VIEWPOINT: 21ST CENTURY COST MANAGEMENT

MANAGING SYSTEM PROFIT

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Focusing on cost by product and customer using activity-based costing (ABC) systems or on production bottlenecks using the theory of constraints (TOC) are two of the many possible ways of viewing the profit equation. Another way to view the profit equation is through system profit (i.e., product profit minus opportunity cost), which combines ABC and TOC considerations and adds competition-based market constraints to provide different, often initially counterintuitive, strategies for long-term maximization of shareholder value. The resulting changes in optimizing product mix can have significantly longer implementation times than occur in most cost management initiatives and produce short-term signals that require unconventional management responses.

In recent years, some progress has been made in reestablishing the relevance of financial systems to

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operational decision making. There is still a long way to go, however, particularly in the area of maximizing shareholder value. In general, the value of a business to its owners is recognized as the present value of its future cash flows, and operating profit is the primary sustainable cash generator for a business. Therefore, maximizing stockholder value is usually tantamount to maximizing long-term profit.

Consider the following simple equation:

$$\Pi = R - C$$

Where profit (Π) equals total revenue (R) minus total cost (C). The way in which this equation is decomposed determines the approach to management of the business profit stream. For example, the equation can be written as follows:

$$\Pi = \sum_{\text{revenue centers}} R_i - \sum_{\text{cost centers}} C_i$$

Where Σ stands for summation and the subscript i represents the ith cost or revenue center. In other

words, to determine profit, add all revenues from the various revenue centers (e.g., regional sales offices), and subtract the sum of all of the costs from the various cost centers (e.g. manufacturing).

Cost management, traditionally the responsibility of the finance function, then deals with minimizing the individual components of the last term in Equation 2. Responsibility for total revenue lies elsewhere, presumably with the vice presidents of sales, marketing, or product development. And the CEO is often the sole owner of profit.

In recent years, business has learned that this smokestack approach subverts significant opportunities for increased profit. Consequently, many firms now express the profit equation as follows:

$$\Pi = \sum_{\text{all products}} (R_j - C_j)$$

Using activity-based costing (ABC), cost is determined by product on the basis of its consumption of resources (e.g., labor, materials, and capital). The *actual*

EXHIBIT 1
Elements of Profit Maximization

EQUIPMENT USAGE	PRODUCT PROFIT	EQUIPMENT AVAILABILITY	SALES REQUIREMENTS

• Determine rates (tons / hr.) by product and process step
 	
   – 1st quarter actual performance: reviewed production logs by rolling
 	
   – Revised standard performance
 	
     • IE studies
     • Consultant studies
     • Record performances
     • Operator estimates
     • O.P. & delay analysis
 	
   – Added mini mill
 	
• Determine yield by product and process step
 	
   – Revised standard yield
	• Determined actual spending / hr. by process step
	
	   – 1st quarter actuals
	
	• Apply equipment usage requirements
	
	     ↓
	
	   Spending by product
	
	• Add yield adjusted hot band cost corrected for cost above
	
	• Added other costs
	
	   – Couplings
	   – Supplies (by product)
	
	• Use July prices
		• Determine historic equipment availability
		
		• Establish maintenance requirement
		
		   – Interviews with maintenance & operating personnel
			• Estimate minimum quantity by product required to service existing customers with current product line
			
			• Estimate maximum quantity by product that can be sold with current product line
			
			• Estimate minimum and maximum for products in 3-year plan

Finished tons / hr. by product and process step	**Product profit**	**Hours / year of equipment availability**	**Initial marketing constraints**

realized price is calculated net of discounts and promotional credits. Together, these determine *true* profit by product. No more arbitrary allocations distorting real unit profits.

The process can be taken even one step further by recognizing that loyal customers are often willing to pay higher prices and that serving them usually incurs lower costs. This is accomplished by applying Equation 3 to each individual customer and then summing across all customers. But knowing profit by customer and product has no intrinsic value.

