A Simplified and Scalable Should-Cost Tool in the Oilfield Services Industry

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Submitted to the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degree of

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Abstract

Third party spend accounts for a significant amount of a business' costs. When procuring unique, highly-engineered components, this cost is often negotiated with suppliers during the procurement process. Due to the limited understanding of the suppliers' true production cost, various techniques and models for determining how much a procured product should cost have been tried. One such approach is known as "should-cost modeling," where estimates for the cost of a product or service are made based on product architecture and/or firm financials. Both these approaches to should-cost modeling require extensive data collection and are time consuming. In this thesis, we expand an approach that uses aggregate industry-specific financial data to develop a simple, scalable tool to estimate a product's should-cost. One major challenge in building this tool is unifying the simple aggregate data available into an estimated price for a complex product. This is a major challenge of developing a should-cost estimate using existing methods. We develop an approach to simplifying a complex product, construct our model, and create a ready-to-use tool. We demonstrate the working of the model and the tool using the case of a semi-complex product (the fluid end of a pump) representative of a company's procured products. We then compare the price estimated by our model with that currently negotiated with our sponsor company's supplier and solicit qualitative feedback from procurement professionals regarding the should-cost tool's accuracy. The price estimated by our tool is within 9% of the actual negotiated price and required significantly less time to compute compared to the current approach based on product architecture. The company's sourcing and procurement executive strongly endorses the benefits of our approach. This tool can remove the reliance on supplier-supplied quotes and strengthen the purchasing company's negotiating position. The tool developed in this thesis is shown to provide a more accurate estimate of product cost, with significantly less estimation effort.

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1 Introduction

CMSP Oil & Gas (CMSP) is a global provider in the oil and gas industry with 2012 revenue exceeding $10 billion and employing over 50,000 people of more than 60 nationalities working in over 40 countries. They provide a wide range of products and services to oil and gas companies that are used in activities from exploration through production. CMSP commits over $5 billion to annual third party spend, which implies that there are many potential opportunities to save money within the sourcing and procurement group. This is an easy task for commodity products, however, for highly engineered products that often have a limited number of suppliers, it is difficult to estimate an appropriate benchmark/reference price.

The company breaks down its purchases into 5 product categories, approximately 15 sub categories, around 100 product families, more than 400 commodities, and in excess of 1 million individual products. The sourcing operation is broken down into three parts: Category Management, where the sourcing process begins; Regional Sourcing, where individual supplier relationships are built; and Procurement, where the transactional process occurs in manufacturing and at field sites. In the current sourcing model, conflicts arise during price negotiations with suppliers because there is little information available on the cost to produce the good – there is only the price quoted by the suppliers.

This problem is not unique to CMSP – price negotiations require a great deal of time and effort. The supplier/buyer relationship is severely strained when the purchasing company is large enough to force lower prices from the supplier or when the supplier has market power and exacts an unfairly high price from the purchaser. Both situations damage the business relationship and prevent either business from maximizing long-term profits. An unbiased, quantitative-based cost analysis can serve as the basis for strategic alliances with key suppliers. These mutually beneficial alliances can be initiated and framed around a comprehensive should-cost analysis. A feature of this arrangement is the cooperation it engenders, which replaces the often-adversarial stance separating buyers and sellers (Bowersox, 1990). The final issue with the current procurement system is its imprecise forecast of third party spend, which results in inaccurate company-wide budget planning.

CMSP currently uses an approach known as should-cost modeling to guide their price negotiations. However, the current approach is time and resource consuming. The main scope of this project is to expand the recently developed should-cost model from CMSP into a simple, yet robust tool that sub-category managers can use to determine the cost of a diverse array of products and use throughout the sourcing section of the supply chain function. This should-cost model will help those responsible for sourcing better understand the underlying costs quoted by third party suppliers, suggest target prices to them, and provide leverage in price negotiations. The expectation from our research is to provide a framework for the implementation of a simple, adaptive should-cost model that can expand to all categories of third party spend.

A simplified, scalable should-cost tool allows the sourcing teams to achieve financial and operational improvements for the company. The tool provides the overall production or service cost for the supplier and accounts for a reasonable profit margin. This removes the reliance on the suppliers' quoted price information. If a company relies on the supplier's price as the only reference point, the supplier has an incentive to quote a higher price – knowing that the negotiation with the company will lower the price – so the supplier can still make profit. This behavior is not in the spirit of true supply chain collaboration. This aids the purchasing company financially in several respects. First, it lowers overall costs for most services or products procured and allows the company to control and accurately predict its third party spend throughout the budget planning process. Second, the model also has the potential to be expanded to help predict the effects of various raw material price fluctuations on the total projected spend, making the budgeting process more representative of current market conditions. Finally, CMSP conservatively estimates they could save $10 million to $20 million if they better understood the underlying costs of the products and services they purchase. At a high level, the company can relatively easily increase profits by cutting sourcing and procurement costs because every one-dollar reduction in third party spend correlates to a one-dollar rise in profit. This 1:1 shift of costs to profit is incredibly efficient compared to the effects of increasing sales, where there is only a marginal increase to profits of approximately 10% due to the associated expenses of each additional sale.

Implementing a simplified should-cost tool that can be scaled for a diverse array of product categories will also improve several aspects of operations. The model will allow the company to estimate the true costs of products it purchases, provide a tool to assist in price negotiation, and serve as a basis for better integration with suppliers. The model will provide a better understanding of the supplier's production process in relation to industry standards and provide opportunities to decrease the time devoted to should-costing. Reaching the pinnacle of these achievements requires a high-level of trust and understanding between the supplier and purchaser. The should-cost model can be the impetus to begin this collaborative relationship and increase efficiency and profit for both companies. To achieve this end, the research questions we intend to answer are: **Can aggregate industry-specific financial data be developed into a simple, scalable tool to estimate a product's should-cost? If so, how does this should-cost tool's price compare to the actual product's negotiated price?**

2 Literature Review

This literature review provides the background and a summary of existing research in the area of should-cost modeling as well as a review of the practical application of these models in the sourcing, procurement, and acquisition process. Previous research on the topic of should-costing is somewhat limited. The preponderance of literature covers aspects of procurement cost analysis such as Total Cost of Ownership (TCO) and Activity Based Costing (ABC). Should-cost is often an ancillary component of these other studies, which provides excellent context for our research in this area. In the first section, we provide an overview of should-cost acquisition based on its introduction by the U.S. military in the 1960s and its continued application through 2012. The second section covers the best practices of should-cost models utilized by major private and public companies. The third section focuses on issues related to the adoption and implementation of should-cost models. The final section concentrates on several of the key technical aspects that previous researchers have uncovered and that are commonly used in should-cost models, including manufacturing and financial costing techniques.

2.1 Examining the Government's Should-Cost Acquisition Process

The concept of should-cost sourcing and procurement has its roots in the 1960s, when the U.S. government decided to curb the rapidly escalating costs in the military acquisition process (Williams, 1985). For much of the next 50 years, literature and academic work – such as theses, research papers, and lectures – were based on the government's use of should-cost models in the acquisition of major military weapon systems. Should-cost reviews were a new technique to determine the potential cost of a military system that was under consideration for purchase. The previous (and still commonly used) price determination system was a three-bid, "will-cost" estimate from the defense contractors. In this system, defense contractors placed a bid to build the weapon system based on historical data from similar weapon systems. The problem was, the will-cost estimate became the "'floor' from which costs escalate, rather than a 'ceiling' below which costs are contained – in many ways creating a self-fulfilling prophecy of budgetary excess" (Carter & Mueller, 2011). The Department of Defense (DoD) then selected the lowest bid from the will-cost estimates provided by the contractors, and the acquisition process continued.

The current Federal Acquisition Regulation (FAR) specifically stipulates should-cost reviews and section 15.407-4(a) specifically describes them as:

> a specialized form of cost analysis. Should-cost reviews differ from traditional evaluation methods because they do not assume that a contractor's historical costs reflect efficient and economical operation. Instead, these reviews evaluate the economy and efficiency of the contractor's existing work force, methods, materials, equipment, real property, operating systems, and management. These reviews are accomplished by a multifunctional team of Government contracting, contract administration, pricing, audit, and engineering representatives. The objective of should-cost reviews is to promote both short and long-range improvements in the contractor's economy and efficiency in order to reduce the cost of performance of Government contracts. In addition [...] the Government will be better able to develop realistic objectives for negotiation (15.4-14).

In 2010, the U.S. Under Secretary of Defense, Dr. Ashton Carter, released a new memorandum for the Armed Forces dictating the use of should-cost management "[d]uring contract negotiations and program execution, our managers should be driving productivity improvement in their programs" (Carter, 2010). Dr. Carter and Professor Mueller expounded on this topic in an article that describes should-cost management as going beyond the simplistic definition in the FAR. Their intent is that the "should-cost management approach should be used throughout the program lifecycle [...] focused on up-front planning and exploring engineering trades to ensure successful outcomes at every milestone" (Carter & Mueller, 2011). Should-cost, the authors noted, is more than just a review as laid out in the FAR or a cursory step added to the acquisition process – it is a tool for actively managing procurement costs, improving efficiency, and solidifying relationships with key suppliers (Carter & Mueller, 2011).

The military has left should-cost estimates to the most expensive acquisitions, usually involving nine or more figures in the potential price tag. From the personal experience of Clay Mealer in the U.S. Army—one of the coauthors of this thesis—the procurement of standard items below the super-expensive threshold are completed by soliciting at least three bids and choosing the least expensive one. Several studies have been conducted to evaluate the effectiveness of should-cost estimates versus traditional three-bid acquisitions of major military systems. David Conway and Michael Howenstine (1983) conducted a statistical evaluation of should-cost contract negotiations in the U.S. Air Force and Army because they noted a distinct lack of "in-depth studies analyzing the costs versus benefits of the Should Cost technique [...] and very little actual empirical analysis." They compared traditional contract negotiations with the employment of should-cost estimates and determined that the Army achieved statistically significant reductions in cost with the latter, but the Air Force did not. This study was conducted with a limited number of samples and only used contracts with a firm, fixed price rather than the cost reimbursement type (Conway & Howenstine, 1983).

A more recent study conducted by the RAND Corporation focused on major Air Force acquisitions between the 1980s and early 2000s. Their study found no correlation between the application of should-cost estimates and cost savings in major Air Force contracts. The RAND team's conclusion was that it was difficult for government contracting teams to: identify areas of contractor inefficiency, bind contractors to firm prices, use bargaining power with single-source defense systems, and exercise strong negotiating when government employees lacked the skills to leverage the should-cost estimate (Boito, et al., 2012). The key recommendation to overcome these difficulties and achieve significant cost savings hinged on establishing a trained, dedicated team capable of developing a comprehensive cost estimate to use in negotiations with contractors. The key points outlined in the RAND report are: technical expertise, objectivity, specific training and experience with cost estimation, understanding defense contractor accounting systems and business practices, and successful communication with management. The report discovered an already existing organization known as the Navy Price Fighters that possessed all these qualities and successfully applied them in their cost estimations. The Price Fighters success at cost estimating for the Navy led the Army and Air Force to use them on several of their projects; doing so achieved cost savings in the high teen percentages (Boito, et al., 2012).

Military should-cost estimation in organizations like the Navy Price Fighters called for six phases of analysis. Phase I occurs at the supplier's location to begin communication and ensure the should-cost candidate is optimal. The team is carefully selected based on specific expertise and to ensure objectivity. Phase II continues on-site with the supplier to determine how their operations are run, communicate building requirements, and outline the should-cost analysis plan. Phase III is data acquisition, often the most contentious stage, where the should-cost team determines cost data for labor, materials, overhead, etc. The supplier will often put up roadblocks or delay data availability to inhibit the team's effort at building an accurate cost model. Phase IV is the team's compilation of findings into a single report that will serve as the principal tool for price negotiations with the contractor and serve as lessons learned for future should-cost efforts. Phases V and VI are the preparation and contract negotiation. The should-cost team leader should serve as the lead negotiator since he or she has the greatest knowledge of the should-cost model and the contractor (Williams, 1985). The Price Fighters use this level of analysis on a project-by-project basis (e.g. the should-cost for a F/A-18 Jet Fighter aircraft). The amount of time and work for this cost estimation is substantial and may be justified only for very expensive systems; this cannot be easily used in industry for applications like CMSP pumping mechanism (Naval Supply Systems Command, 2013).

There are at least two aspects of should-cost models in the military's acquisition process that do not translate well to industry. One, there are only a few defense contractors capable of producing advanced weapon systems, which incentivizes them to "bid low in order to win the development contract because they are normally cost-reimbursable contracts and because the DoD usually awards future production contracts only to the contractor that developed the weapons system" (Boito, et al., 2012). The guaranteed cost-reimbursement does not incentivize the contractor to contain development costs and the future production contract almost guarantees a profit. This reinforces the importance of the government verifying bids. A comprehensive should-cost analysis of the defense contractors' bid proposals could save the government millions – perhaps billions – of dollars in cost overruns because of systemic underbidding to win the contract. Two, the six-phase process of determining a product's should-cost is expensive and time consuming, limiting its application to only the most expensive items where its cost could be justified. As a result, businesses have observed the process of supplier cost modeling, and built upon the estimation techniques developed by government programs and broadened their application to a myriad of procured goods in an effort to cut costs and increase profit margins.

