Strategic Cost Analysis of Technological Investments

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THE DECISION TO INVEST IN NEW MANUFACTURING TECHNOLOGIES IS OFTEN HAMPERED BY USING CONVENTIONAL METHODS OF CAPITAL INVESTMENT ANALYSIS. The authors discuss the limitations of four current approaches and show how their own framework—Strategic Cost Management—applies to a large forest products company that is making a decision on a major technological innovation.

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A frequent charge in recent years has been that many firms fall behind in global markets because they are too slow in implementing the new manufacturing technologies — CIM (Computer Integrated Manufacturing), FMS (Flexible Manufacturing Systems), AMT (Advanced Manufacturing Technology), or the more familiar CAD, CAE, and CAM.[1] A popular argument is that conventional methods of capital investment analysis do not capture the full impact of the technology change decision. A project-level net present value (NPV) framework, it is argued, places such a premium on short-term financial results, and so little emphasis on difficult-to-quantify issues, such as quality enhancement or manufacturing flexibility, that major manufacturing breakthroughs do not pass the NPV test.[2]

Current literature suggests four approaches to evaluating investments in technological change; each of these approaches has significant shortcomings. One approach suggests that we discard all formal financial analysis (such as NPV analysis) and simply "bet" on new technologies. We believe that we can do better than this. A second approach, proposed by Kaplan, calls for a refined NPV model;[3] a major shortcoming of this framework is that it does not give explicit attention to strategic issues and concerns. Porter's approach links technology decisions to strategic analysis;[4] however, Porter's framework does not give explicit attention to financial analysis. The fourth method, suggested by Bromwich and Bhimani, argues for an integrated "strategic-financial" analysis framework;[5] however, these authors have not pushed their ideas far enough to give meaningful guidance to managers in evaluating technology change investments.

After summarizing these four approaches and indicating their strengths and limitations, we then offer an approach — Strategic Cost Management (SCM) — that addresses those limitations (see the sidebar for a brief description of the SCM methodology). We illustrate the strategic power of our framework and the drawbacks of the previous approaches by presenting an example of a large forest products company that must make a decision on a major technological innovation.

The Minimalist Response

Some argue that we should deemphasize, or even eliminate, formal investment analysis techniques when considering major manufacturing technology issues. Studies have shown that as many as 40 percent of firms used no formal evaluation at all for AMT projects.[6] This approach, however, is conceptually troubling because it reduces some of the most important choices a firm faces to "technology roulette" — place your bet, spin the wheel, and hope! This process is not without its own risks. There have been many well-known failures in recent years from poorly conceived technology experiments:

• General Motors pushed the concept of robotics in its factories very hard in the early 1980s, and Westinghouse made an investment in excess of $1 billion in

A Strategic Cost Management Approach to Technological Investment Analysis

Blending these three themes represents the most powerful way to focus cost analysis for technological change–Strategic Cost Management:

1. Value Chain Analysis. The value chain in any business is the linked set of value-creating activities all the way from basic raw materials through to component suppliers, to the ultimate end-use product delivered into the final consumers' hands. Even though a firm may participate in only a part of the value chain, the firm should analyze its technological investments from the standpoint of their impact throughout the chain – the impact on its suppliers, the impact on the firm itself, and the impact on its customers. "Value chain" analysis can be contrasted with "value-added" analysis, which is typically used in conventional NPV framework. Value-added analysis starts with payments to suppliers (purchases) and stops with charges to customers (sales) while focusing on maximizing the difference, the value added (sales minus purchases) for the firm. Value-added analysis is far too narrow a view because it misses the importance of linkages upstream and downstream in the value chain.

2. Cost Driver Analysis. Value chain analysis alone is not a ***sufficient*** test of the desirability of changing technology. A second necessary component is that technology choice must be an important cost driver. Costs are a function of "structural" drivers (such as scale, product line complexity, scope of operations, experience, and technology) and "executional" drivers (such as Total Quality Management, capacity utilization, and workforce participation). In short, there are multiple drivers of cost. Technology must be an important driver of cost at critical steps in the chain.

