

# A Practical Approach for Ship Construction Cost Estimating

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## Abstract

*To succeed commercially, shipyards must be able to accurately estimate costs. Cost estimating is necessary for the bid process, for change orders, and for trade-off studies. Numerous cost estimating approaches exist. They are based on extrapolations from previously-built ships, detailed bottoms-up parametrics, and integrated physics-based analyses. Cost estimating can be frustrating to shipyard personnel. Cost estimators may lack timely technical information and face data inconsistencies. Ship engineers and naval architects commonly lack feed-back on the cost consequences of their technical decisions. Managers often lack information denoting the level of confidence in cost estimates upon which they must make business decisions. Finally, many approaches to cost estimating are mysterious and not formally validated (each cost estimator has his own black book), complicated (too time consuming to be of use to decision makers), or difficult to use (steep learning curve). This paper presents an approach that is simple, yet enables instant sharing of cost and technical data among ship engineers, naval architects and cost estimators; gives confidence measures to managers; and is user friendly. The approach is based on several years' development work in support of shipyard engineers, naval architects, and cost estimators.*

## 1. Introduction

Most readers of this paper tend to view ship construction from a technical perspective: requirements, design, engineering, analysis, production planning, and production. Sometimes forgotten is the fact that ship construction is a businesses venture and must succeed financially as well as technically. This paper focuses on a key financial aspect ship construction: estimating costs.

### 1.1. Background

The ability to estimate ship construction costs is necessary for the commercial success of a shipyard; too high an estimate will place the shipyard out of the competitive range and too low an estimate will result in a financial loss and possible bankruptcy. In practice, an approximate cost estimate is developed during initial discussions with a potential customer. This estimate is refined as the discussions progress and the customer's requirements are defined in greater detail. The refined requirements result in higher levels of technical detail (e.g., concept design, preliminary design, contract design, and a specification of increased detail), which enable increased accuracy of the cost estimate. This process culminates in a cost estimate upon which the shipyard can base a fixed price bid.

Developing and refining a cost estimate is a complex and time-consuming process. Obstacles to success include faulty technical information (e.g., obsolete, incomplete, inconsistent), lack of communication among departments (e.g., rivalries, lack of peer-to-peer communication channels, secrecy), lack of a clearly defined process (e.g., ill-defined lines of authority, no freeze dates on design versions, different data formats), and problems with analytical tools (e.g., incompatible software, varying levels of detail, lack of features, too complex, not user friendly, not capable of being tailored to the needs of the shipyard or to specific projects). Overcoming these obstacles and producing viable cost estimates requires knowledge and skills of management, vendors and, most importantly, numerous shipyard departments, including engineering, production, planning, estimating, and marketing.

### 1.2. Scope of ship cost estimating

Ship cost estimating in general is a wide field, with the scope and depth of a given estimate tailored to

meet the needs of the user. Typical examples include the following:

- Construction (acquisition) costs – shipyard labor and material costs for design/engineering, production and testing
- Life cycle costs – construction costs plus maintenance, operation, support, and modernization
- Total ownership costs (applicable to naval ships or certain large commercial fleets) – construction, life cycle costs plus infrastructure costs for training, and other indirect costs.

Although this paper addresses cost estimating for new construction, a similar approach may be used to estimate costs for major repairs, overhauls, modernization, and disposal.

### **1.3. Example Approaches to Cost Estimating**

Approaches to cost estimating vary from the informal to the formal, as described below:

- “Black book” – cost estimators create formulas, tables, and charts based on years of experience, industry trends, and vendor data. Typically, estimators guard this information closely, thus making its accuracy difficult to confirm. The black book approach can produce acceptable results in cases where the shipyard constructs a single or a few ship types and sizes. This approach is not so dependable for ship types or sizes beyond those normally constructed at the yard, or as costs become outdated.
- Parametric approach – System and subsystem costs are characterized in a spreadsheet or cost estimation program as a proportion of overall metrics such as length, volume, displacement and propulsion power. The proportions are estimated through comparisons with similar ships. As with the black book approach, if correlation levels are high, then the parametric approach yields good predictions; otherwise, the estimates may not be sufficiently accurate for many technical and business decisions.
- Standard ship approach – Some shipyards offer standard ship designs for which cost characteristics are well known. This enables the yards to very quickly and confidently develop detailed bids for prospective customers, and is an excellent solution if the designs match the customers’ requirements. However, even with the flexibility for making limited changes to the design, many customers prefer to purchase a ship that is more closely aligned to their business needs.
- Direct analysis approach – As the design matures, costs may be estimated based on drawings, bills of materials, historical vendor costs, and existing quotes. This approach is only practical after the design has reached a level of significant technical maturity.

