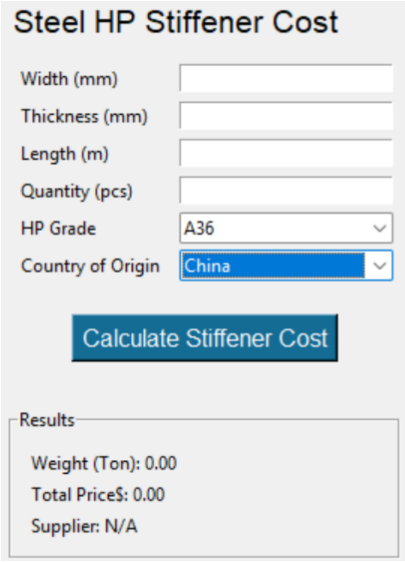

Figure 9: Interface of Ordering Steel Stiffeners

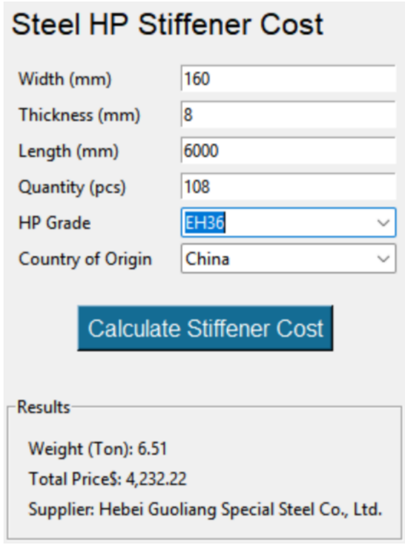

Figure 10: Results of Ordering Steel Stiffeners

As shown in Figure 9, the steel grade and size, plus other parameters to be checked out like certification, priming, country of organ and shipping to be included during input the data to the program by user. In Figure 10, After input the data the output will be summarized to show the total price for all different requests with informing about the supplier who quotes the cheapest price on e-marketplace.

C: Steel Shipping

After calculating the weight of the steel plates and steel stiffeners, the program calculates the Sumption of total weight, and search to get the required fees of shipping according to the departure seaport and destination including the shipping details as shown below in Figure 11.

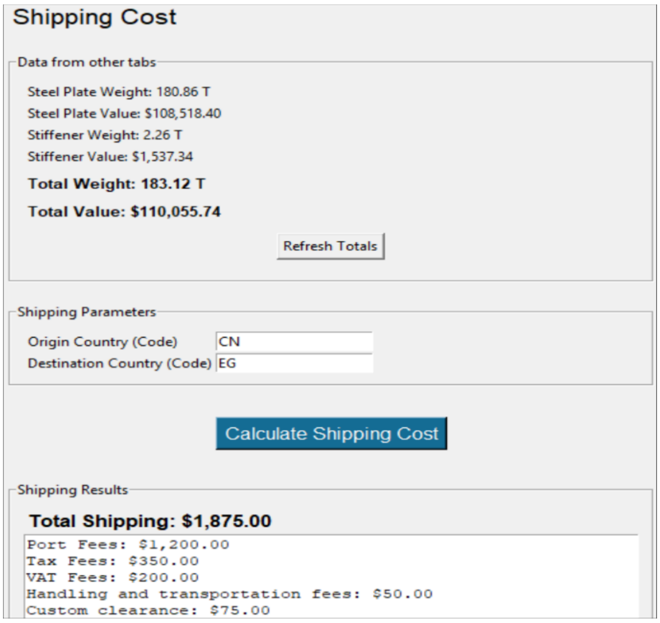

Figure 11: Shipping Details

This integrated methodology enables fast, flexible, and transparent cost estimation, improving decision-making under uncertainty and supporting more competitive tender submissions for shipbuilding projects in the Middle East.