2.2 Application of Should-Cost Purchasing in Private Industry

In the 1980s, private industry began to explore the use of should-cost in their price negotiations with suppliers. Author Jeffrey Wincel (2004) sums up should-cost modeling for industry as the practice of applying "market analysis, cost estimating tools, affordable cost targeting, and design/manufacturing analysis [...] to establish the fair market price." Most large companies or those with market power prefer to demand a price reduction from suppliers to achieve the desired margins or profitability targets mandated by the firm's accountants and executives. Wincel provides a typical example involving a major U.S. automotive Original Equipment Manufacturer (OEM) firing off a memo to all its suppliers requiring a 5% reduction price. Only the large or critical suppliers could defy this directive. Rather than build animosity with its suppliers like the aforementioned example, other companies take the long-term view and develop comprehensive cost models in an effort to identify the most cost effective suppliers that can deliver quality products in a mutually beneficial relationship. There are many examples of these mutual benefits: Wal-Mart and Proctor & Gamble, Sears-Whirlpool and Signal Freight, and General Motors and Robin Transport (Bowersox, 1990). To be beneficial in the long run, the purchasing company must understand the supplier needs to make a reasonable profit and the supplier must understand they need to continually improve efficiency to deliver a high-quality, low cost product.

Japanese companies were some of the first to widely adopt supplier should-cost modeling in an effort to increase quality, decrease costs, and build stronger relationships with their suppliers. Japanese business wanted to pay for the value of the product they received from the supplier and not pay for their supplier's operational or overhead inefficiencies. It was the supplier's duty to use their understanding of their internal cost structure to reduce waste (Newman, Semanik, & Sollish, 1992). Japanese businesses have taken the supplier relationship to a level unheard of in the West through the application of a system known as *keiretsu*, or tightly knit group of interrelated companies working together. In this system, a major OEM establishes strategic relationships with its key suppliers and expands their business with them.

They share cost and pricing information to maximize efficiency and even go as far as having interlocking boards of directors and cross-equity stakes (Burt & Doyle, 1993). This type of transparent OEM-supplier relationship helped the Japanese auto industry reduce costs and gain a prominent foothold in the U.S. auto market. After witnessing the success of supplier cost modeling and integration in Japan – often feeling the effects first hand – American companies began a similar effort.

Several U.S. companies have worked to better integrate and motivate their suppliers. Chrysler initiated a profit-sharing cost improvement plan that split cost savings achieved through efficient production between Chrysler and its suppliers, which resulted in $3 billion of overall savings (Burt & Doyle, 1993). Hewlett-Packard developed a comprehensive quarterly supplier rating system that factored in quality, responsiveness, dependability, and cost. These ratings were shared with suppliers during face-to-face meetings each quarter to help both sides improve and strengthen their relationship (Burt & Doyle). This drove efficiency in lowering costs, but did not actively determine the should-cost of procured products. Because the Japanese were successful using cost models to negotiate prices with suppliers, some U.S. companies followed suit with varying degrees of success. Corporate Executive Board, a leading member-based advisory company, published a report developed by their Procurement Strategy Council extolling the successful application of should-cost models at various major companies (2003). These companies were able to reduce prices, improve service, and raise quality.

The Center for Advanced Purchasing Studies at Arizona State University conducted a study to analyze 11 large North American companies' use of cost modeling (Ellram, 1994). The study showed the following: The companies used cost models for internal and external costing. They focused on high-dollar supplies and were concerned not with absolute accuracy but with understanding cost drivers. The margin for savings was too small to justify the resources to estimate costs on low volume or inexpensive items. The researchers found that the metrics the 11 companies used to quantify their savings were severely limited. Only three firms were able to provide tangible numbers, which included 9% in contract savings, $150 million in a year, and a 2% savings in overhead costs because of process improvements. The companies interviewed in the study felt cost estimation provided a savings mindset for their procurement teams and focused contract negotiations on both price and overall service level – such as material quality, customer service, and total value (Ellram). Should-cost estimates provided different information for different uses to these companies, but the key is that it provided a new insight into the procurement process that they did not have before building their model.

2.3 When to Use Should-Cost Estimation

The aforementioned cases in the literature present a compelling argument for adopting should-cost estimation. Why, then, are they irregularly applied or not used at all? Often, should-cost estimation is not used because there is a lack of support from executives who are focused on short-term costs rather than long-term strategic savings potential. When senior management is not interested in studiously applying should-cost estimates and building supplier relationships, it is imperative to quantitatively relate how these measures contribute directly to cost savings and profits. Success in effectively applying should-cost techniques ultimately hinges on support from senior leaders in the company. With management's support, a comprehensive training and should-cost modeling education program can be implemented. This allows the company to develop skilled, motivated procurement professionals from the Chief Procurement Officer (CPO) down to the entry-level buyer (Pooler, V., Pooler, D., & Farney, 2004).

The application of should-cost estimates makes sense for government defense contracts that can run into the hundreds of millions or billions of dollars because the opportunity for savings is very high. The challenge facing industry is applying should-cost principles to a wide array of procured products, some being very expensive and low volume (think custom-built, diamond-tipped drill bit for an oil well) while others are very inexpensive and high volume (think printer paper). The Pareto principle aptly describes procurement expenditures: 80% of your spend is with 20% of your suppliers (Booth, 2010). The challenge becomes identifying how deep into your spend to apply should-cost estimates and where the effort of the cost estimate outweighs the potential savings.

With Kraljic's Supply Matrix in Table 2-1, below, purchased products can be divided into four categories: Strategic Items, Bottleneck Items, Leverage Items, and Non-critical Items (Kaminsky, Simchi-Levi, D., & Simchi-Levi, E., 2007).

Supply Risk	Cost Impact: Low	Cost Impact: High
High	**Bottleneck Items:** *Ensure Supply*	**Strategic Items:** *Form Partnerships*
Low	**Non-Critical Items:** *Simplify and Automate*	**Leverage Items:** *Exploit Purchasing Power and Minimize Cost*

Table 2-1 Kraljic's Supply Matrix

Leverage items, which have many potential suppliers and are therefore low risk, are a perfect target for achieving cost savings and significantly boosting profitability. Thus, a good strategy is to focus a should-cost tool on these items and simultaneously use the many suppliers to compete against one another for the buyer's business. For strategic items, where supply risk and potential cost impact are high, the most appropriate strategy is to focus on a long-term partnership with those suppliers and achieve mutual profitability. A should-cost model can be the impetus for a partnership and closer integration with strategic item suppliers. For noncritical items, the objective is to simplify and automate the procurement process as much as possible because the products themselves are low cost and relatively simple to obtain. These products are generally not worth the time or effort of applying the should-cost tool. Bottleneck items represent a high supply risk because of limited suppliers and their criticality to production, but do not contribute to a large portion of the production cost. For these items, ensuring continuous supply – possibly at a premium price, is important. This can be achieved through long-term contracts or by carrying extra safety stock. Bottleneck items are not a good candidate for discordant price negotiations. (Kaminsky, Simchi-Levi, D., & Simchi-Levi, E.).

Should-cost tools can be used to help maintain long-term relationships as well as cut and control procurement costs. Therefore, should-cost techniques have the potential to make an impact on strategic, leverage, and non-critical items. Applying a should-cost tool across all three of these product areas is a nebulous area of should-cost modeling that we will attempt to resolve by developing a tool to apply financial should-cost techniques, in a simplified manner, across this breadth of third party spend.

2.4 Technical Elements of Cost Modeling

Now that we know the historical context of should-cost and where it should be used, in this section we review the literature that shows how should-cost models are developed. Researchers have defined the elements necessary to model the costs involved in manufacturing goods and applied those elements to the sourcing process used by the U.S. government and industry. The challenge to overcome is imperfect information concerning the supplier's production processes, labor and material costs, and other associated equipment and facility expenses. At its heart, modeling the costs of a supplier is both qualitative and quantitative – a melding of art and science. Liberties must be taken regarding the final should-cost model to incorporate and monetize elements such as product quality and customer service, which can be difficult to measure (Hurkens, Valk, & Wynstra, 2006).

There are common components that make up the final product price. Table 2-2, below, provides a representation of those components, which is an adaptation of Victor and Christopher Sower's work in *Better Business Decisions Using Cost Modeling* (2012).

Product Price					
Cost of Goods Sold (COGS)			**SG&A**[1]	**R&D**[2]	**Profit**
Direct Material	**Direct Labor**	**Indirect Cost**	Applied as a % of sales	% of sales	% of sales
Cost of material	Amount of labor	Direct labor benefits	Returns		
Amount of material	Wage rate	General overhead	Allowances		
Delivery cost		Material usage variance	Advertising		
		Labor efficiency variance	Headquarter Expenses		
1. SG&A – Sales, General, and Administrative costs 2. R&D – Research and Development cost					

Table 2-2 Product Price Components

The sub costs listed in Table 2-1 are not exhaustive, but are common elements for most product prices. Our research includes these terms and this literature review will introduce a few more that are particular to should-cost models using specific manufacturing information. There are two general techniques for determining a supplier's should-cost: using financial information and using manufacturing information. Next, we will expand on the more traditional and commonly used should-cost technique known as "manufacturing should-cost."

2.4.1 Manufacturing Should-Cost

From very early in the 20^{th} century, there have been movements to standardize work procedures, costs, and other business activities to maximize the profits of a business. Frederick W. Taylor, in his book *The Principle of Science Management*, insisted that the best method to achieve this standardization was through a scientific study and analysis. These studies included all of the methods and implements in use as well as accurate, minute motion and time study (1911). The manufacturing should-cost approach follows in this tradition. It is based on scientific study and analysis of the production process and is considered one of the most accurate methods for determining a supplier's true cost of producing products. These studies and analyses model the internal manufacturing process of the supplier or estimate the production expense for financial measurement. Manufacturing should-cost models have been developed and applied to a wide variety of industries. The manufacturing should-cost approach is used for vendor selection, negotiation, and for guiding the procurement process as noted by Moy (1998).

According to Young Sam Sohn et al. (2012), there are some common, widely used manufacturing should-cost models and equations. Equation (1), below, represents the overall manufacturing should-cost of the purchased product. Further details and subcomponent cost equations are provided in Appendix A.

Manufacturing Should-Cost = **(1)**

Material Cost + Labor Cost + Overhead Cost + SG&A Cost

+ Material Management Cost + Logistics Cost + Royalty Cost + Net Profit

Determining all the sub costs in equation (1) can be challenging. Author Sung Hwan Park has experience in the automotive manufacturing field and attests to these challenges. It can take a team of engineers to estimate production cycle times, expected type and number of laborers, wage scales, etc. For every should-cost calculation, this team of engineers and manufacturing experts must construct a new and very specific model. Appendix A is a testament to the challenges of estimating the manufacturing should-cost. The complexity, time, and cost of basing a should-cost estimate on manufacturing data invites the use of aggregated industry-specific data to determine the expected product cost.

2.4.2 Financial Should-Cost

Zero Base Pricing (ZBP), a technique for determining the financial should-cost of a product, was developed by Polaroid's purchasing department in the 1980s in an attempt to control price increases from their suppliers. The driving force behind ZBP was procurement professionals eliminating avoidable costs by ensuring their suppliers met optimal base costs common to the industry (Anklesaria, Burt, & Norquist, 1990). To determine the base cost scenario for the industry, the purchasing department needed a faster technique than bottom-up, manufacturing should-cost. This led to the idea of using industry-wide data made available by the U.S. government and aggregated by companies that produce key business ratios in a highly organized format. This allowed the procurement professionals to determine the sub costs and estimate the total product price for the base cost scenario so they could eliminate avoidable costs (Anklesaria, Burt, & Norquist, 1990).

The first major sub cost is the Cost of Goods Sold (COGS), which consists of direct material, direct labor, and indirect costs. The other three components of the final price are Sales, General, and Administrative (SG&A) costs, Research and Development (R&D) cost, and Profit. These costs can be derived from generalized industrial data organized by North American Industrial Classification System (NAICS) codes. These are six-digit numbers that identify specific segments of industries in the U.S. (e.g., NAICS code "211111" refers to Crude Petroleum and Gas Extraction) and are available on the U.S. Census Bureau website (2012).

These codes allow modelers to find metrics for wage rates and indirect costs that are standardized as an average for each industry. This provides an apple to apples comparison rather than, for instance, a textile manufacturer to an industrial chemical producer comparison. The NAICS codes can be cross-referenced with free, publicly available data on the Internet at the Bureau of Labor Statistics (BLS), Internal Revenue Service (IRS), and a number of other government agencies. Online subscription services and books, such as the *Risk Management Association (RMA) Annual Statement Studies* and the *Almanac of Business & Industrial Financial Ratios*, also provide a number of key metrics and ratios organized by NAICS code. Figure 2-1, below, depicts an example should-cost formula using financial ratio information (Sower, V. and Sower, C., 2012).

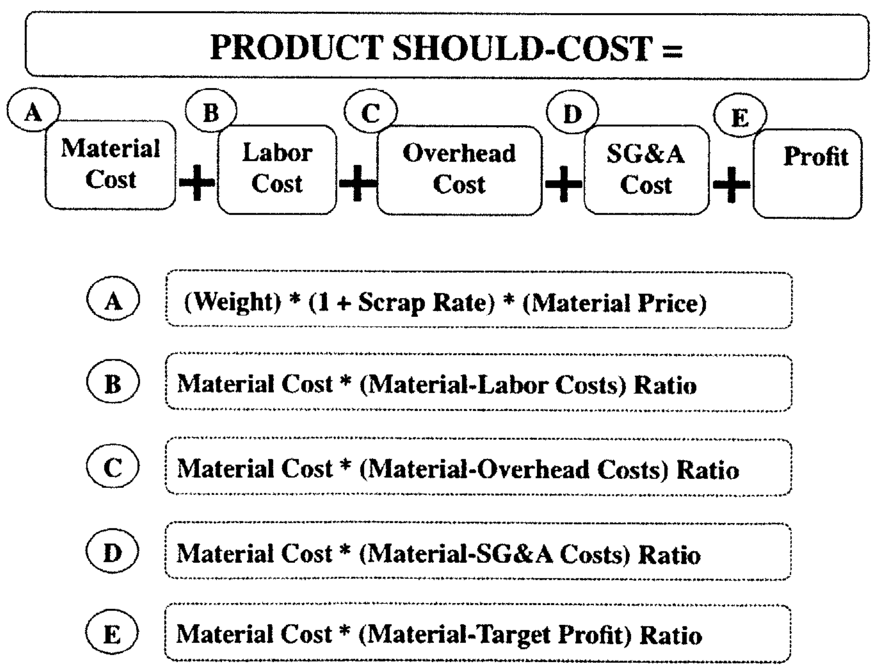


Figure 2-1 Example Financial Should-Cost Formulas

In the absence of partnership with a supplier, building the actual cost model requires a close analysis of the supplier's financial statements to determine the component costs of the product price they are quoting. In the financial should-cost approach, the information necessary to develop should-cost estimates is obtained from one of the aforementioned sources, i.e., the IRS website, the BLS website, a subscription service, or likely a combination of these sources (Sower, V. and Sower, C., 2012). This process, using industry-wide financial data, allows the modeler to estimate the should-cost from the aggregation of industry costs. This is a simple, yet powerful piece of information we will expound upon in section four.

