The Product Oriented Design and Construction (PODAC) Cost Model

A Proposed Procedure for Product-Based and Process-Driven Ship Cost Estimating
The (new) Standard Procedure

1. Define the Product to be Built (Mandatory)
   1.1. Define the item for which an estimate is required.
   1.2. Determine the Product Work Breakdown Structure for the item.

2. Define How the Product will be Built (Mandatory)
   2.1. Determine the Work Types.
   2.2. Determine the Stages of Construction.
   2.3. Determine the Work Centers.
   2.4. Determine the Cost Items
   2.5. Determine the unit of measure for each Cost Item.
   2.6. Determine the direct labor hours per unit of measure, or the total direct labor hours, for each Cost Item.
   2.7. Determine the material cost per unit of measure, or the total material cost, for each Cost Item.

3. Define the Cost Information (Mandatory)
   3.1. Determine the direct labor rates.

The standard procedure has five steps; three set up the problem.
4. **Estimate the Cost of the Baseline Product (Mandatory)**
   4.1. View by Project Summary
   4.2. View by PWBS Summary
   4.3. View by Work Center Summary
   4.4. View by Paragraph Summary
   4.5. View by Cost Item Value by Work Center
   4.6. View by Cost Item Value by PWBS

The standard procedure has five steps; one provides the cost estimate.
5. Perform Studies on the Baseline Cost Estimate (Optional)

5.1. Builder Variations
   5.1.1. Modify Work Center labor cost rates and cost rate application equations
   5.1.2. Modify overhead cost rates and profit margin
   5.1.3. Move selected Cost Items from one Work Center to another
   5.1.4. Changing selected Cost Items from one rate year to another

5.2. Product Variations
   5.2.1. Modify the Cost Item cost data
   5.2.2. Modifying labor-hour estimates, labor costs, or material costs
   5.2.3. Deleting selected Cost Items
   5.2.4. Replacing selected sets of Cost Items with other sets

5.3. Process Variations
   5.3.1. Modify the Cost Item cost data
   5.3.2. Modifying labor-hour estimates, labor costs, or material costs
   5.3.3. Changing selected Cost Items from one rate year to another
   5.3.4. Deleting selected Cost Items
   5.3.5. Replacing selected sets of Cost Items with other sets

The standard procedure has five steps; one provides trade-off opportunities.
New Thinking:

1. Define the Product to be Built (Mandatory)
   1.1. Define the item for which an estimate is required.
   1.2. Determine the Product Work Breakdown Structure for the item.

2. Define How the Product will be Built (Mandatory)
   2.1. Determine the Work Types.
   2.2. Determine the Stages of Construction.
   2.3. Determine the Work Centers.
   2.4. Determine the Cost Items.
   2.5. Determine the unit of measure for each Cost Item.
   2.6. Determine the direct labor hours per unit of measure, or the total direct labor hours, for each Cost Item.
   2.7. Determine the material cost per unit of measure, or the total material cost, for each Cost Item.

3. Define the Cost Information (Mandatory)
   3.1. Determine the direct labor rates.

These items are new to us.
Unit Price Analysis (UPA) Cost Model vs PODAC Cost Model

- UPA is systems-based... PODAC is product-based
- UPA is weight-driven... PODAC is process-driven

There are two basic differences between the two cost models.
System-Based to Product-Based

The PODAC Cost Model uses a different cost accounting system.
Weight-Driven to Process-Driven

**UPA CM**

\[
\text{Labor CER} = \frac{\text{Hours}}{\text{Ton}} = f(\text{Process}) = g(\text{Interim Product, Stage, Work Type})
\]

**PODAC CM**

\[
\text{Material CER} = \frac{\$}{\text{Ton}} = \left(\frac{\$}{\text{Unit of Measure}}\right)_{\text{Interim Product}}
\]

where Hours, Ton, and $ are known via normal bid proposals or cost reporting and ship weight reports.

where Interim Product, Stage, and Work Type are known to the shipyard, but (generally) unknown to the Navy cost estimator.

This is different.

This is the “same.”

