EST.09

Ship Deconstruction Cost Models

Dr. Robert C. Creese, PE CCE, Ashutosh Nandeshwar, Pooja Sibal, et al.

Ship deconstruction is a serious problem for the US Navy and MARAD (MARitime ADministration) as they preside over a fleet of retired naval vessels and merchant ships that grows as ship retirements increase faster than the deconstruction of the ships. There are various estimates of the number of ships that need to be scrapped, from 112 [2] in 2000 to 355 in 2020 [3]. The cost to dismantle a ship in the US has been reported to average between $3-4 million per ship, and the total disposal cost is estimated at $2 billion over 20 years.

The West Virginia Ship Dismantling Team has focused on two major areas: the use of operations research and cost analysis for ship deconstruction and the environmental, health, and safety issues in ship dismantling. The two subgroups first focused on literature reviews and then upon data collection in their respective areas. Our cost models developed have been developed from literature data, since detailed cost information has not been available from the ship dismantling contractors. The cost models developed do appear to give reasonable estimates of the total deconstruction costs. Additional efforts are being started by the cost modeling section to obtain data to develop an estimating model for the revenues obtained from the recyclable materials obtained during the ship deconstruction.

Ship deconstruction has been referred to by many different terms, and nine of these are presented in table 1. Ships are valued primarily on the basis of their light displacement tonnage (ldt), that is the weight of the ship ready for service, including ballast and liquids in machinery, but without its crew, officers, their effects, ammunition, or any other consumable items.

Ship deconstruction costs are higher in the US than in developing countries like Bangladesh, China, India, Mexico, Pakistan, Taiwan, or Turkey because of the lower management and labor costs as well as less stringent environmental regulations and/or enforcement, even though the workhours per ton is lower in the US. Ship dismantling must be done in the US because of the environmental restrictions prohibiting the exporting of ships that contain PCBs and also assurance that the military ships will be dismantled and not resold to a potential enemy. A major advantage for recycling in developing countries, and in particular in India, is that the scrap has higher value and they are able to obtain $150-200 per ton. The recycling value in the US ranges from $50 to 150 per ton.

Companies in developing countries can earn significant profits from disposing of ships because of the increased revenues from the sale of recyclable materials and the lower costs. They can pay up to $1 million for large cargo ships and still earn profits.

Table 1—Equivalent Terms Used for Ship Deconstruction

Ship Breaking
Ship Decommissioning
Ship Deconstruction
Ship Deengineering
Ship Demolition
Ship Dismantling
Ship Disposal
Ship Recycling
Ship Scrapping

Table 2—Ship Complexity Factors as a Function of Ship Type [3]

Ship Type	Ship Complexity Factor
Surface Combatant	6.0
Aircraft Carrier	4.6
Amphibious Warfare	4.0
Auxiliary	1.5
Cargo/Merchant	1.0

MODELS

Two models for the estimation of deconstruction costs were developed: the MARAD model and the RAND model. The MARAD model was developed from the MARAD report [4] and previously presented [2] at an AACE annual meeting. A large amount of data were required for the model, and this information for specific ships typically is not available. The MARAD model was based upon information on cargo ships, and in particular, the Export Challenger. The RAND model was a parametric expression, but it was based upon warships, which have many decks and compartments that are densely packed with equipment. Thus a ship complexity factor was required to compare the results of the RAND and MARAD based models. The ship complexity factors presented in table 2 are based upon the hours needed to construct a ship. These values were adjusted from those in the original reported in the RAND report [3] to use the cargo/merchant ship as the reference rather than the surface combatant ship.

The parametric model [3] used a fully burden labor rate of 45 \$/hr, and the average ship yard rates were estimated to vary from 38 to 53 \$/hr. The parametric equation, developed from examination of the RAND data was:

$$DC(\$) = 12{,}783 \times [FBLR/45] \times [\mathrm{LSW}]^{-0.4909} \times [SCF]$$

where
- *DC* = deconstruction cost(\$);
- *FBLR* = fully burdened labor rate(\$/hr);
- *LSW* = light ship weight(tons); and
  SCF = ship complexity factor.