3 Methodology

This research was designed to develop a simple, scalable tool to estimate a product's should-cost using aggregate industry-specific financial data. The aim is to produce a functional tool capable of estimating the price for a wide variety of procured products. In this section, we illustrate the research method we adopted to define and resolve the research questions. We approached this problem in two phases. First, we will design and build the should-cost tool by interviewing members of the sponsoring company to determine the nature and scope of the tool. Then, we will validate this tool by comparing its price output with previously negotiated supplier prices. The sponsoring company's input is crucial to defining the should-cost problem, refining the estimation tool's parameters, and validating its functionality.

3.1 Phase I – Qualitatively Understanding the Problem

We focused on a qualitative interview study to define our problem and develop a solution. This type of study relies on a small number of respondents who provide a great deal of information in detail (Weiss, 1994). We were interested in a qualitative understanding of the should-cost problem, which we expected would provide the background necessary to develop a functional should-cost tool. Our initial research relied on descriptions from qualitative interviews to guide the development of our should-cost tool. This included identifying the desired parameters for the model, knowing about the expected output, and understanding the role this tool would play in the company's procurement process.

The interviews were conducted in the manner outlined by Rubin and Rubin (2005) in *Qualitative Interviewing: The Art of Hearing Data*. The authors outline a process, but refrain from dictating formal steps that must be followed. The interview process occurs over three phases. First, the researchers introduce themselves and the topic while making an effort to build the confidence and trust of the interviewee. Next, the research team presents the challenging questions (e.g. What are the shortcomings in the current procurement process). Finally, the interviewers ease the intensity of the discussion and conclude. Important considerations include asking the respondent if he or she wishes to be identified in the published work and if he or she would like the opportunity review and edit the remarks (Rubin, H. & Rubin, I., 2005).

The interviews are ideally conducted in-person, but the scheduling constraints of the interviewee and interviewer often make this difficult. Ideally, the initial interview is conducted in-person to establish a relationship and trust with the interviewee. The first interview allows both the interviewer and respondent to develop an understanding of one another's mannerisms, vocal intonations, and a feeling for communication style. Though not preferred, telephone and e-mail can be exceedingly useful for follow-up questions after meeting face-to-face. While interviewing over the phone or other electronic medium, some modifications must be made. For example, interviewees will likely be terser and want to get to the point quickly. It is also much more difficult to gauge non-verbal reactions to sensitive or difficult questions (Rubin, H. & Rubin, I., 2005).

To alleviate these issues, we began this project by traveling to the sponsor company's headquarters to meet all our potential respondents in-person so we could better understand one another and more efficiently use telephonic and electronic communications in follow-up interviews. At CMSP's headquarters, we were able to engage all the key players and meet the majority of the people involved with their global sourcing and procurement group. We began the day by meeting the leader responsible for initiating this project, the head of the company's global procurement and sourcing group. In his office, he provided an overview of the sourcing and procurement group's structure and functional categories. After that, he focused on the nature of the should-cost problem and expectations for the tool. Finally, he took us around the headquarters and allowed us to interview the members of his team about the company's sourcing and procurement processes.

The actual interview process was semi-structured. We asked open-ended questions and allowed the respondents to answer in detail. This precipitated follow-up questions from us that led to a longer discourse and greater understanding of the respondents' perspectives. We asked all the questions from our list of discussion topics (Appendix B) to the Global Manager and Category Managers, because they have a strategic view of the sourcing and procurement processes at CMSP. We reserved select discussion topics for the Sub-category and Supplier Managers, who are the people likely to use this tool on a day-to-day basis. We also reserved specific questions for the Process Improvement Manager, who was primarily reviewing should-cost from the performance improvement position. The interview protocol we followed, and the list of topics discussed during each interview, are presented in Appendix B.

3.1.1 Data Sources

The sponsor of this project was the senior leader of the global sourcing and procurement group at CMSP Oilfield Services. This person identified an untapped potential improvement to their current procurement process. His role as a senior leader provided a broad understanding of the company's current practices, challenges, and overall expectations for a should-cost tool. He also introduced us to the key members of the sourcing and procurement organization, who became the subsequent sources of information of this research.

The next major source of information was one of CMSP's senior supplier managers who had the internal lead on developing a should-cost tool within the company. This manager was a critical source for us because he had should-cost experience with his previous employer and was the one designated to implement this new tool at the sponsoring company.

We also interviewed other members of the company's procurement and sourcing group. They provided a greater understanding of the current processes and initial efforts to implement should-cost techniques. They also gave us a greater appreciation of the details they need to successfully perform their duties as procurement specialists and supplier managers. These additional interviews helped us understand the very diverse nature of CMSP's third party spend and potential challenges to building scalable tool that addresses this diversity. In all, we conducted a total of eight interviews, each lasting between 30 minutes and 3 hours. Table 3-1, below, summarizes the people interviewed.

Interview Summary			
Title	**Function**	**Number Interviewed**	**Average Time**
Global Manager (Project sponsor)	Sourcing	1	180 minutes
Category Manager	Sourcing	2	30 minutes
Sub-category Manager	Sourcing	2	45 minutes
Supplier Manager	Procurement	2	120 minutes
Process Improvement Manager	Sourcing & Procurement	1	45 minutes

Table 3-1 Interview Summary

3.1.2 Data Analysis

In the first phase, we established a relationship with the key members of the sponsoring company. For this research we are considered "known investigators" because our research was authorized and commissioned by the head of the company's sourcing and procurement group (Lofland, et al., 2006). Of note, the same person who commissioned and sponsored the project was also the "gatekeeper;" he led us into the company and introduced us to key members of the sourcing and procurement group. As known investigators, we have direct access to the interviewees, but the "gatekeeper" – the head of the organization that authorized this research project – can affect this. The gatekeeper can protect or limit access to potential interviewees (Lofland, et al.). Bearing this in mind, there are three key pieces of information we expect to learn from our interviews. First, the types of products and breadth of their third party spend. Secondly, the most common technique they currently use to determine purchase prices with their suppliers. Third, their expectations for our should-cost tool and where it will fit in their sourcing and procurement process. This will provide the background for our research and the guidance for constructing the should-cost tool.

3.1.3 Expected Output

Our expected output is a Microsoft Excel-based tool capable of determining a product's should-cost. We expect the users of this tool to be the procurement specialists and supplier managers that have a strong understanding of the products they purchase and manage (e.g. the bill of materials and raw material prices). The intent is to have the tool's users input the financial ratio information based on the NAICS codes as well as the raw material weight and cost based on the bill of materials. Our tool will then put the inputted information through an engine to determine the product's should-cost price.

3.2 Phase II – Quantitative and Qualitative Tool Validation

In this section we explain the example case we chose to use during the construction of our should-cost tool and the reasoning behind that choice. After that, we describe the cases we used to validate the effectiveness of this tool and why we chose those cases. As part of the validation we include a quantitative and qualitative validation measure from the sponsoring company.

3.2.1 Case Chosen to Build the Tool

The case chosen to build the should-cost tool is a pumping mechanism's fluid end used in CMSP's regular operations. This product was chosen for three reasons. The first criterion was data availability – the supplier manager working directly with us was very familiar with this product and could use his expertise to answer our questions while building the tool. The second criterion for selection was representativeness. The fluid end is a moderately complex item consisting of one major sub component that undergoes several manufacturing processes. This makes for an excellent representative case because the majority of CMSP's third party spend is on semi-complex manufactured items and not simple commodities. We reasoned that if our tool could be built to successfully determine the should-cost of the pumping mechanism's fluid end, it would likely be applicable to the bulk of their purchased products. The third criterion was cost and volume. The fluid end chosen for our case had to be of sufficient purchase volume and cost to make a good candidate. The third criterion was to select a case that we could feasibly use to construct a model, refine into a usable tool, and validate in a three-month time frame. This timeline was critical to maintain because the research completion date is non-negotiable.

3.2.2 Validation and Assessment of the Tool

After constructing the tool using the case, we compare its predictions against the supplier's price – which was not used in building the model. With the assistance of the CMSP supplier manager, we know the fluid end's traditionally negotiated price. We used this information to compare our tool's estimated price with the currently negotiated price to validate the tool's accuracy.

In addition to the quantitative metric used to compare our should-cost tool with the price currently negotiated with CMSP's supplier, we will also incorporate qualitative input from the project sponsor. This includes pros and cons of our tool compared to current techniques and the methods provided by a private consulting company. The sponsoring company representatives will also provide qualitative feedback regarding the should-cost tool's functionality based on their experiences in the sourcing and procurement group.

4 Model and Tool Configuration

In this section, we first define the key terms used in the description of the should-cost model. Next, we propose a seven-step process to determine a product's should-cost. After our proposal, we apply the process to the example case – in this instance a pumping mechanism. Throughout this section we provide figures, tables, and illustrations to help convey the should-cost tool and its critical inputs.

4.1 Terminology

Before delving into our model, it is important to introduce some key terms and acronyms that will be used throughout this section. Following the terminology, we will introduce our seven-step process for determining the should-cost.

Procured Product (end item) – A manufactured good or commodity (end item) produced or assembled and offered for sale by one or more external suppliers according to a contract between the buyer and the supplier(s).

Sub Parts (components) – A portion of the final product or end item purchased; the sub parts may undergo one or more manufacturing processes. A procurement specialist will need to examine the product being purchased and if it is complex, break the end product into several sub parts and determine the should-cost for each.

Manufacturing Process – An activity or procedure of production through which raw materials are transformed into a more refined sub part or final product (e.g. forging, stamping, machining, etc.).

Raw Material (RM) – The major material used in producing individual sub parts, such as a specific type of steel or aluminum.

North American Industry Classification System (NAICS) – this represents the standard used by the U.S. government to collect, analyze, and publish statistical data related to the U.S. economy. It evolved to produce common industry definitions for Canada, Mexico, and the United States. In this system, different types of industries are classified with a **NAICS code.** NAICS codes have between two and six digits. The first two digits represent the primary business sector. The main business sector is divided into twenty different areas, depicted in Figure 4-1 below (U.S. Census Bureau, 2012). The NAICS information is updated every five years.

2012 NAICS

The following table provides detailed information on the structure of NAICS. Also included, on this page, are downloadable, Excel and text, concordance files for 2012, 2007 and 2002.

Sector	Description
11	Agriculture, Forestry, Fishing and Hunting
21	Mining, Quarrying, and Oil and Gas Extraction
22	Utilities
23	Construction
31-33	Manufacturing
42	Wholesale Trade
44-45	Retail Trade
48-49	Transportation and Warehousing
51	Information
52	Finance and Insurance
53	Real Estate and Rental and Leasing
54	Professional, Scientific, and Technical Services
55	Management of Companies and Enterprises
56	Administrative and Support and Waste Management and Remediation Services
61	Educational Services
62	Health Care and Social Assistance
71	Arts, Entertainment, and Recreation
72	Accommodation and Food Services
81	Other Services (except Public Administration)
92	Public Administration

Figure 4-1
Primary Business Sectors by NAICS Code

The third, fourth, fifth, and the sixth digits respectively provide the subsector, the industry group, the NAICS industry, and the national industry information. The more digits in the NAICS code, the more precise the associated data is for that industry. Figure 4-2, below, provides an example of the subordinate NAICS codes for the Manufacturing sector (U.S. Census Bureau, 2012).

2012 NAICS Definition

T = Canadian, Mexican, and United States industries are comparable.

Search results for: 31
Number of records found: 652

31-33 **Manufacturing**[T]

311 **Food Manufacturing**[T]

3111 **Animal Food Manufacturing**[T]

31111 Animal Food Manufacturing[T]

311111 Dog and Cat Food Manufacturing

311119 Other Animal Food Manufacturing

3112 **Grain and Oilseed Milling**[T]

31121 Flour Milling and Malt Manufacturing[T]

311211 Flour Milling

311212 Rice Milling

311213 Malt Manufacturing

31122 Starch and Vegetable Fats and Oils Manufacturing[T]

311221 Wet Corn Milling

311224 Soybean and Other Oilseed Processing

311225 Fats and Oils Refining and Blending

31123 Breakfast Cereal Manufacturing[T]

311230 Breakfast Cereal Manufacturing

3113 **Sugar and Confectionery Product Manufacturing**[T]

31131 Sugar Manufacturing[T]

311313 Beet Sugar Manufacturing

311314 Cane Sugar Manufacturing

31134 Nonchocolate Confectionery Manufacturing[T]

311340 Nonchocolate Confectionery Manufacturing

31135 Chocolate and Confectionery Manufacturing[T]

311351 Chocolate and Confectionery Manufacturing from Cacao Beans

Figure 4-2
Example of Subordinate NAICS Codes for Manufacturing

Risk Management Association (RMA) – The RMA is a not-for-profit, member-driven professional association serving the financial services industry. The institution provides industry average financial information in its *Annual Statement Studies - Financial Ratio Benchmarks* publication. In the RMA data, financial information such as Asset Percentage, Liability Percentage, Income Data Percentage, and other financial ratios are presented for each six-digit NAICS code. In addition, RMA segments the financial information for each NAICS code by company revenue into small, medium, and large companies. RMA publishes its statement studies and financial ratios every year (Risk Management Association, 2012).

