Cost Modeling:

A FOUNDATION PURCHASING SKILL

By Julie A. Ask and Timothy M. Laseter

At the heart of best practice in purchasing is a set of skills. One of the most important is the one that enables managers to understand what determines cost.

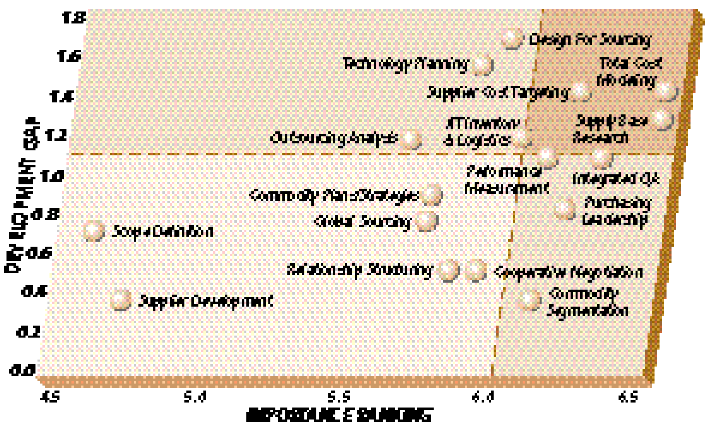
IN A RECENT survey of leading purchasing organizations sponsored by Strategy & Business, cost modeling was ranked among a list of 17 purchasing skills as one of the most critical. More significantly, the difference between the importance ranking and the self-assessed level of skill — the development gap — was among the largest as well. (See Exhibit I.)

Our experience is that this development gap is even greater in the typical purchasing organization — and the skill is just as critical.

In fact, cost modeling is critical even if a company has yet to find the balance between cooperation and competition. When applying a "Darwinian Rivalry" model (see Exhibit II adapted from "Balanced Purchasing," Strategy & Business, Winter 1996, Issue 2), a company negotiates ruthlessly with suppliers. Cost models can provide the understanding needed to squeeze supplier margins to the bare minimum. As Chester Karrass, one of the leading negotiation trainers in the field of purchasing strategies, puts it in his advertising: "In business, you don't get what you deserve, you get what you negotiate."

Research and client experience indicate, however, that cost models developed in cooperation with suppliers

EXHIBIT I
PURCHASING SURVEY



Source: Booz-Allen & Hamilton

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are the most effective. Collaborative development improves the quality of the model by capturing supplier insight. More importantly, a jointly developed model has a greater probability of being fully applied.

For example, over the years the McDonald's Corporation has worked with suppliers to develop a sophisticated model to optimize chicken costs. The model captures expected mortality rates and weight gains to determine the optimal breed mix under various conditions such as humidity and space allocation. Also, by modeling how feed mix affects weight gain and mortality, suppliers are able to adjust feeding programs to optimize weight gain in response to commodity-feed price changes. Such a model provides a competitive advantage for McDonald's.

KEY PRINCIPLES

Although cost modeling generates a lot of interest in most purchasing organizations, the term "cost model" can create some confusion because it can mean a variety of things and the models can have different purposes. For example, a high-level understanding of the direct labor content and shipping economics of a purchased product could result in a strategy to develop suppliers in a low-wage country such as China. At a tactical level, a more detailed cost model could be used to choose between two suppliers of the same materials. Finally, a model that documents set-up cost could be used at an executional level to determine optimal order quantities.

