TECHNICAL
REPORT

Using the Steel-Vessel Material-Cost Index to Mitigate Shipbuilder Risk

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Prepared for the United States Navy

RAND NATIONAL DEFENSE RESEARCH INSTITUTE

The research described in this report was prepared for the United States Navy. The research was conducted in the RAND National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Department of the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community under Contract W74V8H-06-C-0002.

Library of Congress Cataloging-in-Publication Data is available for this publication.

ISBN 978-0-08330-4229-3

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Published 2008 by the RAND Corporation
1776 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
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Preface

The U.S. Navy is in the initial production stages of the Littoral Combat Ship (LCS) program. LCS is designed to operate in littorals where many of the Navy's traditional ships cannot function. The Navy selected a team led by Lockheed Martin to construct two of these ships and another team led by General Dynamics to construct two others. Reports of cost escalation in construction of these vessels led the Navy to ask the RAND Corporation to examine possible sources of material cost escalation, i.e., cost escalation in all elements of ship-construction costs except prime contractor and shipyard labor, overhead, and profits. Keating et al. (forthcoming) discusses what we learned about LCS material costs. It contains competition-sensitive, proprietary information and therefore has distribution limited to appropriate government audiences.

This publicly released technical report, by contrast, discusses more general issues related to Navy material cost indexes that we encountered in the course of the LCS project. However, this report is not about the LCS per se; its focus is much broader. This report should be of interest to persons involved with Navy and U.S. Department of Defense (DoD) weapon-system acquisition issues.

This research was sponsored by the U.S. Navy and conducted within the Acquisition and Technology Policy Center of the RAND National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Department of the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community.

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The U.S. Navy wants to provide its shipbuilders with appropriate incentive to produce militarily effective vessels at minimum cost to the Navy.

The Navy can induce a shipbuilder to agree to any contractual arrangement by offering the shipbuilder a high enough price. But it is likely to be preferable, at least ex ante, for the Navy to dissipate risk external to its shipbuilder to pay less for the systems the Navy needs. The Navy uses external labor- and material-cost indexes to attempt to correct for significant cost risks outside its shipbuilders' control. Shipbuilder profits are greater when actual cost growth is less than the indexes' cost growth and conversely.

A longtime material-cost index in Navy shipbuilding is the steel-vessel index. It is a weighted average of three Bureau of Labor Statistics (BLS) producer price indexes (45 percent iron and steel, 40 percent general-purpose machinery and equipment, and 15 percent electrical machinery and equipment).

One criticism of the steel-vessel index is that it does not accurately cover the materials used in building a modern ship. No modern U.S. Navy ship, for instance, has 45 percent of its material costs in iron and steel. To combat this shortcoming, the DDG-51 and T-AKE programs created their own material-cost indexes with lower weighting on iron and steel.

Historically, BLS's iron and steel price index has been much more volatile than has the general-purpose machinery index, the electrical machinery index, or economywide inflation. Consequently, the steel-vessel index has been more volatile than have material-cost indexes with lower weights on iron and steel.

The known mismatch between the steel-vessel index's composition and a shipbuilder's actual material cost structure is problematic. The shipbuilder bears a risk that the prices of iron and steel may tumble while the shipbuilder's costs do not. A risk-averse shipbuilder will require a premium to bear this cost structure–mismatch-driven risk.

We urge the Navy to develop a modern-vessel index that more appropriately represents the material used in constructing ships. The more accurately a material-cost index captures a shipbuilder's external material cost risk, the less we expect the Navy to have to pay its shipbuilders.

Acknowledgments

We especially thank Robert McHenry, our point of contact (POC) with the LCS program office. McHenry distinguished himself as an unusually proactive and involved POC, including tolerating extensive travels around the country. We also thank his former colleague Captain Donald Babcock for sponsoring this research and Lisa Pfeiffer of Naval Sea Systems Command (NAVSEA) for providing information on Navy material cost indexes.

Kevin Cox, Thomas Hudnell, and Douglas Mangen provided insight on Air Force contracting practices.

James Jondrow of the Center for Naval Analyses provided comments on this work at the Western Economic Association annual conference in Seattle on July 2, 2007. Christopher Deegan of NAVSEA provided useful comments on August 8, 2007.

We received constructive reviews of an earlier draft of this report from our colleague Jack Graser and RAND consultant John "Tal" Manvel.

We also thank Philip Antón, Mark Arena, Frank Camm, Phil Dolan, John Dykema, Donna Fossum, Gordon Lee, Robert S. Leonard, Joan Myers, Barbara Neff, Deborah Peetz, Giles Smith, Kara Steiniger, and Benjamin Zycher. Lisa Bernard edited this document.

Of course, the authors alone are responsible for errors that remain.

Abbreviations

BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
DJIA	Dow Jones Industrial Average
DoD	U.S. Department of Defense
FPIF	fixed price, incentive fee
LCS	Littoral Combat Ship
MARAD	Maritime Administration
NASDAQ	National Association of Securities Dealers Automated Quotation System
NAVSEA	Naval Sea Systems Command
POC	point of contact

Using the Steel-Vessel Material-Cost Index to Mitigate Shipbuilder Risk

The U.S. Navy wants to provide its shipbuilders with appropriate incentive to produce militarily effective vessels at minimum cost to the Navy.