4.2 Process

We developed a seven-step process to estimate the should-cost of a procured product. In the first four steps, we divide the procured product into sub parts, attribute NAICS codes for representative manufacturing processes of each sub part, and estimate the key financial ratios for each NAICS code. In the last three steps, we calculate the RM cost, sub part prices, and the total procured product price.

4.2.1 Step 1 – Identify the Sub Parts

A procured product is usually complex enough that it consists of several readily identifiable sub parts. Because the RM used for each sub part may differ and undergo separate manufacturing processes, we must separate the complex end product into sub parts. Once the end item is divided into sub parts, the RM cost, NAICS data, and RMA financial data can be appropriately assigned and calculated. For this reason, we begin the seven-step process with identifying the sub parts.

There are three main methods for identifying the sub parts. The first is analyzing the blueprint and bill of materials (BOM) of the end item. The second is investigating a manufacturing process map of the product. The third method is to observe the actual manufacturing process to see how the sub parts are assembled into the final product. Procurement specialists can choose among these three methods using Table 4-1, below, based on the situation and conditions. Each method has its respective pros and cons.

	Pros	Cons
Blueprint & BOM Analysis	- Use official documents for the procured product	- Requires the expertise to analyze a blueprint/BOM
Manufacturing Process Map Investigation	- Use actual information from the supplier's manufacturing process	- Requires the expertise to analyze a process map
On-site Manufacturing Process Investigation	- Easy to determine the sub parts and see the actual process(es)	- Requires a strong partnership with the supplier

Table 4-1
Sub Part Identification Method Comparison

Figure 4-3, below, is an example of a notional end item broken down into sub parts. This end item example has three major sub parts. Each of the sub parts can undergo up to three manufacturing processes. Our should-cost tool is built around this same principle to provide the scalability to estimate the should-cost for a wide variety of products.

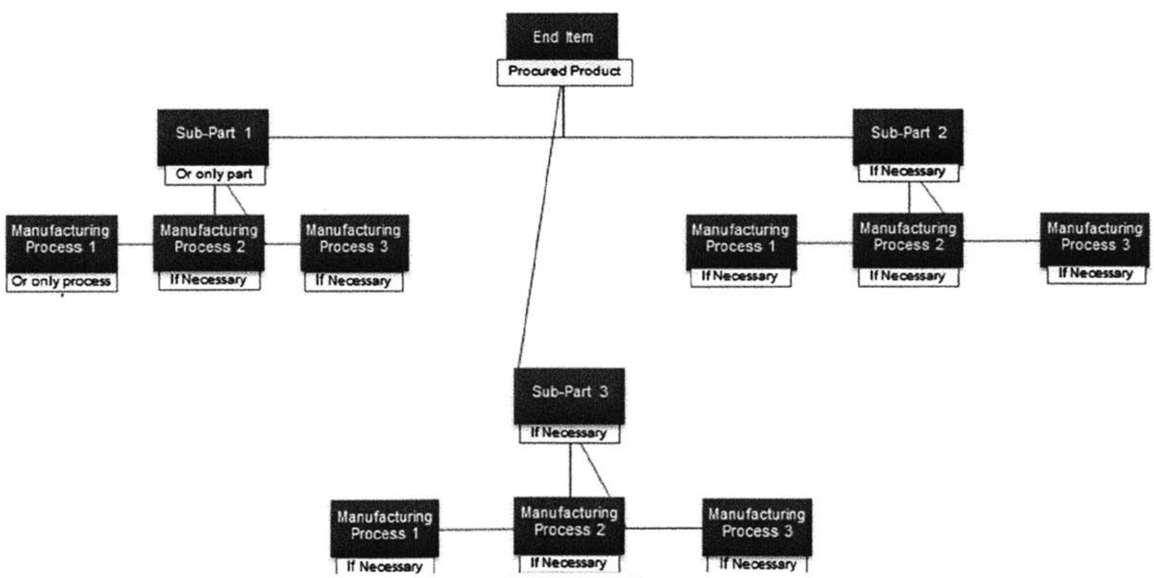


Figure 4-3
Notional End Item Breakdown

4.2.2 Step 2 – Identify the RM and Manufacturing Process

For the should-cost estimation, once an end item is divided into sub parts, additional information must be gathered. First, one must determine the primary RM and major manufacturing processes that each sub part identified in step one undergoes. Like identifying the sub parts of the end item displayed in Table 4-1, the major RM and production processes for each sub part can be examined using three main techniques: analyzing a blueprint and BOM, interpreting a production process map, and observing the manufacturing process as depicted in Table 4-2 below.

	Pros	Cons
Blueprint & BOM Analysis	- Reflects generally-accepted manufacturing processes	- Requires a high-level of technical knowledge and expertise
Manufacturing Process Map Investigation	- Applies actual manufacturing processes	- Includes the supplier's operational inefficiencies or production advantages in the should-cost
On-site Manufacturing Process Investigation		- Includes the supplier's operational inefficiencies or production advantages in the should-cost - Requires an integrated or strategic partnership - Depends on personal expertise

Table 4-2
RM & Manufacturing Process Identification Method Comparison

Of these three methods, obtaining and interpreting the procured product's blueprint and BOM is the easiest and most common. Although this method requires high level of expertise on the part of the procurement specialist, it is often the easiest because most companies have not integrated their supplier as a strategic partner. This restricts access to the manufacturing process map and on-site investigations.

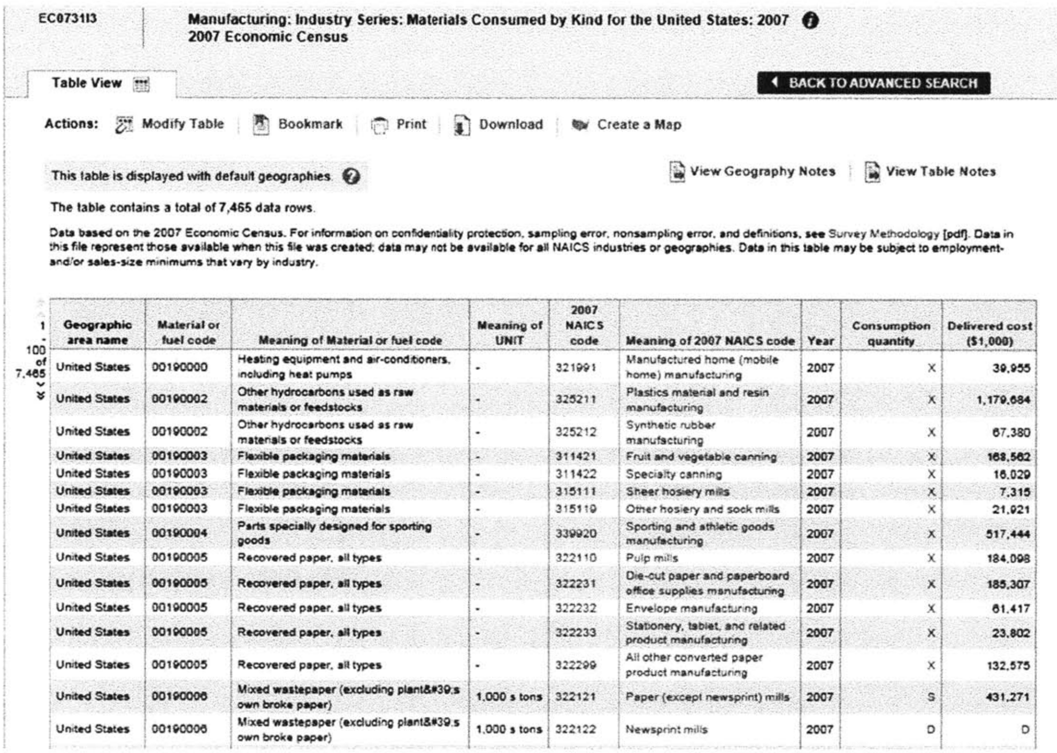
4.2.3 Step 3 – Allocate NAICS Codes

To use the aggregate industry financial data from RMA, we must allocate the appropriate NAICS code to each of the major manufacturing processes identified in the previous step. We assume that procurement specialists, using their technical expertise and knowledge of the products they purchase, would be able to allocate the NAICS codes as listed on the U.S. Census Bureau website and depicted in Figures 4-1 and 4-2. It is important for the intended users of this should-cost tool to build a thorough understanding of the manufacturing processes encompassed within the NAICS database. In the instance where an identified manufacturing process does not fit current NAICS codes and the process cannot be broken down further, the procurement specialist should classify the manufacturing process into the best fitting NAICS code or that of a higher level manufacturing procedure.

4.2.4 Step 4 – Estimate Financial Ratios

Calculating the various cost values, such as RM cost, labor cost, overhead cost, SG&A cost, and net profit enables us to determine each sub part's should-cost. We can determine these individual cost values by using RMA financial data and U.S. Census Bureau data to find the key ratios for each sub part. These financial ratios act as the backbone for calculating the aforementioned cost values. For each sub part (identified by NAICS code), the procurement specialist should estimate the financial ratios between the RM cost and other cost values by using the RMA data and U.S Census Bureau data. These cost values include other material cost, direct labor cost, manufacturing overhead cost, SG&A cost, and target net profit.

Estimating the financial ratios occurs over three main steps. First, the ratio between the RM cost and other material cost is estimated utilizing information on the U.S. Census Bureau's website. The *Economic Census* on the website is organized by NAICS code and links to industry-specific statistics. Among the statistics available is *Materials Consumed by Kind*, depicted below, in Figure 4-4. The user can download that information in a Microsoft Excel format. This allows procurement specialists to distinguish between the RM expense and other material expenses and then calculate the ratio between them. Procurement specialists should pay close attention to this process because an incorrect ratio of RM cost to other material cost information will distort the sub part's should-cost estimate (U.S. Census Bureau, 2012). More detailed information and a step-by-step guide is available in Appendix D.1.


EC0731I3

Manufacturing: Industry Series: Materials Consumed by Kind for the United States: 2007
2007 Economic Census

Table View

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Actions: Modify Table | Bookmark | Print | Download | Create a Map

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View Geography Notes | View Table Notes

The table contains a total of 7,465 data rows.

Data based on the 2007 Economic Census. For information on confidentiality protection, sampling error, nonsampling error, and definitions, see Survey Methodology [pdf]. Data in this file represent those available when this file was created; data may not be available for all NAICS industries or geographies. Data in this table may be subject to employment- and/or sales-size minimums that vary by industry.

1 - 100 of 7,465

Geographic area name	Material or fuel code	Meaning of Material or fuel code	Meaning of UNIT	2007 NAICS code	Meaning of 2007 NAICS code	Year	Consumption quantity	Delivered cost ($1,000)
United States	00190000	Heating equipment and air-conditioners, including heat pumps	-	321991	Manufactured home (mobile home) manufacturing	2007	X	39,955
United States	00190002	Other hydrocarbons used as raw materials or feedstocks	-	325211	Plastics material and resin manufacturing	2007	X	1,179,684
United States	00190002	Other hydrocarbons used as raw materials or feedstocks	-	325212	Synthetic rubber manufacturing	2007	X	67,380
United States	00190003	Flexible packaging materials	-	311421	Fruit and vegetable canning	2007	X	168,562
United States	00190003	Flexible packaging materials	-	311422	Specialty canning	2007	X	16,029
United States	00190003	Flexible packaging materials	-	315111	Sheer hosiery mills	2007	X	7,315
United States	00190003	Flexible packaging materials	-	315119	Other hosiery and sock mills	2007	X	21,921
United States	00190004	Parts specially designed for sporting goods	-	339920	Sporting and athletic goods manufacturing	2007	X	517,444
United States	00190005	Recovered paper, all types	-	322110	Pulp mills	2007	X	184,098
United States	00190005	Recovered paper, all types	-	322231	Die-cut paper and paperboard office supplies manufacturing	2007	X	185,307
United States	00190005	Recovered paper, all types	-	322232	Envelope manufacturing	2007	X	61,417
United States	00190005	Recovered paper, all types	-	322233	Stationery, tablet, and related product manufacturing	2007	X	23,802
United States	00190005	Recovered paper, all types	-	322299	All other converted paper product manufacturing	2007	X	132,575
United States	00190006	Mixed wastepaper (excluding plant's own broke paper)	1,000 s tons	322121	Paper (except newsprint) mills	2007	S	431,271
United States	00190006	Mixed wastepaper (excluding plant's own broke paper)	1,000 s tons	322122	Newsprint mills	2007	D	D

Figure 4-4
U.S. Census Bureau Material Expense Information

Second, on the U.S. Census Bureau's website, procurement specialists need to find the industry average revenue, overall material cost, and direct labor cost information. As described above, the user returns to the website, but selects the *Annual Survey of Manufacturers* to find the *Statistics for Industry Groups and Industries* as depicted in Figure 4-5 below. Use the six-digit

NAICS code for each sub part or manufacturing process to find the values for: Total Value of Shipments, Materials/Parts/Containers/Packaging/Etc./Used, and Production Workers Wage, which represent industrial averages for revenue, material costs, and direct labor cost.

AM1131GS101 | Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2011 and 2010
2011 Annual Survey of Manufactures

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The table contains a total of 1,226 data rows.