Regardless of the immediate purpose of a cost model, five key principles should be considered to create more accurate and robust cost models for purchased goods and services:

Source: Booz-Allen & Hamilton

EXHIBIT II
APPROACHES TO PURCHASING RELATIONSHIPS

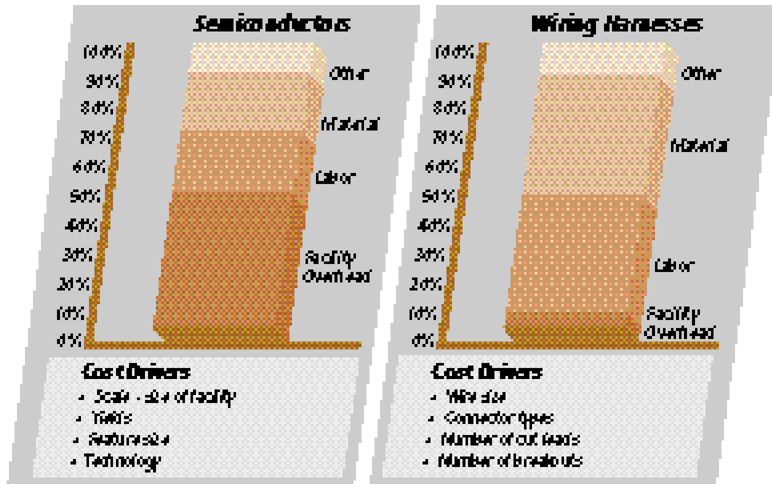
➢*Capture cost drivers, not just cost elements.* The most basic inputs to a cost model are the cost elements captured by accountants: direct labor, materials and overhead. However, documenting the cost elements is only a start. A cost model should capture the drivers of cost such as labor productivity or hourly wage rates. Capturing drivers produces models that support "what if" analysis, not just "what is." Documenting drivers also highlights tradeoffs because the same driver can affect different cost elements in different ways. For example, increasing production-lot sizes can lower production costs because fewer set-ups are needed, but increase inventory costs because more inventory is held on average. As a result, models based on drivers of cost provide far more insight for making decisions.

➢*Build commodity-specific models to highlight key drivers.* Inherent differences in products will cause different cost drivers to emerge among commodities; therefore, models should be commodity-specific. Exhibit III illustrates this point by comparing semiconductors and wiring harnesses for automobiles. The largest cost component for semiconductors is facility overhead, while material and labor costs dominate the harness cost structure. Such differences in relative size of cost components indicate that different cost drivers will dominate the models. For example, design considerations such as the number of cut leads, breakouts and connector types should be captured in a cost model for wiring harnesses. However, a model for a semiconductor manufacturer should focus on the scale and utilization of the facility because spreading capital cost is so critical.

➢*Consider the impact of total cost of ownership.* Common across commodities, however, is the importance of modeling the total cost of ownership. Few purchasing decisions should be made based solely on the price of the purchased product. Accordingly, cost models designed to support such decisions need to include the factors beyond mere price, such as shipping expenses, quality costs and inventory-carrying costs. In fact, in some purchased products, the cost of acquisition and use can be a multiple of the purchase price and/or the supplier's cost. Exhibit IV demonstrates the range of cost of ownership from various cost models Booz-Allen & Hamilton has developed with clients.

➢*Start simple and add complexity only as needed.* The previous principles encourage the cost modeling to incorporate a broad perspective to include the drivers of total ownership cost. Although those principles are critical to developing robust cost models, experience has shown that initial efforts should focus on simple models that include only the most important cost elements and drivers. Many modeling efforts stall because overly complex cost models cannot be populated with good-quality information. No matter how sophisticated the model is conceptually, it depends on the quality of information used in the model (garbage in, garbage out). The most effective models ultimately achieve the "simplicity on the other side of complexity" that Oliver Wendell Holmes valued so highly. Such models strip out unnecessary "noise" by focusing on the handful of critical drivers that need managing.

➢*Triangulate around data to improve accuracy and confidence.* Another trick of the trade is to use multiple data points to bound the numbers and improve accuracy. For example, even though the magnitude of cost elements differs among suppliers, the values generally fall into a small range. At the initial stage of model development, using the cost structures from multiple suppliers helps to hone in on the actual value — even if some suppliers are less than forthcoming in sharing data. Furthermore, alternative indirect sources of information help in triangulation. Observations from facility tours, internal experts, industry literature and published statistics are a few examples.



Source: Booz-Allen & Hamilton

EXHIBIT III
COMMODITY-SPECIFIC COST COMPONENT MODELS

Applying these principles insures maximum benefit from cost modeling. The best models meet Einstein's test for his own theories: as simple as it can be, but no simpler.

