CATALOGUE OF SHIP PRODUCIBILITY IMPROVEMENT CONCEPTS

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16. Abstract

This catalogue is the product of a multi-year project to organize information relating to the improved producibility of Navy ships. This information is largely of a qualitative nature, and deals with all aspects of ship design and construction. Individual concepts are presented in the form of abstracts. These are organized according to the Navy ship Work Breakdown Structure (WBS) coding system. This catalogue is intended to provide a ready reference of producibility information for the student and naval designer.

This report has been prepared under the Memorandum of Understanding to Support Program Development in Naval Architecture and Marine Engineering between the United States Naval Sea Systems Command and the University of Michigan. It has been prepared under Office of Naval Research Grant N00014-90-J-1404.

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FOREWORD

The development of this catalogue is one product of many products and services managed and cost shared under the Memorandum of Understanding to support program development in naval architecture and marine engineering between the University of Michigan and the Naval Sea Systems Command of the U.S. Navy. The principal objective of this joint program is to produce reductions in ship acquisition costs through education and research that will lead to improvement of designs of ships and their supporting specifications.

This catalogue contains a Producibility Check-Off List, followed by associated abstracts. The Producibility Check-Off List presents brief descriptions of the content of each abstract. These abstracts are arranged according to the U.S. Navy ship work breakdown structure (WBS), in the same order that they appear in the preceding listing. Each abstract lists relevant information about the associated article. A more detailed description of the format of this catalogue and a typical search example are presented in the Index Layout section, page vii.

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INDEX LAYOUT

The abstracts that were collected during this study are organized according to the particular feature of the ship that they deal with. The US Navy ship work breakdown structure (WBS) classification scheme is utilized. This system uses a three-digit numerical code to designate a particular ship area, structural component, or system. For this index the following major subject headings are used:

000 General Comments
- Abstracts dealing with generalized producibility ideas, design considerations, and recommendations concerning the overall production philosophy of a shipyard.

100 Hull Structure
- Abstracts dealing with design and construction of the shell, framing, bulkheads, decks and machinery foundations of the ship.

200 Propulsion Plant
- Abstracts dealing with the propulsion engine and associated auxiliary systems.

300 Electric Plant
- Abstracts dealing with shipboard electrical systems and wiring arrangement.

500 Auxiliary Systems
- Abstracts dealing with the climate control system, water piping, steering control and other auxiliary systems.

600 Outfit and Furnishings
- Abstracts dealing with the general idea of pre-outfitting and outfitting in living, service and working spaces.

700 Armament
- Abstracts dealing with Naval weapons systems and auxiliaries.

The Producibility Check-Off List is the starting point for the use of the index. The above-mentioned major subject headings appear in boldface type, followed by underlined sub-headings which classify the abstracts more specifically. Brief summaries of abstracts appear under the appropriate heading or sub-heading, preceded by a unique number. The abstracts are arranged in the body of the index using this number. The (Ref: __) appearing after the summary indicates the book or paper from which the abstract was obtained, along with the page number(s).

Example:

Information concerning transverse framing arrangements is desired. First look in the Producibility Check-Off List under the major subject heading **100 Hull Structure** and read over the numerous sub-headings. Reading down these sub-headings, 117 Transverse Framing is found. After reading over the eight related summaries, the following seems most interesting:

117.8 Increasing frame spacing will generally increase weight but will decrease weld length (Ref: N-19)

N-19 indicates that reference N, page 19 is the source of this abstract. Reference N is listed under the **REFERENCES** section of the Producibility Check-Off List (pages 8-9). Following the Producibility Check-Off List is a detailed abstract of each line item appearing in the check-off list. The detailed descriptions appear in the same order as that shown in the check-off list. The abstract contains relevant information about the article, organized as follows:

UMTRI No. - This refers to the University of Michigan Transportation Research Institute classification number associated with the paper.

Publication, Title, Prepared by, Date - Other information about the paper.

a) **Description of Concept**
- A general synopsis of the content of the paper.

b) **Impact on Ship Characteristics**
- Describes the impact of the concept on ship characteristics such as length, beam, draft, displacement, speed, payload, etc.

c) **Cost Impact**
- The effect of the concept on the acquisition and/or operating cost of the ship.

d) **Performance Influence**
- A qualitative measure of the effect of the concept on performance characteristics such as mobility, survivability, and operability.

e) **Risk Assessment**
- A qualitative assessment of the risk involved by utilizing the concept. This risk could be technical uncertainty, schedule risk, or lack of confidence in cost estimates.

f) **Net Assessment**
- An overall assessment of the effect of the producibility concept on ship construction and subsequent operation.

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UNIVERSITY OF MICHIGAN
Department of Naval Architecture and Marine Engineering

PRODUCIBILITY CHECK-OFF LIST

(Revision 2, October 27, 1993)

000 General Comments

000.1 Design ship to facilitate assembly and erection with structural units, machinery units and piping units (Ref: K-257)
000.2 Establish unit breaks early in the design process (Ref: K-257)
000.3 Locate unit breaks for repetitive design and construction of the units (Ref: K-257)
000.4 Avoid excessively large units (Ref: K-258)
000.5 Block joints for engine-room double-bottom blocks are located above the grating level (Ref: M-55)
000.6 Where possible, each unit should have a flat area on which the remainder of the unit can be built up (Ref: L-71)
000.7 The maximum size of one unit and the maximum size of one flat panel should not exceed the capacity of each shop (Ref: L-71)
000.8 Where possible, P/S units should be similar (Ref: L-71)
000.9 The use of standard plate and stiffener sections should be maximized in a unit (Ref: L-71)
000.10 The maximum unit weight must not exceed the maximum lifting capacity or transporting vehicle which will handle it (Ref: L-71)
000.11 Weight of unit should be evenly distributed (Ref: L-71)
000.12 Allow parallel steel and outfit design to take place (Ref: R-1)
000.13 Provide work instruction information by "interim product" and zone rather than by "ship system" (Ref: R-3)
000.14 Producibility must be formally considered in "basic design" (Ref: R-5)
000.15 Concept of "notional" pipe banks and modules should be applied during allocation of space (Ref: R-7)
000.16 Design alternatives should be quantitatively analyzed for producibility (Ref: S-188-201)

068 <u>Integration and Engineering</u>
068.1 Hull construction, outfitting, and painting should be integrated (Ref: T-31)
068.2 Integrated Design Packages should be used in the overhaul of Navy ships (Ref: U-51-52)

070 <u>General Requirements for Design and Construction</u>
070.1 Preliminary design data should be available when performing detail design (Ref: V-120)
070.2 Standards should be applied to material identification and procurement (Ref: V-126)
070.3 Process capability of shipyard should be considered during design (Ref: W-139-140)

Revision supported by Memorandum of Understanding between Naval Sea Systems Command and University of Michigan. (Office of Naval Research Grant #N00014-90-J-1404). Project directed by Howard M. Bunch, NAVSEA Professor of Ship Production Science, University of Michigan.

090 Quality Assurance Requirements
090.1 Accuracy of ship blocks should be measured to reduce rework during erection (Ref: X-244-246)
090.2 Shape and relative location of ship blocks can be determined using an optical measuring system (Ref: Y-114-119)

100 Hull Structure

100.1 When there is a trade off between steel weight and man hours, conduct further analysis (Ref: K-259)
100.2 Design for use of automatic welding and other high-producibility tools (Ref: K-259)
100.3 Do not carry hull curvature into the structure inside of the hull plating surface (Ref: K-256)
101.1 Interval surfaces within the hull should be continuous wherever possible (Ref: B-3-2/202)

102 CVK
102.1 Height dependant on bilge radius and inner bottom depth (Ref: B-3-2/202)

110 Shell
110.1 Strakes same direction as primary framing (Ref: I-120)
110.2 Plate thickness transitions should be less than 0.5" (possibly 1.5t - needs research) (Ref: B-3-2/528)
110.3 Area of stiffener is less than area of attached effective plating (Ref: B-3-2/528)
110.4 Length of standard shell plates are to be integer multiples of the web frame spacing (Ref: L-71)
110.5 Standard plate size should be a function of stiffener and web spacing, so they are common for each plate (Ref: I-130)
110.6 Bilge strakes have the same thickness as bottom plates (Ref: L-70)
110.7 Insert plates that are the full strake width may reduce work content (Ref: I-130)

111 Shape
111.1 Parallel mid-body extended (Ref: B-3-2/106)
111.2 Sheer eliminated, or problems reduced by use of flat sheer w/ knuckles (Ref: I-49)
111.3 Camber problems eliminated, or problems minimized by use of knuckles (Ref: I-49)
111.4.1 Bulbous bow: use simple shapes, and knuckle attachment to stem, worker access (Refs: I-68, A-IV.1.B)
111.4.2 Simplify bow and stem shape (Ref: I-55)
111.5.1 Stern: skeg w/ knuckles (Ref: I-63.1)
111.5.2 Transom stern should be vertical and flat with sharp corner connection between shell and transom (Ref: I-55)
111.5.3 Stern frame should be easily fabricated as part of the stern module (Ref: I-68)
111.6 Section shape: flat bottom, sloped sides transitions with knuckles (Ref: I-63)

111.7.1 Curvature: flat panels, knuckles, single plane curvature, avoid double curvature (Ref: B-3-2/114)

111.7.2 Double curvature plates in single-screw after bodies can be eliminated by locating the transfer from convex to concave plates at plate seams and erection butts (Ref: I-68)

111.7.3 Hull shape near and above design waterline should be flat or simple curvature (Ref: Z-126)

111.8.1 Locate knuckles at unit breaks. Do not place knuckles either at or between bulkheads or decks but 9 to 12 in. from the bulkhead or deck where the deck will be made (K-258)

111.8.2 Locate chines parallel to the baseline, they can be used as module breaks (I-68)

111.9.1 Width of flat keel should be at least enough to extend over the keel blocks to allow welding of the erection seam for P/S modules (Ref: I-63)

111.9.2 Flat keel width is shipyard maximum plate width (Ref: I-63)

111.9.3 If flat keel seam is used as an erection break, the flat keel width must suit the module-joining method, including the internal structure (Ref: I-63)

111.10 Straight and convex waterlines are preferable (Ref: I-55)

111.11 In achieving maximum section coefficient, sloped sides should be considered as an alternative to deadrise (Ref: I-63)

111.12 Deadrise involves considerable additional work content compared to a flat bottom (Ref: I-63)

111.13 Bilge radius should be determined so that the side module erection joint is above the double bottom height or inboard of the tangent with the bottom in single bottom ships (Ref: I-63)

116 Longitudinal Framing

116.1 Angles preferred over Tees (Ref: A-IV.5.D)

116.2 Continuity of spacing and of shapes (Ref: B-3-2/503)

116.3 Match block breaks to framing direction (Ref: I-120)

116.4 Framing in direction of straking (Ref: I-120)

116.5 Standardization of Brackets and Connecting Arrangements (Ref: A-IV.5.A)

116.6 In a longitudinally framed ship, use bilge brackets rather than longitudinals in way of the bilge radius (Ref: I-148)

117 Transverse Framing

117.1 Best between cargo hatches (Ref: B-3-2/526)

117.2 Matched with strakes (Ref: I-120)

117.3 Advantage for longitudinally-run distributed systems (Ref: I-45)

117.4 Reduce depth of beams to facilitate fitting pipe runs under beams rather than through (Ref: M-55)

117.5 Continuity, with the exception of the peaks (Ref: I-34)

117.6 Include permanent holes in web frames for staging pipe (Ref: I-148)

117.7 Transverse web frame spacing less than 5 m (Ref: L-70)

117.8 Increasing frame spacing will generally increase weight but will decrease weld length (Ref: N-19)

120 Bulkheads
120.1 Consider tank testing before erection (Ref: I-45)
120.2 Match structural functions, e.g., subdivision, fire protection, etc., and maintain continuity (Ref: B-3-2/502)
120.3 Provide portions of bulkheads on block to facilitate fitting pipe penetrations (Ref: M-55)
120.4 Fairing into ends; avoid "crank" into tanks (Ref: B-3-2/208)
120.5 Include permanent holes in N.W.T. bulkheads for staging pipe (Ref: I-148)
123 Trunks, Enclosures, Cofferdams
123.1 Arrange at block divisions (Ref: I-120)
123.2 Similarity in bottom and side (wing) structures (Ref: B-3-2/508)
123.3 Trunks provided in deckhouse for vertical system runs, even at expense of increased weight (Ref: M-55)

130 Decks
130.1 Common deck heights (Ref: C-24)
130.2 Continuity (Ref: B-3-2/202)
130.3 Camber eliminated or straight camber (Ref: L-70)
130.4 Floor spacing should be less than 2.5 m and be half the web frame spacing (Ref: L-70)

136 Double Bottom
136.1 Needs continuity, common spacing and height (Ref: B-3-2/503)
136.2 Innerbottom: keep flat, especially in machinery spaces for foundations (Ref: A-IV.8.C)
136.3 U vs V section (Ref: B-3-2/204)
136.4 Height accessible for workers (Refs: B-3-2/204, I-41)
136.5 Longitudinal floors vice two sets of longitudinal stiffeners in shallow double bottom (Ref: A-IV.8.D)
136.6 Overlap transition in change of inner bottom heights (Ref: B-3-2/204)
136.7 No need to keep traditionally sized lightening holes (Ref: I-41)
136.8 Transverse framing allows smaller double bottom height (Ref: I-41)

150 Deck House
150.1 Flat and vertical surfaces (Ref: I-49)
150.2 Common modules for outfit (Ref: A-III.1)
150.3 Standard deck heights (Ref: C-24)
150.4 Transverse framing for reduced height (Ref: I-45)
150.5 Use of trunks, centerline passageways (Ref: G-11)
150.6 Provide only enough exterior decks to enable safe access and working of the ship (Ref: I-49)
150.7 Tween deck height should allow for high productivity overhead installations. (Ref: I-45)

161 Structural Castings, Forgings, and Equiv. Weldments
161.1 Standardize Navy vehicle tie-down design (Ref: Z-127-128)

180 Foundations
180.1 Use of epoxy chocks (Ref: E-1-2)
180.2 Multiple pieces on a foundation (Ref: I-161)
180.3 Minimize number of parts and unique parts (Ref: I-161)

180.4 Do not mix plate and shapes, i.e. foundation all plate or all shape (Ref: I-161)
180.5 Standardize on a few structural shapes (Ref: I-161)
180.6 Run support vertical (Ref: I-161)
180.7 Integrate "structural back-up" with foundation (Ref: I-161)
180.8 If securing bolts are not easily accessible use studs (Ref: I-161)
180.9 Eliminate fitting joints, maximize lapping design (Ref: I-161)
180.10 Use sheet metal independent drip pans in lieu of built in (Ref: I-161)
180.11 Incorporate foundations for deck machinery into equipment (Ref: I-179)