Release Date: 11/08/12 | Status: Complete
NOTE: For information on confidentiality protection, sampling error, nonsampling error, and definitions, see Survey Methodology. For information on the ASM industry groupings, see Comparability. Data in this table available for all NAICS industries or geographies. Detail items may not add to total due to independent rounding.

1 - 18 of 72

Geographic area name	2007 NAICS codes and NAICS-based rollup code	Meaning of 2007 NAICS codes and NAICS-based rollup code	Year	Number of employees	Relative standard error of total number of employees (%)	Annual payroll ($1,000)	Total fringe benefits ($1,000)	Relative standard error of total fringe benefits (%)	Employer's cost for health insurance ($1,000)	Employer's cost for defined benefit pension plans ($1,000)	Employer's cost for defined contribution plans ($1,000)	Employer's cost for other fringe benefits ($1,000)	Production workers avg per year	Production workers hours (1,000)	Production workers wages ($1,000)
United States	31-33	Manufacturing	2011	10,649,378	1	559,517,837	173,704,551	1	69,542,400	14,930,705	14,983,946	74,247,501	7,440,140	14,866,954	313,709,882
United States	31-33	Manufacturing	2010	10,507,146	1	538,456,595	168,033,161	1	66,578,602	14,288,221	14,295,945	72,870,393	7,289,354	14,550,473	299,613,996
United States	311	Food manufacturing	2011	1,358,996	1	52,828,340	16,175,656	1	6,774,500	1,257,380	1,166,591	6,977,184	1,072,841	2,172,236	36,089,009
United States	311	Food manufacturing	2010	1,363,773	1	52,383,998	16,039,107	1	6,624,439	1,257,761	1,192,829	6,964,078	1,076,443	2,177,377	35,800,855
United States	3111	Animal food manufacturing	2011	43,104	1	2,149,012	626,040	2	259,938	48,495	56,025	261,583	29,749	61,110	1,310,741
United States	3111	Animal food manufacturing	2010	44,168	1	2,110,513	606,233	1	244,745	47,533	53,856	260,100	30,348	62,417	1,289,689
United States	31111	Animal food manufacturing	2011	43,104	1	2,149,012	626,040	2	259,938	48,495	56,025	261,583	29,749	61,110	1,310,741
United States	31111	Animal food manufacturing	2010	44,168	1	2,110,513	606,233	1	244,745	47,533	53,856	260,100	30,348	62,417	1,289,689
United	311111	Dog and cat food	2011	17,155	2	964,812	288,131	2	121,352	24,476	29,066	113,238	12,329	26,607	656,521

Figure 4-5
U.S. Census Bureau Industry Statistics Information

Third, from the RMA's *Annual Statement Studies – Financial Ratio Benchmarks*, the procurement specialists must search, by NAICS code, for the average Gross Profit, Operating Expenses, All Other Expenses, and Profit Before Taxes expressed as a percentage. The RMA data arranges these percentages based on small, medium, and large company revenues for each NAICS code. The user should select the percentages based on their knowledge of the supplier's size according to annual revenue.

All the data from this section is input into the should-cost tool as shown in Appendix D. The underlying equations the should-cost tool uses to calculate the ratios are listed as C-1 through C-14 in Appendix C.

4.2.5 Step 5 – Calculate RM Cost

With the financial ratio information from the previous steps, we can estimate the cost values for the individual sub parts and eventually the end item's overall should-cost. Using the financial ratios for each NAICS code and the RM cost enables us to estimate the cost values for each sub part – such as other material cost, direct labor cost, manufacturing overhead cost, SG&A cost, and target net profit. The basic equation for the RM cost calculation is as below:

RM Cost = (Standard Material Weight) * (Standard Material Unit Price) * **(2)**

(1 + Material Production Defect Rate)

To find the Standard Material Weight, procurement specialists generally use the product's blueprint and BOM. For the Standard Material Unit Price, procurement specialists can use public raw material data, such as the London Metal Exchange (LME) or private organizations that organize raw material prices to determine the current market price. To get the Material Production Defect Rate, procurement specialists must investigate average production defective rate in manufacturing lines. If there are pre-investigated production defective rates in their company or other organizations, procurement specialists can use the values.

4.2.6 Step 6 – Estimate Sub Part Should-Cost

With the information from the previous steps, procurement specialists can estimate the should-cost for each sub part. The detailed equations for this step are listed in Appendix C as C-15 to C-21. Appendix D contains figures depicting this part of the actual tool. Steps 6 must be completed for each sub part.

Sub Part Should-cost = **(3)**

RM Cost + Other Material Cost + Direct Labor Cost + Overhead Cost

+ SG&A Cost + Net Profit + Other Relevant Cost

4.2.7 Step 7 – Calculate the Total Should-Cost

Procurement specialists can now estimate the overall should-cost of the procured product by adding the should-cost estimates for all the sub parts. This value represents the price the purchasing company should be paying for the item.

4.3 Example Case

The example product we used to develop and refine this tool was a fluid end, which is part of a pumping mechanism. At CMSP, the pumping mechanism is used to search for and produce natural resources. A key component of the pumping mechanism is the fluid end. CMSP currently purchases the fluid end from a supplier with a negotiated price. In this section, we analyze the should-cost of the fluid end. For the first, second, third, and part of the fifth step, we rely on the expert analysis from CMSP procurement specialists because they have technical expertise and internal knowledge of this product and its manufacturing processes. Figure 4-6, below, is a simple depiction of the fluid end. Appendix D has additional figures that display the should-cost tool and the numbers we input to determine the values below.

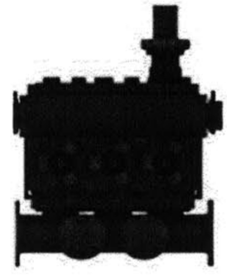

Figure 4-6
Fluid End

4.3.1 Step 1 – Identify the Sub Parts

The fluid end, our end item in this case, consists of only one sub part – a fluid part body. Procurement specialists at CMSP analyzed the procured product and provided this information.

4.3.2 Step 2 – Identify the RM and Manufacturing Process

For the fluid end, the primary RM used is SAE 4330 steel, which is a Nickel-Chromium-Molybdenum alloy (ASM International, 2012). The fluid end goes through two primary manufacturing processes: casting and machining. The procurement specialists at CMSP investigated the RM and manufacturing processes for this product using the blueprints and BOM.

4.3.3 Step 3 – Allocate NAICS Codes

The procurement specialists at CMSP divided the two manufacturing processes into separate NAICS codes: the casting process as *332111 - Iron & Steel Forging* and the machining process as *332710 – Machine Shops*. Figures 4-7 and 4-8, below, depict the NAICS codes for these manufacturing processes (U.S. Census Bureau, 2012).

2012 NAICS Definition

T = Canadian, Mexican, and United States industries are comparable.

332111 Iron and Steel Forging

This U.S. industry comprises establishments primarily engaged in manufacturing iron and steel forgings from purchased iron and steel by hammering mill shapes. Establishments making iron and steel forgings and further manufacturing (e.g., machining, assembling) a specific manufactured product are classified in the industry of the finished product. Iron and steel forging establishments may perform surface finishing operations, such as cleaning and deburring, on the forgings they manufacture.

Cross-References. Establishments primarily engaged in--

- Manufacturing iron and steel forgings in integrated iron and steel mills--are classified in Industry 331110, Iron and Steel Mills and Ferroalloy Manufacturing; and
- Manufacturing nonferrous forgings--are classified in U.S. Industry 332112, Nonferrous Forging.

2002 NAICS	2007 NAICS	2012 NAICS	Corresponding Index Entries
332111	332111	332111	Cold forgings made from purchased iron or steel, unfinished
332111	332111	332111	Drop forgings made from purchased iron or steel, unfinished
332111	332111	332111	Ferrous forgings made from purchased iron or steel, unfinished
332111	332111	332111	Forgings made from purchased iron or steel, unfinished
332111	332111	332111	Gun forgings made from purchased iron or steel, unfinished
332111	332111	332111	Hammer forgings made from purchased iron or steel, unfinished
332111	332111	332111	Horseshoes, ferrous forged, made from purchased iron or steel
332111	332111	332111	Hot forgings made from purchased iron or steel, unfinished
332111	332111	332111	Iron forgings made from purchased iron, unfinished
332111	332111	332111	Press forgings made from purchased iron or steel, unfinished
332111	332111	332111	Steel forgings made from purchased steel, unfinished
332111	332111	332111	Upset forgings made from purchased iron or steel, unfinished

Figure 4-7
NAICS Code 33211 – Iron & Steel Forging

Notice in Figure 4-7 that NAICS code 332111 covers many different types of forging. When there are multiple varieties, the Census website will list descriptions for each type. The same principle is evident for NAICS code 332710 in Figure 4-8, but there are only two varieties.

2012 NAICS Definition

T = Canadian, Mexican, and United States industries are comparable.

332710 Machine Shops

This industry comprises establishments known as machine shops primarily engaged in machining metal and plastic parts and parts of other composite materials on a job or order basis. Generally machine shop jobs are low volume using machine tools, such as lathes (including computer numerically controlled); automatic screw machines; and machines for boring, grinding, and milling.

Cross-References. Establishments primarily engaged in--

- Repairing industrial machinery and equipment--are classified in Industry 811310, Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance; and
- Manufacturing parts (except on a job or order basis) for machinery and equipment--are generally classified in the same manufacturing industry that makes complete machinery and equipment.

2002 NAICS	2007 NAICS	2012 NAICS	Corresponding Index Entries
332710	332710	332710	Chemical milling job shops
332710	332710	332710	Machine shops

Figure 4-8
NAICS Code 332710 – Machine Shops

4.3.4 Step 4 – Estimate Financial Ratios

For the fluid end, the financial ratios are estimated below, in Table 4-3, using equations C-1 through C-14 in Appendix C.

	Iron & Steel Forging (NAICS code: 332111)	Machine Shops (NAICS code: 332710)
Material Expense	$ 3.61 B	$ 8.99 B
RM Expense	$ 2.66 B	$ 5.52 B
Other Material Expense	$ 0.95 B	$ 3.47 B
Material Ratio	73.7%	61.4%
Total Value of Shipments	$ 33.12 B	$ 38.50 B
Materials/Parts/Container/Etc.	$ 15.93 B	$ 10.58 B
Production Workers Wage	$ 3.16 B	$ 7.46 B
Temp RM Cost	$ 11.74 B	$ 6.49 B
Temp Other Material Cost	$ 4.20 B	$ 4.08 B
Gross Profit Percentage (%)	23.9%	29.6%
Operating Expenses Percentage (%)	17.0%	21.4%
All Other Expenses Percentage (%)	1.3 %	1.0 %
RM Percentage (%)	35.4%	16.9%
RM to Other Material Cost Ratio	0.36	0.63
RM to Direct Labor Cost Ratio	0.27	1.15
RM to Overhead Cost Ratio	0.52	1.40
RM to SG & A Cost Ratio	0.52	1.33
RM to Net Profit Cost Ratio	0.16	0.43

Table 4-3
Financial Ratio Estimation

4.3.5 Step 5 – Calculate RM Cost

For the fluid end, SAE 4330 steel is used in throughout the manufacturing processes. The standard material weight, standard material unit price, and material production defective rate were obtained from the CMSP procurement specialists' analysis. The RM cost calculation is below, in Table 4-4.

RM	Standard Material Weight	Standard Material Unit Price	Material Defect Rate	RM Cost
SAE 4330 steel	3,313 Kg	$ 0.8 / Kg	10%	***$ 2,915***

Table 4-4
RM Cost Calculation

4.3.6 Step 6 – Estimate Sub Part Should-cost

To estimate individual parts financial should-cost of the procured Fluid Part product, we used the financial ratios information and raw material cost information from previous steps.

	Fluid End	
	Iron & Steel Forging (NAICS code: 332111)	**Machine Shops (NAICS code: 332710)**
Raw Material Cost	$ 2,915	$ 8,228
Other Material Cost	$ 1,042	$ 5,172
Direct Labor Cost	$ 785	$ 9,458
Overhead Cost	$ 1,519	$ 11,486
SG&A Cost	$ 1,506	$ 10,928
Net Profit	$ 461	$ 3,513
Should-cost (Process)	$ 8,228	$ 48,785
Transportation Cost		$ 14,520
Sub Part Should-cost		**$ 63,305**

Table 4-5
Sub Part Should-Cost Estimate

4.3.7 Step 7 – Calculate the Total Should-Cost

Since the fluid end has one total sub part (that undergoes two manufacturing processes), the final should-cost of the fluid end is the same value determined in step six. If this process was conducted on an end item with multiple sub parts, the individual sub part costs calculated in step 6 would be added here.

Fluid End Should-cost = $ 63,305

Appendix D displays screenshots of the actual Microsoft Excel tool that was produced and used to determine the values in Tables 4-3, 4-4, and 4-5.

5 Conclusion

In this section we validate our tool's results and effectiveness. We compare the estimated price from our tool's output with the price negotiated with the current supplier. We then expand our validation to include qualitative feedback from the project sponsors at CMSP. We then cover the limitations inherent to this tool and discuss, in broad terms, the best scenarios for applying the should-cost tool. Finally, we conclude with potential areas for future research that can expand upon what we have built.

5.1 Validation

After constructing our tool, it is critical to validate its effectiveness. We use a two-part process. First, we compare the tool's output price for our base case – the pumping mechanism – to the price currently negotiated by CMSP. Then we use the considerable experiences of our project sponsors to validate the tool's overall effectiveness in estimating should-cost prices.