BUILDING COST MODELS

To develop cost models systematically across a purchasing function, Booz-Allen employs a top-down methodology using the five principles described above. The approach builds a broad baseline across all categories of the total spend as well as a deep analysis of a few select commodities. Models document a needed level of detail, but the ultimate objective in modeling is to transfer knowledge throughout the organization. Making sure that everyone working with the commodity understands the important cost drivers is far more critical than having an exact model for determining part-level costs.

The evolution of the "cost research" function at Honda of America illustrates this concept. Initially, Honda employed a group of 20 to 25 experts in a central purchasing function who worked cooperatively with suppliers to develop sophisticated cost models. Over the past decade, Honda has systematically codified the expertise into "cost tables" that can be used by anyone — not just a commodity expert — to cost out a part quickly based upon key drivers. Now the central function consists of only a half dozen individuals; cost modeling has become an organizational capability, not just an individual skill. Dave Nelson, senior vice president of purchasing and administrative services at Honda of America Manufacturing, puts it this way: "We know the cost with data, not gut feel."

Unfortunately, the typical pur-

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FRAMEWORK FOR COST DRIVERS

Even when the net-cost difference between suppliers is relatively small, the cost effects of different drivers can be dramatic. Sorting out these pluses and minuses can be complex but well worth the effort.

Our recommended approach is to group the drivers into four categories as indicated in the following table.

Category	Description	Examples
Design	Costs attributable to product design tradeoffs	• Material specifications • Product line complexity
Facility	Costs related to the size of the facility equipment and process technology employed	• Facility scale • Degree of vertical integration • Use of automation
Geography	Cost associated with the location of the facility relative to the customer	• Location-related wage rate difference • Transportation cost to customer
Operations	Costs that differentiate a well run facility from a poorly run facility	• Labor productivity • Facility utilization • Rejection rates

Source: Booz-Allen & Hamilton

A FRAMEWORK FOR THINKING ABOUT COST DRIVERS

Design-related costs are typically the first category to address to make sure that apples-to-apples comparisons are made. Often, different suppliers will use different designs in an attempt to meet the same functional requirement. For example, at one industrial company the cost modeling effort showed two suppliers used different scrap-to-ore mixes in running their foundries. One used a high-grade scrap such as old railroad rails with a low percentage of new ore. Another used lower-grade scrap with a higher mix of fresh ore. Though both met the same quality standards of the end product, the material costs were quite different.

Another factor could be product-line complexity and the resulting impact on the operations. One foundry might make lower-volume parts in shorter-length runs, causing more plant down time due to changeovers.

Design-related costs can be the most significant. For example, changing fundamental design choices, such as using plastic instead of casting, has a huge impact on the final design. Accordingly, many companies are moving toward "black box" specifications to avoid locking a supplier into a technology that may not be appropriate.

Scale effect is typically the most important facility-related cost factor because most facilities demonstrate a decrease in cost as a function of total capacity. For example, a 200-person plant and a 400-person plant both have only one plant manager, but the 400-person plant has less than double the amount of the 200-person plant of other overhead functions such as human resources and finance. Scale is also observable in the factory operations: a building designed to hold 400 people need not be twice the size of one for 200 people — and even if it were, the cost of the building might well be lower on a per-square-foot basis.