The major difference between the two models is the labor CER since the Unit of Measure could be Tons.
Consider the Labor CER

Labor CER = f (Process) = g (Interim Product, Stage, Work Type)

- **Interim Product**
  - Level 1
    - SHIP
  - Level 2
    - CONSTRUCTION ZONE
  - Level 3
    - GRAND BLOCK / OUTFITTING ZONE
  - Level 4
    - BLOCK / UNIT
  - Level 5
    - ASSEMBLY
  - Level 6
    - SUB-ASSEMBLY
  - Level 7
    - PART
  - Level 8
    - COMMODITY / COMPONENT

- **Stage**
  - Non-Construction Related
    - Designing
    - Planning
    - Procurement
    - Purchasing
    - Material Management
    - Launch
    - Delivery
    - Post Delivery
    - Test & Trials
  - Construction Related
    - Fabricating
    - Sub-Assembling
    - Assembly
    - On-Unit Outfitting
    - On-Block Outfitting
    - Grand Block Construction
    - Erecting
    - On-Board Outfitting
    - Set-Up
    - Clean-Up
    - Finishing

- **Work Type**
  - Administration
  - Engineering
  - Hull Outfitting
  - HVAC
  - Joiner
  - Materials
  - Machinery
  - Material Handling
  - Operations Control
  - Paint
  - Pipe
  - Production Services
  - Quality Assurance
  - Structure
  - Test & Trials
  - Unit Construction

Labor CERs are a function of what type of work is being performed on what product, when and where.
Generating the Labor CER

\[ \text{Labor CER} = f \text{(Process)} = g \text{(Interim Product, Stage, Work Type)} \]

- **Option 1**
  - Shipyard(s) Developed
    - Historical records
    - Code of Accounts

- **Option 2**
  - Navy Developed
    - NSRP
    - Experts
    - Etc.

There are two options for generating CERs; they are not mutually exclusive options.
Consider Navy Developed Labor CERs

Labor CER = f (Process) = g (Interim Product, Stage, Work Type)

The CER development procedure is based on work documented in:


Navy Developed
- NSRP
- Experts
- Etc.

We relied heavily on the work of others.
The Procedure for Generating Product CERs

Define the products-type.

The procedure has thirteen steps; the first six are generic.
The Procedure for Generating Product CERs

Potential Work Processes
- Obtain Material
- Flame Cutting
- Edge Preparation
- Shaping
- Fit-up & Assembly
- Welding, Automatic
- Welding, Manual
- Marking
- Handling
- Surface Preparation
- Coating
- Testing

Work Units
- Feet
- Inches
- Joint
- Piece
- Piece or Assembly

Standard Stages
- 1 Fabrication
- 1 Fabrication; 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 1 Fabrication
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 1 Fabrication
- 2 Pre-Paint Outfitting; 3 Paint; 4 Post-Paint Outfitting
- 3 Paint
- 3 Paint
- 2 Pre-Paint Outfitting

Standard Work Stage Factors
- 1.0
- 1.0 or 1.5
- 1.5
- 1.0
- 1.5
- 1.5
- 1.5
- 1.0
- 1.5 or 2.0 or 3.0
- 2.0
- 2.0
- 1.5

Standard Process Factor Values (Labor Hours/Work Unit)
- 0.100
- 0.050 or 0.090
- 0.030 to 0.070
- 0.020 to 15.000
- 0.560
- 0.054
- 1.200 to 1.820
- 0.100
- 0.100 to 5.00
- 0.100 to 0.200
- 0.100
- 0.250 to 0.500

The procedure mimics the PODAC Cost Model approach.
The Procedure for Generating Structural Product CERs


Steel Specification Tables
- Material CER, $/Pound, for profiles and plates

Labor CER = (SCF * APF) in Labor Hours / Work Unit
The Procedure for Generating Structural Product CERs

Interim Product

- Define Interim Product
  - Material Type
  - Dimensions
  - Actual Work Processes
  - Numbers of Work Units
  - Actual Stage

Steel Specification Tables
- Material CER, $/Pound, for profiles and plates

Actual Material CER

Actual Work Processes
- Obtain Material
- Flame Cutting
- Edge Preparation
- Shaping
- Fit-up & Assembly
- Welding, Automatic
- Welding, Manual
- Marking
- Handling
- Surface Preparation
- Coating
- Testing

Actual Work Units
- Feet
- Feet
- Feet
- Feet
- Piece
- Piece or Assembly
- Feet2 or Feet
- Feet2
- Feet

Actual Stages
- 1 Fabrication
- 1 Fabrication
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting; 3 Paint; 4 Post-Paint Outfitting
- 3 Paint
- 3 Paint
- 2 Pre-Paint Outfitting

Actual Work Stage Factors (WSF)
- 1.0
- 1.0 or 1.5
- 1.0
- 1.0
- 1.0
- 1.0 or 1.5
- 1.0
- 1.0
- 1.0

Actual Process Factor Values (Labor Hours/Work Unit)
- 0.100
- 0.050 or 0.090
- 0.030
- 0.020 to 0.070
- 0.020 to 15.000
- 0.560
- 0.054
- 1.200 to 1.820
- 0.100
- 0.100 to 5.00
- 0.100 to 0.200

Stage Correction Factors
SCF = Actual WSF / Standard WSF

These steps mimic the PODAC Cost Model approach.
The Procedure and the PODAC Cost Model

These steps generate Cost Item data needed by the PODAC Cost Model.
Returning to the Standard Procedure.....