Shipyards may use combinations of the above approaches. For example, the parametric approach may be used for structure, but the engineering approach may be used for owner-specified engine and auxiliary equipment. Cost estimates may be carried out by hand, spreadsheet, or on a computer program, and analysis results may be presented at various levels of detail.

### **1.4 Organization of this paper**

The remainder of the paper presents a practical approach for ship construction cost estimating and is organized as follows:

- Cost estimating approach requirements
- Cost estimating approach description
- Case study using the cost estimating approach
- Conclusions
- References.

## **2. Cost Estimating Approach Requirements**

“The cost estimating approach” presented in this paper complies with the following requirements:

- Three-tiered hierarchy of cost estimates to reflect varying levels of detail available to the cost estimator during the design process

- Each tier is independent of the others, permitting the best information to be used at all times, and not requiring that the estimate adhere to the “lowest common denominator” of information
- Material and labor elements are included (some shipyards may desire labor hours instead of labor cost because of confidentiality concerns)
- Confidence levels are presented to reflect the perceived accuracy of the engineering data and the cost estimating relationships.

Each of these requirements is discussed below (*Ross 2002*).

## 2.1 Three-tiered hierarchy

The cost estimating approach is divided into three tiers in order to reflect the three design phases (concept, preliminary, contract) commonly encountered in ship construction, Fig.1. At times, data may be available at different levels, and thus be placed in different tiers (see the following section, “Independence among tiers”). However, the norm is for data to be of a fairly consistent level of detail among the various parts of the ship (e.g., structure, propulsion, electric plant) during a given design phase. Thus, the corresponding tier is populated with technical and cost data during each of the three design phases, as described in the following paragraphs.

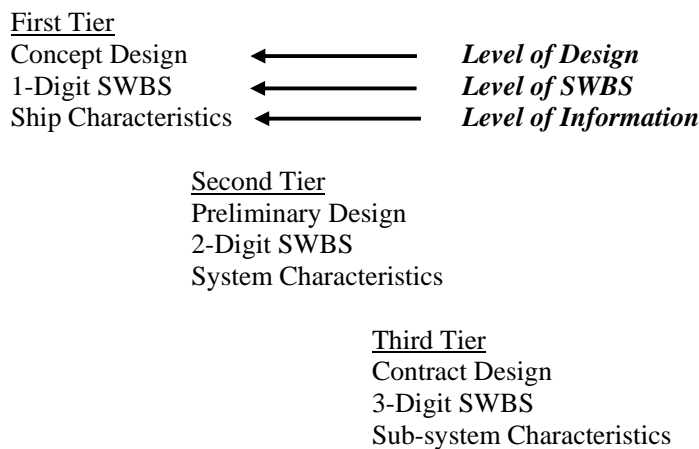


Fig.1: Three-tiered hierarchy of ship construction cost estimating

The first tier is Concept Design and is the least detailed. Typically this tier is used at the start of the cost estimating process when only limited information is available to the shipyard. This corresponds to elements of a 1-digit ship work breakdown structure (SWBS) and is based on about 20 data elements relevant to the whole ship (e.g., length overall, displacement, propulsion power).

The second tier is Preliminary Design. This corresponds to elements of a 2-digit SWBS and is based on about 125 data elements relevant to ship systems (e.g., structural system, propulsion system, heating and ventilation system).

The third tier is Contract Design and is the most detailed. The cost bid is based on the information in this tier. This tier corresponds to elements of a 3-digit SWBS and is based on hundreds or thousands of data elements relevant to sub-systems (e.g., main engine cooling, main engine fuel pumping, main engine starting).

## 2.2 Independence among tiers

Independence among the tiers allows the cost estimator to develop the estimate based on technical data of varying degrees of detail. For example, hull structure data may be available at the 3-digit SWBS level (e.g., 117 – Transverse Framing), but propulsion plant data may be available only at the

2-digit level (e.g., 220 – Engineering Control Systems). The cost estimating approach will accept data and produce reports for each of these SWBS levels. Thus, it is not necessary to wait until 3-digit propulsion data is available before populating structures at the 3-digit level of detail. Independence among tiers enables the cost estimate to be based on the most detailed (and presumably the most accurate) data available.

### **2.3 Material and labor included**

Shipyards commonly divide costs into material and labor (material includes vendor and subcontractor costs, and labor is only that of shipyard employees). In order to best serve the shipyard needs, the cost estimating approach follows this convention by producing estimates for material and labor. Material estimates are provided as costs, but labor estimates are provided as labor hours (to maintain confidentiality of shipyard labor rates). Estimates are provided for each SWBS element for which technical data is available.