200 Propulsion Plant

200.1 Symmetry (Ref: I-35)
200.2 Standardized (Ref: A-III.4)
200.3 Modulize engine room (Ref: Q-151)
200.4 Systemically grouped (Ref: F-7)
200.5 Equipment removal routes (Ref: C-23)
200.6 Avoid unit breaks across machinery spaces, especially major foundations (Ref: I-199)
200.7 Block joints for engine-room double-bottom blocks should be located above the grating level (Ref: M-55)
200.8 Arrange machinery to minimize piping runs and improve operation and maintenance (Ref: K-258)
200.9 Place machinery installations for shop assembly and testing (Ref: K-258)

250 Systems Grouping
250.1 Equipment-association list should be prepared during on-unit outfitting for major machinery (Ref: I-1.7.3)
260 Support Systems
260.1 Integration with structure (Ref: I-199)

262 Lube Oil
262.1 Associate with equipment (Ref: I-1.7.3)

264 Lube Oil Handling
264.1 Minimize piping run lengths (Ref: I-202)
264.2 Valves should come up to the side of the grating and floor plates (Ref: I-206)
264.3 Use FRP piping where applicable (Ref: O-1-24)
264.4 Use removable-stud type pipe couplings between modules (Ref: P-4-5)
264.5 Run pipes parallel to ship's x-y-z axis (Ref: M-55)

300 Electric Plant

300.1 Grouping and Routing (Ref: B-3-2/402)
300.2 Systems grouping near distribution centers (Ref: I-225)

320 Power Distribution
320.1 High voltage main distribution (Ref: C-9)
320.2 Cable breaks at unit breaks (Ref: I-225)
320.3 Post vice two-arm hangers. Avoid wire pulling situations (Ref: I-225)

500 Auxiliary Systems

500.1 Grouping and Routing (Ref: B-3-2/204)
500.2 Proximity to distribution system (Ref: C-9)
500.3 Dedicated distribution system (Ref: H-1,2,9)
500.4 Access and equipment removal (Ref: I-206)
500.5 For zone-oriented pipe runs, locate surfaces of pipes to be on same plane, not their center line (Ref: M-58)
500.6 Minimize piping run lengths (Ref: I-202)
500.7 Valves should come up through and to the side of the grating and floor plates (Ref: I-206)
500.8 Use FRP piping where applicable (Ref: O-1-24)
500.9 Run pipes parallel to ship's x-y-z axis (Ref: M-55)
500.10 Use removable-stud type pipe couplings between modules (Ref: P-4-5)

510 Climate Control
510.1 HVAC runs in trunks (Ref: G-11)
510.2 Combine with other distributed systems (Refs: H-10, I-221)
510.3 Simplify shaped-duct sections (Ref: I-221)

520 Sea Water
520.1 Pipe bends not greater than 2-pipe diameters (Ref: G-13)
520.2 Locate inboard to avoid following hull curves (Ref: H-2,9)

560 Ship Control Systems

561 Thrusters

562 Rudder
562.1 Cantilevered spade is the easiest (Ref: I-161)
562.2 Constant section throughout depth (Ref: I-161)
562.3 Vertical leading and trailing edges (Ref: I-161)
562.4 Horizontal bolting coupling instead of taper with nut (Ref: I-161)

581 Anchor Handling
581.1 Simplicity of system: straight, chain pipe; stowage on deck vice hawse (Ref: A-IV.2.A)

600 Outfit and Furnishings

600.1 Standardize (Ref: C-3)
600.2 Arrange concentrations away from unit breaks (Ref: C-3)
600.3 Arranged for pre-outfit (Ref: C-3)
600.4 Grouping and Routing (Ref: B-3-2/402)

630 Preservatives and Coverings

631 Painting
631.1 Special coating tanks totally within a block (Ref: I-1.3.2 h)

635 Hull Insulation
635.1 Apply hull insulation to joiner linings and ceiling, instead of inside surfaces of hull and deckhouse structure (Ref: I-179)

640 Living Spaces
640.1 Use of composite dividers (Ref: I-179)
640.2 Standardize modules (Ref: I-179)
640.3 Keep furniture off deck, supported by joiner bulkheads (Ref: I-179)
640.4 Use carpet over bare steel in cabins. (Ref: I-179)
640.5 Use modular galley equipment (Ref: I-179)

650 Service Spaces
650.1 Grouping to supply systems (Ref: B-3-2/304)

660 Working Spaces
660.1 Reverse framing in electrical spaces for false floors (Refs: C-16)
660.2 Use troweled-in-place deck covering (Ref: I-179)

700 Armament

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Y. "An Approach to a New Ship Production System Based on Advanced Accuracy Control", Masaaki Yuzaki and Yasuhisa Okomoto, Journal of Ship Production, May 1993, UMTRI# 58785.

Z. "Reducing the Construction Contract Cycle for Naval Auxiliary Ships", Mark H. Spicknall and Michael Wade, Journal of Ship Production, May 1993, UMTRI# 58786.

ABSTRACTS

WBS Reference No. 000.1
General Comments; Unit Construction

UMTRI No.	57859
Publication	Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 257.
Title	"Producibility in Ship Design"
Prepared by	Gilbert L. Kraine and Sigurdur Ingvason
Date	November 1990

Concept Assessment:

a) Description of Concept

Design the ship to facilitate assembly and erection with structural units, machinery units and piping units. This is the key to modular (unit) construction. By building the ship in units, the work can be spread over the area of the shipyard. This improves access to the work and reduces interference, in contrast to the older approach of assembling the ship piece-by-piece on the building ways, which concentrates all of the work in one small area.

b) Impact on Ship Characteristics

c) Cost Impact

Construction by units requires design by units. Units should be designed to simplify the construction and erection processes to attain the greatest cost savings from modular construction.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.2

General Comments; Early Establishment of Unit Breaks

UMTRI No. 57859

Publication . . . . . . Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 257.

Title . . . . "Producibility in Ship Design"

Prepared by . . . . . . Gilbert L. Kraine and Sigurdur Ingvason

Date . . . . November 1990

Concept Assessment:

a) Description of Concept

Establish unit breaks early in the design process and locate the breaks for repetitive design and construction of the units.

b) Impact on Ship Characteristics

c) Cost Impact

The unit break locations can be critical to cost reduction. For ships such as tankers and other bulk carriers, the structure is repetitive, and careful location of the unit breaks allows the units to be fabricated identically. Equipment located across a break cannot be installed until the units have been erected. Equipment installed on the building ways after the units are erected is typically more costly to install. Early location of break units also permits the designer to locate machinery and equipment in positions which facilitate unit outfitting.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.3

General Comments; Establish Unit Breaks for Repetitive Design

UMTRI No. 57859
Publication ...... Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 257.
Title .... "Producibility in Ship Design"
Prepared by ...... Gilbert L. Kraine and Sigurdur Ingvason
Date .... November 1990

Concept Assessment:

a) Description of Concept

Locate unit breaks for repetitive design and construction of the units. The unit break locations can be critical to cost reduction. For ships such as tankers and other bulk carriers, the structure is repetitive, and careful location of the unit breaks allows the units to be fabricated identically. Identical units can be built from one set of plans with a resultant savings in engineering man-hours as well as cost benefits from assembly-line type construction. Location also affects ease of erection. It is easier if the joint in one unit is stiff while the other is flexible.

b) Impact on Ship Characteristics

c) Cost Impact

If identical units can be used for construction, savings can be made due to reduced engineering man-hours required for design, as well as cost benefits from assembly-line type construction.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.4
General Comments; Unit Size

UMTRI No. 57859
Publication ...... Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 258.
Title .... "Producibility in Ship Design"
Prepared by ...... Gilbert L. Kraine and Sigurdur Ingvason
Date .... November 1990

Concept Assessment:

a) Description of Concept

Avoid excessively large units. Unit sizes are frequently established by the maximum lifting capacity of the shipyard. However, as the unit increases in size, the problems of access, congestion and interference at the work site increase. A very large unit may present problems on the order of building a small ship. Making use of the maximum lifting capacity may not be the lowest cost construction approach.

b) Impact on Ship Characteristics

c) Cost Impact

Because difficulties with access and construction congestion increase with increased size, making use of the maximum lifting capacity may not be the lowest cost construction approach.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.5
General Comments; Unit Construction

UMTRI No.	48928
Publication	The National Shipbuilding Research Program (NSRP # 0179, pg. 55)
Title	"Design for Zone Outfitting"
Prepared by	U.S. Department of Transportation, Maritime Administration, in cooperation with Todd Pacific Shipyards Corporation
Date	September 1983

Concept Assessment:

a) Description of Concept

Block Joints for engine room double bottom blocks are located above the grating level so that fittings can progress in this normally congested region to the fullest extent before hull erection. That is, space does not have to be reserved adjacent to block joints for access during erection welding.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.6
General Comments; Unit Configuration

UMTRI No.	57721
Publication	Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 71.
Title	"Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by	K.S. Bong, William Hills, and John B. Caldwell
Date	May 1990

Concept Assessment:

a) Description of Concept

Where possible, each unit should have a flat area on which the remainder of the unit can be built up. This saves man-hours by eliminating the need of constructing a jig system.

b) Impact on Ship Characteristics

c) Cost Impact

Saves man-hours by eliminating the need of constructing a jig system.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.7
General Comments; Maximum Unit Size

UMTRI No.	57721
Publication	Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 71.
Title	"Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by	K.S. Bong, William Hills, and John B. Caldwell
Date	May 1990

Concept Assessment:

a) Description of Concept

The maximum size of one unit, and the maximum size of one flat panel should not exceed the capacity of each shop.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.8
General Comments; Unit Configuration

UMTRI No. 57721
Publication ...... Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 71.
Title .... "Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by .... K.S. Bong, William Hills, and John B. Caldwell
Date .... May 1990

Concept Assessment:

a) Description of Concept

Where possible, units should be made similar port and starboard to minimize production costs.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.9
General Comments; Unit Components

UMTRI No. 57721
Publication . . . . Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 71.
Title . . . . "Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by . . . . . . K.S. Bong, William Hills, and John B. Caldwell
Date . . . . May 1990

Concept Assessment:

a) Description of Concept

The use of standard plate and stiffener sections should be maximized in a unit.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.10
General Comments; Unit Weight

UMTRI No.	57721
Publication	Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 71.
Title	"Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by	K.S. Bong, William Hills, and John B. Caldwell
Date	May 1990

Concept Assessment:

a) Description of Concept

The weight of a unit must not exceed the maximum lifting capacity of the transporting vehicle which will handle it.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.11
General Comments; Unit Weight

UMTRI No.	57721
Publication	Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 71.
Title	"Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by	K.S. Bong, William Hills, and John B. Caldwell
Date	May 1990

Concept Assessment:

a) Description of Concept

If possible, the weight of a unit should be evenly distributed when it is transported.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.12
General Comments; Unit Outfitting

UMTRI No.	81970
Publication	British Shipbuilders Performance Improvement & Productivity Publication, pg. 1.
Title	"Guidelines for the Preparation of a Ship Definition Strategy"
Prepared by	Dr. David R. Martyr, P.I.P. Department
Date	November 1984

Concept Assessment:

a) Description of Concept

Allow parallel steel and outfit design to take place to enable advanced outfitting methods to be achieved, which implies significantly shorter outfit design and procurement lead times.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.13

General Comments; Unit Constuction

UMTRI No.	81970
Publication	British Shipbuilders Performance Improvement & Productivity Publication, pg. 3.
Title	"Guidelines for the Preparation of a Ship Definition Strategy"
Prepared by	Dr. David R. Martyr, P.I.P. Department
Date	November 1984

Concept Assessment:

a) Description of Concept

Provide work instruction information by "interim product" and "zone" rather than by "ship system". Ship construction is becoming more efficient by the application of group technology which enables process lanes for the production of interim products to be established, and organization of work in a consistent manner within zones, by stage.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.14

General Comments; Unit Producibility in Design

UMTRI No.	81970
Publication	British Shipbuilders Performance Improvement & Productivity Publication, pg. 5.
Title	"Guidelines for the Preparation of a Ship Definition Strategy"
Prepared by	Dr. David R. Martyr, P.I.P. Department
Date	November 1984

Concept Assessment:

a) Description of Concept

To become more competitive, producibility must be formally considered in "basic design", since it is at this stage that the designer has maximum influence over the construction cost. Producibility may best be ensured by consideration of the facilities available and preferred production methods and achievable tolerances.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.15
General Comments; Unit Design

UMTRI No..	81970
Publication	British Shipbuilders Performance Improvement & Productivity Publication, pg. 7.
Title	"Guidelines for the Preparation of a Ship Definition Strategy"
Prepared by	Dr. David R. Martyr, P.I.P. Department
Date	November 1984

Concept Assessment:

a) Description of Concept

The concept of "notional" pipe banks and modules should be applied during the allocation of space. A notional pipe-bank reserves space which can be loaded as system diagrammatics become available, and provides a discipline to maximize manufacturing productivity (through the use of 45° and 90° pipe bends) and assembly/installation productivity by providing "natural" pipebanks. Equipment groupings should also be considered at this stage to enable early module indentification.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 000.16

General Comments; Producibility of Design Alternatives

UMTRI No.	(NA)
Publication	Journal of Ship Production, Vol. 9, No. 3, Aug. 1993, pp. 188-201.
Title	"Evaluating the Producibility of Ship Design Alternatives"
Prepared by	James R. Wilkins, Jr., Gilbert L. Kraine, and Daniel H. Thompson
Date	August 1993

Concept Assessment:

a) Description of Concept

Two techniques are presented for evaluating the construction cost difference of design variants, based on actual work content of the design rather than the weight of the resulting structure. The first is the use of spreadsheet-based cost estimating computer programs (CECOPs) to perform a differential analysis on alternative designs. This results in a quantitative cost of one design versus another. The second technique is an application of the Analytic Hierarchy Process (AHP), which yields a relative comparison of the two alternatives. This technique does not require "hard" numerical data to be effective, and it is suggested that the AHP method could be used as a preliminary to the use of CECOPs.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

These techniques are valuable to managers during early design stage decision making as well as during detail design. They can be applied both to small-scale and large-scale design alternative analysis.

WBS Reference No. 068.1
General Comments; Production Process Integration

UMTRI No.	58310
Publication	Journal of Ship Production, Vol. 8, No. 1, Feb. 1992, pg. 31.
Title	"A Return to Merchant Ship Construction: The International Impact of the NSRP and American Technology"
Prepared by	Antonio Sarabia and Rafael Gutierrez
Date	February 1992

Concept Assessment:

a) Description of Concept

The integration of the three production processes, specifically hull construction, outfitting, and painting, leads to an efficiently constructed ship. This integration involves organizing each of the production teams into specialized groups, which then perform their assigned duties. Also, the production processes are broken down using Group Technology logics. Relationships between stages of production based on a "pull" philosophy are then formed.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

This concept is applied to the overall production scheme of the shipyard. It involves a company moving from a traditional production system to an advanced production system.