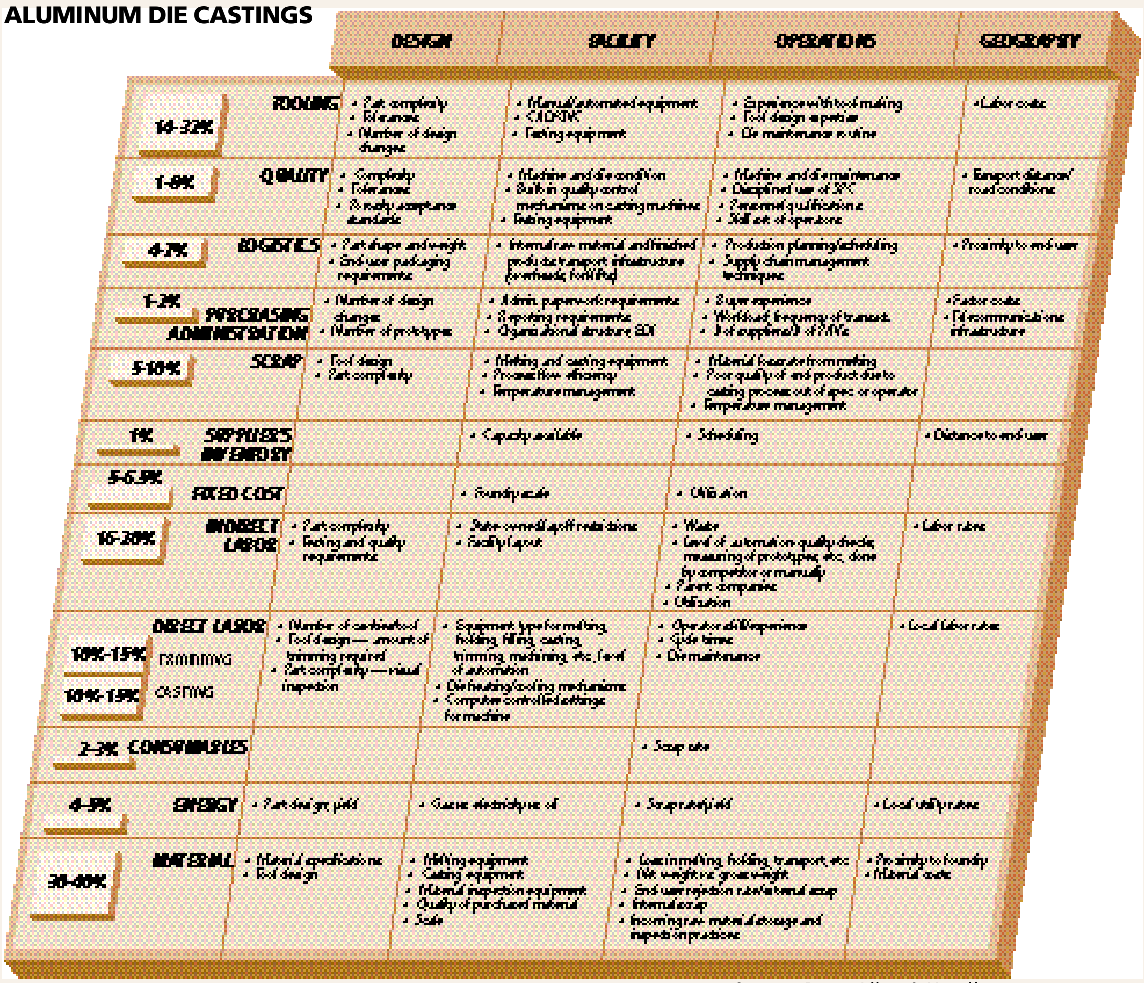
Other facility-related drivers include the degree of vertical integration and automation. A company that produces subassemblies in-house may or may not have lower costs, but the costs will probably differ from those of a supplier buying materials from an outside vendor. The degree of automation typically varies between low-labor-cost countries and high-labor-cost countries where automation is critical for survival.

Geography-related costs are affected by the locale of a facility. Examples are wages, local taxes, utilities and import/export taxes. In die casting, the labor and transportation components are heavily influenced by location-related factors. Moreover, given how heavy, and therefore costly, die castings are to transport, distance from a foundry to final assembly location and proximity to transportation (major roadways, rail and water) are important. Here is a case, also, where low-wage-rate advantages of an emerging market must be weighed against the transport costs to minimize total cost. Since most suppliers already have made significant investments in their "manufacturing footprint," changes to geography-related costs are often best achieved by identifying suppliers in developing markets rather than encouraging suppliers to relocate there.