1. Define the Product to be Built (Mandatory)
   1.1. Define the item for which an estimate is required.
   1.2. Determine the Product Work Breakdown Structure for the item.

2. Define How the Product will be Built (Mandatory)
   2.1. Determine the Work Types.
   2.2. Determine the Stages of Construction.
   2.3. Determine the Work Centers.
   2.4. Determine the Cost Items
   2.5. Determine the unit of measure for each Cost Item.
   2.6. Determine the direct labor hours per unit of measure, or the total direct labor hours, for each Cost Item.
   2.7. Determine the material cost per unit of measure, or the total material cost, for each Cost Item.

3. Define the Cost Information (Mandatory)
   3.1. Determine the direct labor rates.

The standard procedure is now implementable within the PODAC Cost Model.
What This Effort Really Accomplished

A Procedure for Generating Product-Based CERs Based on NSRP Funded Work.

The PODAC Cost Model

The standard procedure supports and enables the PODAC Cost Model.
Demonstration - Example

Baseline: A fabrication cost estimate is made of a simple steel structure Assembly, a tee-stiffened steel plate.

Tradeoff #1:
- Add a Maintenance Stage consisting of two (fabrication) Work Processes: "Surface Preparation - Blasting" and "Coating."
- Re-blasting and re-painting required twice in a six-year period.

Tradeoff #2:
- Four bulb-stiffeners are substituted for every two tee-stiffeners.
- Unit cost of the bulb-stiffeners is 75% greater than tee-stiffeners.
- Blasting and painting of the bulb-stiffeners requires 50% less labor than the tee-stiffeners.
- Re-blasting and re-painting are not required over the six-year period.

Compare the costs of the Baseline, Tradeoff #1, and Tradeoff #2.

The PODAC Cost Model is flexible and tradeoffs are easy to perform.
Using the PODAC Cost Model

This is the PODAC Cost Model opening screen.
Defining the Product
(Tee-Stiffened Panel Assembly)

Three WT 12 X 30.5 Straight Profiles with End Gussets
Eight WT 4 X 7.5 Straight Profiles

Five flat steel plates, butt-welded together to form one large flat steel plate.

The complete Assembly.

This is the Assembly we modeled in the PODAC Cost Model.
Defining The Product
(Tee-Stiffened Panel PWBS)

This is the Product Work Breakdown Structure of the Assembly.
Defining The Product
(Concentrate on the Steel Flat Plates)

Baseline: Tee-Stiffened Plate

Consists of 5, flat steel plates, butt-welded together to form one large flat steel plate.

This is an end-view of the Assembly.
## Flat Steel Plate Interim Product

**Product:** PART 2, #1-5, Steel Plate, Flat  
**Location:** Hold Material

### Commodity Description

<table>
<thead>
<tr>
<th>Item</th>
<th>Value Used</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material:</td>
<td>Steel</td>
<td>MIT, Table 4-2</td>
</tr>
<tr>
<td>Material:</td>
<td>MIL-S-22698 Grade DH-36</td>
<td>MIT, Table 4-2</td>
</tr>
<tr>
<td>Density, Pound / Inch³</td>
<td>0.278</td>
<td>Calculated</td>
</tr>
<tr>
<td>Density, Pound / Feet³</td>
<td>480.00</td>
<td>Calculated</td>
</tr>
<tr>
<td>Thickness, Inches:</td>
<td>0.50</td>
<td>MIT, Table 4-2</td>
</tr>
<tr>
<td>Thickness, Feet:</td>
<td>0.0417</td>
<td>Calculated</td>
</tr>
<tr>
<td>$ / Pound:</td>
<td>$0.45</td>
<td>MIT, Table 4-2</td>
</tr>
</tbody>
</table>