WBS Reference No. 068.2
General Comments; Integrated Design Packages

UMTRI No.	58688
Publication	Journal of Ship Production, Vol. 9, No. 1, Feb. 1993, pp. 51-52.
Title	"Integrated Design Packages: The Link Between Manufacturing and Design"
Prepared by	William Arguto
Date	February 1993

Concept Assessment:

a) Description of Concept

An Integrated Design Package (IDP) is a design document showing all work to be performed in a limited area that provides a more producible installation with no major interferences. IDPs are recommended in the overhaul of Navy ships. Examples include large and complex alterations, compartments involving many different engineering and production shops, and gutted compartments. Shipboard visits are first performed to document the existing conditions of the area. Then a CAD model of the area is created. A producibility review is performed, followed by review for interferences between systems and for adequate clearances in the design. When the CAD model is found to be satisfactory, assembly drawings are developed directly from the model. Also, opportunities for prefabrication and preoutfitting of assemblies are reviewed.

b) Impact on Ship Characteristics

c) Cost Impact

Since an IDP shows all work to be performed in an area, planning, scheduling and sequencing are performed more efficiently. Because a CAD model is generated, CAM information can be transferred electronically, saving a great deal of time and effort. This transfer of information can be extended to include material ordering, scheduling and estimating.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

The main goal of an IDP is to create an interference-free work area, which minimizes rework and delays. The installation of systems is made easier because of the producibility review. The IDP follows the product approach to engineering, since it represents all work in an area, not just system-by-system.

WBS Reference No. 070.1
General Comments; Producibility in Detail Design

UMTRI No.	(NA)
Publication	Journal of Ship Production, Vol. 8, No. 2, May 1992, pg. 120.
Title	"Infrastructure Study in Shipbuilding: A Systems Analysis of U.S. Commercial Shipbuilding Practices"
Prepared by	Michael Wade and Zbigniew J. Karaszewski
Date	May 1992

Concept Assessment:

a) Description of Concept

Detail design, in which ship configuration and material requirements are precisely defined, should not occur separately from the earlier design efforts. If this occurs, redundant design work is likely to be done, wasting a great deal of time. Further, if a design firm independent of the shipyard performs the detail design, the production methods and processes unique to the shipyard will be neglected. This reduces the producibility of the resulting detail design.

b) Impact on Ship Characteristics

c) Cost Impact

Performing the detail design while having access to preliminary design significantly reduces the probability of redundant work being done, thereby reducing the number of man hours required to complete the detail design.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 070.2
General Comments; Application of Standards

UMTRI No.	(NA)
Publication	Journal of Ship Production, Vol. 8, No. 2, May 1992, pg. 126.
Title	"Infrastructure Study in Shipbuilding: A Systems Analysis of U.S. Commercial Shipbuilding Practices"
Prepared by	Michael Wade and Zbigniew J. Karaszewski
Date	May 1992

Concept Assessment:

a) Description of Concept

Standards should be applied to the areas of material identification and procurement. Design modules frequently used in various types of ships should be classified as standard design modules. This would allow material requirements to be quickly defined. Suppliers of material should also be subject to product quality, delivery and cost standards. Once a vendor is found to meet these standards, the vendor should be used as often as possible. Also, custom-built items should be produced from standard shapes and sizes of material.

b) Impact on Ship Characteristics

c) Cost Impact

The use of standards reduces labor hours in a number of ways. First, standard design modules reduce the time necessary for material requirements identification. Second, vendors which meet set standards assure the shipyard that deliveries will be made on schedule, eliminating some worker idleness. Finally, the use of standard shapes and sizes of material when possible minimizes the time required to produce the components of custom assemblies.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 070.3

General Comments; Process Capability Awareness in Design

UMTRI No. 58468

Publication . . . . . Journal of Ship Production, Vol. 8, No. 3, Aug. 1992, pp. 139-140.

Title . . . . "A Future Role of Quality in Shipbuilding - Reducing the Odds"

Prepared by . . . . . . M. Raouf Al-Kattan

Date . . . . August 1992

Concept Assessment:

a) Description of Concept

Appropriate information should be provided to designers and planners to ensure that designs and subsequent production schedules are feasible. This information results from problems uncovered by previous production experiences. When rework occurs, statistical process control techniques and merging equations should be used to determine how much rework is needed and what should be changed to reduce it in the future. When this data is fed back to the planning stage, allowances can be made for rework levels, leading to a more accurate production schedule.

b) Impact on Ship Characteristics

c) Cost Impact

When a vessel is designed without a knowledge of process capability, undesirable levels of rework occur. This is costly in terms of additional labor hours and also because the overall production schedule is delayed.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 090.1

General Comments; Accuracy of Blocks During Erection

UMTRI No.	58621
Publication	Journal of Ship Production, Vol. 8, No. 4, Nov. 1992, pp. 244-246.
Title	"Productive Method and System to Control Dimensional Uncertainties at Final Assembly Stages in Ship Production"
Prepared by	Markku Manninen and Jarl Jaatinen
Date	November 1992

Concept Assessment:

a) Description of Concept

The dimensional and positional accuracy of ship blocks is vital to minimize rework at the hull erection stage in ship production. Vital points, permanently marked on each block, are used for taking control measurements throughout the different assembly stages. A single-operator ACMETER MC-type optical coordinate meter is recommended for this task. These measurements are used by the production team for instant corrective decisions during assembly. The accuracy data can also be fed back to the planning department for future production improvements.

b) Impact on Ship Characteristics

c) Cost Impact

Rework costs during hull erection are reduced through the use of dimensional and positional accuracy controls.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 090.2

General Comments; Hull Structure Accuracy Measurement

UMTRI No.	58785
Publication	Journal of Ship Production, Vol. 9, No. 2, May 1993, pp. 114-119.
Title	"An Approach to a New Ship Production System Based on Advanced Accuracy Control"
Prepared by	Masaaki Yuzaki and Yasuhisa Okomoto
Date	May 1993

Concept Assessment:

a) Description of Concept

A measuring system using near-infrared rays (MONMOS) is incorporated with a personal computer-based hull block measuring system to represent the shape of a hull block. The MONMOS system uses triangulation to record 3-D coordinates of data points on the hull block. The measured form of the block is compared to the designed form and discrepancies are used as guidance during erection. In addition to positioning a block relative to adjacent blocks, this system can be used to position a block in the ship's absolute coordinate system.

b) Impact on Ship Characteristics

c) Cost Impact

Accurately produced blocks will fit up more efficiently during erection. This system saves a great deal of man hours during erection because of the reduction of rework. Also, positioning blocks in the ship's absolute coordinate system increases overall accuracy, thus reducing erection time.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 100.1
Hull Structure; Weight vs. Manhours

UMTRI No.	57859
Publication	Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 259.
Title	"Producibility in Ship Design"
Prepared by	Gilbert L. Kraine and Sigurdur Ingvason
Date	November 1990

Concept Assessment:

a) Description of Concept

Frequently limits on displacement, lightship, or full losd are attempts to limit the cost of the ship. Trade-offs between weight and cost therefore are possible.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 100.2
Hull Structure; Producibility Design

UMTRI No.	57859
Publication	Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 259.
Title	"Producibility in Ship Design"
Prepared by	Gilbert L. Kraine and Sigurdur Ingvason
Date	November 1990

Concept Assessment:

a) Description of Concept

Design for use of automatic welders and other high-productivity tools.

b) Impact on Ship Characteristics

c) Cost Impact

Care in the design of welding details can decrease the man-hours required.

d) Performance Influence

The welding processes to be used should be considered during the design. The use of straight sections and single-curvature plates improve welding productivity by facilitating the use of automatic welding machines for the work. Care in design can permit the erection sequence to be planned for increased downhand of automatic welding. Care in the design of welding details not only can decrease the man-hours required but also can improve the quality of the welds.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 100.3
Hull Structure; Hull Curvature

UMTRI No.	57859
Publication	Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 256.
Title	"Producibility in Ship Design"
Prepared by	Gilbert L. Kraine and Sigurdur Ingvason
Date	November 1990

Concept Assessment:

a) Description of Concept

Do not carry the hull curvature into the structure inside of the hull plating surface. Use straight lines and flat surfaces wherever possible. Even though the hull lines are curved, there is no need to bring the exterior hull shape into the interior hull structure. The internal structure must support the hull plating but also serve as a transition between the curves of the hull exterior and the straight lines and flat surfaces of the interior.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 101.1
Hull Structure; Continuity

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/202.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

It is desirable both from a structural and producibility point of view that internal surfaces within the hull should be continuous wherever possible and that they should lie within the principal planes.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

Structural discontinuity leads to the need for local compensation and hence increased complexity which leads in turn to additional material having to be fitted in a piecemeal fashion. It is also structurally less efficient.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 102.1
Hull Structure; CVK

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/202.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

Classification societies have rules governing the minimum depths of the center girder (or CVK); any depth equal to or greater than this will be acceptable to them. If the rule depth is less than the bilge radius, consideration may be given to increasing the depth. In order to simplify assembly and to reduce the need for jigs to support curved plates, it is desirable that the internal structure should be of greater depth than the bilge radius.

b) Impact on Ship Characteristics

c) Cost Impact

Savings made by eliminating need for jigs.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 110.1
Plate Straking

UMTRI No. 72960
Publication . . . . The National Shipbuilding Research Program
(NSRP # 0219, pg.120, ¶ 3)
Title . . . . "Engineering for Ship Production"
Prepared by . . . . Thomas Lamb, Private Consultant
Date . . . . January 1986

Concept Assessment:

a) Description of Concept

The consideration of the framing method-that is, transverse of longitudinal-and plate straking direction should be performed together. This because, in general, straking should be in the same direction as the framing. This is to eliminate the need for rat holes over plate butt welds or for grinding down plate butt welds in way of frames crossing the welds. Obviously, this cannot be adhered to in all cases, especially bulkheads where the plating thickness varies with depth and vertical stiffening is generally preferred. In cases where the plate strakes vary in thickness, it may be better to locate the stiffeners on the uneven surface running parallel to the plate strakes. This would require horizontal stiffeners with varying scantlings, which is probably not a minimum work content approach. From a producibility point of view it is probably better to use vertical plate straking and vertical stiffeners, even though there will be an increase in weight due to the constant bulkhead plating thickness.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

The age-old practice of keeping the molded side of the plating flush where plating strakes vary in thickness is a problem for panel lines due to requiring the upper surface of the panel to be flat for installation of stiffening.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 110.2
Hull Structure; Shell

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pg. 3-2/528.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

To increase a deficient midship section modulus, material has to be added to the plating or longitudinals, or both, in the region of the deficiency. If material is added to the plating alone, and the thickness of the plating outside the hatchways is greater than that between the hatchways by approximately 0.5 inch, then a strake of plating having a thickness mid-way between these two thicknesses will have to be inserted.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 110.3
Hull Structure; Shell

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pg. 3-2/528.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

To increase a deficient midship section modulus, material has to be added to the plating or longitudinals, or both, in the region of the deficiency. If some or all of the material is added to the longitudinals the following points should be noted: 1) As a general rule the area of longitudinals should not exceed the area of the plating to which they are attached. 2) The amount of material required will be greater than if material was added to the plating alone.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 110.4
Hull Structure; Shell Plating

UMTRI No.	57721
Publication	Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 71.
Title	"Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by	K.S. Bong, William Hills, and John B. Caldwell
Date	May 1990

Concept Assessment:

a) Description of Concept

The maximum length of a standard plate is based upon one cargo hold length and the transverse web frame spacing; that is, the longer length should be the same as one hold length and should also be an integer multiple of web frame spacing. The shorter plate length is half the longer one. If the cargo hold length is prescribed and is larger than the maximum permissible plate length, the longer std. plate length should be defined as half the hold length, based on the idea of minimizing work content (i.e. welding and cutting). In this case, the shorter plates are the same length as the longer ones.

b) Impact on Ship Characteristics

c) Cost Impact

Savings due to minimizing work content, and potentially from reducing material wastage.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 110.5
Shell Plate Size

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.130, ¶ 4)
Title	Engineering for Ship Production
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The obvious goal for shell straking is to standardize the plates. A standard plate should not only be identical in size, but also in marking, bevelling, etc. This can only be accomplished by locating the stiffeners and webs in the same position on each plate. To do this, two options are possible. One is to consider stiffener and web spacing to suit the maximum width and length of plates to be used. The other is to select plate width and length to suit desired stiffener and web spacing.

b) Impact on Ship Characteristics

c) Cost Impact

When this approach is applied to decks, bulkheads, and tank tops, its impact can be a significant reduction of engineering, lofting, and production manhours.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

Correctly applied, the number of different shell plates in the parallel body of a tanker or bulkcarrier can be as few as five. It also makes the use of special tooling practical, as the small number involved can be cost-effective.