### **2.4 Confidence levels**

Shipyard management needs to know the level of accuracy of the cost estimate in order to properly develop the bid. Put another way, management needs to know the level of uncertainty of the estimate. Uncertainty may be quantified either through the application of margin or the provision of confidence levels. Both are commonly subjective, though probabilistic calculations may be used.

The cost estimating approach uses confidence levels instead of margins. This is because confidence levels provide the user (e.g., management) with quantified insight into the accuracy of the estimate. With this knowledge in hand, if certain parts of the estimate have low confidence levels, then attention may be focused there to increase confidence levels, and thus increase the accuracy of the estimate. Confidence levels are assigned to the engineering quantities (e.g., reflecting a 90% confidence that the weight of structure is correct as reported) and also to the cost estimating relationships (e.g., reflecting 95% confidence in the estimated cost per weight factor). The two confidence levels are multiplied to arrive at an overall confidence level (e.g.,  $90\% \times 95\% = 86\%$ ). Confidence levels are presented by SWBS element.

## **3. Cost Estimating Approach Description**

Shipyards commonly develop ship designs in the engineering department and develop ship cost estimates in the cost estimating department. The cost estimating approach is designed to support this division of labor, and was developed through input from engineers, cost engineers, and cost estimators. Key to the development success to date were workshops at which shipyard technical and cost personnel suggested enhancements to early versions of the cost estimating approach.

### **3.1. Description of the architecture**

The cost estimating software is divided into two linked elements, one focused on engineering and the other focused on cost. Each element is comprised of modules which carry out discrete operations. A functional flow chart of the software is shown in Fig.2.

The engineering element comprises the following five modules:

- Baseline ship engineering quantities – This module is used in the case where the design ship (i.e., the ship for which cost is being estimated) is an extrapolation of a baseline ship (i.e., a ship for which costs are known). This module is populated with data which describes both ships in terms of selected physical quantities (e.g., tonnes of structural steel).
- Baseline and design ship principal particulars – Again, this component is used if there is a baseline ship. The module is a repository for general (non-SWBS) data such as length between perpendiculars.
- Parametric engineering quantities – Parametric calculations are carried out in this module to

estimate design ship engineering quantities, based on a constant times the ratio of corresponding design and baseline ship principal particulars (e.g., [constant] x [design ship length overall] / [baseline ship length overall]).

- Assigned engineering quantities – As naval architects and marine engineers develop the design, increasingly accurate engineering quantities become available for use in the cost estimating process. These “assigned quantities” are entered into this module. Normally, these engineering quantities are more accurate (higher confidence level) than the parametric engineering quantities of the previous module.

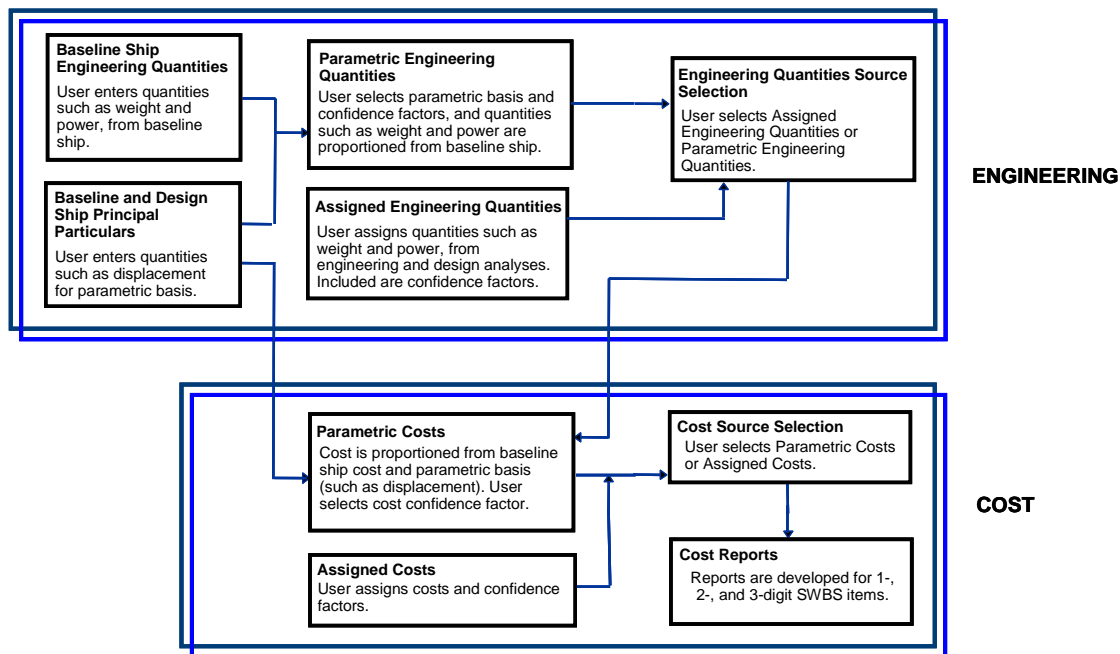


Fig.2: Flow Chart of Cost Estimating Approach

- Engineering quantities source selection – Here the user selects which engineering quantities (parametric or assigned) will be used in the cost estimating process. Normally, at the start of the design process, parametric engineering quantities are selected, and as the design progresses, assigned engineering quantities are selected.