5.1.1 Evaluating the Tool's Output

In the previous section, we went through the steps necessary to build the model and ultimately, a tool for estimating the should-cost of a product. The construction of the model was based upon a semi-complicated pumping mechanism regularly procured by CMSP. Our tool produced an estimated should-cost for this item of **$63,305**. CMSP currently pays their supplier **$68,000** for each of these pumping mechanisms. This puts our tool's estimated price at **91%** of the price currently paid. This fits well within the parameters set at the outset of this project, which was to achieve price estimates from our tool that are at least 80% of the negotiated price.

5.1.2 Qualitative Assessment from the Project Sponsor

In addition to the direct comparison our should-cost tool's output with the price currently negotiated with CMSP's supplier, we solicited qualitative feedback from the company's procurement professionals. Their input will help us gauge whether our tool is accurately capturing the component costs that make up the final product price. The CMSP representatives will also compare our tool with the results achieved by a private consulting company that was brought in to teach should-cost techniques.

After constructing our tool, we sent the final product to CMSP so they could put it through some internal validation exercises. The project sponsor and Global Manager at CMSP made the following remark:

> ***"came back with a tool that was actually very good, good in the sense that it was usable and when [the Category Manager] plugged the numbers into the engine that Clayton and Sung had provided, it was very close to some of the studies that he had done before"*** (Global Manager interview).

The Supplier Manager, after having another month to look at the tool, commented that *"the excel file is accurate and simple enough to run"* (Supplier Manager interview). The overall perception from CMSP was very positive, but they did identify some areas to improve the ease-of-use and areas of their third party spend where the tool would be less accurate.

One con they identified with the tool concerns the import of data from the U.S. Census database. At present, the tool's user looks up each NAICS code and must manually transfer the corresponding data to the tool. The Global Manager feels this is an area of potential improvement because the tool *"is not perfect yet, in the sense that [...] you need to plug in the NAICS code that gives all the industry breakdown and commission so it's still very manual, it doesn't download automatically"* (Global Manager interview). The Supplier Manager that directly assisted us with gathering data and understanding the product we used as a case study shared a similar sentiment. He noted that it would be beneficial to link databases to *"make some* *more cells automated. Other than that we want to keep this the way it is"* (Supplier Manager interview).

Another con that the CMSP procurement team noted was the should-cost tool had low to poor effectiveness when applied to very unique items. *"When we get into the chemicals there are some commodity chemicals, but we have some when you get into some of the specialty chemicals that are not traded, not tracked"* (Global Manager interview). For example, *"you have the case where CMSP is developing chemicals to be sold to customers and we have an [intellectual property] on it and the formula is not disclosed, and it's one of the biggest spend for example, for chemicals. So, we find ourselves a bit limited there [...] and the should-cost is very difficult"* (Global Manager interview).

5.2 Limitations

This tool, though effective based on the validation exercises, has limitations for its application and use in sourcing decisions and supplier contract negotiations.

- ***Limited to high-level segment of CMSP supply chain***: As the Global Manager described the application of the should-cost tool: "in the transactional aspect we absolutely don't do it – on the ground there are too many transactions. The sourcing people that are actually deploying sourcing plans, part of the process is to incorporate should-cost modeling" (Global Manager interview). For purchases on-site (e.g. drilling location), where time is critical, purchases must be made to optimize delivery time and not cost. These types of purchases would fall into the category of Bottleneck Items as we outlined in Kraljic's Supply Matrix in Figure 2-4, making them a poor fit for the should-cost tool.
- ***Limited effectiveness of should-cost in services:*** The should-cost tool works well for manufactured goods and commodities, but some additional challenges arose. For

example, the Global Manager noted "The other [problem] is on the services side ... that isn't always easy to ... how to apply this, but not overcharge" (Global Manager interview). The NAICS includes information for services under codes "56 – Administration and Support Services, 72 – Accommodation and Food Services, and 81 – Other Services" (U.S. Census Bureau, 2012). The service sector data aggregated by the government does not provide enough granularity to encompass the wide variations in specific services, quality, and scope. It may be possible, with input from CMSP, to further refine the model to specifically address these variations and make the tool more responsive to should-cost in the service sector.

- ***Geographic limits:*** Another limitation for the tool is its dependency on U.S. and North American-based data. Because this model relies on meticulously collected and organized data from every business in the U.S. and many across the rest of North America, there is no way to compare this information with businesses overseas. NAICS codes provide a simple way to organize and aggregate industry data collected by the U.S. Census Bureau and the Bureau of Labor Statistics along with third party organizations that provide key financial ratios based on this data. A multinational company, like CMSP, has operations around the world and can source globally. The lack of statistics like those maintained for U.S. businesses makes it impossible to use our tool to find the should-cost of a product sourced abroad. We began researching data similar to the NAICS in South Korea, China, and Japan, but were unable to find any comparable sets of data.

5.3 Potential Future Research

Based on our time with this research material and interactions with the sponsor company, we have identified several potential areas to extend our tool's capabilities and provide additional insights from the should-cost results. Many of our recommendations for future research will address the limitations identified above. The other recommendation for follow-on research could provide new insights into the affects of raw material price fluctuations on third party spend.

- ***Should-cost in service industry:*** One area to investigate is the application of this should-cost tool in the service industry. Follow-on research, in conjunction with a company that can provide example cases, can refine the accuracy of this tool for services. For example, services are traditionally sourced geographically close to the location where the service is needed. This means wage differences in this often people-driven industry are crucial to determining an accurate should-cost (e.g. wages in New York, NY versus Des Moines, IA).
- ***Geographic expansion:*** Another area to expand this research is in finding similar data sources in countries outside of North America. With the international nature of modern business, many large companies source globally and would value comparing North American prices with other locations. We tried finding similar business data, akin to the NAICS, but were unsuccessful. We searched Chinese, Japanese, and South Korean government economic and trade government databases. There may be other countries that do maintain this type of data or other non-governmental organizations that have this type of information available.
- ***Projecting third party spend fluctuations:*** The last area we have identified for broadening this tool's capability lies in projecting future third party spend based on fluctuations in raw material costs. Because this tool requires the users to input material quantity and price for the components and subcomponents, there exists the possibility of linking all the major should-cost estimates together. From this

linkage, it may be possible to adjust the major raw material costs if there is a large downturn or uptick in material price (e.g. resin or a specific grade of steel). Any of the cost estimates that use that particular raw material would then reflect the new purchase price and allow the company to project the change in third party spend for the next year.

5.4 Summary

A should-cost tool, using aggregate industry-specific financial data, can be constructed. Breaking the procured end item into smaller and smaller sub parts effectively makes the tool scalable to a wide array of simple to complex products. This allows procurement professionals to model prices quoted by suppliers to assist in price negotiations. The should-cost tool, compared to manufacturing should-cost, can decrease the time and effort devoted to should-costing while still achieving similar results. Of even greater potential is using this tool and should-cost to create a high-level of trust and understanding between the supplier and purchasing company through a better understanding of the supplier's production processes in relation to industry standards. This can serve as the start to a collaborative partnership with strategic goals that result in increased efficiencies and profit for both companies.

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Appendix A: Manufacturing Should-Cost Example

Below, we provide a more detailed example of manufacturing should-cost in subsections from A.1 through A.8. Equation (A-1), immediately below, represents the overall should-cost of the purchased product and was also listed Section 2.4.1. To better convey and illustrate the challenges associated with determining this type of should-cost, we fully elaborate on the eight subcomponent costs in the equations and definitions below. There are other techniques to determine the manufactured should-cost of a product; this is one example.

Total Product Manufacturing Should-Cost = **(A-1)**

Material Cost + Labor Cost + Overhead Cost + SG&A Cost

+ Material Management Cost + Logistics Cost + Royalty Cost + Net Profit

A.1 Material Cost

The Material cost represents the value of materials used for producing the procured product or end item. To fully and accurately determine this cost, it must be divided into Direct Material cost, Indirect Material cost, Outsourcing Part cost, and Imported Material cost. Direct Material is the material used in the manufacturing process and remains after it is transformed into a component or the final product. Indirect Material means the material consumed during the manufacturing process. Outsourcing Parts are completed sub parts purchased from tier two suppliers and assembled into the end item without going through further manufacturing procedures. Imported Material represents the special materials purchased and delivered from overseas companies.

Material Cost = **(A-2)**

Direct Material Cost + Indirect Material Cost + Outsourcing Part Cost

+ Imported Material Cost

The Direct Material cost is usually estimated in the following manner. First, the RM weight is multiplied by the RM unit price. Second, the material scrap weight is multiplied by the scrap unit cost. Finally, by deducting the value gained from the first step from the number determined in the second step, one can calculate the Direct Material cost.

For the Indirect Material cost, except in the case when the amount of material used is not traceable, companies must consider the Indirect Material cost, which is not included in Direct Material cost. If the cost needs to be considered, each company needs to estimate the cost with its own standards.

Outsourcing Part cost is the expense for the outsourced components and it is generally the amount of money the company paid to its suppliers for the product acquisition.

For Imported Material cost, each company use different methods to estimate the cost. Generally, companies consider material import price, currency rate, and additional import expenses. Additional import expenses include costs such as finance-related costs, transportation-related costs, and tariff.

Direct Material = **(A-3)**

(Material Weight * Material Unit Price) – (Scrap Weight * Scrap Unit Cost)

Each company, according to its standards, situations, and assumptions, determines the equations for Indirect Material Cost and Imported Material Cost.

A.2 Labor Cost

The Labor cost is the amount spent on labor to produce the goods.

Labor Cost = Standard Labor Rate * Standard Production Cycle Time **(A-4)**

To estimate the labor cost accurately, standard labor rates for manufacturing types and standard production cycle times of individual manufacturing activities should be calculated.

Standardizing labor rates for different manufacturing processes and production cycle times of individual manufacturing activities requires significant time and effort by industrial engineers or other manufacturing experts.

A.3 Overhead Cost

The Overhead cost represents the expense, excluding material and labor cost, of manufacturing the product. It generally consists of employee welfare benefits, electricity cost, depreciation cost, maintenance cost, consumable expenses, consumable machinery cost, rent expense, tax for manufacturing activities, outsourcing labor cost, and so forth. Often, it is estimated by multiplying the Overhead Cost Rate with the Standard Production Cycle Time.

Overhead Cost = Overhead Cost Rate * Standard Production Cycle Time **(A-5)**

The Overhead Cost Rate is determined by dividing the total overall overhead cost of individual companies by its entire production time during a specific period.

A.4 SG&A Cost

The SG&A Cost is the expense from the overall sales and sales management activities, while the Overhead Cost only occurs in the manufacturing activities. In a manufacturing should-cost model, the SG&A Cost is generally estimated by multiplying the Manufacturing Cost by the standard SG&A Rate or by multiplying the Labor Cost and Overhead Cost with the standard SG&A Rate.

SG&A Cost = Manufacturing Cost * SG&A Rate **(A-6)**

or

SG&A Cost = (Labor Cost + Overhead Cost) * SG&A Rate **(A-7)**

Each company uses one of the two equations according to its situation or internal standards. In most cases, equation A-7 is preferred because companies like to relate the SG&A cost to the added values of the companies performing the manufacturing process. Added values during the manufacturing process include Labor and Overhead Cost, but not Material Cost.

A.5 Material Management Cost

The Material Management Cost represents the costs that arise from material control activities, such as: material administration, material inspection, material preservation, material movement, material expense interest expense, and material management-loss. If a company wants to use the Material Management Cost, it needs to exclude the aforementioned costs from the estimations of Material Cost, Labor Cost, Overhead Cost, and SG&A Cost that were determined earlier. Then, the company can define the Material Management Rate by dividing the summation of the costs by the Material Cost for a specific period.

Material Management Cost = Material Cost * Material Management Rate **(A-8)**

A.6 Logistics Cost

Although the Logistics Cost for sales is included in the SG&A Cost, it can be estimated individually for manufacturing should-cost estimation as necessary. This is because the actual logistics cost sometimes varies significantly according to the delivered product type, quantity, and customer location. To estimate and apply the cost, each company should exclude the Logistics Cost for sales from the SG&A cost in section A.4.

A.7 Royalty Cost

The technology transfer cost and patent use fee are calculated as the Royalty Cost. To use this term in manufacturing should-cost estimation, the company conducting the analysis should exclude this cost from the Overhead Cost Rate and SG&A Cost Rate estimation. Usually, the Royalty Cost per product is estimated by dividing the overall Royalty Cost with expected or contracted product sales quantity. Or, the Royalty Cost can be calculated by multiplying the product's contract price with the royalty rate dictated in a royalty contract.

A.8 Net Profit

An appropriate level of profit margin should be allocated and controlled considering the perspective of the buyer and seller.

Net Profit = (Labor Cost + Overhead Cost + SG&A Cost) * Net Profit Rate **(A-9)**

Buyers and sellers have different opinions regarding net profit because of individual viewpoints and incentives. If the theoretical and scientific method to estimate the Net Profit Rate is not developed, a buyer's actual situation and the industry average should be used to determine the Net Profit Rate (Young Sam, Suk Ha, & Je Sung, 2012).

Appendix B: Interview Protocol

Figure B-1, below, outlines the questions we used during our interviews organized by phase. Phase I and Phase III were directed at all interviewees. In Figure B-1, under Phase II, we list all the discussion topics and questions. We directed all the questions from our list of discussion topics to the Global Manager and Category Managers, because they have a strategic view of the sourcing and procurement processes at CMSP. We reserved discussion topics five through seven for the Sub-category and Supplier Managers, who are the people likely to use this tool on a day-to-day basis. We reserved questions six and seven for the Process Improvement Manager, who was primarily reviewing should-cost from the performance improvement position.