Fixed-price contracts provide incentive to a shipbuilder to produce at minimum cost. After contract award, cost savings that the shipbuilder can implement flow directly to the shipbuilder, resulting in higher profit. Conversely, the shipbuilder bears cost overruns, resulting in lower-than-anticipated profits.

Fixed-price contracting becomes problematic, however, when a shipbuilder is forced to bear risk outside of its control. For instance, ship construction requires material inputs such as steel, wire, cable, and a myriad of others. If the global prices of these commodities rise, a fixed-price shipbuilder will have lower profits (or increased losses) external to the shipbuilder's efforts.

Ultimately, the Navy can induce a shipbuilder to agree to any arrangement, including having the shipbuilder bear material-cost risk, by offering the shipbuilder a high enough price. But it is likely to be preferable, at least ex ante, for the Navy to dissipate risk external to its shipbuilder to pay less for the systems the Navy needs.

Conversely, the Navy should not fully immunize a shipbuilder against risks within the shipbuilder's control, e.g., if the shipbuilder's own failures cause a cost overrun. In such a case, the shipbuilder should incur at least a portion of the loss. Of course, it can sometimes be difficult to distinguish problems within a shipbuilder's control from those caused or exacerbated by Navy decisions (e.g., changing requirements) and from those related to external issues (e.g., the rising global price of steel). The Navy uses labor- and material-cost indexes to attempt to correct for several significant cost risks outside its shipbuilders' control. The indexes reflect industry- or economywide costs, not the costs of the specific shipbuilder.

How the Navy Uses Labor- and Material-Cost Indexes

In this section, we present illustrative examples of how the Navy uses labor- and material-cost indexes. To illustrate the basic concept, we start with a highly oversimplified example of a fixed-price contract. Subsequently, we turn to an enhanced (though still less complex than reality) example of a contract more in accord with current Navy practices. This latter example is a fixed-price, incentive-fee (FPIF) contract. An FPIF contract is no longer a "pure" fixed-price contract, in that it requires the Navy and the shipbuilder to share cost changes from the negotiated level with incentives and disincentives for underruns and overruns (whereas a textbook fixed-price contract would not). The shipbuilder's actual costs are considered in an FPIF contract; they are not in a fixed-price contract.

A Very Simple Example

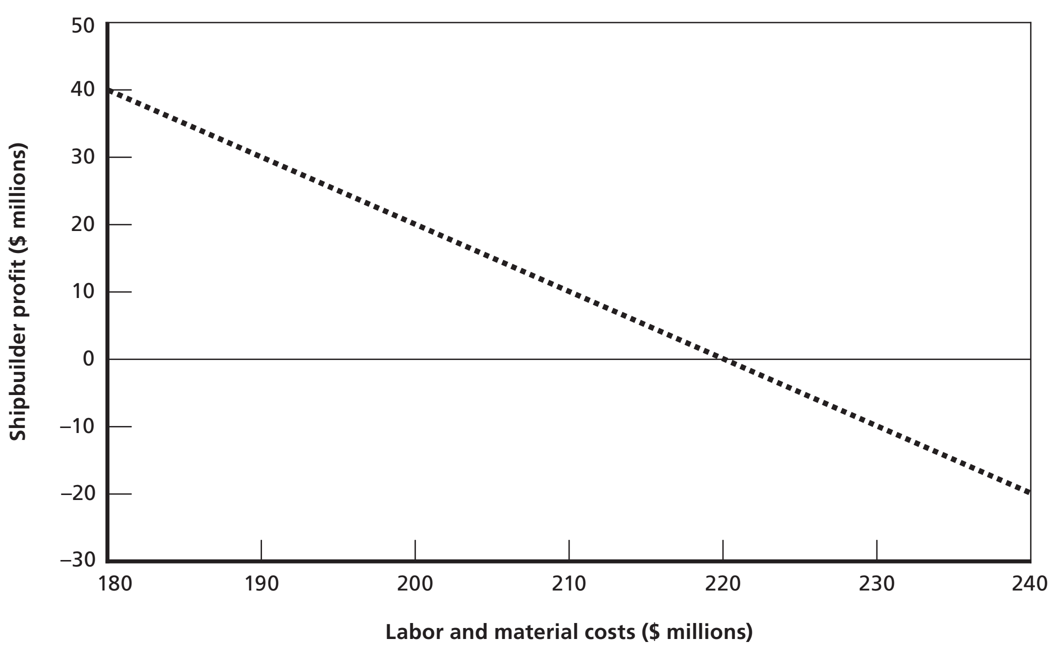
Suppose the Navy signs a fixed-price contract for a $220 million ship on January 1, 2007, with completion scheduled for January 1, 2010. Suppose $100 million of the payment is to cover expected labor costs, another $100 million is to cover expected material costs, and the final $20 million is intended to be contractor profit. Of course, the actual cost the shipbuilder incurs determines the shipbuilder's profit. Figure 1.1 shows the shipbuilder's profit as a function of the actual labor and material cost of the ship. Increasing costs reduce shipbuilder profits dollar-per-dollar.

Adding material-cost indexes to this fixed-price contract would protect the shipbuilder against exogenous cost risk.

Suppose, during the period 2007–2010, the external labor-cost index designated in the contract goes up 5 percent while the designated material-cost index goes up 20 percent. Then the Navy's actual payment to its shipbuilder would be $245 million ($105 million for labor, $120 million for materials, $20 million in intended or target profits—assuming that the profit level does not increase with the indexes). The shipbuilder's actual profit would then go up or down based on whether its actual cost growth was above or below the indexes'. Obviously, it is of central importance that the cost indexes are agreed on up front.