**Pre-Cut Dimensions**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>NSRP 0406, Table C6.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length, Meters:</td>
<td>11.06</td>
<td></td>
</tr>
<tr>
<td>Width, Meters:</td>
<td>2.29</td>
<td></td>
</tr>
<tr>
<td>Area, Meters²</td>
<td>25.33</td>
<td></td>
</tr>
<tr>
<td>Length, Feet:</td>
<td>36.29</td>
<td></td>
</tr>
<tr>
<td>Width, Feet</td>
<td>7.51</td>
<td></td>
</tr>
<tr>
<td>Area, Feet²</td>
<td>272.62</td>
<td></td>
</tr>
<tr>
<td>Weight, Pounds</td>
<td>5,452</td>
<td></td>
</tr>
<tr>
<td>Cost, $</td>
<td>$2,453.60</td>
<td></td>
</tr>
</tbody>
</table>

**Cut Dimensions**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length, Feet:</td>
<td>30.00</td>
</tr>
<tr>
<td>Width, Feet:</td>
<td>6.00</td>
</tr>
<tr>
<td>Area, Feet²</td>
<td>180.00</td>
</tr>
<tr>
<td>Weight, Pounds</td>
<td>3,600</td>
</tr>
<tr>
<td>Cost, $</td>
<td>$1,620.00</td>
</tr>
</tbody>
</table>

Interim product definition: the flat steel plate.
Flat Steel Plate Interim Product

Labor Required Work Processes:

1. Obtain Material: 545 Feet$^2$
2. Flame Cut to size: 37.8 Feet
3. Edge Preparation: 72.0 Feet
4. Mark for inventory control: 1 Piece

Material:

Mild Steel: 0.50 Inch Thick
CER = $0.45 / Pound @ 5,452 Pounds

Interim product definition: the flat steel plate.
Setting up the Generic Procedure for Generating CERs


1. **Define Product-Type**
   - Structural
   - Piping
   - Electrical
   - HVAC

2. **Potential Work Processes**
   - Obtain Material
   - Flame Cutting
   - Edge Preparation
   - Shaping
   - Fit-up & Assembly
   - Welding, Automatic
   - Welding, Manual
   - Marking
   - Handling
   - Surface Preparation
   - Coating
   - Testing

3. **Work Units**
   - Feet²
   - Feet
   - Piece
   - Piece or Assembly

4. **Standard Stages**
   - 1 Fabrication
   - 1 Fabrication; 2 Pre-Paint Outfitting
   - 2 Pre-Paint Outfitting
   - 3 Paint
   - 4 Post-Paint Outfitting
   - 1 Fabrication
   - 1 Fabrication; 2 Pre-Paint Outfitting
   - 2 Pre-Paint Outfitting
   - 2 Pre-Paint Outfitting
   - 2 Pre-Paint Outfitting
   - 2 Pre-Paint Outfitting

5. **Standard Work Stage Factors**
   - 1.0
   - 1.0 or 1.5
   - 1.5
   - 1.0
   - 1.5
   - 1.5
   - 1.5
   - 1.0
   - 1.5 or 2.0 or 3.0

6. **Standard Process Factor Values**
   (Labor Hours/Work Unit)
   - 0.100
   - 0.050 or 0.090
   - 0.030 to 0.070
   - 0.020 to 15.000
   - 0.560
   - 0.054
   - 1.200 to 1.820
   - 0.100
   - 0.100 to 5.00
   - 0.100 to 0.200
   - 0.100
   - 0.250 to 0.500

The generic process is for a structural product-type.
Setting Up Work Centers to Equal Work Processes

Work Centers and Rate Tables mimic the structural Work Processes.
Applying the Procedure to Estimate Flat Steel Plate CERs


Actual Work Processes
- Obtain Material
- Flame Cutting
- Edge Preparation
  - Shaping
  - Fit-up & Assembly
  - Welding, Automatic
  - Welding, Manual
- Marking
  - Handling
- Surface Preparation
- Coating
- Testing

Actual Work Units
- 545 Feet2
- 37.5 Feet
- 72 Feet
  - Bend, Piece, or Inches3
  - Joint
  - Feet
- 1 Piece
  - Piece or Assembly
  - Feet2 or Feet
- 2 Pre-Paint Outfitting

Actual = Standard Stages
- 1 Fabrication
- 1 Fabrication
- 2 Pre-Paint Outfitting
  - 1 Fabrication
  - 2 Pre-Paint Outfitting
  - 2 Pre-Paint Outfitting
  - 2 Pre-Paint Outfitting
  - 1 Fabrication
  - 2 Pre-Paint Outfitting; 3 Paint; 4 Post-
    Paint Outfitting
  - 3 Paint
  - 3 Paint
  - 2 Pre-Paint Outfitting