3. Competitive Advantage Analysis. Technological choices cannot be justified by just un derstanding the value chain and understanding the key cost drivers. A final component in the analysis involves analyzing whether technological change enhances the way the firm has chosen to compete – either on the basis of cost or on the basis of differentiation.

robotics manufacturing in 1983. Yet the projected improvements proved difficult to achieve. Many of the robots purchased were never used, and Westinghouse closed down its robotics subsidiary in 1989.

- General Electric's spectacularly abortive venture in new condenser technology for refrigerators cost the firm hundreds of millions of dollars and irreplaceable momentum in product leadership.
- Sky Channel, the widely heralded $2 billion experiment in satellite distribution of TV signals ("wireless cable") by RCA, News Corp., and CableVision, was quietly disbanded in the late 1980s in the face of mounting costs and implementation problems.

The point of these examples is certainly not that technological experimentation is always a mistake, nor that conventional NPV analysis techniques must be used despite their limitations. We also do not mean to imply that these firms made some simplistic mistake that they could have readily avoided. Deciding when and how to implement change in product or process technologies is a very difficult and, at the same time, critically important task that demands the best thinking senior managers can muster. But to argue that no formal analysis is a plausible alternative to overly restrictive financial analysis seems to us to be just as misguided. The idea is to find an appropriate analytic framework.

Expanded Financial Analysis Framework

Kaplan's attempt at an appropriate framework has been widely hailed for its insight in getting beyond the narrow perspective often imposed in NPV analysis.[7] In summary, Kaplan argues that conventional financial analysis has four major weaknesses when applied to major investments in technological change. The first is misassessment of the appropriate discount rate. It has been fairly common to see companies use *real* hurdle rates in the range of 15 percent to 20 percent. Kaplan presents persuasive arguments based on the weighted average cost of capital concept, actual returns over the past sixty years, and comparative risk assessments to show that *real* hurdle rates closer to 8 percent to 10 percent are more appropriate. Using significantly lower hurdle rates can dramatically improve the attractiveness of new investments.

A second major factor he cites is undue optimism in projecting continuing stable returns under the "no investment" alternative. If one recognizes that failure to adopt technological advances can often lead to rapid deterioration of the "base case," then the attractiveness of projected modest growth or even stable profits from new investments is cast in a much different light. Combining these first two points may suggest that rejecting new technological advances is often more risky than adopting them.

A third area Kaplan highlights is concern about "intangible" versus "tangible" benefits. He challenges the belief that it is not practical to quantify the benefits from better product quality, enhanced manufacturing flexibility, or shorter factory cycle times. Quantifying such benefits is often possible, he argues. This can dramatically improve projected returns from so-called "soft benefit" investments. Reductions in work-in-process inventory from FMS conversions, for example, can often offset the cost of much of the equipment required by the new system. Finally, he notes the importance of giving explicit attention to often overlooked spin-off benefits of technology investments. Early investment, for example, in computer-aided manufacturing in one area of a factory can yield dramatic improvements later when the new technology is extended to other areas of the factory.

Kaplan illustrates his thesis very effectively in his study of a tap and die manufacturing subsidiary of TRW.[8] The company had an excellent history of market leadership and strong financial returns throughout the 1950s, 1960s, and early 1970s. By the late 1970s, numerically controlled technology was beginning to alter competitive relationships in the industry. The subsidiary's management was exploring options to convert significant manufacturing operations from electromechanical to electronic technologies. Since corporate management emphasized financial control systems very heavily, the subsidiary submitted a conventional capital expenditure proposal for new machines that was fraught with the problems Kaplan has identified. The conventional financial justification for the project did not even come close to meeting corporate financial targets.

From a conventional financial perspective, the proposal was marginal at best. However, because of line management's strong belief in the new technology, the subsidiary went ahead with the investment in spite of the inability to present a compelling financial rationale. Its decision resulted in dramatic success for the firm, but the opportunity might well have been missed. Several of TRW's competitors in this market did not change quickly enough and did not survive the next ten years. For example, one major consumer of taps and dies, Caterpillar, cut its list of drill bit suppliers from twenty-four to three between 1981 and 1986. The TRW subsidiary was one of the three to survive.