(equation 1)

The RAND report gave considerably more information on the towing costs than the MARAD model, so the towing cost expression developed from the RAND report was used in both models. The towing costs were estimated to be:

$$TC(\$) = TPC + TR \times TD \times LSW$$

where
- *TC* = towing cost(\$);
- *TPC* = tow preparation cost(outfitting cost) (\$);
- *TR* = tow rate(\$/mile-ton);
- *TD* = tow distance(miles); and
- *LSW* = light ship weight(tons).

The tow preparation cost, also called the outfitting cost, and the tow rate values were obtain from data in the RAND report. The values obtained from the report were \$100,000 for the tow preparation cost, and a tow rate of 0.24 \$/mile-ton was derived from the data.

The MARAD model was developed from data from the Export Challenger, and the validation of the RAND model also used the data from the Export Challenger. The estimated costs from the two models for the Export Challenger are presented in table 3. The same expression was used for the towing costs, but the deconstruction costs were calculated using each model. The MARAD model gives individual components, whereas the RAND model gives a single value for the deconstruction costs.

Table 3—Estimated Deconstruction and Towing Costs by the MARAD and RAND Models for the Export Challenger (Light Ship Weight = 7,684 Tons)

	MARAD \$/LSW)	RAND (\$/LSW)
1) Tow Costs	8.5	8.5
2) Deconstruction Costs		
Purchase	13.0	
Direct Labor	29.3	
Direct Material	4.0	
Safety	8.6	
Environmental & Waste Removal		67.0
Indirect Costs	32.3	
Total Deconstruction Cost	154.2	158.2
Total Costs (\$/LSW)	162.7	166.7
Total Costs (Million Dollars)	1.25	1.28

The results of the two models were extremely close, considering the vast differences in the model approaches. The effect of the difference in the light ship weight for the two models is shown in figure 1 over the range of 2,000 to 20,000 tons. The values are very close in the 3,000 to 20,000 ton range, and the parametric model appears to give estimates that are too high in the 2,000-3,000 range.

The ship multiplying factor effects on the two models is shown in figure 2. This indicates that the ship complexity factor did not change the results significantly, as it is applied to both models in the same manner.

A comparison of the results from the two models versus some data for seven additional ships reported by NAVSEA [1] and the Press Book [6] is presented in table 4 and summarized in figure 3. The results from the models are in good agreement with each other and give good estimates for the costs reported. The only data available for the seven ships were the LSW, the location where the ships were deconstructed, and the company performing the deconstruction. The towing distances were estimated from where the ship was last berthed before dismantling. No other data were available, so the base data from the Challenger were used as default data for the other required values. This assumes that the labor rates were the same for all companies, but the Gulf Coast region typically has lower rates than the East or West Coast regions.

The cost model results do not include any profit values for the contractor, so the model results would be lower than the costs reported by NAVSEA [4], as they would include profits for the contractor. For the contract sales, the revenues from the sales were to be retained by the contractor, and thus the total cost can be considered as the contract cost plus the revenues from the sale of the scrap materials. Since very little information was known about the particular ships other than the light ship weight and the base data, the results from the models are good estimates for the deconstruction costs. The ship complexity factor used was four since it gave the best overall results, although a factor of six would normally be recommended for surface combatants. These were relatively small ships and would not be as difficult as larger surface combatant vessels.

The parametric ship deconstruction cost model developed from the RAND report data gave results similar to those obtained from the model developed from the MARAD data. The results of the two models gave results similar to the reported ship deconstruction costs reported by NAVESEA and MARAD, and these were very good, considering that only one labor rate was used.

The parametric cost model can be useful for quick cost estimates when data is sparse. Further validation of the models is needed as more data becomes available, but the agreement between the RAND and MARAD models gives some assurance as to the validity of the estimates.