The Middle East is a key hub in the modern maritime and shipbuilding industry, given its strategic geographic location linking Europe, Asia, and Africa, as well as its presence in major ports and advanced logistics zones such as the Suez Canal in Egypt, the Islamic Port of Jeddah, and Khalifa Port in the UAE. The region is also witnessing a growing expansion in shipbuilding and maintenance projects to support international trade and services for national maritime fleets. With the growing demand for digital transformation in the maritime industry, there is a need to develop digital costing systems and electronic procurement platforms (e-marketplaces) that help shipyards in the Middle East improve efficiency and reduce response time to global market fluctuations. Furthermore, companies in the region face unique challenges such as fluctuating imported steel prices, reliance on external suppliers, and varying international accreditation standards. This makes the implementation of an integrated digital platform for costing and e-procurement of strategic importance. Therefore, this research focuses on the Middle East as an ideal model for testing the effectiveness of digital solutions in improving procurement, costing, and production processes in a rapidly changing and globally competitive maritime environment.

In this paper, we will validate the price against on-line manual search, that will be discussed in the result discussion.

4. RESULTS AND DISCUSSION

A case study of tugboat under construction in the Middle East, focusing on the procurement of marine-grade steel plates and stiffeners. The developed Python system processed multiple steel specifications - grade, thickness, dimensions, certification, and country of origin - and compared live market prices from e-marketplace datasets.

4.1 Framework Validation and Performance

As mentioned in Methodology, the results of program about the extracted websites for steel plates and stiffeners to be checked and the price to be checked as well.

A: Steel Plates

The result of program is total price: $108,518.40 per 180.86 ton, it means $600.013 per ton, by manual on-line search for the same supplier (qingdao runteng international trade co. ltd) on Made in China electronic marketplace just after using the program to get the real price at the same time the price was $600 per ton.

By manual on-line search to compare this price with other suppliers to check the cheapest one, in this regard we will take a random sample from Alibaba electronic marketplace and divide the sample price to our program price to get the deviation as the following:

Table 5: Sample prices for steel plates

Alibaba Sample	Sample price Per ton	Program accuracy (price $600 per ton)	Program is cheapest (Yes / No)
Shandong Zhongxuan Steel Group Co., Ltd.	$700	116.67%	Yes
Jiangsu Zhengkuan Iron And Steel Co., Ltd.	$460	76.67%	No
Shandong Renai Iron & Steel Co., Ltd.	$630	105%	Yes
Shandong Wanteng Steel Co., Limited	$800	133.33%	Yes
Tianjin Rarlon Import And Export Co., Ltd.	$520	86.67%	No
Guomai Iron and Steel (Tianjin) Co., Ltd.	$420	70%	No
Tjyct Steel Co., Ltd.	$615	102.5%	Yes

Tangshan Fushunde Trade Co., Ltd.	$459	76.5%	No
Wuxi Hongye New Material Co., Ltd.	$600	100%	Same price
Shandong Kunda Steel Co., Ltd.	$590	98.33%	No

By calculating the average for the 10 samples the program accuracy is 96.57%, the deviation is to be considered as a cost reserve.

According to these samples the deviation is 3.43% of the search time and to be considered this deviation may be continuously changed.

B: Steel Stiffeners

The result of program is total price: $4,232.22 per 6.51 ton, it means $650.11 per ton, by manual on-line search for the same supplier (Hebei Guoliang Special Co., Ltd.) on Alibaba electronic marketplace just after using the program to get the real price at the same time the price was $650 per ton.

By manual on-line search to compare this price with other suppliers to check the cheapest one, in this regard we will take a random sample from Made in China electronic marketplace and divide the sample price to our program price to get the deviation as the following:

Table 6: Sample prices for steel stiffeners

Made in China Sample	Sample price Per ton	Program accuracy (price $650 per ton)	Program is cheapest (Yes / No)
Shandong Xinghuasheng Steel Group Co., Ltd	$440	68%	No
Wuxi Jinbao Special Steel Co., Ltd	$520	80%	No
Jiangsu Rongyi Metal Co., Ltd	$445	68%	No
Tangshan Zuoqiu Steel Trade Co., Ltd	$400	62%	No
Liaocheng Shengteng New Material Co., Ltd	$460	71%	No
Shanghai Changzeng Metal Co., Ltd	$490	75%	No
Shandong Jichang Import And Export Co., Ltd	$500	77%	No
Guangzhou Long Sheng Hing Trading Co., Ltd	$600	92%	No
Jingjiang Trust Trading Co., Ltd	$1,000	154%	Yes
Guangzhou Longyuhing Trading Co., Ltd.	$500	77%	No

By calculating the average for the 10 samples the program accuracy is 82%, the deviation is to be considered as a cost reserve.

According to these samples the deviation is 18% of the search time and to be considered this deviation may be continuously changed.

C: Program Accuracy

The accuracy of program is different between the plates and the stiffeners, it is 96.57%, for plates and 82% for stiffeners.

In this stage, the program provides a valid result for steel plates and stiffeners but with minor deviation for plates and high deviation for stiffeners. To be more clarified, we have considered a deviation rate about 5% for plates and 20% for stiffeners in order to be added to the obtained price from the program. The cost estimation after considering the deviation rate will be:

- (600+(600*0.05) = $630 for plates.
- (650+(650*0.2) = $ 780 for stiffeners.

Furthermore, the results from our program for the total weight of steel plates and stiffeners is 183.12 tons with shipping fees $1,875.00, therefore the shipping fee per ton is $10.24.

According to my own experience as working a shipbuilder for many tugboats in shipyards in Egypt and Saudi Arabia, the suppliers of steel material normally put a margin cost for material cost and shipping fee approximately 15~20% more than the shown prices in the final contract. Therefore, we can consider adding about 18% for the material cost after adding deviation rate and shipping fee, the price will be calculated as the following:

The final cost estimation for material =

(Obtained material price from the program + deviation rate + Shipping fee) to be multiplied to Supplier margin cost (18%)

(Obtained material price from the program + deviation rate + Shipping fee) x 1.18

For ***steel plates*** the final cost estimation = ($600 + ($600 x 0.05) + $10.24) x 1.18 = ***$755.48***, where deviation rate is 5% of program cost for steel plates.	For ***Steel Stiffeners*** the final cost estimation = ($650 + ($650 x 0.2) + $10.24) x 1.18 = ***$932.48***, where deviation rate is 5% of program cost for steel stiffeners

Now we can check our final cost estimation by applying to our case study for new building three tugboats 32-meter length and 70 T bollard pull; A Saudi shipyard already contracted with Chinese supplier for steel plate price per ton including the shipping fees was $943 and for steel stiffener price per ton including the shipping fees was $1,077.

Comparing the actual contractual price with the final cost calculated by our Program, we can observe that program could save the cost of steel material approximately (1-($755.48/$943)) = (20%) for steel plates and (1-($932.48/$1,077)) = (13%) for steel stiffeners.

The following table shows and concludes the comparison between the case study and program results:

A: Program Cost Estimation

Cost Discription regaridng the program	***Plates***	***Stiffeners***
Obtained price from the program per ton	$600.00	$650.00
Deviation Rate according to random 10 samples	5%	20%
Cost estimation after deviation rate per ton	$630.00	$780.00
shipping fee per ton	$10.24	$10.24
Adding shipping fee ($10.24) to Cost estimation after deviation rate per ton	$640.24	$790.24
Rate of Supplier margin cost	18%	18%
Adding supplier margin cost to cost estimation after deviation rate and shipping fee per ton	$755.48	$932.48

B: Comparing Program Vs. Case study

Cost Estimation for material including the shipping fee	Plates	Stiffeners
Final cost estimation according to program results	$755.48	$932.48
Contractual Price according to existing case study	$943.00	$1,077.00
Saving cost achieved by using program	20%	13%