INTERVIEW PROTOCOL

PHASE I:

- Greetings. Introduce ourselves (name, affiliation, etc.)
- Introduce topic and the sponsor of the project

PHASE II:

- Begin the official interview with the following topics/questions:

1. How is the company's sourcing and procurement group organized?
2. What products and how many does the company purchase from external suppliers?
3. What is the current process/technique for negotiating prices with suppliers?
4. What led you to investigate should-cost for procurement? Why?
5. What do you want to use should-cost for?
6. What are your expectations for a should-cost tool?
7. What do you think are the critical factors to account for in a should-cost tool?

PHASE III:

- Ask if the respondent would like to be quoted by name
- Ask if the respondent has any questions
- Ask if we can follow up on the discussion via phone/e-mail
- Thank for the time and input

Figure B-1: Interview Protocol

Appendix C: Should-Cost Tool Equations

In Appendix C, we introduce the underlying equations used to estimate the procured product should-cost in our tool. These equations can be divided into two groups: one group for the calculation of the financial ratios and the second for calculating the sub part should-cost estimate. Equations **C-1** through **C-14** are used in Section 4.2.4 for the financial ratios estimation (Sower, V. and Sower, C., 2012):

Material Expense = RM Expense + Other Material Expense **(C-1)**

Material Ratio = RM Expense ÷ Material Expense **(C-2)**

Temp RM Cost = **(C-3)**

Materials/Parts/Containers/Packaging/Etc./Used * Material Ratio

Temp Other Material Cost = **(C-4)**

Materials/Parts/Containers/Packaging/Etc./Used * (1 - Material Ratio)

Gross Profit = Gross Profit Percentage from RMA * Total Value of Shipments **(C-5)**

Overhead Cost = **(C-6)**

Total Value of Shipments – Temp RM Cost – Temp Other Material Cost

– Production Workers Wage – Gross Profit

SG&A Cost = **(C-7)**

Total Value of Shipments * (Operating Expenses Percentage +

All Other Expenses Percentage from RMA)

Net Profit = **(C-8)**

Total Value of Shipments – Temp RM Cost – Temp Other Material Cost

– Production Workers Wage – Overhead Cost – SG&A Cost

RM Percentage (%) = Temp RM Cost ÷ Total Value of Shipments **(C-9)**

RM to Other Material Cost Ratio = **(C-10)**

Temp Other Material Cost ÷ Temp RM Cost

RM to Direct Labor Cost Ratio = Production Workers Wage ÷ Temp RM Cost **(C-11)**

RM to Overhead Cost Ratio = Overhead Cost ÷ Temp RM Cost **(C-12)**

RM to SG&A Cost Ratio = SG&A Cost ÷ Temp RM Cost **(C-13)**

RM to Net Profit Ratio = Net Profit ÷ Temp RM Cost **(C-14)**

The equations that follow, **C-15** through **C-21,** are used to estimate the sub part should-costs in Section 4.2.6 (Sower, V. and Sower, C., 2012).

Sub Part Financial Should-cost = **(C-15)**

RM Cost + Other Material Cost + Direct Labor Cost + Overhead Cost

+ SG&A Cost + Net Profit + Other Relevant Cost

Other Material Cost = RM Cost * RM to Other Material Cost Ratio **(C-16)**

Direct Labor Cost = RM Cost * RM to Direct Labor Cost Ratio **(C-17)**

Overhead Cost = RM Cost * RM to Overhead Cost Ratio **(C-18)**

SG&A Cost = RM Cost * RM to SG&A Cost Ratio **(C-19)**

Net Profit = RM Cost * RM to Net Profit Cost Ratio **(C-20)**

Other Relevant Cost = **(C-21)**

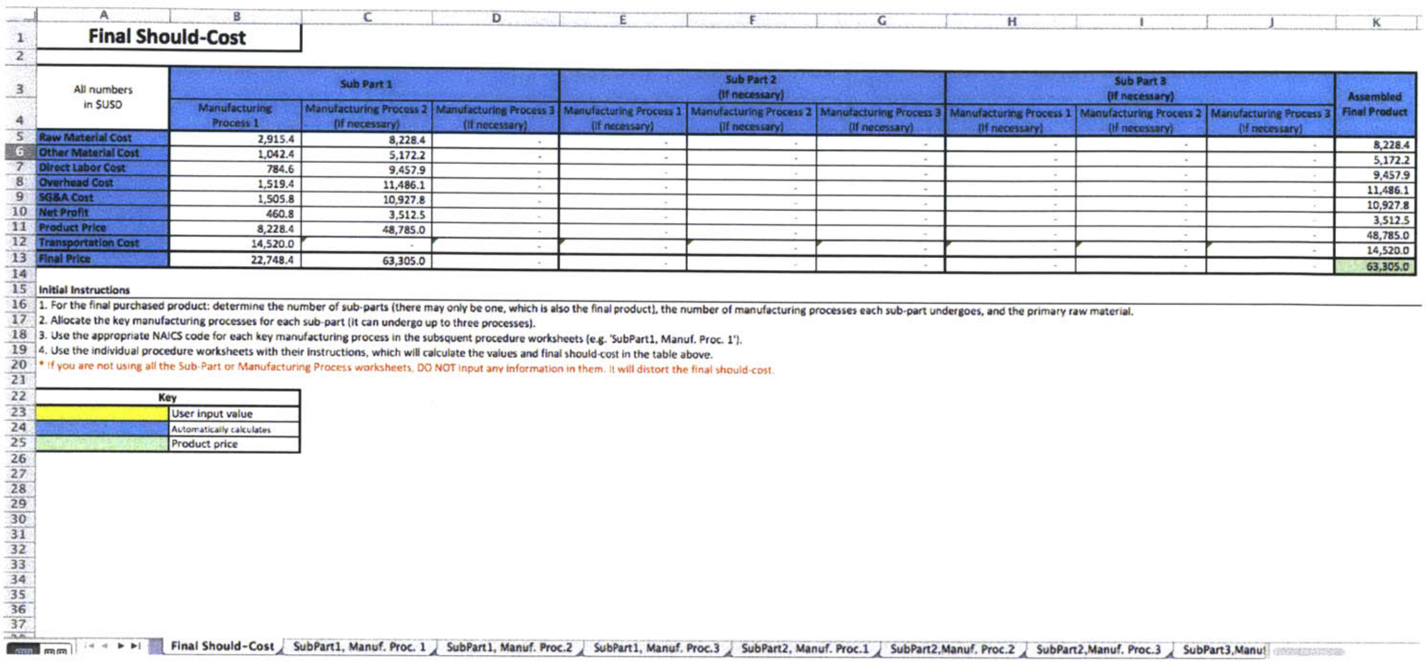
(Cost factors that may not be captured in the underlying aggregate data)

We included the "Other Relevant Cost" factor based on our interviews and conversations with the experts at CMSP. Sometimes, industry-wide data does not capture a specific cost that the procurement team knows the supplier incurs. This extra factor is our way of building additional flexibility into the model to account for known additional costs. An example of an "Other Relevant Cost" is a transportation cost that is considerably higher than the industry norm. To illustrate: if the supplier we purchase the fluid end from has to source a specific sub part from overseas, we may want to account for that additional freight cost to accurately model their price quote. NAICS and RMA data is built around North American businesses that generally source within the continent. Sourcing sub parts overseas could be assumed to be an unusual business activity in that industry (e.g. manufacturing the fluid end). In other words, transportation costs included in the aggregate data may not cover transportation costs from overseas or other unforeseen costs. Knowing this, procurement specialists can estimate the cost independently and add it in as an "Other Relevant Cost."

Appendix D: Should-Cost Excel Tool

To help procurement specialists estimate a procured product's should-cost simply and effectively, we have developed a should-cost estimation tool in Microsoft Excel. The tool consists of ten Excel sheets: One summary sheet (Figure D-1) and nine cost estimation sheets (Figures D-2 through D-5). On the summary sheet, the procured product's sub part cost estimates, individual cost values, and overall should-cost is displayed. Individual cost values include RM cost, Other Material cost, Direct Labor cost, Overhead cost, SG&A cost, Net Profit, and Other Relevant cost. On the nine cost estimation sheets, procurement specialists can calculate the should-cost estimates of up to three sub parts. For each of the three potential sub parts, up to three additional cost estimation sheets may be used for multiple manufacturing processes that the sub part may undergo. Each cost estimation sheet must be tied to an individual NAICS code.

The summary sheet appears in Figure D-1 on the following page. Procurement specialists do not need to input any information in the summary sheet because all the sub part and manufacturing cost values will be drawn from the subsequent cost estimation sheets and automatically tabulated here. Figure D-1 depicts the final should-cost estimate from the example case we used in Section 4.3.



Final Should-Cost										
All numbers in $USD	Sub Part 1			Sub Part 2 (If necessary)			Sub Part 3 (If necessary)			Assembled Final Product
	Manufacturing Process 1	Manufacturing Process 2 (If necessary)	Manufacturing Process 3 (If necessary)	Manufacturing Process 1 (If necessary)	Manufacturing Process 2 (If necessary)	Manufacturing Process 3 (If necessary)	Manufacturing Process 1 (If necessary)	Manufacturing Process 2 (If necessary)	Manufacturing Process 3 (If necessary)	
Raw Material Cost	2,915.4	8,228.4	-	-	-	-	-	-	-	8,228.4
Other Material Cost	1,042.4	5,172.2	-	-	-	-	-	-	-	5,172.2
Direct Labor Cost	784.6	9,457.9	-	-	-	-	-	-	-	9,457.9
Overhead Cost	1,519.4	11,486.1	-	-	-	-	-	-	-	11,486.1
SG&A Cost	1,505.8	10,927.8	-	-	-	-	-	-	-	10,927.8
Net Profit	460.8	3,512.5	-	-	-	-	-	-	-	3,512.5
Product Price	8,228.4	48,785.0	-	-	-	-	-	-	-	48,785.0
Transportation Cost	14,520.0	-	-	-	-	-	-	-	-	14,520.0
Final Price	22,748.4	63,305.0	-	-	-	-	-	-	-	63,305.0

Initial Instructions
1. For the final purchased product: determine the number of sub-parts (there may only be one, which is also the final product), the number of manufacturing processes each sub-part undergoes, and the primary raw material.
2. Allocate the key manufacturing processes for each sub-part (it can undergo up to three processes).
3. Use the appropriate NAICS code for each key manufacturing process in the subsquent procedure worksheets (e.g. 'SubPart1, Manuf. Proc. 1').
4. Use the individual procedure worksheets with their instructions, which will calculate the values and final should-cost in the table above.
* If you are not using all the Sub-Part or Manufacturing Process worksheets, DO NOT input any information in them. It will distort the final should-cost.

Key	
(yellow)	User input value
(blue)	Automatically calculates
(green)	Product price

Final Should-Cost | SubPart1, Manuf. Proc. 1 | SubPart1, Manuf. Proc.2 | SubPart1, Manuf. Proc.3 | SubPart2, Manuf. Proc.1 | SubPart2,Manuf. Proc.2 | SubPart2,Manuf. Proc.3 | SubPart3,Manu

Figure D-1 Summary Sheet

Procurement specialists input the required information on the individual cost estimation sheets following the seven-step process outlined in Section 4.2 (also described throughout the Excel tool). In the Excel should-cost tool, the user only needs to input data in the yellow cells. The blue cells automatically calculate the cost values based on the inputs to the yellow cells using the equations listed in Appendix C.

There are three cost estimation sheets for each sub part: one for the NAICS code of the first manufacturing process and two more for the NAICS codes of the second and third manufacturing processes. If the number of sub parts and manufacturing processes are less than three, the user can ignore the sheet.

D.1 Sub Part 1, Manufacturing Process 1

For our example case, the fluid end of a pumping mechanism, we identified one sub part that underwent two manufacturing processes. Figure D-2 depicts the first values we input for

"Manufacturing Process 1." Following this, Figure D-3 shows the remaining values the user must input to complete the cost estimation for this first manufacturing process.