WBS Reference No. 110.6
Hull Structure; Shell

UMTRI No.	57721
Publication	Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 70.
Title	"Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by	K.S. Bong, William Hills, and John B. Caldwell
Date	May 1990

Concept Assessment:

a) Description of Concept

In determining the scantlings, bilge strakes should have the same thickness as bottom plates.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 110.7
Shell Insert Plates

UMTRI No. 72960
Publication . . . . . . The National Shipbuilding Research Program (NSRP # 0219, pg.130, ¶ 5)
Title . . . . "Engineering for Ship Production"
Prepared by . . . . . . Thomas Lamb, Private Consultant
Date . . . . January 1986

Concept Assessment:

a) Description of Concept

Work content can be reduced by making the insert plate the full strake width, thus significantly reducing the amount of additional welding. The chamfering of the insert plate can be eliminated by increasing the plating surrounding the insert plate to that necessary to gradually build up to the required insert plate thickness in steps allowed by the classification rules without chamfering.

b) Impact on Ship Characteristics

c) Cost Impact

Work content can be reduced by following this practice.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.1
Hull Structure; Shape- Parallel Midbody

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pg. 3-2/106.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

Increasing the parallel midbody length will increase the number of identical elements within the midship portion of the ship.

b) Impact on Ship Characteristics

If the "shoulders" formed at the fore and aft of the parallel midbody section due to extension become "hard" (too severe), hydrodynamic problems can occur. If the angle of run into the propeller is too steep, flow separation can occur which will drastically reduce propulsive efficiency.

c) Cost Impact

d) Performance Influence

If the angle of run into the propeller is too steep, flow separation can occur which will drastically reduce propulsive efficiency.

e) Risk Assessment

Care should be taken when extending the parallel midbody section to avoid performance degradation due to excessive shape.

f) Net Assessment

WBS Reference No. 111.2
Deck Sheer

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.49, ¶ 3)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Eliminate deck sheer when possible. So-called "straight line" sheer has higher work content than no sheer but less than a traditionally sheered deck. "Straight line" consists of a straight horizontal deck line over the amidship portion of the ship, and straight line angled decks forward and sometimes aft.

b) Impact on Ship Characteristics

It is true that sheer impacts the survivability of a ship due to the greater depth to the margin line forward and aft, and this is why ships with no sheer pay a freeboard penalty. Sheer also influences deck wetness, but ships with no sheer can counteract this disadvantage by incorporating a forecastle and/or proper bow flare forward.

c) Cost Impact

Eliminating sheer reduces work content when compared with a sheered deck. This is due to eliminating the need to shape the deck, angle the beams, and bend the longitudinal girders.

d) Performance Influence

e) Risk Assessment

May affect deck wetness if not incorportated with proper bow flare and/ or a forecastle.

f) Net Assessment

WBS Reference No. 111.3
Deck Camber

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.49, ¶ 4)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Work content can be reduced by eliminating camber or by using "straight line" camber. Straight line camber is made up of either two lines peaking at the center or three lines with the middle line horizontal, and the outboard lines sloping down to the deck edge. If the deckhouse is designed with a minimum of weather deck area, then there is no need for camber on the decks in the deckhouse.

b) Impact on Ship Characteristics

c) Cost Impact

Eliminating camber reduces work content when compared with a cambered deck. This is due to eliminating the need to shape the deck, angle the beams, and bend the transverse girders.

d) Performance Influence

Some argue that that it is operationally acceptable to eliminate camber because ships are seldom level when at sea, and even when in port they have trim and list.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.4.1
Bulbous Bow

UMTRI No.	(1) 72960
	(2) 84701
Publication	(1) The National Shipbuilding Research Program (NSRP # 0219, pg.68, ¶ 3)
	(2) AOE-6 Producibility Review, Sec. IV.1.B
Title	(1) "Engineering for Ship Production"
	(2) "AOE-6 Producibility Review"
Prepared by	(1) Thomas Lamb, Private Consultant
	(2) Advanced Technology, Inc.
Date	(1) January 1986
	(2) August 1985

Concept Assessment:

a) Description of Concept

From a producibility point of view, the preferred shape of the bulb in the transverse plane is a circle. This can have some operating disadvantages such as bottom slamming in seaway. Next preferred shape that does not have the slamming problem is an inverted teardrop, but it has a higher work content than a circle. A good compromise between design and production requirement is an inverted tear-drop constructed from parts of two cylinders, two spheres, a cone, and two flats. A similar approach to developing producible details should be applied to other types of bulbous bows for large slow-speed full-hull-form ships, such as tankers.(1)

Partial stem castings have been used for bulbous bows where they are faired into the shell. The casting can be omitted if the bulb connection to the shell is a knuckle.(1)

The use of a straight knuckle, instead of a curved one, to join the bulb to the hull would simplify the construction in this area.(2)

b) Impact on Ship Characteristics

WBS Reference No. 111.4.1
Bulbous Bow (cont'd.)

c) Cost Impact

Work content will be reduced if simple shapes are used to construct the bulbous bow.(1)

Joining the upper surface of the bulb to the stem with a straight piece instead of a complex curve radius piece will reduce the cost of construction. (2)

d) Performance Influence

e) Risk Assessment

The overall pupose of the bulbous bow, to reduce wave making resistance of the ship, should not be forgotten when striving for a producible bow shape.(1)

f) Net Assessment

WBS Reference No. 111.4.2
Bow Stem Shape

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.55, ¶ 1)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Use a straight line stem where practical. The fore foot radius should be selected to assure fair shell plates at the foot shell stem connection. The simplest stem is one formed from a cone. To ensure that the fore foot shell plating will be fair, it is necessary to treat this part of the hull in more detail with closer water lines and additional frames. By proper attention to the production aspects of the stem shape, the need for a stem casting can be eliminated. The only reason stem castings are used today is because the complexity of the design necessitates it.

b) Impact on Ship Characteristics

Using a stem formed from a cone will give elliptical waterline endings, *not* circular, as most designers use.

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

Curved stems may look good but are costly. Even slight departures from a straight-line stem will add to the difficulty in fabricating it.

WBS Reference No. 111.5.1
Stern Frame

UMTRI No. 72960
Publication . . . . . . The National Shipbuilding Research Program
(NSRP # 0219, pg.63, ¶ 1)
Title . . . . "Engineering for Ship Production"
Prepared by . . . . . . Thomas Lamb, Private Consultant
Date . . . . January 1986

Concept Assessment:

a) Description of Concept

Select stern lines and propeller aperture shape to enable the stern frame to be easily fabricated as part of the stern module. Stern frame should be designed not as a casting but as a fabricated shape.

b) Impact on Ship Characteristics

Stern frame castings enable complex shape to be incorporated in the design. Complex shape cannot be incorporated in the stern frame when designing for it to be fabricated as part of the stern module.

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.5.2

Stern-above waterline

UMTRI No. 72960
Publication . . . . . . The National Shipbuilding Research Program
(NSRP # 0219, pg.55, ¶ 5)
Title . . . . "Engineering for Ship Production"
Prepared by . . . . . . Thomas Lamb, Private Consultant
Date . . . . January 1986

Concept Assessment:

a) Description of Concept

Transom stern should be considered because of its construction economy and its ability to maintain deck width aft. By sloping the stern in profile and providing curvature in plan view as well as large radius corner connection between shell and transom, additional work content is introduced. To be of minimum work content, the transom should be vertical and flat, with sharp corner connection between shell and transom.

b) Impact on Ship Characteristics

The transom stern when used on high speed ships can result in an effective increase in waterline length, which proves beneficial from the resistance point of view.

Transom sterns allow for more deck area aft, due to the additional deck width.

c) Cost Impact

Transom sterns are generally more economical to construct.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.5.3

Single Screw Stern-below waterline

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.68, ¶ 1)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The reverse curvature commonly found in single-screw aft bodies can be eliminated by carefully locating the transfer from convex double-curvature plates to concave plates at plate seams and erection butts. Even though double-curvature plates have less work content than reverse-curvature plates, it still significant. One way to reduce the work content of the after-body even further is to separate the normal single-screw after-body into two parts, namely, the main hull and a skeg. This can be done in two ways. The first way is to attempt to follow the normal single-screw hull form lines as closely as possible by incorporating a chine or multi-chines joined in section by straight lines or simple curves. The chine should lie in flow lines to prevent cross-flow turbulence. the second way is to design the after-body as a twin-screw warship type, and to add a skeg which can incorporate the shaft and its bearings.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

Both methods mentioned above of reducing work content even further can usually be used without any adverse impact on propulsion power.

e) Risk Assessment

f) Net Assessment

The latter approach mentioned above has the least work content.

WBS Reference No. 111.6
Sectional Shape

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.63, ¶ 3)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Sloped sides should be considered as an alternative to rise of floor as a means of achieving the required maximum section coefficient.

b) Impact on Ship Characteristics

When using sloped sides there are layout advantages of wider decks without resistance penalty for increased waterline beam required with vertical sides.

Better heeled stability with sloped sides.

c) Cost Impact

Rise of floor involves considerable additional work content compared to a flat bottom.

d) Performance Influence

e) Risk Assessment

Eliminating rise of floor could present tank drainage problems in some situations. Rise of floor aids in tank drainage when the ship is in drydock completely upright. Any other time, the ship will be either trimmed or listed or both, and the usual small amount of rise of floor is of no benefit.

Sloped sides can present docking and tug handling problems.

f) Net Assessment

Rise of floor involves considerable additional work content compared to a flat bottom.

WBS Reference No. 111.7.1
Hull Structure; Shape- Hull Curvature

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/114-119.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

Design time spent on the above water form removing as much curvature as possible can be repaid many times over during production of the hull structure. Items meriting consideration when reducing hull curvature include: flare, cargo stowage, sheer, camber, stern, and deckhouses/ superstructure.

b) Impact on Ship Characteristics

Flare- the amount of flare influences the quantity of forward deck area, and deck wetness.

Cargo Stowage- flattening hull envelope will have beneficial effect on stowage of cargo.

Sheer- best sheer from production aspect is straight line form on the forecastle deck only.

Camber-best camber from production aspect is fitted in the form of three straight lines with the center being horizontal. This provides flat deck for hatches.

Stern- best stern from production aspect is vertical flat transom type with areas of flat or nearly flat plating leading into the transom.

Deck Structure- an area where all of the plating can be flat panels.

c) Cost Impact

Production costs improved by: 1) plates need not be formed, 2) frames need not be bent, 3) jigs not required to ensure correct curvature, 4) no need for increased level of technical information to define plate curvature, frame curvature and sets, and jig heights.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.7.2
After Body Curvature

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.68, ¶ 1)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Reverse curvature can be eliminated by carefully locating the transfer from convex double-curvature plates to concave-curvature plates at plate seems and erection butts. Even though double-curvature plates have less work content than reverse-curvature plates, it is still significant. One way to reduce the work content of the after-body even further is to separate the normal single-screw after-body into two parts, namely, the main hull and a skeg. This can be done in two ways. The first way is to attempt to follow the normal single-screw hull form as closely as possible by incorporating a chine or multi-chines joined in section by straight lines or simple curves. The chine(s) should lie in flow lines to prevent cross-flow turbulence. The second way is to design the after-body as a twin-screw warship type, and to add a skeg which can incorporate the shaft and its bearings. The latter approach has the least work content.

b) Impact on Ship Characteristics

Both approaches to separate after-body into two parts can usually be used without any adverse impact on propulsion power.

c) Cost Impact

Eliminating or reducing reverse curvature will reduce work content in this area.

d) Performance Influence

e) Risk Assessment

If chine lines are used, they must be carefully engineered so as not to produce cross flow turbulence.

f) Net Assessment

WBS Reference No. 111.7.3
Hull Structure; Shape Above Design Waterline

UMTRI No.	58786
Publication	Journal of Ship Production, Vol. 9, No. 2, May 1993, pg. 126.
Title	"Reducing the Construction Contract Cycle for Naval Auxiliary Ships"
Prepared by	Mark H. Spicknall and Michael Wade
Date	May 1993

Concept Assessment:

a) Description of Concept

The shape of the hull near and above the design waterline should result in flat and simple curved structure. Flat shell plate requires no forming, and simple curvatures can be easily machine formed. Complex curvatures require more difficult machine forming and heat forming. Automatic and semi-automatic welding can be used on flat and simple curved hull plate, while complex curvature requires much more manual welding. Also, complex curved blocks require either unique fixtures or pin jigs for assembly.

b) Impact on Ship Characteristics

c) Cost Impact

A great deal of labor hours are saved by designing for a flat and simple curved hull. Specifically, forming operations are greatly simplified as opposed to a complex curved hull. More automatic welding reduces associated labor hours. Unique fixtures or pin jigs involve a substantial capital investment to produce a complex curved hull. Also, complex curved blocks require significantly higher labor hours for layout, fitting, and accuracy control.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.8.1
General Comments; Knuckle Location

UMTRI No.	57859
Publication	Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 258.
Title	"Producibility in Ship Design"
Prepared by	Gilbert L. Kraine and Sigurdur Ingvason
Date	November 1990

Concept Assessment:

a) Description of Concept

Locate knuckles at unit breaks. Do not place knuckles either at or between bulkheads or decks but 9 to 12 inches from the bulkhead or decks where the breaks will be made. Knuckles are easier to fabricate if they occur at a unit break than if they occur midway in a unit. The proper location of a knuckle requires coordination between the lines, arrangements and structure at an early stage of a design.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

A knuckle has little or no hydrodynamic effect if it is above the waterline.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.8.2
Chines

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.68, ¶ 4)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

From a producibility point of view, it is better to locate the chine parallel to the baseline, as this enables the chines to be logical module breaks used for alignment of modules, and permits standardization of design details for floors, frames, brackets, etc.

b) Impact on Ship Characteristics

A chine which is parallel to the baseline could increase the vessel's resistance if it crosses the flow lines.

c) Cost Impact

Many ship designers utilize chine hull form designs on the assumption that they are easier to build than round bilge forms. Although this is generally true for small ships, it is appreciated that chines can add work content to a design.

d) Performance Influence

e) Risk Assessment

Chines are often located to follow flow lines as an attempt to prevent cross-flow over the chines, which will cause increased resistance. Therefore, a chine which is parallel to the baseline could increase the vessel's resistance if it crosses the flow lines.

f) Net Assessment

When a chine is introduced into a design and it is curved in two views, it can present a problem if the ship is constructed in modules, as the chine is an obvious module break line. In addition, a chine that crosses a deck line introduces increased work content due to construction design details, including varying frame lengths and additional frame brackets.

WBS Reference No. 111.9.1-3
Flat of Keel Width

UMTRI No. 72960

Publication ...... The National Shipbuilding Research Program (NSRP # 0219, pg.63, ¶ 2)

Title .... "Engineering for Ship Production"

Prepared by ...... Thomas Lamb, Private Consultant

Date .... January 1986

Concept Assessment:

a) Description of Concept

The width of the flat keel should be at least enough to extend over the keel blocks to allow welding of the erection seam for port and starboard modules. Where the bottom erection modules span the blocks, this is not important, although for ships where this occurs it is usually only for the midship modules, and it changes to port and starboard modules towards the ends.

The shipyard maximum plate width should be used as the flat keel width.

If one of the flat keel seams is used as an erection module break, the flat keel width must suit the module-joining method including the internal structure.

b) Impact on Ship Characteristics

c) Cost Impact

Eliminating the need to move the keel blocks during welding processes will reduce work content.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.10
Bow Waterline Shape

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.55, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

For ease of production, straight and convex waterlines are preferable.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

Most ships can be designed without the need for concave waterlines in the bow.