The cost element comprises the following four modules:

- Parametric cost – As with parametric engineering quantities, cost is estimated for the design ship based on a proportionality with regard to the baseline ship.
- Assigned costs – As with assigned engineering quantities, assigned costs are directly entered into the module. These costs are based on data such as initial estimates from vendors and from purchase orders.
- Cost source selection – Again, as with the parametric engineering quantities source selection, the user selects between the parametric and the assigned values.
- Cost reports – This module produces three reports: 1-digit, 2-digit, and 3-digit SWBS cost estimates, with overall (engineering and cost) confidence levels provided for each cost entry.

### 3.2 User interface and data entry

The cost estimating software is hosted by a smart product model, to which various other components besides cost estimating may be added (e.g., structures, stability, hull form), *ROSS et al. (2001), Ross, (2002)*. Engineering quantities, parametric constants, confidence levels, and cost data are entered and

reviewed in dialogue boxes and on Excel worksheets all of which may be tailored to the needs of specific users. Although the cost estimating software may operate in a stand-alone mode, the smart product model host offers several advantages:

Integration of cost with engineering models – the engineering basis of the cost estimates (e.g., weight, volume, engine power) can be automatically linked to receive input from the engineering components.

Enhanced communication within the design team – engineers, cost estimators, production planners, and management view a consistent set of technical and cost data.

Configuration control – permission can be assigned to ensure that only authorized users enter and revise data in their respective task areas.

One-stop high level modeling and estimating – the engineering and cost information developed by the smart product model is at a level at which sufficient detail is available to develop data on which meaningful technical and cost decisions can be based, yet the quantity of data is small enough to permit quick side studies, and to reflect the present state of an ongoing design.

Single database for engineering and cost data – data can be stored in one place for all aspects of the design and cross referenced, presented in various hierarchies, and formatted for reports. A single database helps ensure data consistency.

#### **4. Case Study Using the Cost Estimating Approach**

A case study will illustrate the cost estimating approach with a double hull tanker as the example ship. The tanker is similar to the Double Eagle tanker design of Newport News Shipbuilding (now Northrop Grumman Newport News) shown in Fig.3, with the ship's principal characteristics presented in Table I, *HATFIELD, 1999*. This tanker design was featured in Maritech ASE Project 21, *DUNCLIFT, 2001*. Slightly revised versions of the Double Eagle SWBS and weight breakdown are used in the case study.

##### **4.1 Cost and labor hour conventions**

All costs and hour information and certain weight information are notional, and are not based on actual Double Eagle data. With regard to cost, much depends upon where (country and shipyard) the ship is constructed. Actual costs are not as relevant to this case study as showing the cost estimating approach. Thus, an approximate cost is considered sufficient. *BROWN, 1996* quotes \$39,400,000 for constructing a 40,000 dwt double hull tanker, based on *National Research Council, 1991*. Accounting for the increased deadweight of the example tanker and assuming a 3% annual inflation rate, the cost in 2003 would be \$64,200,000. *MARINE LOG, 2003* listed a pending contract for three 45,000 dwt crude/product tankers at \$68,000,000. The average of those two estimates (\$66,000,000) will be used for the case study (estimated construction cost based on engineering drawings and input from vendors).

Half of the construction cost is assumed to be absorbed by shipyard labor, and the assumed labor rate is \$30/hour, resulting in total labor hours of 1,100,000. Subdivision of cost and hours is based on weight.

##### **4.2 Cost estimating process**

Fig.4 shows the host smart product model user interface. The "Tasks" pull-down menu is shown, with "Cost" highlighted. After selecting Cost, the user enters the cost module and proceeds through a series of forms to enter project information, enter and calculate engineering and cost data, and print reports. The process is described below.

Project information applies to the project as a whole, that is, to management, engineering, and cost estimating, Fig.5.