Operations-related costs are those affected by how well a facility is operated, and as a result can be changed in the shorter term. The drivers of operations-related cost have to do with day-to-day management, including plant productivity, number of shifts, efficiency, scrap rates, etc. Going back to the die casting example, the key operational cost driver of material cost for the supplier would be scrap rates, while labor would be driven by efficiency and productivity of the work force.

The operations-related cost drivers are among the easiest to influence in the near term. For example, driving a supplier to adopt "best practice" man/machine ratios can create a significant impact on the bottom line quickly.

COST DRIVERS FOR HIGH-PRESSURE ALUMINUM DIE CASTINGS



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chasing organization has not achieved Honda's level of sophistication. Accordingly, the following methodology describes a process for developing the capability by beginning simply and advancing over time. By concentrating resources and approaching the problem systematically, a company can begin to develop sophisticated models quickly.

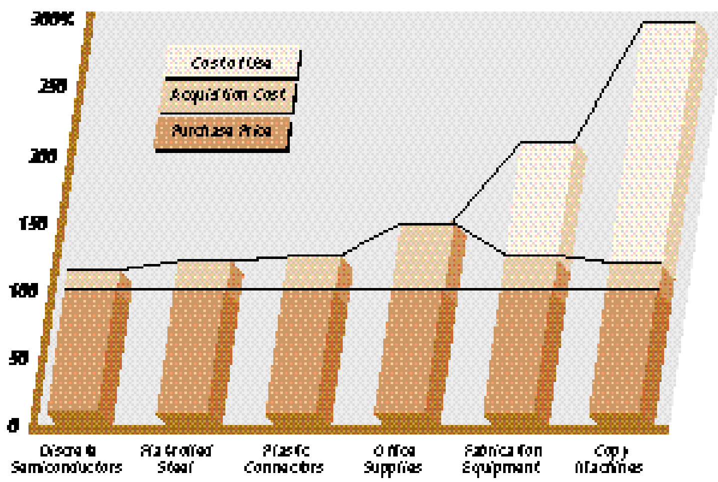
1. BASELINE AND SEGMENT THE SPEND. Baselining and segmenting the spend helps a company combine individually purchased items and services into logical groupings called commodity families. Although baselining the spend may seem straightforward, it often is not. Few companies have good commodity-coding systems and those that do often find the codes are inconsistently applied. Furthermore, large companies often find that each business unit has completely different purchasing systems with incompatible data formats.

Even in companies with standard, company-wide purchasing systems, a significant amount of outside purchases (such as advertising and travel expenses) is not processed through the purchasing function. This phenomenon is so pervasive that Daryl Skaar, the chief procurement officer at Lucent Technologies (and formerly head of the 3M Corporation's purchasing organization), considers the percentage of total outside purchases managed through the purchasing function to be a key performance measure. If this figure reaches 90 percent, he calls it "world class."

After baselining the total spend, the purchases should be aggregated into logical groupings conducive to cost modeling. As an example, consider the simple pie chart in Exhibit V illustrating a baseline of the total spend of a hypothetical manufacturer of industrial equipment. In developing segments this company could define all castings as a commodity or separate them into ferrous and non-ferrous materials. Another topology might be process, or types of mold. Sand casting and permanent mold casting could be considered separate categories regardless of the material, as could horizontal and vertical molding. Generally, the best segmentation groups the items by "supply industries" or "process technology" because understanding supplier economics provides the foundation of the initial cost models. The least effective segmentation scheme (one used by many companies) groups parts based on the end-product application. For example, castings used for a compressor are grouped separately from castings used in a motor, even though both could come from the same supplier and be manufactured on the same type of casting equipment.