Steel Specification Tables
- Material CER, $0.45 / Pound for Steel Plate

"Actuals" identified; Labor CER = (SCF*APF) in Labor Hours/Work Unit.
Generating PODAC Cost Model
Input for the Flat Steel Plates

These steps generate Cost Item data needed for the flat steel plate.
### Cost Items for the Five Flat Steel Plates

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Uom</th>
<th>Labor Unit Hours</th>
<th>Material Unit Cost (CER)</th>
<th>Sub Unit Hours (CER)</th>
<th>Travel Unit Cost (CER)</th>
<th>Total Labor Hours</th>
<th>Total Material Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>P3-Obtain Material - Plates (36.29% x 3.5&quot;)</td>
<td>5.00</td>
<td>EA</td>
<td>54.5000</td>
<td>2453.6000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>272.30</td>
<td>12,268.00</td>
</tr>
<tr>
<td>P2-Flame cut to size - auto plates (30&quot;) (Note to minimize cut)</td>
<td>5.00</td>
<td>EA</td>
<td>1.8750</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>9.38</td>
<td>0.0000</td>
</tr>
<tr>
<td>P2-Mark each piece to facilitate identification steel plates</td>
<td>5.00</td>
<td>EA</td>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.50</td>
<td>0.0000</td>
</tr>
<tr>
<td>P2-Edge Preparation - flat (ground 4 sides per unit) - steel plates</td>
<td>5.00</td>
<td>EA</td>
<td>2.8800</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>14.40</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

**Item: 1 Origin Info**

<table>
<thead>
<tr>
<th>Labor CER</th>
<th>Mat't CER</th>
</tr>
</thead>
<tbody>
<tr>
<td>54.5000</td>
<td>2,453.6000</td>
</tr>
</tbody>
</table>

**Manual:** This item was developed manually.
# Options for Units of Measure vs Quantity

<table>
<thead>
<tr>
<th>Interim Product Situation</th>
<th>Option #1</th>
<th>Option #2, Labor</th>
<th>Option #2, Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>One or more, identical interim products</td>
<td>Unique, interim product</td>
<td>Unique, or more than one identical, interim products</td>
</tr>
<tr>
<td>Labor and/or Material Cost Item?</td>
<td>Labor and Material</td>
<td>Labor</td>
<td>Material</td>
</tr>
<tr>
<td>COST ITEM Worksheet Variable</td>
<td>Uom (Unit of Measure)</td>
<td>Each</td>
<td>Feet²</td>
</tr>
<tr>
<td></td>
<td>Quantity</td>
<td>Total number of identical, interim products</td>
<td>Numer of Feet² for the unique, interim product</td>
</tr>
<tr>
<td>Labor Unit Hours (CER)</td>
<td>Hours / Each</td>
<td>Hours / Feet²</td>
<td>NA</td>
</tr>
<tr>
<td>Material Unit Cost (CER)</td>
<td>$ / Each</td>
<td>NA</td>
<td>$ / Each</td>
</tr>
</tbody>
</table>

(1) Each = per unit, per pound, or per any other dimension of interest.
(2) Feet² is a typical unit of measure.
(3) Hours / Each = (Feet² / Each) * (Hours / Feet²)
(4) (Hours / Feet²) is the Actual Process Factor

Optional methods exist for using Units of Measure and Quantity.
### Cost Items for Joining the Five Flat Steel Plates

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Uom</th>
<th>Labor Unit Hours (CER)</th>
<th>Material Unit Cost (CER)</th>
<th>Sub Unit Hours (CER)</th>
<th>Travel Unit Cost</th>
<th>Total Labor Hours</th>
<th>Total Material Cost</th>
<th>Total Sub Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. F2-obtain material - plates (36.29% x 31&quot; x 5&quot;)</td>
<td>3.00</td>
<td>EA</td>
<td>54.000</td>
<td>2432.000</td>
<td>0.000</td>
<td>0.000</td>
<td>272.50</td>
<td>12,268.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2. F2-flame cut to size - auto - plates (30&quot;) (Note to minimize cutting)</td>
<td>5.00</td>
<td>EA</td>
<td>18750</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>9.38</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>3. F2-mark each piece to facilitate identification, steel plates</td>
<td>5.00</td>
<td>EA</td>
<td>10000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.50</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>4. F2-edge Preparation - flat (4 sides per unit) - steel plates</td>
<td>5.00</td>
<td>EA</td>
<td>28000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>14.40</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>5. SA1-mark sub-assembly to facilitate identification</td>
<td>1.00</td>
<td>EA</td>
<td>10000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.10</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>6. SA1-fit up &amp; assembly</td>
<td>4.00</td>
<td>EA</td>
<td>168000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>67.20</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>7. SA1-welding, Auto/Machine - Fillet</td>
<td>4.00</td>
<td>EA</td>
<td>144000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>57.60</td>
<td>0.000</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Item: 1 Origin Info**