- Project information form – the user enters project name, point of contact (e.g., project manager), date, ship type, and contact information.
- Baseline ship general information form and (not shown) design ship general information form – the user enters ship characteristics (e.g., length overall) that may be used in parametric formulas for estimating engineering quantities (e.g., weight of the main deck structure), material costs (e.g., cost of main deck structure), and labor hours (e.g., hours to construct main deck structure).
- Ship element hierarchy entry – in a tabular format, the user enters the desired ship element hierarchy (in this case study, a SWBS hierarchy)

Engineering data and calculations apply to the quantities and confidence levels for baseline ship and design ship SWBS elements.

- The user enters engineering quantities for the baseline ship in the tabular format shown in Fig.6. In this instance, weight in tons is used. Weight is normally preferred for SWBS Group 100 (structure), because weight will provide an accurate estimate of material cost. In other SWBS groups, other engineering quantities may be more appropriate; for example, power may be more appropriate for SWBS Group 200 (propulsion).
- The user assigns design ship quantities if available in a like manner as for the baseline quantities, as shown in Fig.7. Normally, as the ship design matures, these quantities become available. They may be directly input from other linked components of the host smart product model. Note that at the beginning of the design process, this level of detail will normally not be available, and an estimate is made as shown in Fig.8.
- The user selects either the assigned quantities or the estimated quantities for further use in the cost estimating process (form not shown).

Cost data and calculations apply to the engineering quantities selected in the last step above, and to the costs associated with the baseline ship SWBS elements.

- The user enters baseline material costs and labor hours in for each SWBS element in a tabular format, as above.
- The user assigns design ship costs for each SWBS element in a tabular format. Again, these costs may become available only at the later stages of the design, and during the beginning of the design process, cost estimating relationships (CERs) are used as shown in Fig.9.
- The user selects either the assigned or the parametric material costs/labor hours.

Print reports for three SWBS levels of detail. The reports show the combined confidences of “engineering quantities confidence” and “cost confidence.” 2- and 3-digit SWBS reports employ roll-ups from the detailed to general levels (e.g., 1-digit SWBS elements are sums of their respective 2-digit sub-elements), Figs. 10 to 12.

Table I: Principal characteristics of example double hull tanker

<b>CHARACTERISTIC</b>	<b>MAGNITUDE</b>
Length between perpendiculars	180.0 m
Maximum beam	32.2 m
Depth (at side)	19.2 m
Design draft	11.2 m
Deadweight	45,700 t
Engine power (bhp)	13,390 hp
Speed	16 kt
Accommodations	35



Fig.3: Example tanker (HMI BRENTON REEF)(Northrop Grumman Newport News)

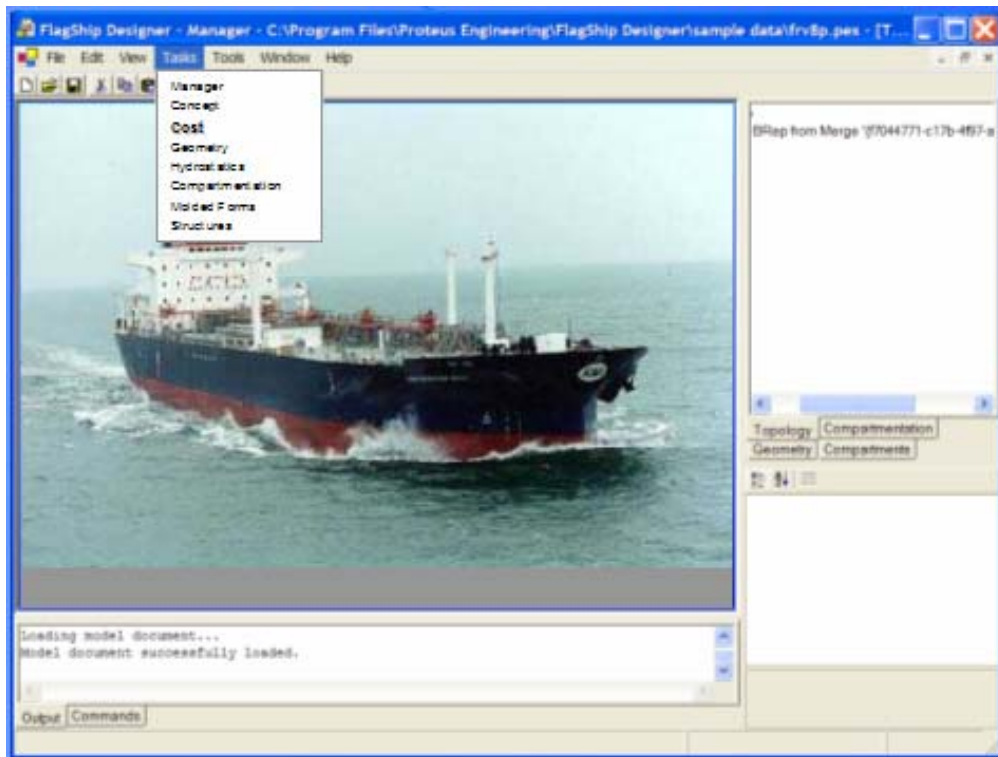


Fig.4: Selection of cost module in host smart product model



# PROJECT INFORMATION FORM

Project Name  
Double Hull Product Tanker

Point of Contact (POC)  
Harry Smith

Ship Type  
Tanker

Date  
1/16/2004

POC Phone  
[REDACTED]