WBS Reference No. 111.11
Sloped Sides

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.55, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Sloped sides may appear strange, but they actually make more sense, from a design for ship production point of view, than rise of floor. This should be considered as an alternative to rise of floor as a means of achieving the required maximum.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

Naval architecture design advantages of wider decks without resistance penalty for increased waterline beam required with vertical sides. They also provide better heeled performance.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.12
Rise of Floor

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.55, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Rise of floor involves considerable additional work content compared to a flat bottom.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

Only benefit is that it aids in the tank drainage when the ship is in drydock completely upright.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 111.13
Bilge Radius

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.63, ¶ 3)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Bilge radius should be determined so that the side module erection joint is above the tangent of the bilge radius, and above the double bottom height or inboard of the tangent with the bottom in single bottom ships. The use of conic sections for the hull bilge as it moves forward and aft from the maximum section would result in the bilge shape being an ellipse and not a radius. This fact must be appreciated by those designers that conveniently and cleverly try to maintain radii in the bilge shape in the forward and aft bodies of the hull.

b) Impact on Ship Characteristics

c) Cost Impact

The use of conic sections results in considerable increased work content as the shell plate former must form ellipse sections instead of circular.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 116.1
Hull Structure; Stiffeners

UMTRI No.	84701
Publication	AOE-6 Producibility Review, Sec. IV.5.D
Title	"AOE-6 Producibility Review"
Prepared by	Advanced Technology, Inc.
Date	August 1985

Concept Assessment:

a) Description of Concept

Below the DWL, use L profile (angles) sections instead of T sections as stiffeners. This avoids oil pooling in the upper portion of the T which complicates tank cleaning, and allows for easier erection penetrations, and connections.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 116.2
Hull Structure; Longitudinal Spacing

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/503.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

The spacing of longitudinals and girders will be a function of the breadth of the ship but there will not necessarily be an exact number of longitudinal spaces to make up the breadth. Girder spacing will be a multiple of long. spacing and will be affected by the anticipated cargoes to be carried (such as the ability to support the vertical sides of containers). When cargo considerations do not pose a constraint, it may be possible to relate the long. spacing to maximum material size (such as equal to max. plate width).

b) Impact on Ship Characteristics

c) Cost Impact

Savings made by use of max. plate width by reducing volume of welding and number of units.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 116.3
Module Boundaries

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.120, ¶ 3)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Module breaks should be located to minimize ship erection work content. For example, in a longitudinally framed ship it would be better to have long modules, whereas for transversely framed ship, wide modules would be better. The module boundaries should also be located at natural plate butts and seams.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 116.4
Framing Direction

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.120, ¶ 3)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The consideration of the framing method-that is, transverse or longitudinal and plate straking direction should be performed together. This because, in general, straking should be in the same direction as the framing. This is to eliminate the need for rat holes over plate butt welds or for grinding down plate butt welds in way of frames crossing the welds. Obviously, this cannot be adhered to in all cases, especially bulkheads where the plating thickness varies with depth and vertical stiffening is generally preferred. In cases where the plate strakes vary in thickness, it may be better to locate the stiffeners on the uneven surface running parallel to the plate strakes. This would require horizontal stiffeners with varying scantlings, which is probably not a minimum work content approach. From a producibility point of view it is probably better to use vertical plate straking and vertical stiffeners, even though there will be an increase in weight due to the constant bulkhead plating thickness.

b) Impact on Ship Characteristics

The use of vertical plate straking and vertical stiffeners will increase the weight due to the constant bulkhead plating thickness.

c) Cost Impact

When straking is in the same direction as the framing it eliminates the need for rat holes over plate butt welds or for grinding down plate butt welds in way of frames crossing the welds, thus reducing work content.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 116.5
Hull Structure: Brackets

UMTRI No. 84701
Publication . . . . . . AOE-6 Producibility Review, Sec. IV.5.A
Title . . . . "AOE-6 Producibility Review"
Prepared by . . . . Advanced Technology, Inc.
Date . . . . August 1985

Concept Assessment:

a) Description of Concept

Use of standardized straight connecting brackets instead of curved brackets. This will allow the use of automatic welding machines to improve production.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 116.6
Bilge Framing

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg. 148, ¶ 5)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

In a longitudinally framed ship, the use of bilge brackets in place of the longitudinals is a productivity-improving alternative.

b) Impact on Ship Characteristics

c) Cost Impact

The longitudinals in way of the bilge radius are of high work content due to their shaping, twisting, closing angles, and cut-out chocking, thus replacing the longitudinals with bilge brackets will reduce the work content.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

This approach of bilge brackets also provides simpler and better control of the shape of the bilge shell plates, along with improving productivity. Obviously with computer-aided lofting and N/C burning, the bilge brackets are easily produced.

WBS Reference No. 117.1
Hull Structure; Transverse Spacing IWO Cargo Hatches

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/526.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

The stiffening of the deck plating between hatchways can be in the form of beams in association with the girders, using the tip of the bulkhead as the span point.

b) Impact on Ship Characteristics

Beams are considered to play an important part in the transverse strength of the ship by tying together the deck structures outside the line of hatchway openings. For ships with wide hatchway openings, deck beams between hatchways should be seriously considered.

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 117.2
Framing Direction

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.120, ¶ 3)
Title	Engineering for Ship Production
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The consideration of the framing method-that is, transverse or longitudinal and plate straking direction should be performed together. This because, in general, straking should be in the same direction as the framing. This is to eliminate the need for rat holes over plate butt welds or for grinding down plate butt welds in way of frames crossing the welds. Obviously, this cannot be adhered to in all cases, especially bulkheads where the plating thickness varies with depth and vertical stiffening is generally preferred. In cases where the plate strakes vary in thickness, it may be better to locate the stiffeners on the uneven surface running parallel to the plate strakes. This would require horizontal stiffeners with varying scantlings, which is probably not a minimum work content approach. From a producibility point of view it is probably better to use vertical plate straking and vertical stiffeners, even though there will be an increase in weight due to the constant bulkhead plating thickness.

b) Impact on Ship Characteristics

The use of vertical plate straking and vertical stiffeners will increase the weight due to the constant bulkhead plating thickness.

c) Cost Impact

When straking is in the same direction as the framing it eliminates the need for rat holes over plate butt welds or for grinding down plate butt welds in way of frames crossing the welds, thus reducing work content.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 117.3
Framing Direction

UMTRI No. 72960
Publication . . . . The National Shipbuilding Research Program
(NSRP # 0219, pg.45, ¶ 1)
Title . . . . "Engineering for Ship Production"
Prepared by . . . . . . Thomas Lamb, Private Consultant
Date . . . . January 1986

Concept Assessment:

a) Description of Concept

When the tween deck height must be kept to a minimum, it may be better to provide deeper deck transverse beams or non-structural steel bulkheads, and run systems through at constant height rather than work to minimum depth for the deck transverses, and drop the systems. It is usually possible to select a smaller tween deck height in accommodation spaces with transverse beams rather than longitudinals. This is because longitudinally framed deck deep transverses add to the required height for fore and aft run services.

b) Impact on Ship Characteristics

Usually can reduce tween deck height in accommodation spaces with transverse beams.

c) Cost Impact

In way of accommodation, a minimum tween deck height increases productivity of installation of the overhead ventilation ducting, piping, and wiring.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 117.4
Framing Size

UMTRI No. 48928

Publication . . . . The National Shipbuilding Research Program (NSRP # 0179, pg.55)

Title . . . . "Design for Zone Outfitting"

Prepared by . . . . U.S. Department of Transportation, Maritime Administration, in cooperation with Todd Pacific Shipyards Corporation

Date . . . . September 1983

Concept Assessment:

a) Description of Concept

Reducing the depth of beams should be considered to facilitate fitting pipe runs below beams rather than through beams.

b) Impact on Ship Characteristics

Reducing beam height will result in thicker beams, i.e. more weight per beam.

c) Cost Impact

Despite the additional weight, sometimes additional structural weight or hull construction man-hours can result in outfit savings which more than offset the added costs.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

The man-hours saved more than compensate for the thicker beam plates required as compared to those for beams designed only form a strength viewpoint.

WBS Reference No. 117.5
Frame Spacing

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.34, ¶ 4)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The frame spacing should be constant throughout the ship's length with the exception of the peaks, where the usual practice of incorporating smaller spacing can be followed if it has no adverse impact on the producibility of the bow and the stern.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

The hold or tank length should be a multiple of the frame spacing and be duplicated for each hold or tank as much as possible. This will allow the structural modules to be standardized.

WBS Reference No. 117.6
Web Frames to Aid Access

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.148, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Provide permanent holes in web frames and/or deck transverses in which staging pipe can be placed. Three inch diameter holes can be cut in web frames and/or deck transverses through which 2.5 inch diameter staging pipe can be placed and staging planks laid across the pipes. Hand and toe holes in web frames can also be cut to assist access throughout the ship.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

These staging and access holes can be efficiently cut by the automatic burning machine when cutting the plate and, as mentioned before, assist access throughout the ship.

WBS Reference No. 117.7
Hull Structure; Transverse Framing

UMTRI No.	57721
Publication	Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 70.
Title	"Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by	K.S. Bong, William Hills, and John B. Caldwell
Date	May 1990

Concept Assessment:

a) Description of Concept

In structural arrangement, the transverse web frame spacing should be less than five meters.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 117.8
Transverse Frame Spacing

UMTRI No.	71150
Publication	The National Shipbuilding Research Program (NSRP #0031, pg.19)
Title	"Frame Spacing, Alternate Shapes for Longitudinals, and Wider Plates for Productivity"
Prepared by	U.S. Department of Commerce, Maritime Administration, in cooperation with Todd Shipyards Corporation
Date	August 1973

Concept Assessment:

a) Description of Concept

For the investigated cases of tankers and container ships, the total erected weight of steel increases with increased frame spacing. The weight increases are due primarily to the increase in stiffener size. However, the linear feet of welding and burning, excluding that required for fabricated stiffeners, decreases with increased frame spacing in all of the investigated cases.

b) Impact on Ship Characteristics

As noted above the total erected weight of steel increases with increased frame spacing, for the investigated cases of tankers and container ships.

c) Cost Impact

The influence on cost by changing frame spacing is dependent on many variables. Influencing variables are: method of frame fabrication, blasting and coating of material, burning, welding methods, and penetration preparation. The noted resource should be consulted for methods to evaluate the economics of alternate frame spacing.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

There is a tradeoff between steel weight and welding length, this tradeoff must be examined on a case by case basis.

WBS Reference No. 120.1
Tank Bulkhead Testing

UMTRI No. 72960
Publication .... The National Shipbuilding Research Program (NSRP # 0219, pg.45, ¶ 6)
Title .... "Engineering for Ship Production"
Prepared by .... Thomas Lamb, Private Consultant
Date .... January 1986

Concept Assessment:

a) Description of Concept

From a producibility point of view, it would be ideal if the tanks in each erection module could be complete and tested before erection. This would enable any defects to be easily corrected on the module construction platens. This is not possible when common tank boundaries cross or are located at an erection joint Usually only a portion of the tanks needs to be hydraulically tested, then the erection joints can be located in the tanks which do not need to be tested.

One way to achieve this ideal would be to provide cofferdams in way of erection joints. This could be a productivity net improvement, depending on design, extent of required testing, and tank coatings.

b) Impact on Ship Characteristics

The use of cofferdams, mentioned in **Description of Concept,** would reduce the amount of usable space in the hull for tanks, and would increase the steel weight.

c) Cost Impact

Testing of tanks is more economical if done at earlier construction stages.

d) Performance Influence

e) Risk Assessment

If the tanks are to be coated, it would be preferable to have no module connecting welding which would damage the coating, thus requiring rework

The work content would also increase due to additional manholes, sounding tubes, and air vents. Obviously, there could still be some coating damage where the bulkheads are welded to the tank top, but this can be avoided by incorporating a strip of bulkhead onto the double-bottom module before it is coated. It could also be solved by increasing the cofferdam size to two frame spaces, but this may be unacceptable due to the cost.

f) Net Assessment

WBS Reference No. 120.2
Hull Structure; Bulkhead, Structural Function

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/502.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

When determining the structural configuration within any region of a hull due account has to be taken of the purposes which any material has to serve, such as: watertight barrier, support for cargo or equipment, overall hull strength, local strength only, and fire barrier. Additionally, structural continuity with adjacent parts of the structure has to be considered.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 120.3
Bulkheads: Pipe Penetrations

UMTRI No.	48928
Publication	The National Shipbuilding Research Program (NSRP # 0179, pg. 55)
Title	"Design for Zone Outfitting"
Prepared by	U.S. Department of Transportation, Maritime Administration, in cooperation with Todd Pacific Shipyards Corporation.
Date	September 1983

Concept Assessment:

a) Description of Concept

Provide portions of bulkheads on block to facilitate fitting pipe penetrations.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 120.4
Hull Structure; Longitudinal Bulkheads

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/208.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

Avoid "crank" in longitudinal bulkheads if possible when extending into aft end engine rooms or forward cargo spaces. Cranking the bulkheads may be necessary, however, to form sensible sized side compartments in those regions, and may be unavoidable if it is necessary to minimize the amount of segregated ballast in a tanker. To maintain the bulkheads in the plane parallel to the centerline, consideration should be given to allowing the bulkheads to run alongside other long. bulkheads for a short distance. This allows all of the transverse structure on either side of the bulkhead to be normal to it.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 120.5
Bulkheads to Aid Access

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.148, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Provide permanent holes in web frames and/or deck transverses in which staging pipe can be placed. Three inch diameter holes can be cut in N.W.T. bulkheads, web frames and/or deck transverses through which 2.5 inch diameter staging pipe can be placed and staging planks laid across the pipes. Hand and toe holes in web frames and N.W.T. bulkheads can also be cut to assist access throughout the ship.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

These staging and access holes can be efficiently cut by the automatic burning machine when cutting the plate and, as mentioned before, assist access throughout the ship.

WBS Reference No. 123.1
Placement of Cofferdams

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg 120, ¶ 1)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

As mentioned in No. 120.1, it can be beneficial to utilize cofferdams and duct keels as the location for the module breaks when the tanks are to be coated, as this allows adjacent tanks to be completed and tested before erection on the berth.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

In the case of only staggered tanks requiring hydro testing, this approach increases the number of different modules required, and that a duct keel is still required.

f) Net Assessment

Note that double cofferdams are only necessary for coated tanks. In fact, if it is necessary to hydro test only staggered tanks, there is no need for cofferdams if the tanks are not coated.

WBS Reference No. 123.2
Hull Structure; Side Tanks

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/508.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

Designing bottom, side, bulkhead, and deck blocks as nearly identical as possible allows the maximization of high cost capital equipment such as a panel line.

b) Impact on Ship Characteristics

c) Cost Impact

Production costs improved by maximizing use of items such as panel line and smoother operation of semi-automatic or mechanized welding machines.

d) Performance Influence

Panel line use can also be maximized by longitudinally stiffening the shell and longitudinal bulkhead where possible.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 123.3
Hull Structure: Trunks

UMTRI No.	48928
Publication	The National Shipbuilding Research Program (NSRP # 0179, pg. 55)
Title	"Design for Zone Outfitting"
Prepared by	U.S. Department of Transportation, Maritime Administration, in cooperation with Todd Pacific Shipyards Corporation.
Date	September 1983

Concept Assessment:

a) Description of Concept

Trunks are provided in deckhouses for vertical pipe and electric-cable runs, even at the expense of increased weight.

b) Impact on Ship Characteristics

Pipe passages are planned against the sides of a vertical trunk which is included in the accomodation house arrangement specifically to enhance productivity.