Using Kaplan's *extended* financial analysis framework shows much more clearly the justification for the new manufacturing technology in this industry segment. There is no question in our minds that Kaplan is right.

> The lack of formal evaluation for AMT projects reduces the choices to "technology roulette"— place your bet, spin the wheel, and hope!

The limitations he cites are very real impediments to effective use of the NPV framework. There is also no question that expanding the model in the ways he recommends will significantly enhance its usefulness in the CIM context.

While we appreciate Kaplan's pioneering effort, we believe we can go beyond just expanding the NPV model. In our view, strategic issues need to be given much more explicit attention than a project evaluation model permits, no matter how carefully the project model is carried through.

Competitive Advantage Framework

Another approach, proposed originally by Porter, explicitly addresses the strategic dimensions of the problem using the competitive advantage perspective on strategic management.[9] This approach sees the relationship between technological change and competition as more complex than it first appears. Technological change is often viewed as valuable for its own sake. Any technological modification a firm can pioneer is believed to be good because it represents progress. But, from a business perspective, technological progress is not always a good thing. For example, the sailboard and snow ski industries today are suffering from continuing technological evolution that just does not translate into profits. The products are overengineered for the average customer. From a business perspective, technological change is important only to the extent that it affects competitive advantage or industry structure.

Technology, however, does pervade a firm's value chain. It extends far beyond those technologies associated directly with the product. There is no such thing as a low-technology industry if one takes a broader view. Viewing any industry as technologically mature can well lead to strategic disaster. For example, magazine publishing is in turmoil today because of the emergence of desktop publishing in an industry deemed technologically mature just ten years ago. The belief in the old technology for page layout, color separations, or typesetting is preventing many large firms from competing effectively. Moreover, many important innovations for competitive advantage are mundane and involve no scientific breakthroughs, such as Federal Express's overnight delivery. Of course, the erosion of overnight delivery market share by fax technology is a counterexample. But innovation can have important implications for low-tech as well as high-tech companies.

> Technological change can affect competition through its impact on virtually any value activity.

Technology and Competition

Everything a firm does involves technology of some sort, even though one or more technologies may appear to dominate the product or production process. For example, imaging technology may dominate the copier business, but paper feed technology is also an issue. Any particular technology is important for competition if it significantly affects a firm's competitive advantage or industry structure.

Technology and the Value Chain. The basic tool for understanding the role of technology in competitive advantage is the value chain. A firm, as a collection of activities, is a collection of technologies. Technology is embodied in every value activity of the firm, and technological change can affect competition through its impact on virtually any activity. Every value activity uses some technology to combine materials and machinery with human resources to produce some output. This technology may involve several scientific disciplines or subtechnologies. The existing technology of a value activity represents one combination of these subtechnologies.

The technologies in different value activities can be related. This linkage is a major source of competitive advantage within the value chain. For example, product technology can be linked to the technology for servicing a product (such as self-diagnosing computer systems that relay maintenance information directly to the manufacturer). Or component technologies can be linked to end-product technology. Desktop layout of advertising pages, for example, makes possible a lower-cost magazine. Thus a technology choice in one part of the value chain can have implications for other parts of the chain. In extreme cases, changing technology in one activity can require a major reconfiguration of the value chain. When the basic oxygen furnace replaced the open hearth furnace in steel making, scale became much less important. This resulted in the emergence of the minimill, which has fundamentally changed the structure of the steel industry.

A firm's technologies are also clearly interdependent with its buyer's technologies. The points of contact between a firm's value chain and its customers' or suppliers' chains define another area of potential interdependence of technologies. For example, Union Camp put PCs linked to its warehouses into paper distributors' offices and increased sales by offering immediate product availability and order status information. A firm's product technology influences the product and process technology of the customer and vice versa.