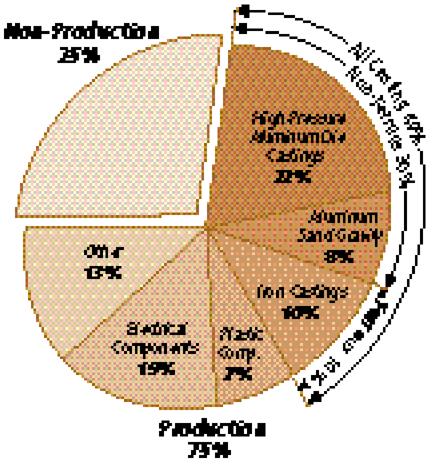
2. QUANTIFY SIGNIFICANT ELEMENTS OF THE COST OF OWNERSHIP. Once the overall spend is documented and segmented into logical groupings, a general total-cost-of-ownership model should be developed. Clearly, such a model should capture obvious cost elements such as transportation and material rejections. However, there are other cost elements that are less obvious yet often significant — and typically difficult to quantify. For example, many companies capture the cost of the purchasing function in ordering, expediting, managing returns and qualifying suppliers. However, capturing the materials-related costs of down time, warranty and disposal are less obvious and sometimes forgotten.

At this stage the cost-of-ownership model may be at the company-wide level only. For example, the best



Source: Booz-Allen & Hamilton

EXHIBIT IV
TOTAL COST OF OWNERSHIP FOR SELECTED COMMODITIES



Source: Booz-Allen & Hamilton

EXHIBIT V
BASELINE OF THE TOTAL SPEND

an organization may be able to measure is that inbound transportation costs average 2 percent of material purchases or that materials-related warranty is estimated to be 60 percent of total warranty costs. Though not particularly accurate, such estimates broaden the organization's thinking about the purchasing process and materials costs by highlighting the magnitude of such costs.

3. USE COST DRIVERS TO BUILD TOTAL-COST-OF-OWNERSHIP MODEL AT THE COMMODITY LEVEL. Although simply capturing the absolute value of numbers helps, the analysis should not stop there. As noted before, an effective model captures cost drivers — not just elements. For example, an obvious driver for the cost of supplier certification is the number of suppliers. For transportation, however, part weight, travel distance and transportation mode are critical drivers. With this type of information, the overall total-cost model can be refined to allocate cost differently across commodities. As shown in Exhibit IV, the relative size of the total-cost-of-ownership components can differ significantly across commodities.

To demonstrate how an understanding of the cost drivers and the elements of total cost of ownership are combined, look again at the die-casting example for the industrial products company. As seen in Exhibit VI, the cost-of-ownership model highlights several interesting issues around castings. First, for this company, the total cost adds 30 percent to the piece price — well worth considering when developing buying strategies. Also, given that tooling is such a significant cost, examination of tooling policies such as capacity buffers and dual sourcing (and accordingly dual tooling) is critical. An additional question is whether a lower-cost mode of transportation would unduly affect inventory.

The total-acquisition cost model encourages thinking about the sourcing strategy for a commodity. However, at this stage, the modeling has only illustrated the broader set of issues beyond purchase price. To move further, there needs to be an understanding of the drivers of cost within the suppliers' operations because purchase price is still likely to be the largest component of total cost.

4. BUILD A SUPPLIER-LEVEL, TOTAL-COST MODEL BASED ON KEY DRIVERS. The cost model resulting from the third step is actually a compendium of costs by a mix of suppliers. If done well, the "ownership costs" reflect the fact that the suppliers are not all the same. For example, shipping costs are a higher percentage of price from a supplier that is farther away. However, the commodity-level model does not capture the difference in production costs of different suppliers. For example, one could have lower labor rates; another could have lower overhead costs due to economies of scale. Even fairly similar suppliers might have different costs due to differences in capacity utilization and the resulting overhead absorption rate.

Building the supplier-cost model follows the same path as building the total-cost-of-ownership model at the commodity level. First, break the supplier's overall cost structure into key components: direct labor; materials; manufacturing overhead; selling, general and administrative costs; and profit. With the exception of profit, most suppliers are willing to provide such detail as part of a site visit, even if you have fairly adversarial relations with them.

Supplier estimates will be somewhat variable and understanding the variances provides the initial insight into cost drivers.