The knowledge gained from such an analysis is useful only if it leads to actions that increase long-term profit for a given level of investment. These actions usually involve special treatment for the most profitable customers and influence mix changes toward the more profitable products. Unfor-

tunately, this task is often easier said than done, particularly when operating or market constraints exist.

Theory of constraint (TOC) proponents argue that significant distortions remain, even with the massive effort required to determine actual profit by product and customer. They reject Equation 3 in favor of a variant of Equation 2:

$$\Pi = \sum_{\text{all products}} (R_j - C_{vj}) - C_f$$

Where the subscripts v and f refer to the variable and fixed components of total cost. In application, TOC identifies and manages the internal bottlenecks to maximize throughput (i.e., the first term on the right-hand side of equation 4) from a given set of fixed resources (i.e., the second term). Prices are adjusted to sell whatever is produced—as long as the short-term

variable cost can be recovered for each product.

This empirical approach, however, leaves open the question of whether shareholder value is really being maximized. In effect, this strategy strongly discounts future profits by not considering the impact of short-term decisions on long-term market dynamics and the requirements for maintaining an ongoing business.

GOING BEYOND ABC AND TOC

The basic challenge that these two cost management methods try to address is managing business complexity. ABC proponents attempt to face it square on, whereas TOC advocates sidestep the issue by substituting a set of simple rules they assert will provide better results. A third approach, however, builds on both these schools of profit management, though it is

EXHIBIT 2
System Profit Versus Product Profit
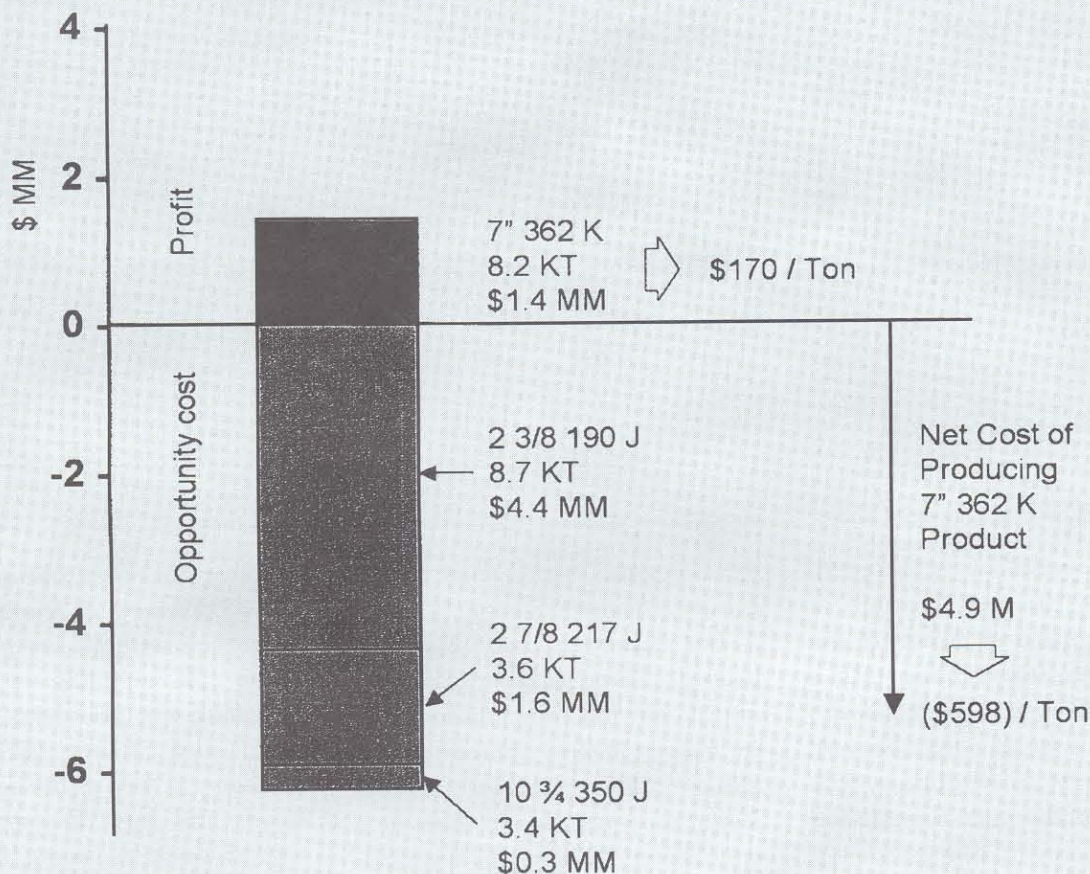
not really new. It is called *simulation modeling.*