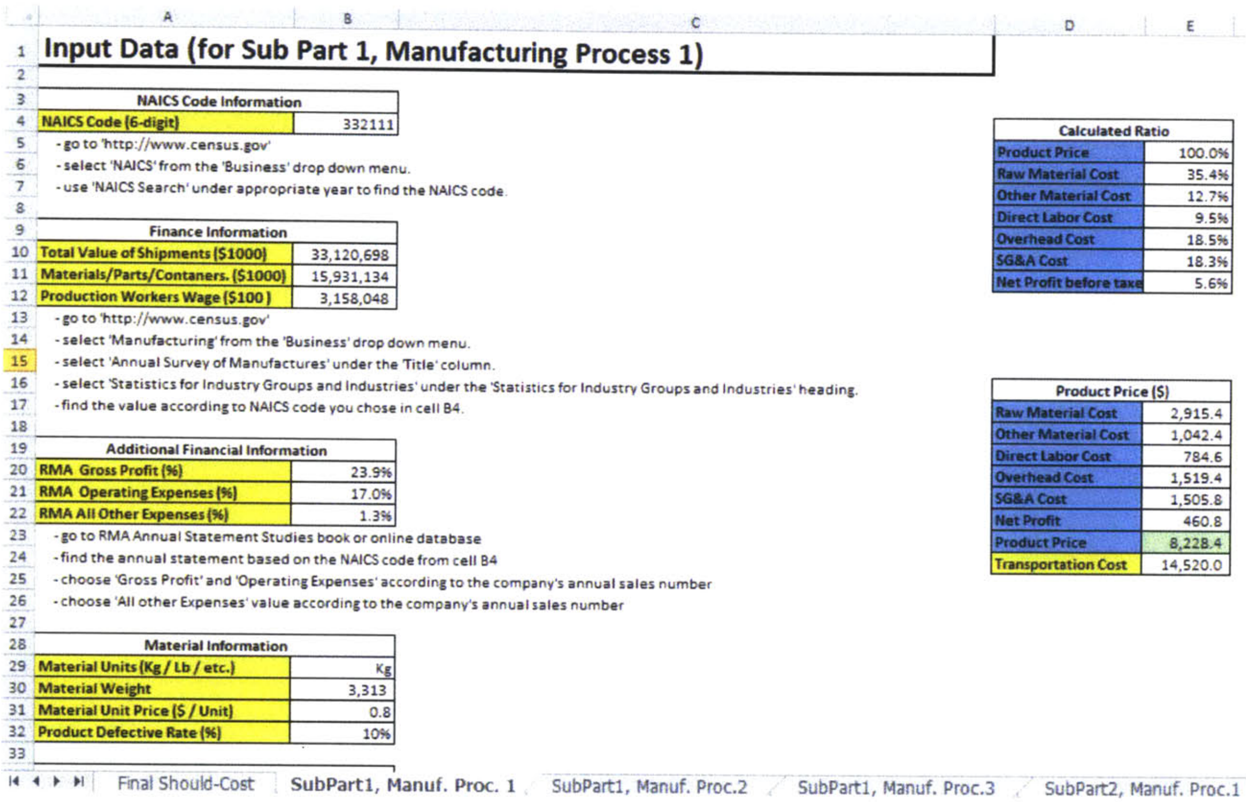


Figure D-2

Sub Part 1, Manufacturing Process 1

For "Sub Part 1, Manufacturing Process 1," the user can input the values next to the yellow cells. The "NAICS code (6-digit)" input is based on the procurement specialist's breakdown of the end item and is simply inserted to maintain track of what process is being estimated on a particular sheet. The "Total Value of Shipments," "Materials/Parts/Containers/Packaging/Etc./Used," and "Production Workers Wage" are obtained from the U.S. Census Bureau website and used to estimate the financial ratios (in blue at the top right of Figure D-2). Begin on the U.S. Census Bureau's homepage and select *Business*, which produces a drop-down menu where the user then selects *Manufacturing*. When the manufacturing page loads, the user scrolls down and in the *Title (with link to data)* column, there is a link called *Annual Survey of Manufacturers.* After selecting that link, the user then selects *Statistics for Industry Groups and Industries* for the most recent year. In the list that loads, the user scrolls down to find the six-digit NAICS code for the sub part or manufacturing process. The procurement specialist can now see the values for: "Total Value of Shipments," "Materials/Parts/Containers/Packaging/Etc./Used," and "Production Workers Wage," which represent industrial averages for revenue, material costs, and direct labor cost (U.S. Census Bureau, 2012).

"RMA Gross Profit," "RMA Operating Expenses," and "RMA All Other Expenses" percentages can be found online through a subscription to RMA or at a library. Simply find the sequentially listed six-digit NAICS code in the *RMA Annual Statement Studies* book, sub-organized by revenue into small/medium/large companies, and copy the appropriate percentages into the tool under "Additional Financial Information."

Find the "Material Units," "Material Weight," and "Material Unit Price" using the analytical process we outlined in Section 4.2.5.

Material Ratio Information	
Raw Material Ratio (%)	73.7%
Other Material Ratio (%)	26.3%

- go to 'http://www.census.gov'
- select 'Manufacturing' from the 'Business' drop down menu.
- select 'Economic Census' under the 'Title' column.
- select appropriate NAICS 2-digit code in 'Table by Economic Census Sector.'
- Select 'Manufacturing: Industry Series: Materials Consumed by Kind for the United States: 2007.'
- Select 'Download' from the Actions menu bar; download the file as 'Data and annotations in a single file.'
- In the downloaded folder, select the file named 'ECN_2007_US_31I3_with_ann.csv' and filter the data according to your NAICS code (create filter if necessary).
- Copy the material info from the file, ensuring to distinguish 'Raw Material' and 'Other Material' into the below table.

Category	MFCODE.id	MFCODE.display-label	MATFUELCOST	Ratio
Raw Material	00971000	Materials, ingredients, containers, and supplies, nsk	579,535	16%
	33100014	Steel ingot & semifinished shapes (incl blooms,billets,slabs)	611,789	17%
	33120065	Steel bars/bar shapes/other shapes/forms (excl. castings/etc.)	712,099	20%
	33131016	Alum/Alum-base alloy shapes/forms (excl castings, forgings, etc)	94,423	3%
	33149101	Ti/Ti-base alloy shapes/forms (excl. castings/forgings/etc.)	187,457	5%
	33149103	Ni/Ni-base alloy (excl. castings/forgings/etc.)	473,307	13%
				0%
				0%
		Sum	2,658,610	74%
Other Material	00970099	All other materials/components/parts/containers/supplies	197,878	5%
	33200057	Fabricated metal products, excluding forgings	115,332	3%
	33211000	Forgings	580,233	16%
				0%
				0%
				0%
				0%
				0%
		Sum	893,443	25%
		Others	57,172	2%
Material Total			3,609,225	100%

Final Should-Cost | SubPart1, Manuf. Proc. 1 | SubPart1, Manuf. Proc.2 | SubPart1, Manuf. Proc.3 | SubPart2, Manuf. Proc.1

Ready

Figure D-3

Sub Part 1, Manufacturing Process 1 (cont'd)

For the remaining inputs of "Sub Part 1, Manufacturing Process 1" depicted in Figure D-3, return to the U.S. Census Bureau home page and again select *Business*, which produces a drop-down menu where the user then selects *Manufacturing*. When the manufacturing page loads, the user scrolls down and in the *Title (with link to data)* column, there is a link called *Economic Census* to select. There, appropriate two-digit NAICS code hyperlinks are listed under the *Table by Economic Census Sector*. The user selects the two-digit NAICS code that corresponds to the six-digit code for each sub part and industry-specific statistics will appear (likely NAICS code 31-Manufacturing). Among the information displayed, the user selects *Manufacturing: Industry Series: Materials Consumed by Kind for the United States: 2007* (or more recent year). Then, the user can download that file by selecting *Download* and downloading the file as *Data and annotations in a single file* in the *Excel* format. In the downloaded file, users can find and distinguish RM expense and other material expense information and estimate the ratio between them. Procurement specialists should pay close attention to this process because an incorrect assortment of RM cost and other material cost information will distort the sub part's should-cost estimate (U.S. Census Bureau, 2012).

D.2 Sub Part 1, Manufacturing Process 2

The cost estimation sheets for the second and (if necessary) third manufacturing processes for Sub Part 1 follow the same procedure, except for "Material Units," "Material Weight," and "Material Unit Price." The RM cost is drawn from the previous cost estimation sheet for each manufacturing process and its value will be the "Product Price" in the next process (e.g. the cost estimate from "Sub Part 1, Manufacturing Process 1" becomes the raw material cost in "Sub Part 1, Manufacturing Process 2"). This is based on the assumption that the manufacturing of a single part is a sequential process – the part must undergo one process (e.g. forging) before it can undergo another process (e.g. machining).

The cost estimation sheet for the second manufacturing process is depicted below, in Figures D-4 and D-5.

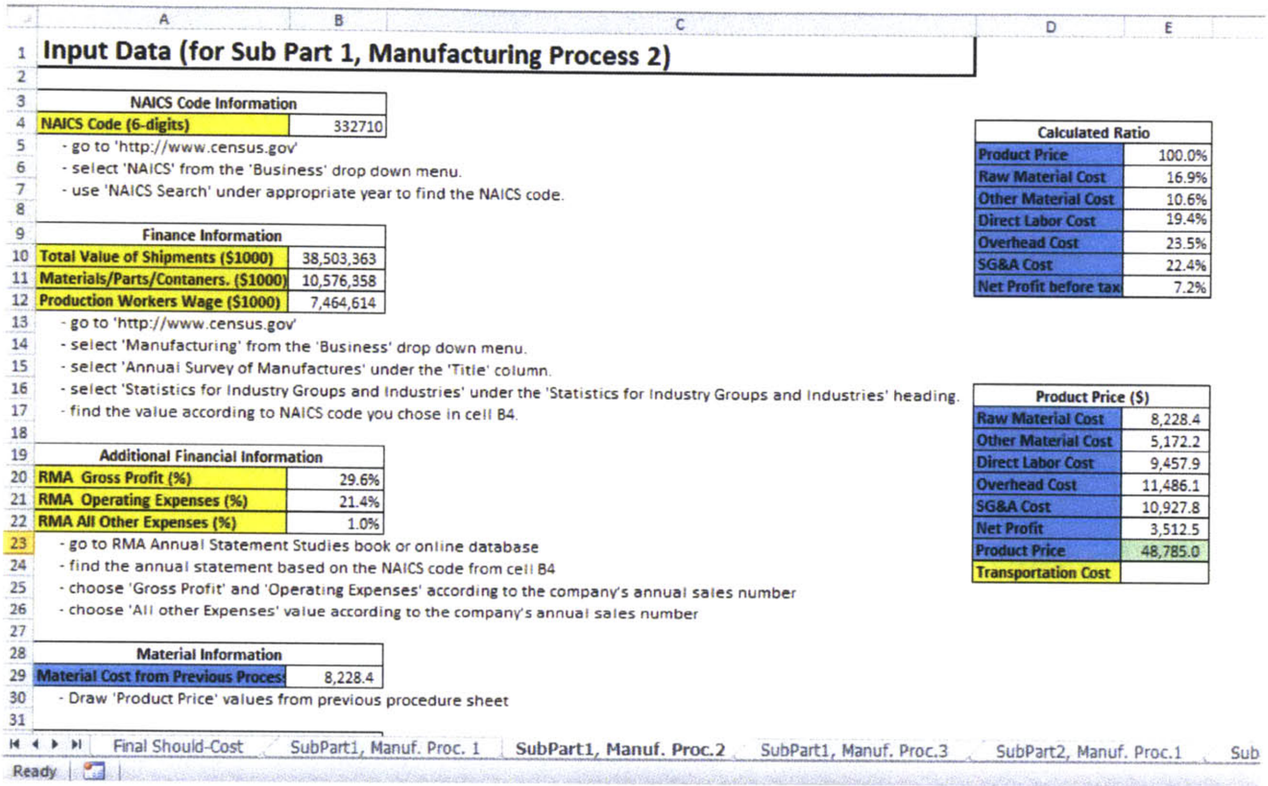


Figure D-4

Sub Part 1, Manufacturing Process 2

Input Data (for Sub Part 1, Manufacturing Process 2)

Material Information	
Material Cost from Previous Process ($)	8,228.4

- Draw 'Product Price' values from previous procedure sheet

Material Ratio Information	
Raw Material Ratio (%)	61.4%
Other Material Ratio (%)	38.6%

- go to 'http://www.census.gov'
- select 'Manufacturing' from the 'Business' drop down menu.
- select 'Economic Census' under the 'Title' column.
- select appropriate NAICS 2-digit code in 'Table by Economic Census Sector.'
- Select 'Manufacturing: Industry Series: Materials Consumed by Kind for the United States: 2007.'
- Select 'Download' from the Actions menu bar; download the file as 'Data and annotations in a single file.'
- In the downloaded folder, select the file named 'ECN_2007_US_31I3_with_ann.csv' and filter the data according to your NAICS code (create filter if necessary).
- Copy the material info from the file, ensuring to distinguish 'Raw Material' and 'Other Material' into the below table.

Category	MFCODE.id	MFCODE.display-label	MATFUELCOST	Ratio
Raw Material	00971000	Materials, ingredients, containers, and supplies, nsk	3,179,932	35%
	33120007	Steel bars/bar shapes/plate (excl. castings/forgings/etc.)	740,660	8%
	33142146	All other copper and copper-base alloy shapes and forms	87,578	1%
	33151001	Iron and steel castings (rough and semifinished)	944,892	11%
	33152004	Other nonferrous metal castings, rough/semifin. (inc. AL/CU)	110,062	1%
	33152005	Aluminum/aluminum-base alloy castings (rough/semifinished)	232,667	3%
	33211000	Forgings	226,851	3%
				0%
				0%
				0%
				0%
				0%
				0%
				0%
	Sum		5,522,642	61%
Other Material	00970099	All other materials/components/parts/containers/supplies	1,478,556	16%
	33100003	All other nonferrous metal shapes and forms	73,574	1%
	33100022	Steel sheet and strip (including tinplate)	181,823	2%
	33100025	Steel struct shapes & sheet piling (excl castings/forgings/etc.)	118,789	1%
	33100054	All other alum/alum-base alloy shapes/forms (excl castings, etc)	150,429	2%
	33120092	All other steel shapes/forms (exc. castings/forgings/etc.)	109,052	1%
	33131500	Aluminum/aluminum-base alloy sheet/plate/foil/welded tubing	238,533	3%
	33142105	Brass shapes/forms (excl. castings/forgings/fab. metal prods.)	57,912	1%
	33200101	Other fabricated metal products (excluding forgings)	586,208	7%
	33272203	Metal bolts/nuts/screws/other screw machine products	198,103	2%
	33351505	Machine tool accessories (including cutting tools)	278,409	3%
				0%
				0%
				0%
	Sum		3,471,388	39%
	Others		-	0%
Material Total			8,994,030	100%

Final Should-Cost | SubPart1, Manuf. Proc. 1 | SubPart1, Manuf. Proc.2 | SubPart1, Manuf. Proc.3 | SubPart2

Figure D-5

Sub Part 1, Manufacturing Process 2 (cont'd)

The user fills in the information for "Sub Part 1, Manufacturing Process 2" following the same methods described for "Manufacturing Process 1" in Section D.1. Figures D-4 and D-5 display the values we input for our should-cost estimate of the fluid end. If the number of sub parts exceeds three or the number of manufacturing processes for one or more of the sub parts exceeds three, user should extend the existing excel tool based on this format. There may be very unique or highly complex end items that require a substantially bigger tool. Based on discussions with CMSP, the tool as it is constructed should cover most scenarios.