**PROJECT INFO**

## BASELINE SHIP GENERAL INFORMATION FORM

ITEM: Length Between Perpendiculars    NAME: BLP    UNITS: M    METRIC: LENGTH    QUANTITY: 180

Record: 1	SVBS NUMBERS AND CATEGORIES >>	SVBS NO	SVBS CATEGORY
		100	STRUCTURE
		110	SHELL AND SUPPORTING STRUCTURE
		111	PRIMARY STRUCTURE
		112	SHELL PLATING AND STIFFENERS
		150	DECK HOUSE STRUCTURE
		152	FWD DECKHOUSE SUPERSTRUCTURE
		153	AFT DECKHOUSE & FUNNEL
		160	SPECIAL STRUCTURES
		161	STRUCTURAL CASTINGS & FORGINGS
		167	HULL STRUCTURAL CLOSURES

Fig.5: Project information

SVBS NO.	SVBS CATEGORY	BASELINE MATERIAL QUANTITIES >>	BASELINE MTL QTY	BASELINE MTL UNITS	BASELINE MTL BASIS	QU
100	FANTAIL		10208.26	T	WEIGHT	
110	SHELL AND SUPPORTING STRUCTURE		9113.44	T	WEIGHT	
111	PRIMARY STRUCTURE		7754.16	T	WEIGHT	
112	SHELL PLATING AND STIFFENERS		1359.28	T	WEIGHT	
150	DECK HOUSE STRUCTURE		423.44	T	WEIGHT	
152	FWD DECKHOUSE SUPERSTRUCTURE		286.12	T	WEIGHT	
153	AFT DECKHOUSE & FUNNEL		137.32	T	WEIGHT	
160	SPECIAL STRUCTURES		179.89	T	WEIGHT	
161	STRUCTURAL CASTINGS & FORGINGS		43.76	T	WEIGHT	
167	HULL STRUCTURAL CLOSURES		25.09	T	WEIGHT	
168	SUPERSTRUCTURE STRUCTURAL CLOSURES		2.15	T	WEIGHT	
169	SPEC PURP CLOSURES & STRUCTURES		108.89	T	WEIGHT	

Fig.6: Baseline ship material quantity entry table

ASSIGNED DESIGN SHIP MATERIAL QUANTITIES >>	ASSIGNED DESIGN SHIP MTL QTY	ASSIGNED DESIGN SHIP MATERIAL CONFIDENCE	ASSIGNED DESIGN SHIP MTL UNITS	ASSIGNED DESIGN SHIP MTL BASIS	AS DES L QUAI
	11229.09	0.92	T	WEIGHT	
	10024.78	0.92	T	WEIGHT	
	8529.58	0.92	T	WEIGHT	
	1495.21	0.92	T	WEIGHT	
	465.78	0.92	T	WEIGHT	
	314.73	0.92	T	WEIGHT	
	151.05	0.92	T	WEIGHT	
	197.88	0.92	T	WEIGHT	
	48.14	0.92	T	WEIGHT	
	27.60	0.92	T	WEIGHT	
	2.37	0.92	T	WEIGHT	
	119.78	0.92	T	WEIGHT	
	10.73	0.92	T	WEIGHT	
	10.73	0.92	T	WEIGHT	