Consider NPT, a division of a major U.S. steel company. Its product was pipe used in the oil industry, referred to as *oil-country tubular goods.* In 1980, with the second-oil-crisis rise in prices, the industry was operating on allocation. NPT's factory was running at full capacity. Although its order book was bursting, the question remained whether it could increase profits even more. Doing so would provide much needed cash for NPT's struggling parent.

NPT had 56 products and a manufacturing process with 15 major process steps. Some of the products could be manufactured using alternate flows (including outsourcing some steps) through the mill. Exhibit 1 summarizes the four major elements that were analyzed to optimize its product line for maximum profit (each element is discussed in the following sections).

Product and Process

The first step was to determine finished throughput (i.e., units per machine hour) by product and process. This required reconciliation between the production standards (which were created by the industrial engineering department) and actual operating performance (OP) in terms of both throughput and yield. By synthesizing all of the available information, a consensus was established on what could be expected for actual, yield-adjusted throughput by product.

Product Profit

The second element was product profit. Previously, NPT had purchased a new ABC-like product costing system. This exercise was somewhat complicated by the fact that the major raw material (i.e., steel) was purchased from the parent company at market prices.

In addition, each product had a standard run-length determined by wear of costly, product-specific tooling, so changeover cost—both actual and opportunity (see later sections for more detailed infor-

EXHIBIT 3
Maximizing Profit

Most Desirable Products	Product Profit per Ton (in $)	System Profit per Ton (in $)
2 3/8 190 J	503	362
2 7/8 217 J	434	314
5 1/2 304 L	823	314
5 1/2 361 L	817	311
4 1/2 350 L	897	228
4 1/2 290 N	653	115
Least Desirable Products	**Product Profit per Ton (in $)**	**System Profit per Ton (in $)**
2 3/8 190 N	951	(427)
7 408 N	453	(280)
4 1/2 205 K	207	(205)
7 362 N	463	(201)
2 7/8 217 N	871	(155)
7 362 K	170	(126)

mation)—needed to be included, depending on the number of rollings required to comprise the desired quantity. Fortunately, a simplification was made on the price side of the equation, because the industry, an oligopoly, followed the undiscounted published price book of the market leader, especially in times of excess demand.

Equipment Availability

The third consideration was equipment availability. Again, historic performance and a new program of preventive maintenance aimed at maximizing actual equipment uptime determined the level of availability.

Initial Marketing Constraints

Finally, the results needed to be tempered by the realities of the marketplace. Working with the sales and marketing group, the range of possible sales by product were analyzed on an account-by-account basis. At this point, not only issues of product bundling, but also long-term competitive dynamics and market share implications, were considered.