If, on the other hand, the labor-cost index had risen 5 percent while the material-cost index had fallen 10 percent, the Navy's payment to the shipbuilder would be $215 million ($105 million in labor, $90 million in materials, $20 million for target profit). Again, actual

Figure 1.1
Shipbuilder Profit as a Function of Labor and Material Costs with a Fixed-Price Contract



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profit would depend on whether the shipbuilder's total costs had fallen less than or more than the indexes suggested.

Both this example and the one that follows are oversimplified. Both examples assume that all labor is incurred and material purchased on the last day of the contract. If one alternatively assumes that the postulated inflation, labor hours, and material purchases occur uniformly between 2007 and 2010, the average inflation rate would be half as large. In reality, material purchases peak before labor hours incurred, so there are two cost-timing distributions for which to account. Actual Navy escalation clauses calculate these effects on actual costs incurred monthly. The appendix discusses such an enhancement.

A More Realistic Example

The Navy does not generally write shipbuilding contracts that are as simple as the preceding example. Instead, the norm is to use FPIF contracts with "compensation adjustment clauses" or "escalation provisions" to

- ensure that the incentive provision operates independently of outside economic forces that impact shipbuilder costs
- keep the shipbuilder from including contingent amounts in its price to cover economic uncertainty associated with external cost pressure.

In this approach, subsequent changes in specified cost indexes result in payments (or refunds) tied to the shipbuilder's actual labor and material costs incurred. Notice that this approach no longer results in a "pure" fixed-price contract; shipbuilders' actual costs are considered. FPIF contracts actually operate as cost-type incentive contracts within a certain range of costs.

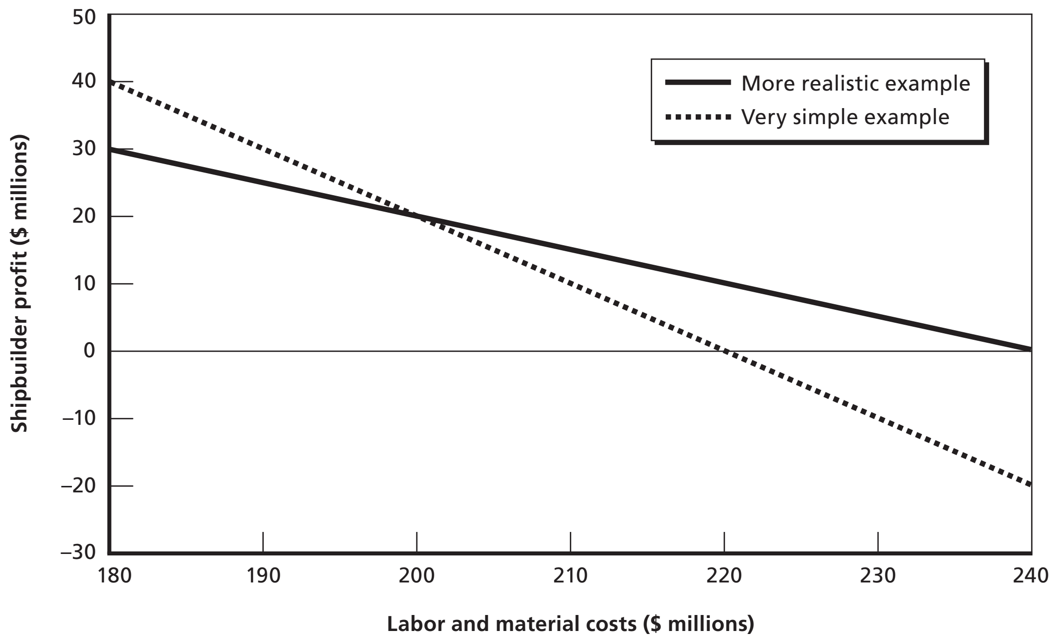
Consider an example similar to this one with the Navy signing a contract for a ship on January 1, 2007, with completion scheduled for January 1, 2010. It is anticipated that $100 million will be spent on labor and another $100 million on material. Suppose the Navy also agrees to a 10 percent target profit rate and a sharing ratio of 50/50 for increases or decreases in cost. Figure 1.2 compares shipbuilder profit under this FPIF contract with the preceding fixed-price case (prior to consideration of cost-index issues). Since this FPIF contract has cost change shared between the Navy and the shipbuilder, the "More realistic example" line is flatter.

As seen in Figure 1.2, it would enhance realism to include labor- and material-cost indexes into this contract.

Suppose, during the period 2007–2010, the labor-cost index designated in the contract goes up 5 percent while the designated material-cost index is up 20 percent. We assume base period labor and material costs of $100 million each. If the shipbuilder's actual labor cost were $105 million, the Navy would pay a compensation adjustment of $5 million ([0.05/1.05] × $105 million).[1] If actual material costs turned out to be $115 million, the Navy would make a material compensation adjustment of $19.17 million ([0.2/1.2] × $115 million). The "de-escalated base cost" of the ship would be $195.83 million (the actual $105 million plus $115 million less the compensation adjustments of $5 million and $19.17 million). The $4.17 million decrease between the initial base cost and the de-escalated base cost would translate into a $2.08 million increase in profit for the shipbuilder, given the assumed 50/50 cost

[1] For expositional simplicity, we are assuming that actual labor costs match the increase in the labor-cost index, allowing us to concentrate on material-cost issues.