- Labor CER: 54,000
- Mfg CER: 2,453,000

MANUAL: This item was developed manually
The Baseline Study Results

<table>
<thead>
<tr>
<th>Contract Id</th>
<th>Project Description</th>
<th>Labor Hours</th>
<th>Labor Cost</th>
<th>Material Cost</th>
<th>Sub Con Hours</th>
<th>Sub Con Cost</th>
<th>Travel Cost</th>
<th>Direct Cost</th>
<th>Indirect Cost</th>
<th>Total Cost</th>
<th>Profit</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assembly</td>
<td>1,440</td>
<td>28,791</td>
<td>15,444</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>44,235</td>
<td>0</td>
<td>84,543</td>
<td>0</td>
<td>84,543</td>
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<tr>
<td></td>
<td>Product Breakdown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tee-Stiffened Baseline

Labor $ = $28,791  
Material $ = $15,444  
Indirect $ = $40,307  

Total $ = $84,543
Tradeoff #1: Typical Adding of Maintenance “Stages”

We modeled two re-occurring Maintenance Stages using two fabrication Work Processes, Surface Preparation and Coating.

Actual Work Processes:
- Obtain Material
- Flame Cutting
- Edge Preparation
- Shaping
- Fit-up & Assembly
- Welding, Automatic
- Welding, Manual
- Marking
- Handling
- Surface Preparation
- Coating
- Testing

Actual Work Units:
- 545 Feet2
- 37.5 Feet
- 72 Feet
- Bend, Piece, or Inches3
- Joint
- Feet
- Feet
- 1 Piece
- Piece or Assembly
- 545 Feet2
- 545 Feet2
- Feet

Actual Stages:
- 1 Fabrication
- 1 Fabrication
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 2 Pre-Paint Outfitting
- 2 Paint
- 3 Paint
- 3 Paint
- 2 Pre-Paint Outfitting

Actual Stage Factors (WSF):
- 1.0
- 1.0 or 1.5
- 1.5
- 1.0
- 1.5
- 1.5
- 1.5
- 1.0
- 1.5 or 2.0 or 3.0
- 2.0
- 2.0
- 0.100 to 0.500
- 0.100
- 0.100 to 5.000

Steel Specification Tables:
- Material CER, $/Pound, for profiles and plates

Stage Correction Factors:
SCF = 1.0

Maintenance Stages can be identified for the flat steel plate.
More Thoughts on Adding Maintenance Stages

More considerations should be given to the addition of Maintenance Stages.

<table>
<thead>
<tr>
<th>Level</th>
<th>Stage of Construction</th>
<th>Location</th>
<th>Standard Difficulty Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fabrication</td>
<td>In Shop</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Pre-Paint Outfitting</td>
<td>On Plate Line - Hot Work</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>Paint</td>
<td>Paint Shop / Stage</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Post-Paint Outfitting</td>
<td>On Platen - Cold Work</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Erection</td>
<td>Erection Site</td>
<td>4.5</td>
</tr>
<tr>
<td>6</td>
<td>On-Board Outfitting</td>
<td>Erection Site</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>Waterborne</td>
<td>Pierside After Launch</td>
<td>10</td>
</tr>
</tbody>
</table>

We modeled the two re-occurring Maintenance Stages, Surface Preparation and Coating, using Level 3 Standard Difficulty Factors.

Perhaps, we should have used Level 5 or 6.
The Baseline and Tradeoff #1 Study Results

### Project Summary by Contract

<table>
<thead>
<tr>
<th>Contract Id</th>
<th>Structure Steel - Starboard Panel of Forward Oil Tank on Container Ship using 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Product Breakdown Structure Ex</td>
</tr>
<tr>
<td>TO1</td>
<td>Trade Off - Tee stiffened w/2 yr.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project</th>
<th>Labor Hours</th>
<th>Labor Cost</th>
<th>Material Cost</th>
<th>Sub Con Hours</th>
<th>Sub Con Cost</th>
<th>Travel Cost</th>
<th>Direct Cost</th>
<th>Taxes</th>
<th>Indirect Cost</th>
<th>Total Cost</th>
<th>Profit</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tee-Stiffened Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline w Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Labor $ =            | $28,791     | $56,463    |
| Material $ =         | $15,444     | $15,444    |
| Indirect $ =         | $40,307     | $70,048    |
| Total $ =            | $84,543     | $150,955   |

We added two re-occurring Maintenance Stages, Surface Preparation and Coating, using fabrication Work Processes and Level 3 Standard Difficulty Factors, and we need to re-painting twice in the first six years.
Tradeoffs: Changing the Product and the Assumptions

Baseline: Tee-Stiffened Plate

- Baseline: steel structure Assembly, a tee-stiffened steel plate.