For example, customers typically preferred to purchase their entire pipe and tube requirements for a given drilling operation from a single supplier for legal accountability purposes, should there be a well failure. In addition, a natural relationship between the amounts of the various products that they ordered developed on the basis of well geology and depth. This required an understanding of each customer's drilling plans by oil-field.
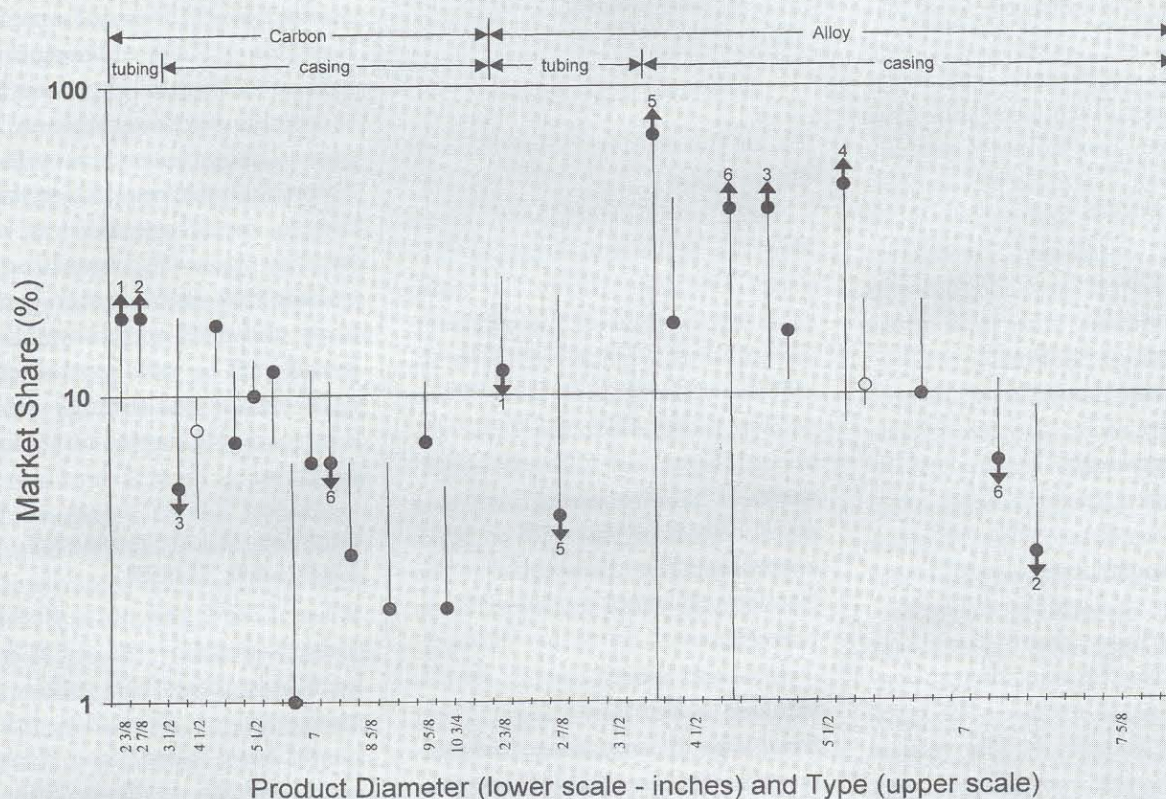
THE OPTIMUM MIX

Combining all this information to determine the most profitable product mix, subject to both operating and marketplace constraints, is no easy matter—particularly with the computational technology that was available 20 years ago. Linear programming techniques were used to calculate the optimum mix, with the reasoning being that a linear program is an efficient mathematical optimization tool.

Once the initial optimum mix was determined, its feasibility was confirmed with all key personnel at the mill, including the division president, vice presidents of operations and finance, IE and QA managers as well as the operations heads and key operators who would need to make the plan work. When necessary, constraints were modified and the optimum mix recalculated. The entire process took about six months to complete.

The linear program, in addition to optimizing the product mix (for maximum profit subject to the specified constraints), identifies the individual production and market bottlenecks as well as the incremental profit increases that would result from their relaxation. Not only did this affect NPT's capital investment strategy (with a major element focused on manufacturing "debottlenecking"), but it also drove the sales and marketing plan and the commission system.