Fig.7: Assigned material tabular entry

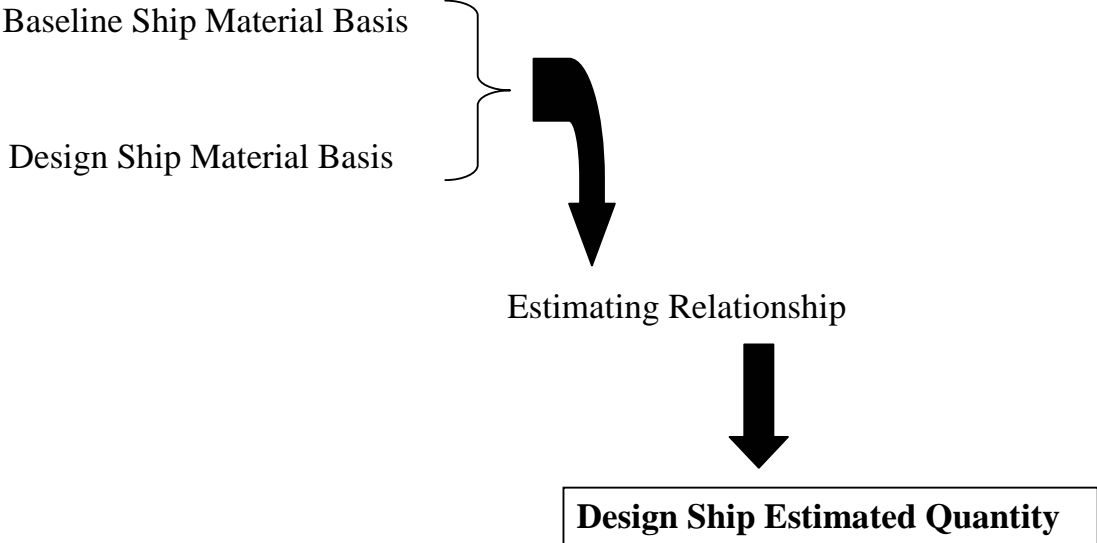


Fig.8: Approach to derive design ship estimated engineering material quantities

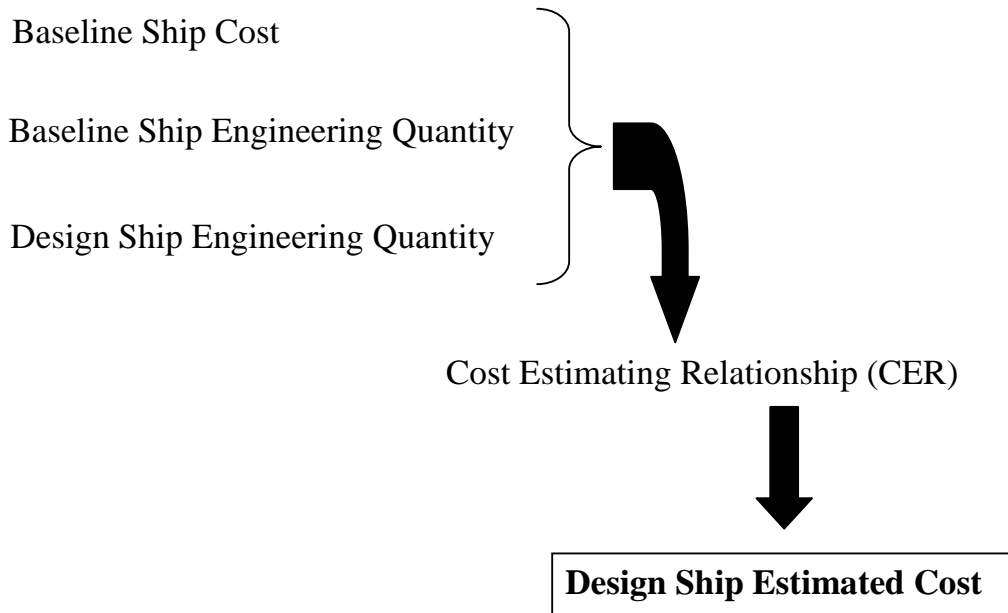


Fig.9: Approach to derive design ship estimated material costs and labor hours

<b>DESIGN SHIP 1-DIGIT SWBS COST AND LABOR REPORT</b>							
<b>MATERIAL DOLLARS</b>				<b>LABOR HOURS</b>			
	<b>COST</b>	<b>CON</b>	<b>TOL (+/-)</b>	<b>LABOR</b>	<b>CON</b>	<b>TOL (+/-)</b>	
<b>GRAND TOTALS &gt;</b>	\$ 29,871,725	0.96	\$ 1,194,869	995,724	0.96	39,829	
<b>SWBS NO. AND CATEGORY</b>							
100	STRUCTURE	\$ 24,614,665	0.96	\$ 984,587	820,489	0.96	32,820
200	PROPULSION	\$ 1,680,545	0.96	\$ 67,222	56,018	0.96	2,241
300	ELECTRIC PLANT	\$ 375,340	0.96	\$ 15,014	12,511	0.96	500
400	COMMAND AND CONTROL	\$ 41,208	0.96	\$ 1,648	1,374	0.96	55
500	AUXILIARY SYSTEMS	\$ 2,319,454	0.96	\$ 92,778	77,315	0.96	3,093
600	OUTFIT AND FURNISHINGS	\$ 840,513	0.96	\$ 33,621	28,017	0.96	1,121