Figure 1.2
Shipbuilder Profit as a Function of Labor and Material Costs with Different Contract Structures



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change–sharing ratio. The shipbuilder is rewarded because actual material costs did not rise as rapidly (15 percent) as did the material cost index (20 percent).

The Navy's actual payment to the shipbuilder would be comprised of $195.83 million in de-escalated base cost, $5 million in labor escalation payments, $19.17 million in material escalation payments, $20 million in target profit, plus $2.08 million in incentive profit, totaling $242.08 million. Shipbuilder profit would be $22.08 million.

By contrast, holding the shipbuilder's incurred costs the same as above, suppose that the labor-cost index had again risen 5 percent and the material-cost index fell 10 percent. The labor compensation adjustment would remain $5 million ([0.05/1.05] × $105 million). The material compensation adjustment would now be a reimbursement from the shipbuilder of $12.78 million ([–0.1/0.9] × $115 million). The de-escalated base cost of the ship would be $227.78 million ($105 million + $115 million – $5 million + $112.78 million). This increase in the de-escalated base cost would result in a $13.89 million profit penalty for the shipbuilder ([$227.78 million – $200 million] × 50 percent). Then the Navy would pay the shipbuilder $226.11 million ($227.78 million in de-escalated base cost plus $5 million in labor escalation payments less a $12.78 million material de-escalation reimbursement plus $20 million in target profit less a $13.89 million incentive profit penalty). The shipbuilder profit would be $6.11 million.

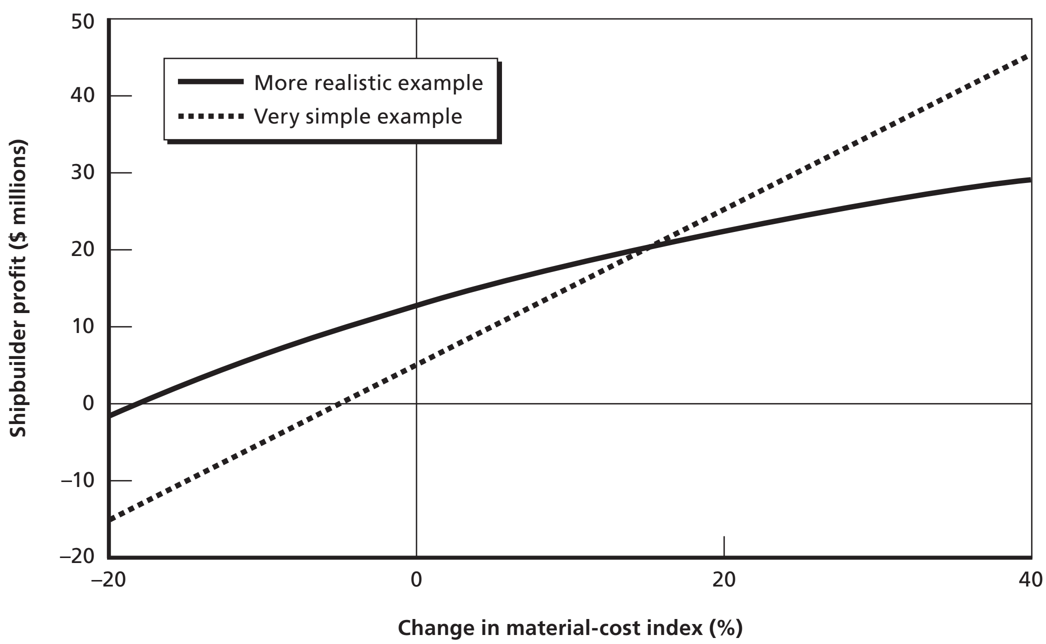
As in the very simple example, we have ignored realistic timing issues, e.g., that the median material cost probably precedes the median labor cost and that neither cost is incurred, on average, in 2010. The appendix discusses the effects of incorporating labor and material-cost time-phasing.

Figure 1.3 summarizes the differential results of these examples, holding fixed that the labor-cost index increased 5 percent while realized shipbuilder costs were $115 million for material and $105 million for labor. Not surprisingly, when the shipbuilder spends more on material than included in the original price while the overall material market has falling prices, the cost disincentive built into the contract reduces the Navy's payment and, therefore, the shipbuilder's profit. (The shipbuilder would have performed very poorly if it paid $115 million for material while material prices were, on average, falling.)

The "Very simple example" and "More realistic example" lines cross at a 15 percent increase in the material-cost index. We have assumed that the shipbuilder's actual material cost increase was 15 percent or $15 million. If the shipbuilder can keep its actual material cost growth below the index level, its reward is greater in the very simple example, in which there is no cost-change sharing with the Navy. Conversely, the shipbuilder's profit does not diminish as rapidly if its actual material costs increase more than the material-cost index with the more realistic example's cost-change sharing.

If the shipbuilder's skillful management kept ship costs from rising as much as similar costs had in the general economy, greater profits are an appropriate reward. However, if greater profits result from escalation payments calculated by an external price index that does not accurately reflect what the shipbuilder purchases, then greater profit is not warranted. Conversely, it would be unfair to penalize a shipbuilder if an inappropriate cost index declines or increases less than the shipbuilder's actual cost environment.