Before this analysis, profit management at NPT favored high-profit-per-ton products in both

EXHIBIT 4
Optimum Product Mix

Product Diameter (lower scale - inches) and Type (upper scale)

manufacturing and sales. On the other hand, corporate management viewed NPT's role as a major buyer of its steel and encouraged the division to maximize tons per year. Both views suboptimized the real goal of maximizing total profit per year. Given the complexity associated with real optimization, it is understandable that simple, but unfortunately incorrect, mental models had emerged.

THE IMPORTANCE OF SYSTEM PROFIT

The use of a linear program permitted the introduction of a new way of thinking about profitability at NPT and its corporate parent.

Termed *system profit,* it was defined as product profit minus opportunity cost. Exhibit 2 demonstrates an example of this distinction (i.e., system versus product profit), using one of NPT's most profitable products (on the basis of price per ton) as an example.

For this particular product, NPT was selling 8,200 tons per year at an apparent profit of $1.4 million. Had the division reduced production to the minimum required by its customers and used the freed-up capacity to produce the three other lower-profit-per-ton products identified by the linear program (bringing two to their sellable maximums), however, it would have made a net addi-

tional $4.9 million in profit. Therefore, rather than making $170 per ton, NPT was losing $598 of potential profit for each ton it produced.

Although not all products showed such a dramatic difference between product profit and system profit, the list of surprises was significant (see Exhibit 3). It is clear from the data presented in Exhibit 3 that system profit is always lower than product profit when production or market constraints are present. In fact, what was thought to be the most profitable of NPT's products, on the basis of its ABC product profitability, was in fact its biggest loser.

By using a linear program, not only were many initially counterintuitive actions for profit maximization discovered, but on the basis of a sensitivity analysis, for example, the robustness of the new plan with respect to market prices was determined. The analysis led to a fundamental shift from NPT's previous business strategy, which even if successfully executed would have left nearly $100 million in unclaimed, yet accessible, profits. And these added profits were obtainable with little or no investment in "debottlenecking" and a feasible market repositioning to a nearby niche. Too often, strategy and capability are analytically disconnected. In this case, capability was used to drive strategy rather than the more common use of strategy to drive capability.

One single graphic visually summarizes the market implications of maximization of total profit (see Exhibit 4). The vertical lines show the constrained range of NPT's market share by product. The dots show the linear program's choice as to whether maximizing (i.e., bold), minimizing (i.e., shaded), or somewhere in between (i.e., open) was the most profitable strategy subject to the manufacturing and marketplace constraints. The numbers show the rank ordering of the top six choices in each category.

This display makes it apparent that NPT's marketing strategy should be refocused on maximizing sales of small-diameter carbon tubing and small-diameter alloy casing for its current manufacturing capability and market environment. This new strategy would actually reduce the use of steel, yet maximize the net cash contribution to the parent company. This was a fundamentally new insight

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for all the managers involved in the analysis.

From a TOC perspective, there were no real manufacturing surprises. The mill already had more than one bottleneck (it had been designed as a balanced factory), and the optimum mix created one or two more. Although TOC advocates frown on multiple bottlenecks, a benchmarking visit to a nearly identical pipe mill in Japan convinced the division that the bottlenecks were manageable in practice.

It is also worth noting that as valuable as the new insights were from a profit maximization perspective, immeasurable organizational benefits resulted as the linear program made functional silos more transparent. For the first time, many key executives had a framework that gave them an opportunity to understand the constraints that existed outside of their own functional world.

Unfortunately, the NPT example does not have a happy ending. The subsequent oil glut soon led to a dramatic reduction in oil prices and, consequently, drilling activity plummeted. Exacerbated by an inventory buildup that had occurred in the pipeline, NPT's business collapsed over a period of a few months. Owing to small market share combined with the inroads made during the period of allocation by Japanese producers whose products were higher in quality and lower in delivered

price, NPT did not survive the resulting shakeout.