Figure 1—Total Cost Versus Light Ship Weight

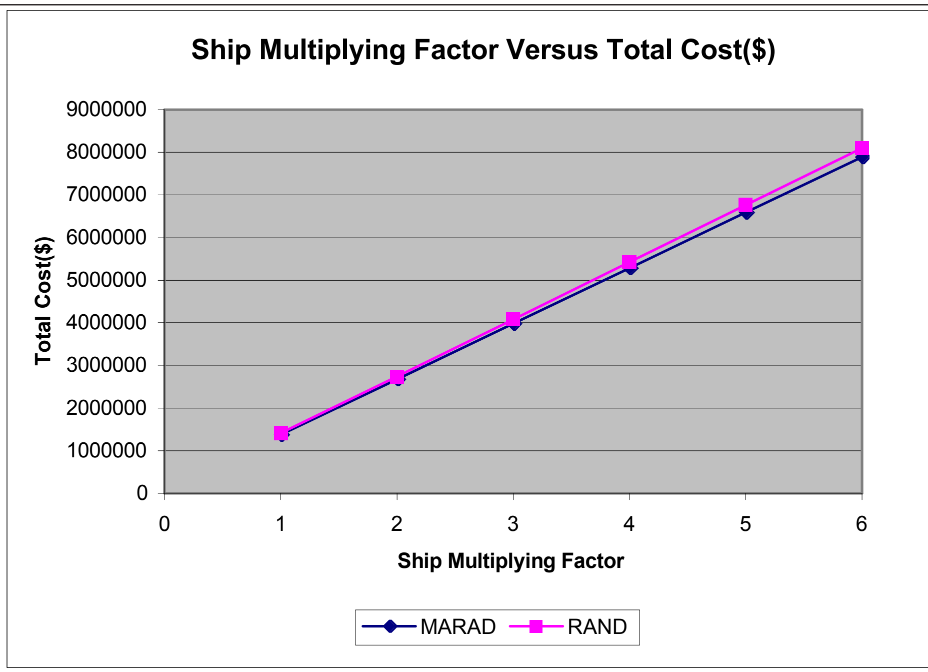

Figure 2—Ship Multiplying Factor Versus Total Cost

ACKNOWLEDGMENTS

This work was sponsored by grant DACA 39-95-0001-P00008 made to the National Environmental Education and Training Center, Inc. (NEETC) by the Strategic Environmental Research and Development Program of the US Department of Defense. The content of information does not necessarily reflect the position or policy of the government, and no official endorsement should be inferred.

REFERENCES

1. Clark, Glen. **U.S. Navy Ship Disposal Project Update**. NAVSEA, 14 Nov 2000. Online: www.navsea.navy.mil/jinii/Ship%20Scrapping%2011-00.ppt
2. Creese, Robert C., and Pooja Sibal. *Ship Dismantling Cost Review*. **2001 AACE International Transactions**. Morgantown, WV: AACE International, 2001.
3. Hess, Ron, Denis Rushworth, Michale V. Hynes, and John E. Peters. **Disposal Options for Ships**. National Defense Research Institute, 2001.

Table 4—Model Results Versus Cost Values Reported by NAVSEA [4] and MARAD [5]

Ship	Type	Tow details			Ship Breaker	Ship Complexity Factor	LSW (tons)	Tow Preparation Cost($)	Total Estimated Cost (Million dollars)		Reported Cost (Million dollars)	Contract Cost + Estimated Scrap Sales
		From	To	Tow Distance (miles)					RAND	MARAD		
Lockwood	Frigate	Benecia, CA	San Francisco, CA	10**	SDR	4	3192	100,000	3.4	3.6	3.7	-
Gray	Frigate	Bremerton, WA	San Francisco, CA	1000**	SDR	4	3202	100,000	3.5	3.6	3.2-C****	3.2+0.4 =3.6
Bagley	Frigate	Benecia, CA	Brownsville, TX	4759**	ISL	4	3209	100,000	3.8	4.0	3.3	-
Blakely	Frigate	Philadelphia, PA	Philadelphia, PA	0**	MMC	4	3243	100,000	3.4	3.6	5.8	-
Patterson	Frigate	Philadelphia, PA	Baltimore, MD	200*	BMI	4	3246	100,000	3.4	3.6	4.5	-
Voge	Frigate	Philadelphia, PA	Philadelphia, PA	0**	MMC	4	3200*	100,000	3.4	3.6	2.7-C	2.7+0.4 =3.1
Builder	Dry Cargo	Ft. Eustis, VA	Brownsville, TX	1752**	ISL	1	6915	100,000	1.6	1.6	1.6-C	1.6+0.4 =2.0