For example, if one company has low direct-labor but higher manufacturing overhead than another, it probably indicates a difference in the degree of automation. However, it may also mean that one pays lower labor rates. Is one unionized and the other not? Or if comparing suppliers across countries, are wage rates driving the differences? If material costs are significantly lower, it probably means that the supplier is more vertically integrated, buying raw materials and per-

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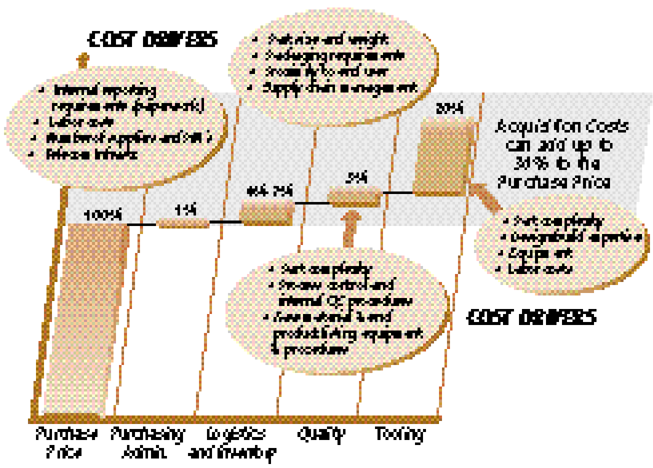

Source: Booz-Allen & Hamilton

EXHIBIT VI
HIGH-PRESSURE ALUMINUM DIE CASTING
TOTAL COST OF OWNERSHIP

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forming the basic "transformation processes" in-house rather than simply doing final assembly.

The next task in building a solid cost model at a supplier facility level is to get quantification of the key drivers for each major element. For example, an initial facility model will capture the number of hourly employees and their annual wage rates. If a more sophisticated model is desired, it may be appropriate to separate direct laborers from indirect hourly laborers and capture their different wage rates. Though the mix between direct and indirect labor may be more detail than needed at this stage, such information can provide insight into manufacturing practices at different suppliers. Lean manufacturers tend to have proportionately fewer indirect laborers versus direct laborers because much of the material handling and off-line inspection is eliminated.

By applying the principle of adding complexity only as needed, a facility-level model can be simple but powerful. For example, a comparison between a high-labor-cost-country supplier and one with the same facilities but lower labor cost requires knowing only the differences in wage rates between suppliers — or maybe simply the differences in average wage rates between countries. This analysis alone might be adequate to convince senior management to support efforts to begin sourcing from emerging markets.

However, most sourcing decisions are more complicated: suppliers are seldom found with identical facilities across countries. For example, high-labor-cost suppliers typically offset their disadvantage by investing in automation and have larger facilities that provide "economies of scale." Also, productivity levels, duties and transportation costs can often offset low-labor-cost manufacturing, which reconfirms the need to model total cost and not just supplier price.

For more information about a structure for capturing cost drivers to build a facility-level model, see: "Framework for Cost Drivers."

5. BUILD COST TABLES AT THE ITEM LEVEL. Creating item-level cost models drives the process to the next level of detail. Facility-level models are adequate for driving sourcing strategies and joint improvement efforts by identifying world-class standards. However, cost estimating and target setting for a specific part demands a more detailed model. Such models add additional variables to the supplier-level model and/or use specific part-number estimates rather than facility averages.

For example, returning to the die-casting model, several of the key inputs to a detailed cost model are facility-specific, such as wage rates, equipment up time and material cost. However, estimates at a part-number level require additional part-specific information such as finished weight, machine-cycle times and material yield. A more complicated model might take into account drivers of part complexity such as wall thickness or number of inserts to calculate a complexity factor to be applied to the cost estimated from the tables.

Such information can be organized into a simple spreadsheet application with input screens for the primary variables.