4.2 Reduction in Estimation Time and Human Error

The implementation of the Python GUI reduced the overall cost estimation cycle from 3-5 working days to less than one hour. Manual processes such as quotation requests, spreadsheet comparisons, and validation were replaced by automated computation through the AI system's integrated API. The interface enabled rapid entry of multiple steel requests and instant aggregation of total project costs. In normal process cost engineers in shipyards have to communicate with different suppliers by e-mails and phone calls to request a quotation with the bottom price for steel material and waiting them to reply considering the suppliers are working for 5 working days and their holidays are different were in Europe is different rather than Middle East after getting the quotation may be some negotiation is required to discuss about the price but in our case study it is just pressing button to calculate the steel price and getting if in few seconds from the electronic markets as per our above mentioned examples for thickness 5mm and 10 mm.

4.3 Economic and Strategic Implications

From an operational perspective, integrating AI into steel cost estimation reshapes procurement and budgeting strategies. The results indicate that AI systems can enhance financial transparency, supplier diversification, and risk mitigation in the face of steel price volatility. Furthermore, the research validates that e-marketplace integration allows for continuous monitoring of supplier performance, enabling proactive responses to market shifts.

For example, during a simulated 10% increase in global steel prices, the AI framework automatically adjusted its recommendations to Favor regional suppliers with lower shipping costs, demonstrating its adaptability under fluctuating market conditions. This adaptive intelligence supports resilient decision-making in marine procurement - an increasingly crucial factor for sustainable shipbuilding operations.

4.4 Practical Validation

The system's estimations were validated through a real-world procurement scenario where the AI-generated steel cost estimates differed from final contract prices. This close alignment confirmed the system's robustness and its ability to generalize across various project sizes. Engineers and procurement officers who participated in the testing phase reported that the AI tool enhanced their confidence in cost planning, supplier negotiation, and budget allocation.

5. CONCLUSION

This research demonstrates that the integration of Artificial Intelligence (AI) into marine steel cost estimation significantly enhances the accuracy, speed, and reliability of estimation processes in tugboat construction. By leveraging real-time data from global e-marketplaces. The developed AI-based framework bridges the gap between engineering design inputs and dynamic market fluctuations. The Python-based system efficiently analyzes parameters such as steel grade, thickness, certification, and origin to deliver precise, data-driven cost outputs. Through this approach, traditional multi-day quotation cycles are reduced to a single semi-automated process, enabling shipyards to obtain competitive pricing and make timely procurement decisions. The study confirms that AI-driven cost systems not only minimize financial risks caused by volatile steel prices but also support strategic purchasing, supply chain transparency, and sustainable shipbuilding practices. Therefore, adopting AI-enabled cost estimation models represents a transformative advancement toward smarter, more resilient, and economically efficient shipbuilding operations in the global maritime industry.

6. Bibliography

1) Alblas, Gerrit, and Jeroen Pruyn. 2024. "A Novel Concept for Steel Building Cost Estimation in Shipbuilding Using Process and Product Similarities". Journal of Marine Science and Engineering 12 (11). https://doi.org/10.3390/jmse12111936.

2) Bertram, Volker, Jean-Jacques Maisonneuve, Jean-David Caprace, and Philippe Rigo. 2005. "Cost Assessment in Ship Production". RINA.

3) Bruce, George. 2020. "Ship Project Strategy". In Shipbuilding Management. Springer.

4) Čajka, P., and R. Koteš. 2020. "Analysis of Structural Steels Used in Shipbuilding". Procedia Structural Integrity 28: 224-31. https://doi.org/10.1016/j.prostr.2020.10.028.

5) Chen, Lifei, Chongyong Xu, Wei Hong Lim, and others. 2025. "Transparent and Reliable Construction Cost Prediction Using Advanced Machine Learning and Explainable AI". Engineering Science & Technology, an International Journal 70. https://doi.org/10.1016/j.jestch.2025.102159.

6) Chou, J.-S. 2011. "Cost Simulation in an Item-Based Project Involving Construction Engineering and Management". International Journal of Project Management 29 (6). https://doi.org/10.1016/j.ijproman.2010.10.006.