Figure 1.3
Shipbuilder Profits Are Greater When the Material Cost Index Rises More and Realized Costs Are Held Constant



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The Steel-Vessel Index

A longtime material-cost index in Navy shipbuilding is the steel-vessel index. Based on an estimate by the Maritime Administration (MARAD) of the mix of materials in a typical commercial cargo ship constructed in the 1950s (see GAO, 1972), it is a weighted average of three Bureau of Labor Statistics (BLS) producer price indexes (45 percent iron and steel, 40 percent general-purpose machinery and equipment, and 15 percent electrical machinery and equipment). If, for instance, the iron and steel price index increased 3 percent in a year, the general-purpose machinery index increased 2 percent, and the electrical machinery index fell 1 percent, the steel-vessel index would increase 2 percent ([0.45 × 0.03] + [0.4 × 0.02] – [0.15 × 0.01]).[2]

One criticism of the steel-vessel index is that it does not accurately cover the materials used in building a modern ship.[3] No modern U.S. Navy ship, for instance, has 45 percent of its material costs in iron and steel. To combat this shortcoming, the DDG-51 and T-AKE programs created their own material-cost indexes, using different weights on the same three underlying BLS indexes (DDG-51: 20 percent iron and steel, 43 percent general-purpose machinery, 37 percent electrical machinery; T-AKE: 10 percent iron and steel, 60 percent general-purpose machinery, 30 percent electrical machinery).[4] In the preceding example, whereas the steel-vessel index would increase 2 percent, the DDG-51 index would increase 1.09 percent ([0.2 × 0.03] + [0.43 × 0.02] – [0.37 0.01]), and the index for T-AKE would increase 1.2 percent ([0.1 × 0.03] + [0.6 × 0.02] – [0.3 × 0.01]).

There is an additional challenge with any of these indexes: Even if one correctly identified the mix of materials that went into the ship, the materials would be purchased at different stages of ship construction. Steel, for instance, is required early in the construction process. Conversely, combat systems and electrical equipment (perhaps more akin to general-purpose or electrical machinery) are not delivered to the shipyard and consequently do not become incurred costs until much later in construction. Time-phasing the mix of an overall material-cost index could provide greater fidelity. However, it is unlikely that any material-cost index will completely dissipate a shipbuilder's exogenous material-cost risk.

Historically, BLS's iron and steel price index has been much more volatile than the general-purpose machinery or electrical machinery indexes. Figure 1.4 displays these indexes' quarterly returns (with a positive "return" if the cost-index value went up, negative if it fell) between the second quarter of 1947[5] and the fourth quarter of 2006. We also display the

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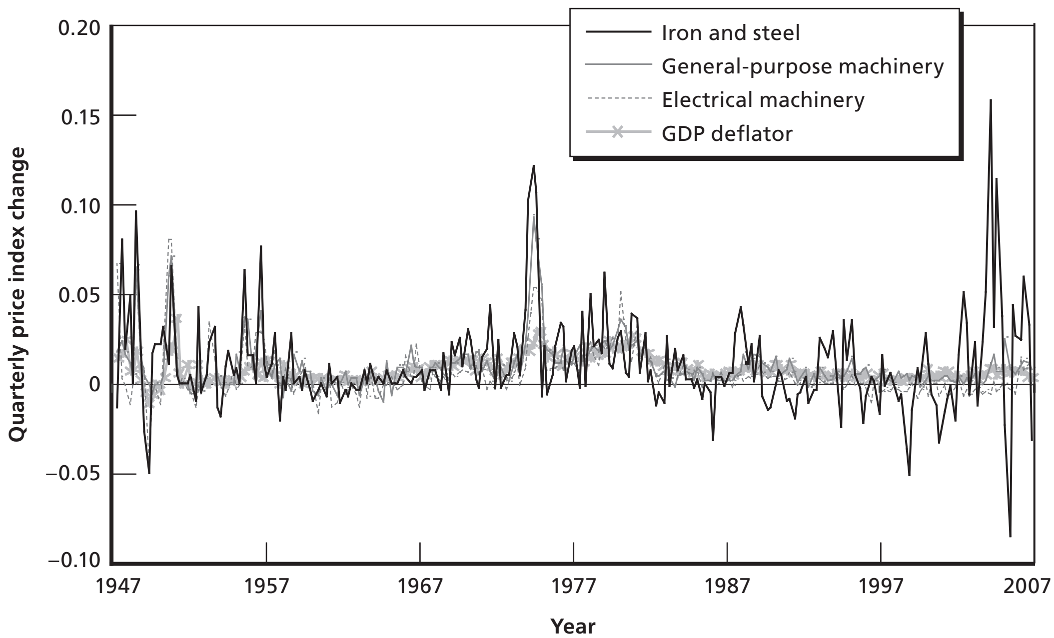
2 There does not appear to be an Air Force analogue to the steel-vessel index. Air Force procurement contracts may include BLS-based labor or material cost indexing, but this is done on a case-by-case basis at the discretion of the program office. There is no standard aircraft material-cost index. An aircraft's construction duration is typically much briefer than that of a ship, so inflation issues are less prominent.

3 Indeed, criticism of the steel-vessel index predates what we might term "modern" ships. Geismar (1975) suggested that the steel-vessel index was ill suited to the DD-963 *Spruance*-class destroyer and the LHA Marine amphibious assault ship, two 1970s-era ship programs. (Both of these ships were very late in delivering, implying that inflation issues proved to be more important than would have been the case had their production been timelier.)