"Cost tables" are created by calculating a range of scenarios using the model and organizing the results in tabular form. For example, a table for a given supplier (or simply for a "best practice" compendium) could show a range of part weights for column headings and machine cycle times for rows. A set of these tables could be developed showing the effect of different yield assumptions since part design often affects the yield. The output of such analysis is a simple look-up table that allows even an inexperienced buyer (or better still, designer) to estimate the cost of a part using only three variables: weight, cycle time and yield. (See Exhibit VII.)

Creating a good total-cost-of-ownership model at the part-number level generally requires combining different cost tables. For example, another set of cost tables could provide part-number estimates of transportation for the casting. Such a set of tables could use part weight as the column heading (as was done in the original castings model) and distance shipped for the rows. Separate tables could be used for each of a variety of "modes": normal full-truck-load (TL) delivery, less-than-truck-load (LTL) delivery, and expedited air freight.

Cost tables simplify the model output and make costing knowledge available to everyone. As a result, even an inexperienced person can make use of the information. However, as expressed previously, understanding cost drivers — and operating to manipulate them — is far more powerful. For example, rather than simply estimating the cost of a casting, a far more powerful use occurs when the design engineer understands that increasing wall thickness by 2 millimeters adds an extra half pound that adds 50 cents to the cost.

CRITICAL CAPABILITY

Based upon our research, modeling total cost is one of the most critical purchasing capabilities. Understanding the cost provides the foundation for virtually everything that a purchasing organization does, from setting strategy, to simplifying designs, to improving supplier operations and negotiating piece prices.

Furthermore, research highlights that few organizations have evolved this capability as much as desired.

This road map can help organizations close the development gap. From our client experience, useful models can be developed surprisingly quickly, using a focused effort and applying these principles and methodology.

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EXHIBIT VII
COST TABLES FOR HIGH-PRESSURE ALUMINUM DIE CASTINGS

95% YIELD	Part Weight in Kilos								
Cycle Time	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13
50	$0.45	$0.49	$0.53	$0.57	$0.61	$0.65	$0.69	$0.72	$0.76
52	0.46	0.50	0.54	0.58	0.62	0.66	0.70	0.73	0.77
54	0.47	0.51	0.55	0.59	0.63	0.67	0.71	0.74	0.78
56	0.48	0.52	0.56	0.60	0.64	0.68	0.72	0.75	0.79
58	0.49	0.53	0.57	0.61	0.65	0.69	0.73	0.76	0.80
60	0.50	0.54	0.58	0.62	0.66	0.70	0.74	0.77	0.81
62	0.51	0.55	0.59	0.63	0.67	0.71	0.75	0.78	0.82
64	0.52	0.56	0.60	0.64	0.68	0.72	0.76	0.79	0.83
66	0.53	0.57	0.61	0.65	0.69	0.73	0.77	0.81	0.84
68	0.54	0.58	0.62	0.66	0.70	0.74	0.78	0.82	0.85
70	0.55	0.59	0.63	0.67	0.71	0.75	0.79	0.83	0.86

90% YIELD	Part Weight in Kilos								
Cycle Time	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13
50	$0.47	$0.51	$0.55	$0.59	$0.64	$0.68	$0.72	$0.76	$0.81
52	0.48	0.52	0.56	0.60	0.65	0.69	0.73	0.77	0.82
54	0.49	0.53	0.57	0.62	0.66	0.70	0.74	0.78	0.83
56	0.50	0.54	0.58	0.63	0.67	0.71	0.75	0.79	0.84
58	0.51	0.55	0.59	0.64	0.68	0.72	0.76	0.80	0.85
60	0.52	0.56	0.61	0.65	0.69	0.73	0.77	0.81	0.86
62	0.53	0.57	0.62	0.66	0.70	0.74	0.78	0.82	0.87
64	0.54	0.59	0.63	0.67	0.71	0.75	0.79	0.83	0.88
66	0.55	0.60	0.64	0.68	0.72	0.76	0.80	0.84	0.89
68	0.56	0.61	0.65	0.69	0.73	0.77	0.81	0.85	0.90
70	0.57	0.62	0.66	0.70	0.74	0.78	0.82	0.86	0.91

Source: Booz-Allen & Hamilton