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 130.1
Hull Structure; Standard Deck Height

UMTRI No.	(NA)
Publication	Graduate Student Technical Paper, pg. 24.
Title	"A Review of DDGX Producibility Studies Done by U.S. Shipyards for the DDGX Design Manager."
Prepared by	Geoffrey Hummel, Graduate Student, University of Michigan, Dept. of Naval Architecture & Marine Engineering.
Date	March 1987

Concept Assessment:

a) Description of Concept

Studies recommend standardization of deck heights as much as possible.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 130.2
Hull Structure; Deck Continuity

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/202.
Title	'The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

It is desirable from both a structural and producibility point of view that internal surfaces within the hull should be continuous wherever possible and that they should lie within the principal planes. Structural discontinuity leads to the need for local compensation and hence increased complexity which leads in turn to additional material having to be fitted in a piecemeal fashion. It is also structurally less efficient.

b) Impact on Ship Characteristics

Discontinuities are less structurally efficient, resulting in lower structural strength (section modulus).

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 130.3
Hull Structure; Decks- Camber

UMTRI No.	57721
Publication	Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 70.
Title	"Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by	K.S. Bong, William Hills, and John B. Caldwell
Date	May 1990

Concept Assessment:

a) Description of Concept

In geometry and structural arrangement, the camber should be straight-line if any.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 130.4
Hull Structure; Decks- Floors

UMTRI No.	57721
Publication	Journal of Ship Production, Vol. 6, No. 2, May 1990, pg. 70.
Title	"Methods of Incorporating Design-for-Production Considerations Into Concept Design Investigations"
Prepared by	K.S. Bong, William Hills, and John B. Caldwell
Date	May 1990

Concept Assessment:

a) Description of Concept

In structural arrangement, the floor spacing should be less than 2.5 m and be half the web frame spacing.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 136.1
Hull Structure; Double Bottom Within Cargo Holds

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/503-4..
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

In order to simplify assembly and to reduce the need for jigs to support curved plates, it is desirable that the internal structure should be of greater depth than the bilge radius.

Girder and longitudinal spacing will be a function of ship breadth, but there will not necessarily be an exact number of long. spaces to make up the breadth. Girder spacing will be affected by the anticipated cargoes, and should be spaced equidistant, if possible, so that floors between girders will be identical sub-assemblies.

The cargo hold length will be an exact multiple of frame and floor spacing. Transverse web frames fitted in the hold, particularly those required at the end of hatchways, should be aligned with a double bottom floor to provide a strong transverse ring structure. When structural spacings are not cargo dependent, it may be possible to relate them to maximum material size (i.e. long. spacing can be arranged so that maximum plate width can be used: reducing weld volume and number of units).

Adequate manholes must be provided in non-watertight floors and girders, and should be positioned to provide easy access while double bottom is inverted or right-side up.

b) Impact on Ship Characteristics

c) Cost Impact

Savings due to: maximum material size, identical sub-assemblies, eliminating use of jigs.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 136.2
Double Bottom: Machinery Spaces

UMTRI No.	84701
Publication	AOE-6 Producibility Review, Sec. IV.8.C
Title	"AOE-6 Producibility Review"
Prepared by	Advanced Technology, Inc.
Date	August 1985

Concept Assessment:

a) Description of Concept

In fact, one result is to provide a double curved tank top to which the machinery foundations must be fitted. It is recommended that a flat inner bottom tank be considered for the machinery space.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 136.3
Hull Structure; Forward Double Bottom Height

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/204.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

It is quite common in finer ships to find that the height of the inner bottom in the forward hold has been raised to provide a platform having reasonable width for cargo loading. The increased width of the cargo loading area will provide increased utilization of the available hold volume. The need to raise the height of the inner bottom can sometimes be avoided if 'U' shaped sections are incorporated forward, in preference to 'V' shaped sections.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 136.4
Double Bottom Height

UMTRI No.	(1) 72960
	(2) 73531
Publication	(1) The National Shipbuilding Research Program (NSRP # 0219, pg.41, ¶ 4)
	(2) NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/204.
Title	(1) "Engineering for Ship Production"
	(2) "The Application of Production Engineering"
Prepared by	(1) Thomas Lamb, Private Consultant
	(2) Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	(1) January 1986
	(2) December 1985

Concept Assessment:

a) Description of Concept

Double bottom height should allow for easy worker access. The height for access between the shell and inner bottom frames or longitudinals should not be less than 15 inches, and if possible, 24 inches.(1)

There are trade-offs to be considered by the designers and production engineers at the conceptual and concept design stages. An increased double bottom height provides better access during construction. A reduced double bottom height has poorer access but is structurally more efficient. Consideration of this kind of trade-off would logically lead to the possible use of robots for internal double bottom welding. This would allow minimum height double bottoms to be adopted as standard.(2)

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

A problem often results from deciding the double-bottom height based on only the midship section. The bottom hull shape rises both forward and aft of the midship section. This obviously reduces the height in the double bottom outboard of the center line and below the minimum acceptable height for construction. Therefore, it is necessary to consider double-bottom height at the location where the hull shape reduce to a minimum over the required length of double bottom.(1)

WBS Reference No. 136.5
Double Bottom

UMTRI No.	84701
Publication	AOE-6 Producibility Review, Sec. IV.8.D
Title	"AOE-6 Producibility Review"
Prepared by	Advanced Technology, Inc.
Date	August 1985

Concept Assessment:

a) Description of Concept

Use of longitudinal flooring instead of longitudinal frames in a shallow double bottom. This allows for easier and less costly construction.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 136.6
Hull Structure; Double Bottom Height Transition

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/204.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

The height of the inner bottom in the hold area of a ship is normally made as low as possible to reduce material quantities for double bottom structure and for stability reasons. The height of the inner bottom within the engine room is determined by the minimum height required by the prime mover or by the required height of shaft centerline to accommodate the propeller. It is unusual that the most desirable heights for both the engine room inner bottom and the hold inner bottom would coincide. The usual manner in which the two different heights are accommodated is by allowing the heights to change over a number of frame spaces. In order to maintain horizontal surfaces, a method of scarping the structures by continuing the lower height some way under the higher may be worth consideration.

b) Impact on Ship Characteristics

increased double bottom height- better access during construction/maintenance.
decreased double bottom height- poorer access but structurally more efficient.

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 136.7
Double Bottom Access Holes

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.41, ¶ 5)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

For large ships (over 400 feet) U.S. ad measurers will allow larger holes if they are necessary for construction equipment access. Therefore, access holes do not need to be restricted to 23-inch by 15-inch ovals. If the shipowner desires the ship to be measured under the 1969 Tonnage Convention, there is no restriction on hole size, and therefore no need to keep the traditional access and lightening hole sizes. Sizes should be maximum allowable from a structural point of view.

b) Impact on Ship Characteristics

c) Cost Impact

Maximum sized access holes allow for easier movement of both equipment and workers, thus increasing productivity.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

Maximum sized access holes allow for easier movement of both equipment and workers, thus increasing productivity.

WBS Reference No. 136.8
Double Bottom Height

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.41, ¶ 5)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

It is possible to use a smaller double-bottom height with transversely framed ships than with longitudinally framed ships. This is because with longitudinal framing in the double bottom, the transverse plate floors need to be deeper to allow for a reasonable distance between the longitudinal cut-outs and access holes.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

Double bottom height should not be reduced so that access between the shell and innerbottom frames is less than 15 inches and if possible 24 inches, as mentioned in No. 136.4.

WBS Reference No. 150.1
Deck House Shape

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.49, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The ship designer should develop simple deckhouse designs utilizing vertical and flat sides. Sloping house fronts and sweeping side screens add significant work content to the task of constructing a suitable deckhouse to accommodate the crew and provide the necessary service spaces.

b) Impact on Ship Characteristics

c) Cost Impact

Utilizing vertical and flat sides will not only decrease construction cost but they also will also cost less to maintain during the ship's operational life.

d) Performance Influence

e) Risk Assessment

Vertical surfaces and surfaces joining at a right angle can have an adverse affect on radar signature for ships wanting to decrease their signature.

f) Net Assessment

While certain ships such as passenger and cruise ships can justify the cost of such aesthetic treatment, in general they are unnecessary additions for all other types ships.

WBS Reference No. 150.2
Deck House: Outfit

UMTRI No. 84701
Publication ...... AOE-6 Producibility Review, Sec. III.1
Title .... "AOE-6 Producibility Review"
Prepared by .... Advanced Technology, Inc.
Date .... August 1985

Concept Assessment:

a) Description of Concept

Common modules for outfitting will help reduce the total number of manhours needed.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 150.3
Hull Structure; Standard Deck Height

UMTRI No.	(NA)
Publication	Graduate Student Technical Paper, pg. 24.
Title	"A Review of DDGX Producibility Studies Done by U.S. Shipyards for the DDGX Design Manager."
Prepared by	Geoffrey Hummel, Graduate Student, University of Michigan, Dept. of Naval Architecture & Marine Engineering
Date	March 1987

Concept Assessment:

a) Description of Concept

Studies recommend standardization of deck heights as much as possible.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 150.4
Accommodation Space Tween Deck Height

UMTRI No. 72960
Publication . . . . The National Shipbuilding Research Program (NSRP # 0219, pg.45, ¶ 1)
Title . . . . "Engineering for Ship Production"
Prepared by . . . . . . Thomas Lamb, Private Consultant
Date . . . . January 1986

Concept Assessment:

a) Description of Concept

It is usually possible to select a smaller tween deck height in accommodation spaces with transverse beams rather than longitudinals. This is because longitudinally framed deck deep transverses add to the required height for fore and aft run services. When the tween deck height must be kept to a minimum, it may be better to provide deeper deck transverse beams or non-structural steel bulkheads, and run systems through at constant height rather than work to minimum depth for the deck transverses, and drop the systems. It is usually possible to select a smaller tween deck height in accommodation spaces with transverse beams rather than longitudinals. This is because longitudinally framed deck deep transverses add to the required height for fore and aft run services.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 150.5
Hull Structure; Deck House

UMTRI No. 73231
Publication ...... DDGX Program Producibility Study 7C1, pg. 11.
Title .... "Deck Heights: A General Report Summarizing Techniques for Reducing Deck Heights for DDG 51."
Prepared by ...... Bath Iron Works Corporation
Date .... December 1982

Concept Assessment:

a) Description of Concept

Study shows that additional usable deck area can be obtained by eliminating port and starboard fore and aft passageways, and replacing these with a centerline passageway.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 150.6
Deck House Exterior Decks

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.49, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The ship designer should only provide exterior decks that are required for the safe access and working of the ship.

b) Impact on Ship Characteristics

c) Cost Impact

Additional exterior decks not only increase the construction cost, but they also cost more to maintain during the ship's operational life.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

While certain ships such as passenger and cruise ships can justify the cost of extra exterior decks, in general they are unnecessary additions for all other types of ships.

WBS Reference No. 150.7
Accommodation Space Tween Deck Height

UMTRI No. 72960
Publication . . . . The National Shipbuilding Research Program
(NSRP # 0219, pg.45, ¶ 1)
Title . . . . "Engineering for Ship Production"
Prepared by . . . . . . Thomas Lamb, Private Consultant
Date . . . . January 1986

Concept Assessment:

a) Description of Concept

In way of accommodation, the tween deck height should be selected to allow high productivity installation of the overhead ventilation ducting, piping, and wiring.

b) Impact on Ship Characteristics

c) Cost Impact

In way of accommodations, a minimum tween deck height increases productivity of installation of the overhead ducting, piping, and wiring.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

If it is difficult of the designer to squeeze such systems into the allowable space, it will be many items more difficult and with high manhours for the production worker to install the systems.

WBS Reference No. 161.1
Hull Structure; Vehicle Tie-Downs

UMTRI No.	58786
Publication	Journal of Ship Production, Vol. 9, No. 2, May 1993, pp. 127-128.
Title	"Reducing the Construction Contract Cycle for Naval Auxiliary Ships"
Prepared by	Mark H. Spicknall and Michael Wade
Date	May 1993

Concept Assessment:

a) Description of Concept

Existing vehicle tie-downs on Navy ships are castings that must be welded into the deck from both above and below. These castings are expensive, and the installation is labor-intensive, requiring early access to both sides of the deck. This design should be standardized to allow for automated fitting and welding, as well as the elimination of deck repositioning for these items.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 180.1
Hull Structure; Use of Epoxy-Resin Chock Foundations

UMTRI No.	73204
Publication	DDGX Program Producibility Study 7C1, pp. 1-2.
Title	"Epoxy Resin Chocks for Shipboard Machinery and Equipment"
Prepared by	David Pasciuti, Todd Pacific Shipyards Corporation, Seattle Division
Date	January 1982

Concept Assessment:

a) Description of Concept

Install chocks for machinery foundations made of epoxy resin in place of machining and fitting metal chocks.

b) Impact on Ship Characteristics

c) Cost Impact

Metal chocks require large expenditure of manhours to accomplish machining and fitting, additionally require skilled craftsmen with considerable experience.

d) Performance Influence

Metal chocks suffers from fretting, a type of wearing due to relative motion between similar metals and is caused primarily by the excessive vibration as may be experienced with diesel engine foundations. Fretting has been known to require replacement of chocks.

Epoxy-resin chocks can be used in severe environments of high compressive loads, excessive vibration, and high temperature. Easy to apply: poured in liquid form and then hardened to provide sufficient support at the required alignment.

e) Risk Assessment

Reluctance for extensive epoxy-resin chock applications is apparently based on concern for the material's mechanical properties in the areas of high temperature creep, shock and vibration resistance when compared to steel.

f) Net Assessment

WBS Reference No. 180.2-10
Equipment Foundations

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.161, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Foundation design for production depends on shipyard equipment and worker capability, but in general the following approaches have provided least work content design:

- Minimize number of parts.
- Minimize number of unique parts.
- Do not mix plate and shapes. That is, make a specific foundation either all plate or all shapes.
- Standardize on a few structural shapes such as angle, channel, or square tube.
- Run support vertical
- Provide required "structural back-up" on same side of structure as the foundation. That is, integrate it with the foundation.
- Eliminate fitting joints. Maximize lapping design.
- Use sheet metal independent drip pans in lieu of built in.
- Foundation designer and equipment arranger should work together during design of foundation. Sometimes moving the equipment a few inches can significantly simplify the foundation design and construction with no adverse impact on arrangement.
- Securing bolts must be easily accessibly. Otherwise provide studs.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

WBS Reference No. 180.2-10
Equipment Foundations (cont'd.)

e) Risk Assessment

f) Net Assessment

The use of standard foundations is obviously worthwhile, due to reducing engineering and lofting effort, and production manhours due to multiple runs and work familiarization.