4 See Pfeiffer (2006). The DDG-51, the USS *Arleigh Burke*, is a destroyer commissioned on July 4, 1991. The moniker *DDG-51* refers to the class of destroyers of which the USS *Arleigh Burke* was the first. See U.S. Navy (2006). *T-AKE* refers to the *Lewis and Clark* class of dry cargo and ammunition ships. The USNS *Lewis and Clark*, the USNS *Sacagawea*, and the USNS *Alan Shepard* have been delivered to the Navy; the USNS *Richard Byrd* is under construction. See U.S. Navy (2007) and Bigelow (2007).

5 Monthly BLS data on these cost indexes are available back to January 1947. However, the BEA GDP deflator data are available only quarterly, so we aggregated the BLS data to the quarter level.

Figure 1.4
Quarterly Changes in Different Cost Indexes



SOURCE: BLS (undated), BEA (undated).
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quarterly change in the Bureau of Economic Analysis' (BEA's) GDP price deflator, a measure of overall inflation in the economy.

Naturally, given the steel-vessel index's greater relative weighting of the iron and steel price index, it has been more volatile than the DDG-51 or T-AKE indexes. In Figure 1.5, we plot the standard deviation in the quarterly return and the mean quarterly return for the three ship material-cost indexes and the GDP deflator between the second quarter of 1947 and the fourth quarter of 2006.[6] The steel-vessel index has the greatest standard deviation in its quarterly return.

What Figure 1.5 does not show is how closely correlated any of these indexes is with the actual cost variability a shipbuilder experiences. The best cost index is the one that minimizes a shipbuilder's exogenous risk and therefore minimizes the risk premium that the Navy must pay the shipbuilder. We know, however, that the steel-vessel index overrepresents iron and steel costs in current naval warship contracts.

The fact that the steel-vessel index has had a mean quarterly return greater than the other indexes, and the economywide inflation rate is not prima facie bad news for the Navy. In a competitive setting, a shipbuilder will submit a lower bid up front if it expects super-normal escalation. So the Navy's expected costs are not, in equilibrium, affected by the index's mean.

What is more problematic is the known mismatch between the steel-vessel index's composition and a shipbuilder's material cost structure. The shipbuilder bears a risk, for instance, that the prices of iron and steel may tumble while the shipbuilder's do not. A risk-averse shipbuilder will require a premium to bear this cost structure–mismatch-driven risk.

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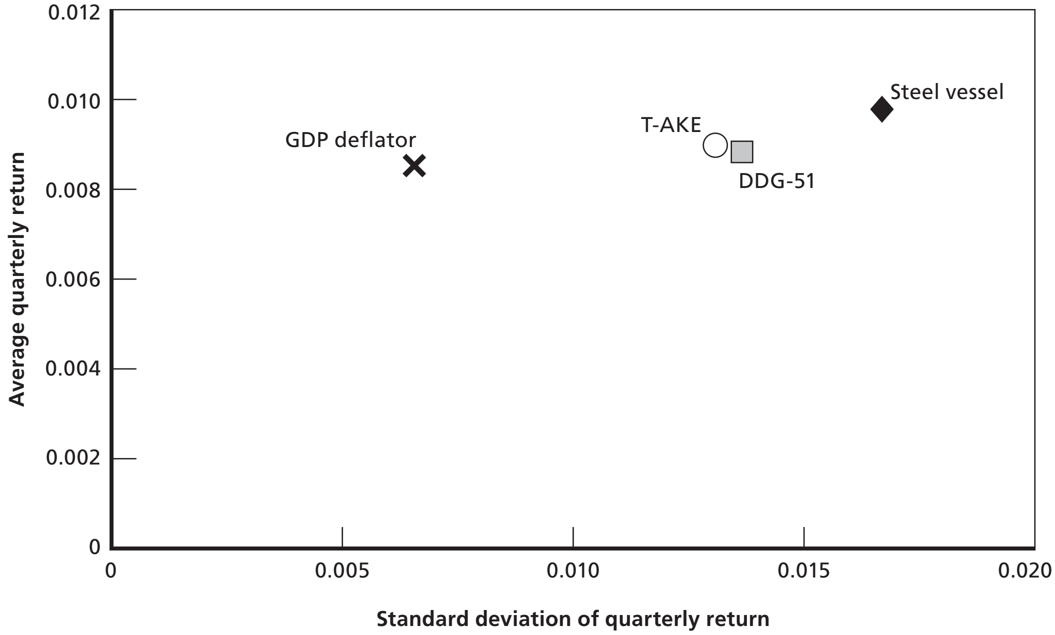
6 None of the three ship material-cost indexes existed in 1947. But we can use BLS data to retrospectively compute how they would have evolved.

Figure 1.5
Quarterly Standard Deviation and Average Return of Different Material-Cost Indexes, Second Quarter of 1947 Through Fourth Quarter of 2006



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This mismatch-driven risk could be reduced if the shipbuilder could take a short position on steel futures, i.e., hedge against the risk that steel prices will fall. Currently, however, there is no functioning steel-future market.[7]

Paradoxically, if the shipbuilder locked in its steel input prices through a long-term, fixed-price contract with a steel mill, the shipbuilder's cost structure–mismatch-driven risk could be exacerbated, not mitigated. If future steel prices fell, the shipbuilder would receive no advantage on the cost side while receiving reduced revenue from the Navy.