Notes:
* LSW not available, average LSW taken for Frigates.
Taken from DOVE(5)[A **Database for Dismantling of **O**bsolete **VE**ssels]
*** Taken from Disposal options for ships, Table3.7 and 3.8, PN 32, 33.
**** C This was a contract where the contractor kept the revenues obtained from the scrap scales.
Tow Preparation Cost Estimated to be $ 100,000 Estimate Scrap Sales for Contract estimated at $ 400,000($ 0.4 Million dollars)
SDR = Ship Dismantlement and Recycling, Inc. BMI = Baltimore Marine Industries
ISL = International Shipbreaking, Limited MMC = Metro Machine Corporation

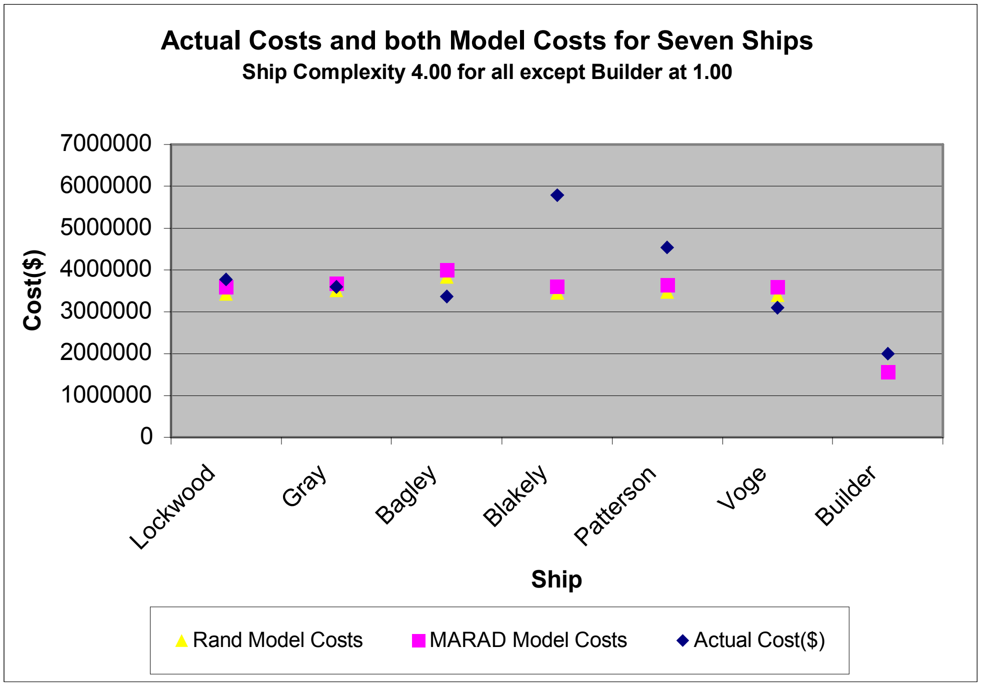

Figure 3—Rand Model and MARAD Model Costs Versus Actual Cost

4. MARAD. **US DOT Environmental Assessment on the Sale of National Defense Reserve Fleet Vessels for Scrapping**. Report Number MA-ENV-820-96003.
5. Sibal, Pooja. *A Database for Dismantling of Obsolete Vessels*. Master's thesis. West Virginia University, 2001.
6. U.S. Department of Transportation. **Maritime Administration, Press Book**. BOO-145, Dec 12, 2000. Online: www.marad.dot.gov/headlines/announcements/2000/dec12.html.

Dr. Robert C. Creese, PE CCE
West Virginia University
Industrial and Management Systems Engineering Dept.
PO Box 6070
Morgantown, WV 26505-6070
E-mail: robert.creese@mail.wvu.edu

Ashutosh Nandeshwar
West Virginia University
Industrial and Management Systems Engineering Dept.
PO Box 6070
Morgantown, WV 26505-6070
E-mail: ashutoshnandeshwar@hotmail.com

Pooja Sibal
West Virginia University
Industrial and Management Systems Engineering Dept.
PO Box 6070
Morgantown, WV 26505-6070
E-mail: pooja_sibal@hotmail.com

Other coauthors include:

Rashpal Ahluwalia
Wafik H. Iskander
Michael Klishis
Allan McKendall
David Whaley
John Boettner
Juan Jaramillo
Michelle Martin
Karen Oganezov