7) Eong, D., D. Kim, T. Choi, and Y. Seo. 2020. "A Process-Based Modeling Method for Describing Production Processes of Ship Block Assembly Planning". Processes 8 (7). https://doi.org/10.3390/pr8070880.

8) Eyres, D.J., and G.J. Bruce. 2012. Ship Construction. 7th edn. Butterworth-Heinemann. https://doi.org/10.1016/C2010-0-64832-1.

9) Gunasekaran, V., C. Patel, and R. E. McGaughey. 2017. "A Framework for Supply Chain Management in E-Marketplaces". International Journal of Production Economics, ahead of print. https://doi.org/10.1016/j.ijpe.2017.07.029.

10) Jiang, Liping, Erik Bastiansen, and Siri P Strandenes. 2013. "The International Competitiveness of China's Shipbuilding Industry". Transportation Research Part E: Logistics and Transportation Review 60: 39-48. https://doi.org/10.1016/j.tre.2013.10.001.

11) Princz, Gábor, Fabian Reisacher, and Selim Erol. 2025. "AI-Based Procurement System: Optimization of Material Ordering and Inventory Management in Volatile Markets". Procedia CIRP 134. https://doi.org/10.1016/j.procir.2025.02.214.

12) Qu, Shuang, Zhi Jiang, and Ning Tao. 2013. "An Integrated Method for Block Assembly Sequence Planning in Shipbuilding". International Journal of Advanced Manufacturing Technology 69 (5-8): 1123-35. https://doi.org/10.1007/s00170-013-5050-2.

13) Salian, Dharmender, Geeta Sandeep Nadella, Gasan Elkhodari, et al. 2025. "The Impact of Digitalization on Shipbuilding as Measured by Artificial Intelligence (AI) Maturity Models: A Systematic Review". Advances in Science, Technology and Engineering Systems Journal 10 (3). https://doi.org/10.25046/aj100303.

14) Sarker, Iqbal H. 2021. "Machine Learning: Algorithms, Real-World Applications and Research Directions". SN Computer Science 2 (3): 160. https://doi.org/10.1007/s42979-021-00592-x.

15) Shamim, Md Mahfuzul Islam, Abu Bakar bin Abdul Hamid, Tadiwa Elisha Nyamasvisva, and Najmus Saqib Bin Rafi. 2025. "Advancement of Artificial Intelligence in Cost Estimation for Project Management Success: A Systematic Review of Machine Learning, Deep Learning, Regression, and Hybrid Models". Modelling 6 (2): 35.

16) Shetelig, Haakon. 2013. "Shipbuilding Cost Estimation". Master's thesis, Norwegian University of Science and Technology. https://ntnuopen.ntnu.no.

17) Strandhagen, Jo Wessel, Sven-Vegard Buer, Marco Semini, Erlend Alfnes, and Jan Ola Strandhagen. 2022. "Sustainability Challenges and How Industry 4.0 Technologies Can Address Them: A Case Study of a Shipbuilding Supply Chain". Production Planning & Control 33 (9-10): 995-1010. https://doi.org/10.1080/09537287.2020.1837940.

18) Tunca, T. I., and Q. Wu. 2019. "Industrial E-Marketplaces and Online Procurement". Manufacturing & Service Operations Management 21 (2): 303-18. https://doi.org/10.1287/msom.2017.0667.

19) Wahidi, Sufian Imam, Vialdo Muhammad Virmansyah, and Triwilaswandio Wuruk Pribadi. 2021. "Study on Implementation of Activity-Based Costing (ABC) System on Determination of Indirect Costs in Ship Production". Kapal: Jurnal Ilmu Pengetahuan Dan Teknologi Kelautan 18 (1): 1-7.

20) Zhang, Guoping, and Qiuyue Zhang. 2025. "Machine Learning-Based Construction Cost Prediction Model and Optimization Design". International Journal of High Speed Electronics and Systems, ahead of print. https://doi.org/10.1142/S0129156425407740.