We do not know the "right" material-cost index to use to minimize a shipbuilder's material-cost risk. We do know, however, the steel-vessel index is imperfect due to its over-representation of iron and steel. As shown in Figure 1.5, there is little difference between the DDG-51 and T-AKE approaches; their quarterly returns are positively correlated at the 0.985 level. (By contrast, the steel-vessel index has a 0.936 correlation with the DDG-51 index and 0.873 with T-AKE.)

Of the three Navy material-cost indexes, T-AKE (0.655) and DDG-51 (0.636) are more highly correlated with the GDP deflator than is the steel-vessel index (0.538). The explanation for the steel-vessel index's relative lack of correlation with overall inflation in the economy is that the iron and steel cost index has a much lower correlation (0.360) with the GDP deflator than do the general-purpose machinery (0.634) and electrical machinery (0.609) cost indexes. So a material-cost index that oversamples iron and steel moves away from representation of economywide costs.

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7 There is an ongoing debate as to the feasibility and desirability of a steel-future market. See, for instance, Anderson (2006).

The foremost argument in favor of the steel-vessel index is its familiarity and, consequently, the comfort that some shipbuilders have with the index. Almost everyone we met in the nautical construction industry knows of the steel-vessel index, and most have experience with contracts tied to it. The steel-vessel index is, perhaps, akin to the Dow Jones Industrial Average (DJIA), in that one would not invent it anew (or at least not with its current weightings) but its fame and tradition keep it in use.[8]

Having shipbuilders being familiar and comfortable with the index is desirable for the Navy and the government if it implies that shipbuilders can be paid less when the index is in use. The best material-cost index minimizes the exogenous risk that shipbuilders perceive themselves to face so as to therefore minimize Navy ship acquisition costs. Unless one believes familiarity is extremely important, however, the manifest cost-structure mismatch of the steel-vessel index suggests that its usage does not minimize the Navy's expected costs.

Conclusions

We do not think that the Navy should use the steel-vessel index to adjust for material cost changes in future shipbuilding contracts. The steel-vessel index clearly puts excessive weight on iron and steel relative to the materials actually used in constructing a modern ship. Usage of the steel-vessel index does not appropriately mitigate contractor material cost risk. Indeed, from a shipbuilder's perspective, a new risk is created: the risk that the prices of what the shipbuilder actually buys will rise faster than the price of steel.

The shortcomings of the steel-vessel index have been known for many years. The DDG-51 and T-AKE programs created their own material-cost indexes with less weight on iron and steel. Their material-cost indexes, which empirically have been highly correlated with one another, are doubtlessly better indexes than the steel-vessel index, though they still appear to put too much weight on iron and steel (DDG-51: 20 percent, T-AKE: 10 percent).

We urge the Navy to develop a modern-vessel index that more appropriately represents the material used in constructing ships. Moving toward a better index would also be an opportunity to explore a time-phased material-cost index, e.g., reflect the fact that shipbuilders typically buy keel steel early in production with onboard electronics procured much later in the construction process. The more accurately a material-cost index captures a shipbuilder's external material-cost risk, the less we expect the Navy to have to pay its shipbuilders.

8 Discussing an earlier version of this paper, Jim Jondrow of the Center for Naval Analyses raised the following analogy to the Navy's continued use of the steel-vessel index: Suppose one owned a portfolio that mirrored the National Association of Securities Dealers Automated Quotation System (NASDAQ) Composite Index but observed the DJIA (or vice versa). On March 10, 2000, the NASDAQ Composite Index closed at an all-time high of 5,046 but then fell precipitously, ultimately hitting a bottom of 1,114 on October 9, 2002. See Wikipedia (undated). Meanwhile, the DJIA closed at 9,929 on March 10, 2000, and at 7,286 on October 9, 2002. See Yahoo! Finance (undated). The indexes were positively correlated with one another, but the magnitudes of the changes were sharply different.

APPENDIX

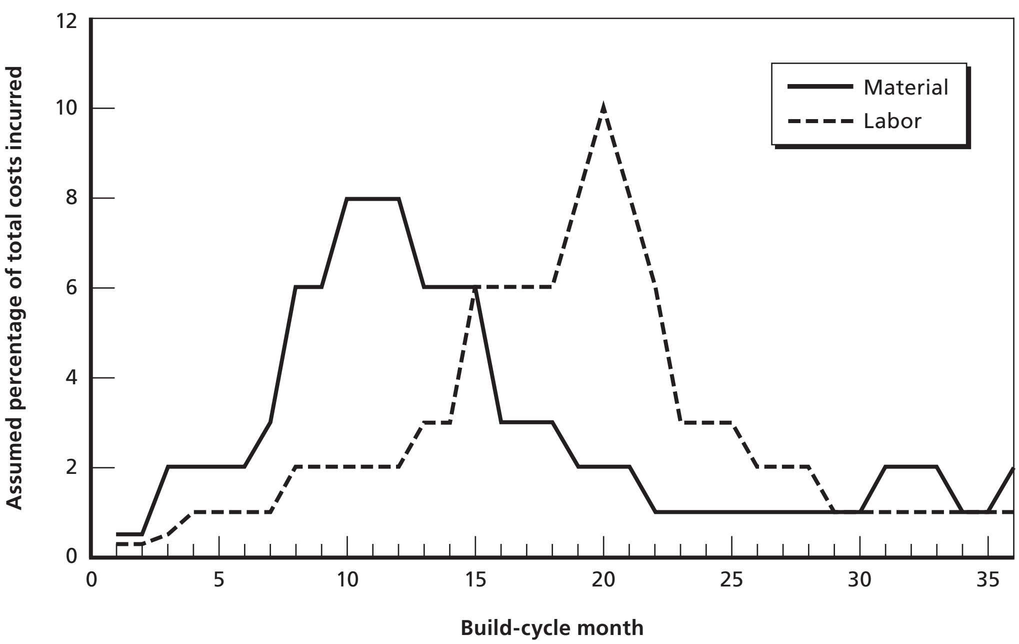
Time-Phasing Material- and Labor-Cost Indexes