This example clearly demonstrates that optimizing the mix on the basis of a rank ordering by product profit does not maximize Equation 3. Rank ordering on the basis of TOC throughput per hour at a single bottleneck would also give a suboptimum answer. In addition, such a maximization would fail to recognize market constraints, including bundling requirements, market size limitations, and long-term competitive dynamics. The only way to get the right answer was through simulation modeling, in this case a linear program.

PROFIT MANAGEMENT AND LAG TIMES

What if NPT had not suffered its sudden demise? Would it have been able to shift its mix in the marketplace? Probably, but it would have taken time, perhaps years. Which leads to another complication in profit management: different lag times for revenue and cost.

In 1988, the half-life method was proposed as an empirical model for setting improvement goals.[1] The rate of improvement of business processes depended on their relative complexity, with greater complexity leading to slower rates of improvement. Externally focused, revenue-driving processes (e.g., sales, marketing, customer satisfaction) are far more complex than their internally focused, cost-reduction counterparts (e.g., yield, quality, and cycle time improvement), and therefore improve at a much slower rate.

As a result, when both legs of profit management are pursued aggressively, costs often go down before revenues go up. In fact, whereas time constants for cost

management efforts are typically measured in months, those on the revenue side are more likely measured in years. As evidence, consider what needs to happen for customer's upside buying patterns to change.

First of all, customers need to become aware that a company's product is a better value to them than their current supplier's. Then, they need some time to establish that a company's competitive advantage is sustainable and that it is likely to continue to be the better value as time goes on. Finally, customers need to make the change, often in the presence of long-term contractual as well as relational commitments to the company's competition. In all but commodity businesses, this can take years rather than months.

If unanticipated, this lag between cost reduction and revenue improvement can lead to poor business decisions. When costs initially go down faster than unit volume increases, labor utilization rates usually fall. Pressure to layoff excess labor is soon followed by the need to rehire. The effects of this whipsawing of the workforce can have a highly negative impact on employee morale as well as incur significant unnecessary costs in unemployment compensation premiums, retraining, and lost sales.

Implementing an optimized product mix is a complex process, and it must be robust to a business environment that is likely to change before its completion. Flexibility and patience are clear prerequisites for effective profit maximization.

PIECES OF THE PUZZLE

The business community's response to the complexity and chaos increasingly present in its environment is striking. Whether it is ABC, TOC, or other soon-to-be passing fads, businesses tend to be irresistibly attracted to over-simplified answers to situations that, by their very nature, require complex analysis.

The sibling rivalry between proponents of ABC and TOC results from failure to recognize that both systems need to be addressed if profits are to be managed effectively. Maximizing throughput and discounting to clear the marketplace of excess inventories is as irrational a long-term strategy as setting product mix solely on the basis of simple product or customer profitability.

The operating, market, and competitive environments form a system in which the total is not simply the sum of its individual parts. Although it is the interaction of those parts that is the source of complexity, it is also the place at which real value is created. Only powerful mathematical tools are able to decipher these real-world, constrained situations.

None of these concepts is new, as the NPT example from 1981 demonstrates. To come up with the best answers requires the marriage of such analytical tools as linear programming or system dynamics modeling with the expert knowledge that resides in isolated pockets scattered within every organization. This needs to be done in a nonbureaucratic manner, however, to maintain the nimbleness needed to change directions in an uncertain, often chaotic world.

As a final note, one of the greatest benefits to organizations results from the process followed, not the specific analytical results obtained. Drawing and using knowledge from throughout an organization is an act of empowerment. Understanding how one piece of the puzzle fits with another is the real destroyer of functional barriers. Doing the math may require the skill of a specialist, but assembling the parts, when done through a high-level team effort, can be a major contributor to organizational learning and improved bottom-line performance. ■

Notes
1. A. Schneiderman, "Setting Quality Goals," *Quality Progress* (April 1988): 51.