WBS Reference No. 180.11
Equipment Foundation

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.179, ¶ 4)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Incorporate foundations for deck machinery into equipment design, and weld directly to ship structure.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

The advantages of modular hull outfit units include:

- Relocation of work from ship to shop, resulting in easier access, and cleaner and safer environment.
- Possibility of assembly line techniques for multiple units.
- Elimination of transporting many small parts to ship.
- Simpler material control.
- Shorter installation time onboard the ship

WBS Reference No. 200.1
Machinery Arrangements

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.35, ¶ 5)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

It is essential that producibility be adequately considered during the development of the machinery arrangement, not only in the equipment layout but for the surrounding structure. From a producibility point of view, both main machinery rooms (MMRs) should be identical arrangements, but that is obviously not possible in a twin screw ship. The next best arrangement is to make the MMRs mirror images about the center line of the ship. This is possible if the shaft center lines are parallel to each other, and are horizontal. Unfortunately, this is often not possible, and the different plan angles and declevities of the shafts prevent exact mirror image spaces. However, even in case the machinery spaces can be mirror images except for the propulsion machinery setting.

b) Impact on Ship Characteristics

c) Cost Impact

The productivity benefits to be gained justify this approach.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 200.2
Propulsion Plant: Standardized

UMTRI No. 84701
Publication . . . . AOE-6 Producibility Review, Sec. III.4
Title . . . . "AOE-6 Producibility Review"
Prepared by . . . . . . Advanced Technology, Inc.
Date . . . . August 1985

Concept Assessment:

a) Description of Concept

An attempt should be made to standardize the amount of information provided for the items of machinery and equipment.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 200.3
Propulsion plant: Modulize Engine Room

UMTRI No.	56031
Publication	Journal of Ship Production. Vol. 1, No. 3, Aug. 1985, pg. 151.
Title	"Considerations Regarding Improved Productivity Based Upon Experience from Series Production of Merchant Ships"
Prepared by	C.F. Sverdrup
Date	August 1985

Concept Assessment:

a) Description of Concept

The load on facilities can be reduced by dispersing work content to other and earlier stages, as shown by module production.

b) Impact on Ship Characteristics

c) Cost Impact

The principle of such prefabrication is to execute the work at an initial stage under better working conditions, thus reducing the total manhours.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 200.4
Propulsion Plant; System Grouping

UMTRI No. 73229
Publication . . . . . . DDGX Program Producibility, pg. 7.
Title . . . . "Study No. 7 Design Review Part C1"
Prepared by . . . . Ingalls Shipbuilding Division
Date . . . . July 1982

Concept Assessment:

a) Description of Concept

Study recommends palletization of components on a common multi-unit foundation for those items that can logically be grouped together.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 200.5
Propulsion Plant; Equipment Removal Routes

UMTRI No. ...... (NA)
Publication ...... Graduate Student Technical Paper, pg. 23.
Title .... "A Review of DDGX Producibility Studies Done by U.S. Shipyards for the DDGX Design Manager."
Prepared by ...... Geoffrey Hummel, Graduate Student, University of Michigan, Dept. of Naval Architecture & Marine Engineering
Date .... March 1987

Concept Assessment:

a) Description of Concept

Studies recommend that consideration by given to equipment removal routes, and accessibility for installation of components.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 200.6
Engine Room Block Breaks

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.199, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Assembly and module breaks should be carefully developed between hull and machinery groups to ensure that no major equipment or their foundations extend over the breaks, as this will prevent installation of the equipment into the modules before erection and joining.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 200.7
Engine Room Block Joints

UMTRI No.	48928
Publication	The National Shipbuilding Research Program (NSRP # 0179, pg.55)
Title	"Design for Zone Outfitting"
Prepared by	U.S. Department of Transportation, Maritime Administration, in cooperation with Todd Pacific Shipyards Corporation
Date	September 1983

Concept Assessment:

a) Description of Concept

Block joints for engine-room double-bottom blocks should be located above the grating level so that fitting can progress in this normally congested region to the fullest extent before hull erection. That is, space does not have to be reserved adjacent to block joints for access during erection welding.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 200.8
Propulsion Plant; Machinery Arrangements

UMTRI No.	57859
Publication	Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 258.
Title	"Producibility in Ship Design"
Author	Gilbert L. Kraine and Sigurdur Ingvason
Date	November 1990

Concept Assessment:

a) Description of Concept

Arrange machinery to minimize piping runs and improve operation and maintenance.

b) Impact on Ship Characteristics

c) Cost Impact

Machinery arrangements can contribute to decreased costs by reducing the amount of piping, electrical cable, exhaust pipes, etc. which must be installed. Arranging machinery symmetrically in a space can result in unnecessary additional costs as contrasted to careful grouping. Also, grouping pipe runs and treating them as units can transfer work from the machinery or other shipboard space to the shop, where greater productivity can be achieved.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 200.9
Propulsion Plant; Machinery Installation

UMTRI No.	57859
Publication	Journal of Ship Production, Vol. 6, No. 4, Nov. 1990, pg. 258.
Title	"Producibility in Ship Design"
Author	Gilbert L. Kraine and Sigurdur Ingvason
Date	November 1990

Concept Assessment:

a) Description of Concept

Plan machinery installations for shop assembly and testing.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

Assembling machinery on skids for installation aboard ship as a fully tested, complete unit permits the work to be accomplished in the more efficient ship as opposed to the shipboard space.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 250.1
Propulsion Plant: System Grouping

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, 1.7.3)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

It is good practice to prepare an equipment-association list for a major piece of machinery to be arranged and installed in a ship for advanced outfitting "on-unit" construction. It is necessary to use the equipment-association list and network to select the grouping of the equipment in the unit.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 260.1
Propulsion Support Systems

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.199, ¶ 4)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Association lists should be used to develop location in the system of all items, and the connections between then. Only equipment which requires a foundation is listed. The addition of valves, gauges, switches, etc. is accomplished when preparing the diagrammatic.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

For advanced outfitting "on-unit" construction, it is necessary to use the equipment-association list and network to select the grouping of the equipment in the unit.

WBS Reference No. 262.1
Propulsion Plant

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, 1.7.3)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Use equipment-association lists to associate lube oil service with the equipment on the unit.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 264.1
Lube Oil Piping

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.202, ¶ 1)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The arrangement of the equipment, and the overall dimensions of the unit, will be affected by the space available in the machinery space, and the other equipment/units therein. It is therefore normal for the design of the unit and the arranging of the machinery space to be performed concurrently. Units should be arranged so that all piping runs are as short as possible, and only in the transverse and longitudinal directions. Diagonal runs should be avoided unless absolutely necessary to suit unit design.

b) Impact on Ship Characteristics

c) Cost Impact

Minimizing piping runs and aligning with ship's X and Y axis will reduce the piping work content.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 264.2
Lube Oil System Valves

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.206, ¶ 7)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Valves should be located so as to come up at the side of the grating and floor plates, and not below or through the middle of the floor plates.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 264.3
Propulsion Plant; FRP Piping for Lube Oil Handling

UMTRI No.	48814
Publication	NSRP #0060, pp. 1-24.
Title	"Fiberglass Reinforced Piping for Shipboard Systems"
Prepared by	G. A. Uberti, Chief of Development Engineering, NASSCO
Date	August 1976

Concept Assessment:

a) Description of Concept

Use fiberglass reinforced piping in place of steel for certain ship systems.

b) Impact on Ship Characteristics

c) Cost Impact

Minimum savings to the shipbuilder by installing FRP piping in place of steel is on the order of 15%-20%, and will improve as the shipyard gains experience. No capital outlay is required for installing FRP piping. No specially skilled craftsmen are necessary.

d) Performance Influence

Due to the non-corrosive nature of FRP, systems subject to corrosion can be designed for longer life, perhaps the life of the ship. FRP has lower frictional resistance to fluid flow and will not generate rust build-up, therefore retaining a constant fluid flow.

Valves require special supports, making freedom of placement limited. FRP pipes cannot be bent requiring small bends and offsets to be laid up by hand or "designed around".

e) Risk Assessment

f) Net Assessment

WBS Reference No. 264.4

Auxiliary Systems; Pipe Coupling of Lube Oil Handling Systems

UMTRI No.	48813
Publication	NSRP #0096, pp. 4-5.
Title	"Outfit Planning"
Prepared by	C.S. Johnson & L.D. Chirillo, Science Applications Inc. & Todd Pacific Shipyards Corporation, respectively.
Date	December 1979

Concept Assessment:

a) Description of Concept

The joining of units/outfitted blocks can be facilitated by the use of removable-stud type flexible couplings for pipe connections.

b) Impact on Ship Characteristics

c) Cost Impact

Flexible couplings increase material costs, but compensate by decreasing manpower, facilities, and overall time required for joining.

d) Performance Influence

Planning is simplified, no welded clips and straps or elongated bolts are required, and some misalignment can be compensated for.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 264.5
Lube Oil Handling

UMTRI No.	48928
Publication	The National Shipbuilding Research Program (NSRP # 0179, pg.55)
Title	"Design for Zone Outfitting"
Prepared by	U.S. Department of Transportation, Maritime Administration, in cooperation with Todd Pacific Shipyards Corporation
Date	September 1983

Concept Assessment:

a) Description of Concept

Align pipe runs parallel to the ship's X, Y, and Z axis to achieve consolidation of pipe pieces for efficient assembly on-unit instead of "tangled spaghetti" pipe runs that must be assembled piece by piece on-board.

b) Impact on Ship Characteristics

c) Cost Impact

On-unit assembly of pipe runs is more efficient than on-board.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

Aligning pipe runs parallel with the ship's main axes is an approach for achieving zone oriented out-fitting. This is an essential means for shifting much fitting work from inefficient piece-by-piece outfitting on-board to outfitting on-unit in a shop where safety, quality, and productivity are considerably enhanced.

WBS Reference No. 300.1
Electric Plant; Systems Grouping and Routing

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/402.
Title	The Application of Production Engineering
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

In parallel with the development of functional spaces, the systems which connect them are defined, and assigned to predetermined orthogonal routes. From a production perspective, the objectives are: 1) to maximize the opportunities to create and manufacture outfit assemblies, 2) to simplify pipe and other system geometry, 3) to increase standardization, 4) to reduce material costs.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 300.2
Electrical Systems

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg. 225, ¶ 1)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Electrical systems should be grouped near the distribution centers.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 320.1
Electric Plant; High Voltage Main Distribution

UMTRI No.	(NA)
Publication	Graduate Student Technical Paper, pg. 9.
Title	"A Review of DDGX Producibility Studies Done by U.S. Shipyards for the DDGX Design Manager."
Prepared by	Geoffrey Hummel, Graduate Student, University of Michigan, Dept. of Naval Architecture & Marine Engineering.
Date	March 1987

Concept Assessment:

a) Description of Concept

Studies show that changing the power distribution system and related components from 450 volts to 460 volts results in a weight savings of 12 long tons on the DDGX.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 320.2
Electrical Cable

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.225, ¶ 1)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The provision of "natural" cable breaks by equipment or panels in way of assembly and module breaks facilitates advanced outfitting. Routing zones for wireways should be assigned during basic design and used for cable routing as the design is developed.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 320.3
Electrical Cable

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.225, ¶ 4)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Open single arm cable wireways which do not necessitate the cable to be "threaded and pulled" through each enclosed section formed by the supports for dual arm wireways reduce cable laying work content.

b) Impact on Ship Characteristics

c) Cost Impact

Cable laying work content is reduced by the use of open single arm cable wireways.

d) Performance Influence

e) Risk Assessment

The use of open single arm wireways is disliked by some due to cable falling out when pulling. This can be prevented by providing lips or retaining clips.

f) Net Assessment

WBS Reference No. 500.1
Auxiliary Systems; Systems Grouping and Routing

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/402.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

In parallel with the development of functional spaces, the systems which connect them are defined, and assigned to predetermined orthogonal routes. From a production perspective, the objectives are: 1) to maximize the opportunities to create and manufacture outfit assemblies, 2) to simplify pipe and other system geometry, 3) to increase standardization, 4) to reduce material costs.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 500.2
Auxiliary Systems

UMTRI No.	(NA)
Publication	Graduate Student Technical Paper, pg. 9.
Title	"A Review of DDGX Producibility Studies Done by U.S. Shipyards for the DDGX Design Manager."
Prepared by	Geoffrey Hummel, Graduate Student, University of Michigan, Dept. of Naval Architecture & Marine Engineering.
Date	March 1987

Concept Assessment:

a) Description of Concept

Auxiliary systems should be located near the distribution system it is related to.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 500.3
Auxiliary System Routing

UMTRI No.	73224
Publication	Bath Iron Works Corporation Study No.7 - PRODUCIBILITY: Task C1 (Contract N00024-81-C-2052), pg.1, 2, 9.
Title	"A Report on the Routing of Distributive Systems Within DDG 51"
Prepared by	Bath Iron Works Corporation
Date	October 15, 1982

Concept Assessment:

a) Description of Concept

An alternate to conventional practice is to use a centralized distributive system. A central distributive system can be described as a pre-defined, open systemway containing piping, cabling and/or ventilation, running on or near the centerline of the ship. Both longitudinal and vertical segments are used and pre-define packages of shop fabricated outfit.

b) Impact on Ship Characteristics

c) Cost Impact

Pre-defining major distributive system routes ensures a total ship evaluation of system priorities and routes, and reduces the length, weight and cost of most systems.

d) Performance Influence

By locating systems on or near the centerline of the ship, the maximum possible amount of structure is placed between them and outside destructive forces. This added protection may also allow for the reduction in the redundancy necessary in many systems.

e) Risk Assessment

f) Net Assessment

Centralization of distributive systems allows unobstructed, rectilinear runs with a minimum of bends. In addition, rectilinearity in distributive runs enhances interconnection outfit packaging. Shop fabricated outfit packages would be installed a board ship as a unit, leaving only the connection of lines at unit breaks to be done after erection on the ways. Locating distributive runs on the main deck and above the damage control "vee" lines reduces the number of watertight, as opposed to , penetrations required thereby saving manhours required for penetrations.

By grouping major systems feeders in a central systemway, the time required for inspection is diminished, thereby reducing the time necessary to maintain the ship.

WBS Reference No. 500.4
Auxiliary System Units

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.206, ¶ 4)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Auxiliary system units should be arranged with maintenance lifting or pulling arrangement considerations in mind, and incorporated on the unit where practical.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 500.5
Auxiliary System Piping

UMTRI No.	48928
Publication	The National Shipbuilding Research Program (NSRP # 0179, pg.58)
Title	"Design for Zone Outfitting"
Prepared by	U.S. Department of Transportation, Maritime Administration, in cooperation with Todd Pacific Shipyards Corporation
Date	September 1983

Concept Assessment:

a) Description of Concept

Even when attempting to develop zone-oriented methods zone designers persist on locating parallel pipe runs so that their centerlines are in the same plane. Locating such runs so that one of their surfaces (i.e. bottom, top, or side) are in the same plane is far more productive.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

Pipe runs with similar surfaces in the same plane allows for similar hangers or supports to be used for the pipe runs.