Tradeoff #1:
- Add a Maintenance Stage: "Surface Preparation - Blasting" and "Coating."
- Re-blasting and re-painting required twice in a six-year period.

Tradeoff: Bulb-Stiffened Plate

Tradeoff #2:
- Four bulb-stiffeners are substituted for every two tee-stiffeners.
- Unit cost of the bulb-stiffeners is 75% greater than tee-stiffeners.
- Blasting and painting of the bulb-stiffeners requires 50% less labor than the tee-stiffeners.
- Re-blasting and re-painting are not required over the six-year period.

The structural details and the maintenance needs/philosophy change for Tradeoff #2.
“Cost Items” for the Bulb-Stiffeners

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Uom</th>
<th>Labor Unit Hours (CER)</th>
<th>Material Unit Cost (CER)</th>
<th>Sub Unit Hours (CER)</th>
<th>Travel Unit Cost (CER)</th>
<th>Total Labor Hours</th>
<th>Total Material Cost</th>
<th>Total Sub Hours</th>
<th>Total Tran Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1-edge preparation - flat</td>
<td>16.00</td>
<td>EACH</td>
<td>1.2000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>19.20</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>F1-flame cut, auto - 16 bulb profile</td>
<td>16.00</td>
<td>EACH</td>
<td>0.0350</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>0.56</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>F1-marking - 16 bulb profile</td>
<td>16.00</td>
<td>EACH</td>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>1.60</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>F1-obtain, receipt and prep</td>
<td>16.00</td>
<td>EACH</td>
<td>4.3000</td>
<td>14.3700</td>
<td>0.0000</td>
<td>0.00</td>
<td>78.24</td>
<td>2,285.92</td>
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</tbody>
</table>

Item 1 Origin Info

Labor CER: 1.2000
Mat'1 CER: 0.0000

MANUAL: This item was developed manually
## Cost Item Summary for the Assembly

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Quantity</th>
<th>Uom</th>
<th>Labor Unit Hours (CER)</th>
<th>Material Unit Cost (CER)</th>
<th>Sub Unit Hours (CER)</th>
<th>Travel Unit Cost (CER)</th>
<th>Total Labor Hours</th>
<th>Total Material Cost</th>
<th>Total Sub Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P1-edge preparation - flat - 3</td>
<td>8.00</td>
<td>EACH</td>
<td>1.2000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>9.60</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>SA1-welding - manual - fillet</td>
<td>3.00</td>
<td>EACH</td>
<td>1.0020</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>3.00</td>
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</tr>
<tr>
<td>3</td>
<td>F2-obtain material - plates (G)</td>
<td>5.00</td>
<td>EACH</td>
<td>3.5000</td>
<td>2452.6000</td>
<td>0.0000</td>
<td>0.00</td>
<td>272.50</td>
<td>12,268.00</td>
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<tr>
<td>4</td>
<td>F2-flame cut to size - auto - p</td>
<td>5.00</td>
<td>EACH</td>
<td>1.8750</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>9.38</td>
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</tr>
<tr>
<td>5</td>
<td>F2-flame cut to size - auto - p</td>
<td>5.00</td>
<td>EACH</td>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>0.50</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>F4-flame cutting, auto - 3 gu</td>
<td>3.00</td>
<td>EACH</td>
<td>0.0950</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>0.29</td>
<td>0.00</td>
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</tr>
<tr>
<td>7</td>
<td>F3-flame cutting, Auto - 3 T</td>
<td>3.00</td>
<td>EACH</td>
<td>0.0800</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>0.24</td>
<td>0.00</td>
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<tr>
<td>8</td>
<td>F2-marking - Tec Bars</td>
<td>3.00</td>
<td>EACH</td>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>0.30</td>
<td>0.00</td>
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</tr>
<tr>
<td>9</td>
<td>A1-fit up and assembly - 3 p</td>
<td>3.00</td>
<td>EACH</td>
<td>16.3000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>50.40</td>
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<tr>
<td>10</td>
<td>A1-welding, auto / machine -</td>
<td>3.00</td>
<td>EACH</td>
<td>12.6000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>12.60</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>11</td>
<td>F2-edge Preparation - flat (ca)</td>
<td>5.00</td>
<td>EACH</td>
<td>2.8800</td>
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<td>0.0000</td>
<td>0.00</td>
<td>14.40</td>
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</tr>
<tr>
<td>12</td>
<td>A1-mark sub-assembly to r</td>
<td>1.00</td>
<td>EACH</td>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>0.10</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>13</td>
<td>A1-marking - A1</td>
<td>1.00</td>
<td>EACH</td>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>0.10</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>14</td>
<td>A1-fit up &amp; assembly</td>
<td>4.00</td>
<td>EACH</td>
<td>16.3000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>67.20</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>15</td>
<td>A1-welding, Auto/Machine -</td>
<td>4.00</td>
<td>EACH</td>
<td>14.4000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>57.60</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>16</td>
<td>F2-obtain material - Tec Bars</td>
<td>3.00</td>
<td>EACH</td>
<td>11.4000</td>
<td>841.1100</td>
<td>0.0000</td>
<td>0.00</td>
<td>34.20</td>
<td>2,523.30</td>
<td>0.00</td>
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<tr>
<td>17</td>
<td>SA2-marking SA2</td>
<td>3.00</td>
<td>EACH</td>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.00</td>
<td>0.30</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Item 1 Origin Info**