In the examples in the body of the report, we unrealistically assume that all shipbuilder expenses are borne at the end of the three-year build cycle, so we then use the material- and labor-cost index values at the end of the build cycle to determine the Navy's payment to the shipbuilder.

In fact, actual Navy shipbuilding contracts are more sophisticated. Instead of assuming that all costs are incurred at the end of the build cycle, a month-by-month expenditure pattern is assumed, an illustrative example of which is presented in Figure A.1.

Figure A.1, like most Navy shipbuilding contracts, assumes that the shipbuilder generally bears material costs (e.g., buying keel steel) in front of labor costs.[1]

Figure A.1
An Illustration of Assumed Percentages of Total Costs Incurred, by Month



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[1] Standard shipbuilding contracts do not, however, differentiate between types of material. An enhancement that we urge the Navy to consider would be to break up material costs, e.g., assume that steel expenditures for the keel precede electronic-type expenditures for onboard weapon systems.

The effect of this time-phasing assumption is to move forward the implicit median date of contractor expenditure and therefore to reduce (assuming that the labor- and material-cost indexes generally increase) the inflation-related adjustment that the shipbuilder receives. This reduction is generally more marked for material costs because of the standard assumption that material costs are borne sooner.

Revisiting a Very Simple Example

As above, suppose the Navy signs a fixed-price contract for a ship on January 1, 2007, with completion scheduled for January 1, 2010. We assume that the ship has $100 million each in expected labor and material costs plus an additional expected or target profit of $20 million. Suppose, however, labor and material costs are expected to be borne in accord with Figure A.1's pattern.

Suppose, during the period 2007–2010, the external labor-cost index designated in the contract goes up 5 percent while the designated material-cost index goes up 20 percent. Suppose (though one need not make this pedagogically simplifying assumption) those increases occur uniformly over the 36-month build period. Then the effective increase in assumed labor costs, given Figure A.1's cost-incurrence pattern, is 2.6 percent, while the increase in material costs is 8.1 percent. Note that the effective increase in labor costs is 52 percent of the three-year total increase, while the effective increase in material costs is 40 percent of the three-year total increase; this differential reflects the assumption that material costs generally precede labor costs.

In the contract in the very simple example, the Navy's actual payment to the shipbuilder would be $230.7 million ($102.6 million for labor, $108.1 million for material, $20 million for target profit).

Time-phasing contracts does not axiomatically imply reduced shipbuilder profits (though one might draw such an inference from juxtaposing this example with the very simple example in the body of the report). The shipbuilder will make its initial bid cognizant of how (and whether) labor and material costs are to be indexed. A less generous (but more accurate) indexing approach of this sort will doubtlessly cause the shipbuilder's bid to be greater.

Revisiting a More Realistic Example

In our more realistic example, the Navy provided the shipbuilder with an FPIF contract with a 50/50 sharing ratio on increases or decreases in costs.

As noted, if the labor-cost index designated in the contract goes up 5 percent in three years while the designated material-cost index goes up 20 percent, the effective increases in the indexes are 2.6 percent and 8.1 percent, respectively, adjusting for Figure A.1's assumed expenditure pattern.

In "A More Realistic Example" in the body of the report, we had actual labor costs of $105 million. If we scaled this value down in accord with Figure A.1, the adjusted actual labor costs would be $102.6 million. Similarly, adjusted actual material costs would be $106.1 million. The labor compensation adjustment would now be $2.6 million:

$$\left(0.026/1.026\right)\times \$102.6 \text{ million.}$$

The material cost adjustment would be $8.0 million:

$$\left(0.081/1.081\right)\times \$106.1 \text{ million.}$$

The de-escalated base costs of the ship would be $198.1 million:

$$\text{adjusted actual labor and material} - \text{compensation adjustments for labor and material, or}$$
$$\left(\$102.6 \text{ million} + \$106.1 \text{ million}\right) - \left(\$2.6 \text{ million} + \$8.0 \text{ million}\right).$$

The shipbuilder profit would be increased by $0.9 million.

As in the body of the report, the shipbuilder's profit is greater, holding its actual incurred costs constant, when the material-cost index grows more. The effect of time-phasing is to roughly halve (more of a reduction for material than for labor) the measured indexed inflation rate. But the comparative static result that the shipbuilder is better off when the material-cost index rises more, holding costs constant, remains. Again, such rewards are appropriate if the shipbuilder held costs down better than might have been expected. Conversely, if greater profits were received because an index used to calculate escalation payments is flawed, unwarranted profits may result.

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