WBS Reference No. 500.6
Auxiliary Systems; Length of Piping Runs

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.202, 206)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

An equipment -association list should be used for any major piece of machinery to be installed. This list shows all auxiliary equipment requiring foundations which is needed for the operation of the machinery. This equipment should be grouped by function and laid out as a unit (or units). These units should be arranged so all piping runs are as short as possible, and diagonal runs should be eliminated.

b) Impact on Ship Characteristics

c) Cost Impact

Reduced piping run lengths and pipe runs exclusively in the transverse and longitudinal directions reduce the piping work content.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 500.7
Auxiliary Systems; Valve Arrangement

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.206)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Valves should be located to come up at the side of grating and floor plates, rather than below or through the middle of floor plates. This reduces or eliminates cutting grating and floor plating to accomodate valves and increases functionality during later operation.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 500.8
Auxiliary Systems; Use of FRP Piping

UMTRI No.	48814
Publication	NSRP #0060, pp. 1-24.
Title	"Fiberglass Reinforced Piping for Shipboard Systems"
Prepared by	G. A. Uberti, Chief of Development Engineering, NASSCO
Date	August 1976

Concept Assessment:

a) Description of Concept

Use fiberglass reinforced piping in place of steel for certain ship systems.

b) Impact on Ship Characteristics

c) Cost Impact

Minimum savings to the shipbuilder by installing FRP piping in place of steel is on the order of 15%-20%, and will improve as the shipyard gains experience. No capital outlay is required for installing FRP piping. No specially skilled craftsmen are necessary.

d) Performance Influence

Due to the non-corrosive nature of FRP, systems subject to corrosion can be designed for longer life, perhaps the life of the ship. FRP has lower frictional resistance to fluid flow and will not generate rust build-up, therefore retaining a constant fluid flow.

Valves require special supports, making freedom of placement limited. FRP pipes cannot be bent requiring small bends and offsets to be laid up by hand or "designed around".

e) Risk Assessment

f) Net Assessment

WBS Reference No. 500.9
Auxiliary Systems; Piping Arrangement

UMTRI No.	48928
Publication	The National Shipbuilding Research Program (NSRP # 0179, pg.55)
Title	"Design for Zone Outfitting"
Prepared by	U.S. Department of Transportation, Maritime Administration, in cooperation with Todd Pacific Shipyards Corporation
Date	September 1983

<u>Concept Assessment:</u>

a) Description of Concept

Align pipe runs as much as possible with the ship's X, Y and Z axes. This allows for efficient on-unit assembly as opposed to on-board assembly.

b) Impact on Ship Characteristics

c) Cost Impact

On-unit assembly involves greatly reduced labor hours when compared to on-board assembly. Straight pipe lengths are also much easier to fabricate and handle than extensively-bent pipe sections.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 500.10

Auxiliary Systems; Use of Flexible Couplings

UMTRI No.	48813
Publication	NSRP #0096, pp 4-5.
Title	"Outfit Planning"
Prepared by	C.S. Johnson and L.D. Chirillo, Science Applications Inc. & Todd Pacific Shipyards Corporation, respectively.
Date	December 1979

Concept Assessment:

a) Description of Concept

The joining of units/outfitted blocks can be facilitated by the use of removable-stud type flexible couplings for pipe connections.

b) Impact on Ship Characteristics

c) Cost Impact

Flexible couplings increase material costs, but compensate by decreasing manpower, facilities, and overall time required for joining.

d) Performance Influence

Planning is simplified, no welded clips and straps or elongated bolts are required, and some misalignment can be compensated for.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 510.1
Hull Structure; Deck House

UMTRI No.	73231
Publication	DDGX Program Producibility Study 7C1, pg. 11.
Title	"Deck Heights: A General Report Summarizing Techniques for Reducing Deck Heights for DDG 51"
Prepared by	Bath Iron Works Corporation
Date	December 1982

Concept Assessment:

a) Description of Concept

Study proposes running distributive systems (HVAC and Firemain) in trunks which could be protected with armor for runs high in the ship or near the shell.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 510.2
HVAC Systems

UMTRI No.	(1) 72960
	(2) 73224
Publication	(1) The National Shipbuilding Research Program (NSRP # 0219, pg.221, ¶ 1)
	(2) Bath Iron Works Corporation Study No.7 - PRODUCIBILITY: Task C1 (Contract N00024-81-C-2052), pg. 10.
Title	(1) Engineering for Ship Production
	(2) A Report on the Routing of Distributive Systems Within DDG 51
Prepared by	(1) Thomas Lamb, Private Consultant
	(2) Bath Iron Works Corporation
Date	(1) January 1986
	(2) October 15, 1982

Concept Assessment:

a) Description of Concept

Planned integration of systems will reduce the shipboard conflicts, i.e. "filed run pipe" and "who gets there first" problems. In traditional design and construction of ships, systems such as piping, HVAC, and electrical are always "fighting" each other for space. To overcome this problem some designers allocate space priorities to different systems such as HVAC first - large-diameter pipe next - electrical wireways - and so on. Unfortunately, this approach does not work well. This traditional conflict does not end with design and engineering, it continues out on the ship during construction.(1)

The inclusion of ventilation in the centralized distribution system design should be considered as an alternative.(2)

b) Impact on Ship Characteristics

c) Cost Impact

Reducing shipboard conflicts will increase productivity during these construction stages.(1)

d) Performance Influence

e) Risk Assessment

The inclusion of ventilation in the centralized distribution system design would present challenges. Routing ventilation through the systemway increases the length of ducting in the case of the DDG 51.(2)

f) Net Assessment

An essential step to ensure a production-friendly design of HVAC systems is to plan the distribution zones early in the design development at the same time as the development of the zones for piping and electrical systems.(1)

WBS Reference No. 510.3
HVAC Systems

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg 221.)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

The use of standards for HVAC components and diagrammatics is an effective design for production approach. Obviously, the standards should be minimum-work-content designs.

b) Impact on Ship Characteristics

c) Cost Impact

If standards are designed for minimum-work-content then the concept of standards will be easier to construct and minimize work content.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 520.1
Auxiliary Systems; Sea Water

UMTRI No.	73231
Publication	DDGX Program Producibility Study, pg. 13.
Title	"Deck Heights: A General Report Summarizing Techniques for Reducing Deck Heights for DDG 51"
Prepared by	Bath Iron Works Corporation
Date	December 1982

Concept Assessment:

a) Description of Concept

Study proposes pipe bends with a radius of twice the nominal pipe diameter. This allows a reduction in the volume assigned over bends of larger radius.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 520.2
Sea Water Systems Routing

UMTRI No.	73224
Publication	Bath Iron Works Corporation Study No. 7 - PRODUCIBILITY: Task C1 (Contract N00024-81-C-2052), pg. 2, 9.
Title	"A Report on the Routing of Distributive Systems Within DDG 51"
Prepared by	Bath Iron Works Corporation
Date	October 15, 1982

Concept Assessment:

a) Description of Concept

In order to derive the greatest benefit from pre-outfit, each system run should be as nearly rectilinear as possible, ex. centralized distributive system. Since major passages are located adjacent to the shell, distributive runs would follow the curvature of the hull. Due to this non-rectilinearity, each pre-outfit system run would require custon plans, sketches, fabrication, etc., hence, pre-outfitting these areas becomes more complex.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

By locating systems on or near the centerline of the ship, the maximum possible amount of structure is placed between them and the outside destructive forces. This added protection may also allow for the reduction in the redundancy necessary in many systems.

e) Risk Assessment

f) Net Assessment

Centralization of the distributive systems allows unobstructed, rectilinear runs with a minimum of bends. In addition, rectilinearity in distributive runs enhances interconnection outfit packaging. Shop-fabricated outfit packages would be installed aboard ship as a unit, leaving only the connection of lines at unit breaks to be done after erection on the ways. Locating distributive runs on the main deck and above the damage control "vee" lines reduces the number of watertight, as opposed to non-watertight, penetrations required thereby saving manhours required for penetrations. By grouping major systems feeders in a central systemway, the time required for inspection is diminished, thereby reducing the time necessary to maintain the ship.

WBS Reference No. 562.1
Rudder Design

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg. 161)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Spade rudders should be considered as an alternative to "closed" apertures due to lower work content if properly integrated in the design of the stern structure, and modern bearings are utilized.

b) Impact on Ship Characteristics

Spade rudders have larger diameter rudder stocks compared to "closed" apertures.

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 562.2-4
Rudder Design

UMTRI No. 72960

Publication . . . . . . The National Shipbuilding Research Program (NSRP # 0219, pg. 161)

Title . . . . "Engineering for Ship Production"

Prepared by . . . . . . Thomas Lamb, Private Consultant

Date . . . . January 1986

Concept Assessment:

a) Description of Concept

The traditional design of rudders results in high work content which can be reduced by simplifying the design through the following approaches:

- Constant section throughout the depth
- Vertical leading and trailing edges
- Horizontal bolting coupling instead of taper with nut

b) Impact on Ship Characteristics

Vessel's maneuvering characteristics will change along with rudder changes, these changes should be investigated on a ship-by-ship basis.

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 581.1
Anchor Handling System

UMTRI No. 84701
Publication ...... AOE-6 Producibility Review, Sec. IV.2.A
Title .... "AOE-6 Producibility Review"
Prepared by .... Advanced Technology, Inc.
Date .... August 1985

Concept Assessment:

a) Description of Concept

Stow the anchor in a recess in the 01 deck edge. Locate the chain pipe vertically above the chain locker thereby permitting a straight run for the chain.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

Benefits include: increased clearance for the anchor, hawse pipes not required, and easier inspection and maintenance of anchor handling system.

e) Risk Assessment

f) Net Assessment

WBS Reference No. 600.1
Outfit and Furnishings; Standardization

UMTRI No.	(NA)
Publication	Graduate Student Technical Paper, pg. 3.
Title	"A Review of DDGX Producibility Studies Done by U.S. Shipyards for the DDGX Design Manager"
Prepared by	Geoffrey Hummel, Graduate Student, University of Michigan, Dept. of Naval Architecture & Marine Engineering
Date	March 1987

Concept Assessment:

a) Description of Concept

Study recommends standardization of materials and equipment when possible.

b) Impact on Ship Characteristics

c) Cost Impact

Reduce handling and installation costs.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 600.2-3
Outfit and Furnishings; Unit Breaks

UMTRI No.	(NA)
Publication	Graduate Student Technical Paper, pg. 3..
Title	"A Review of DDGX Producibility Studies Done by U.S. Shipyards for the DDGX Design Manager."
Prepared by	Geoffrey Hummel, Graduate Student, University of Michigan, Dept. of Naval Architecture & Marine Engineering.
Date	March 1987

Concept Assessment:

a) Description of Concept

Study recommends arrangement of outfitting materials away from unit breaks and arrangement for pre-outfitting.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 600.4
Outfit and Furnishings; Systems Grouping and Routing

UMTRI No. 73531
Publication . . . . NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/402.
Title . . . . "The Application of Production Engineering"
Prepared by . . . . Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date . . . . December 1985

Concept Assessment:

a) Description of Concept

In parallel with the development of functional spaces, the systems which connect them are defined, and assigned to predetermined orthogonal routes. From a production perspective, the objectives are: 1) to maximize the opportunities to create and manufacture outfit assemblies, 2) to simplify pipe and other system geometry, 3) to increase standardization, 4) to reduce material costs.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 631.1
Painting

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, 1.3.2 h, ¶ 4)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

If the tanks are to be coated, it would be preferable to have no module connecting welding which would damage the coating, thus requiring rework. One way to achieve this ideal would be to provide cofferdams in way of erection joints.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

It would still be a productivity net improvement depending on design, extent of required testing, and tank coating.

WBS Reference No. 635.1
Hull Insulation

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.179, ¶ 3)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Apply hull insulation to joiner linings and ceilings, instead of inside surfaces of hull and deckhouse structure.

b) Impact on Ship Characteristics

c) Cost Impact

This eliminates work effort for fitting insulation between and around frames and beams, as well as cutting flaps for welded supports for ventilation ducts, pipes, and wireways.

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 640.1-5
Living Spaces

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.179, ¶ 2)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Standardization is an essential design-for-production approach, not only for individual items, but for units such as modular toilets, modular furniture, complete cabins, galleys, and storerooms.

A number of design-for-production ideas for hull outfit are:

- Use of composite dividers.
- Use modular accommodation units, if not complete cabin units at least modular toilets and common outfitted joiner bulkheads
- Keep furniture off the deck, supported by joiner bulkheads. This eliminates fitting of sub-bases
- Use modular galley equipment/walls
- Use carpet over bare steel in cabins
- Use trowelled-in-place deck covering for passageways, storerooms, and work areas
- Use non-grinding terrazzo in galley and toilets

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

There are numerous advantages of modular accommodation units, namely:

- Relocation of work from ship to shop, resulting in easier access, and cleaner and safer environment
- Possibility of assembly line techniques for multiple units
- Elimination of transporting many small parts to ship
- Simpler material control
- Reduction in material scrap
- Shorter installation time onboard the ship

WBS Reference No. 650.1
Service Spaces; Grouping

UMTRI No.	73531
Publication	NSRP #0236, Design for Production Manual, Vol. 3., pp. 3-2/304.
Title	"The Application of Production Engineering"
Prepared by	Bethlehem Steel Corp., A&P Appledore Limited, J.J. Henry Co.
Date	December 1985

Concept Assessment:

a) Description of Concept

Equipment and services to be located in machinery spaces should be analyzed to produce an arrangement in which items with common functions are grouped together. In addition, a standard layout of machinery spaces can be developed for various prime movers. This facilitates the grouping of equipment to form outfitting modules.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 660.1
Outfit and Furnishings; Working Spaces

UMTRI No.	(NA)
Publication	Graduate Student Technical Paper, pg. 16.
Title	"A Review of DDGX Producibility Studies Done by U.S. Shipyards for the DDGX Design Manager."
Prepared by	Geoffrey Hummel, Graduate Student, University of Michigan, Dept. of Naval Architecture & Marine Engineering.
Date	March 1987

Concept Assessment:

a) Description of Concept

Study recommends using deck plating with stiffeners on both the upper and lower sides. This allows the stiffeners on the upper side of the deck plating to be used as a base for the false floors normally found in the electronics spaces.

b) Impact on Ship Characteristics

Results in reduction in the overall deck height necessary in electronics spaces.

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment

WBS Reference No. 660.2
Working Spaces

UMTRI No.	72960
Publication	The National Shipbuilding Research Program (NSRP # 0219, pg.179, ¶ 4)
Title	"Engineering for Ship Production"
Prepared by	Thomas Lamb, Private Consultant
Date	January 1986

Concept Assessment:

a) Description of Concept

Use trowelled-in-place deck covering for passageways, storerooms, and work areas.

b) Impact on Ship Characteristics

c) Cost Impact

d) Performance Influence

e) Risk Assessment

f) Net Assessment