Fig.10: Design ship 1-digit SWBS report

## DESIGN SHIP 2-DIGIT SWBS COST AND LABOR REPORT

	MATERIAL DOLLARS			LABOR HOURS		
	COST	CON	TOL (+/-)	LABOR	CON	TOL (+/-)
<b>GRAND TOTALS &gt;</b>	\$29,871,725	0.96	1,194,869	995,724	0.96	39,829

NOTE: ONE-DIGIT ENTRIES BELOW ARE ROLL-UPS OF TWO-DIGIT ENTRIES

SWBS NO. AND CATEGORY	MATERIAL DOLLARS			LABOR HOURS		
100 STRUCTURE	\$ 24,614,665	0.96	\$ 984,587	820,489	0.96	32,820
110 SHELL AND SUPPORTING STRUCTURE	\$ 21,974,781	0.96	\$ 878,991	732,493	0.96	29,300
150 DECK HOUSE STRUCTURE	\$ 1,021,020	0.96	\$ 40,841	34,034	0.96	1,361
160 SPECIAL STRUCTURES	\$ 433,760	0.96	\$ 17,350	14,459	0.96	578
170 MASTS, KINGPOSTS, AND SERVICE PLATFORMS	\$ 23,510	0.96	\$ 940	784	0.96	31
180 FOUNDATIONS	\$ 191,381	0.96	\$ 7,655	6,379	0.96	255
190 SPECIAL PURPOSE SYSTEMS	\$ 970,215	0.96	\$ 38,809	32,340	0.96	1,294
200 PROPULSION	\$ 1,680,545	0.96	\$ 67,222	56,018	0.96	2,241
230 PROPULSION UNITS	\$ 966,260	0.96	\$ 38,650	32,209	0.96	1,288
240 TRANSMISSION AND PROPULSOR SYSTEMS	\$ 121,358	0.96	\$ 4,854	4,045	0.96	162
250 PROPULSION SUPPORT SYS. (EXCEPT FUEL AND LUB	\$ 285,733	0.96	\$ 11,429	9,524	0.96	381

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Fig.11: Design ship 2-digit SWBS Report

## DESIGN SHIP 3-DIGIT SWBS COST AND LABOR REPORT

	MATERIAL DOLLARS			LABOR HOURS		
	COST	CON	TOL (+/-)	COST	CON	TOL (+/-)
<b>GRAND TOTALS &gt;</b>	\$ 29,871,724	0.96	1,194,869	995,724	0.96	39,829

NOTE: ONE-DIGIT ENTRIES BELOW ARE ROLL-UPS OF TWO-DIGITS; TWO-DIGIT ENTRIES ARE ROLL-UPS OF THREE-DIGITS

SWBS NO. AND CATEGORY	MATERIAL DOLLARS			LABOR HOURS		
100 STRUCTURE	\$ 24,614,665	0.96	\$ 984,587	820,489	0.96	32,820
110 SHELL AND SUPPORTING STRUCTURE	\$ 21,974,781	0.96	\$ 878,991	732,493	0.96	29,300
111 PRIMARY STRUCTURE	\$ 18,697,217	0.96	\$ 747,889	623,241	0.96	24,930
112 SHELL PLATING AND STIFFENERS	\$ 3,277,564	0.96	\$ 131,103	109,252	0.96	4,370
150 DECK HOUSE STRUCTURE	\$ 1,021,020	0.96	\$ 40,841	34,034	0.96	1,361
152 FWD DECKHOUSE SUPERSTRUCTURE	\$ 689,907	0.96	\$ 27,596	22,997	0.96	920
153 AFT DECKHOUSE & FUNNEL	\$ 331,113	0.96	\$ 13,245	11,037	0.96	441
160 SPECIAL STRUCTURES	\$ 433,760	0.96	\$ 17,350	14,459	0.96	578
161 STRUCTURAL CASTINGS & FORGINGS	\$ 105,516	0.96	\$ 4,221	3,517	0.96	141
167 HULL STRUCTURAL CLOSURES	\$ 60,498	0.96	\$ 2,420	2,017	0.96	81
168 SUPERSTRUCTURE STRUCTURAL CLOSURES	\$ 5,184	0.96	\$ 207	173	0.96	7

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Fig.12: Design ship 3-digit SWBS report

## 5. Conclusions

The cost estimating approach has the potential to improve ship construction cost estimate accuracy and timeliness by:

- Increasing the ease by which technical and cost information is shared among shipyard users (e.g., management, engineering department, estimating department)
- Ensuring that appropriate technical information is provided to cost estimators in the correct quantity and format
- Providing a common cost estimating and reporting framework
- Functioning at a level of detail where changes may be quickly made.

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