- Labor CER: 1.2000
- Mat'l CER: 0.0000

**Manual**: This item was developed manually.
# The Baseline, Tradeoff #1, and Tradeoff #2 Study Results

<table>
<thead>
<tr>
<th></th>
<th>Tee-Stiffened Baseline</th>
<th>Baseline w Maintenance</th>
<th>Bulb-Stiffened w New Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor $ =</td>
<td>$28,791</td>
<td>$56,463</td>
<td>$26,299</td>
</tr>
<tr>
<td>Material $ =</td>
<td>$14,444</td>
<td>$15,444</td>
<td>$17,077</td>
</tr>
<tr>
<td>Indirect $ =</td>
<td>$40,307</td>
<td>$70,048</td>
<td>$36,721</td>
</tr>
<tr>
<td>Total $ =</td>
<td>$84,543</td>
<td>$150,955</td>
<td>$80,027</td>
</tr>
</tbody>
</table>

We used bulb-stiffeners and we never need to re-paint in the first six years.
Summary, Conclusions, and Recommendations

- Develop a Standard Procedure
  - Summary
    - PODAC Cost Model was related to UPA Cost Model.
    - A generic procedure was developed and a structural products procedure was developed.
    - A process was defined for creating standard, work process, re-use packages for typical, fabricated, structural items.
    - Procedures for piping systems, electrical systems, and hull ventilation and air conditioning systems were suggested.
    - Procedures for outfitted structural products was suggested.
    - A cost tradeoff study was performed.
  - Conclusions
    - The PODAC Cost Model can replicate the UPA Model.
    - *Without specific shipyard data*, generic procedures can be developed for using the PODAC Cost Model.
    - The Navy can use the PODAC Cost Model to perform comparative, relative, tradeoff studies.
  - Recommendations
    - Incorporate typical spreadsheet capabilities.
    - Refine the generic and structural product procedures.
    - Create standard, work process, re-use packages typical, fabricated, structural items.
    - Extend the generic procedure to piping systems, electrical systems, and hull ventilation and air conditioning systems.
    - Integrating the structural product procedure with the distributed system procedures.
    - Perform more PODAC Cost Model studies.
Summary, Conclusions, and Recommendations

- Determine the Benefits

  - **Summary**
    - It provides a new cost estimating capability.
    - It estimates the cost of interim products according to the way in which they are fabricated.
    - It provides multiple views of a cost estimate including by Project, by PWBS, by Work Center, by Cost Item Value by Work Center, and by Cost Item Value by PWBS.
    - It is inherently flexible such that Maintenance Stages can be modeled; it is a life cycle cost model.
    - It allows rapid cost, tradeoff studies and it provides a variety of cost sensitivity capabilities.

  - **Conclusions**
    - Training and example problem experience are required.
    - An understanding of several new issues is required.
    - New databases are required.

  - **Recommendations**
    - Training should be offered and an illustrative, example problem set should be created.
    - Training, supporting documentation, and databases should be made available.
    - The concept of a "cost estimating system," with the PODAC Cost Model as a key feature of the system, should be explored.
    - Enhancements to the model should be made: spreadsheet capability, construction sequence, schedule variations, dynamic feedback loops, and other manufacturing issues.