Technology and Competitive Advantage. Technology affects competitive advantage if it has a significant role in determining relative cost or differentiation. Since technology is embodied in every value activity and is involved in achieving linkages among activities, it can have a powerful effect on both cost and differentiation. Computer airline reservations systems represent an excellent example of technology impacting differentiation (such as American Airlines and the Saber system). Technology affecting relative cost is illustrated by the rise of continuous casting in steel making; continuous casters significantly reduce manufacturing cost.

In addition to affecting cost or differentiation in its own right, technology affects competitive advantage through changing or influencing the other drivers of cost or uniqueness. For example, the development of the interstate highway system dramatically changed the basis of competition between trucking and railroads in many basic ways. The successful railroads today (Burlington Northern, for example) are the ones that have adapted to those changes.

Tests of a Desirable Technological Change. The link between technological change and competitive advantage suggests a number of tests for a desirable direction of technological change. According to Porter, a firm's technological change will lead to sustainable competitive advantage under any of the four following circumstances:[10]

1. The technological change itself lowers cost or enhances differentiation and the firm's technological lead is sustainable. Procter & Gamble's patented dry fluffing technology for tissue papers provides softer paper at no increase in drying cost.

2. The technological change shifts cost or uniqueness drivers in favor of a firm. A new assembly process that is more scale sensitive than the previous will benefit a large-share firm that pioneers it even if competitors eventually adopt the process.

3. Pioneering the technological change translates into first-mover advantages besides those inherent in the technology itself. A firm that moves first may establish a reputation as the pioneer or leader, a reputation that emulators will have difficulty overcoming (e.g., Kodak in film or Coca-Cola in beverages). A first mover also may be first to serve buyers and thus to establish loyal relationships.

It is interesting how many firms that were first movers have remained leaders for decades. In consumer goods, for example, such current leading brands as Crisco, Ivory soap, Life Savers, Coca-Cola, Campbell Soup, Wrigley gum, Kodak film, Lipton tea, and Goodyear tires were already leaders by the 1920s. Of course, early leaders do not always persist, evidenced by Singer sewing machines, Bowmar calculators, Bulova watches, and RCA television sets.

A first mover may be at a disadvantage if early investments are specific to the current technology and cannot be easily modified for later generations. In semiconductors, for example, Philco moved early for leadership with a large automated plant. It enjoyed a period of success, but the later development of a different manufacturing process for semiconductor chips made its earlier investment obsolete. Similarly, the early mover will be disadvantaged if its product or process reflects factor costs or factor quality levels that have changed.

Technological discontinuities can also work against the first mover by making its investments in the established technology obsolete. Technological discontinuities are major shifts in technology to which a first mover may be ill prepared to respond, given its investment in the old technology. Weyerhaeuser, for example, pioneered the introduction of the technology for "oriented strand board" (a plywood substitute). But later innovations cut the cost of a new plant in half, leaving Weyco at a competitive disadvantage in its early plants. Discontinuity favors the fast follower who does not bear the high cost of pioneering.

4. The technological change improves overall industry structure. For example, the jet engine improved the competitive position of all airlines versus substitute forms of transportation.

Although Porter's approach to understanding technological change investments is clearly very insightful at a conceptual level, it suffers from a significant drawback: Porter does not explicitly link his strategic framework to financial analysis. Without such a linkage, it is difficult to decide on specific technological investments. It is not surprising that we find no examples in the literature using Porter's framework to resolve technological choices in the seven years since it was introduced. This is in strong contrast to the extensive literature applying and testing other aspects of Porter's model.

Strategically Augmented Financial Analysis Framework

A fourth approach, proposed by Bromwich and Bhimani, addresses the lack of explicit attention to strategic issues in conjunction with project evaluation models.[11] They envision a formal financial analysis, broadly based and carefully executed, but augmented by explicit consideration of strategic issues that do not lend themselves to quantification in project terms. As Bromwich and Bhimani note, "Many of the effects of AMT may be plant or division or even corporatewide, . . . while also frequently flowing from the interaction with other systems. . . .The full benefits of AMT investments are unlikely to be captured by investment appraisal techniques which rely solely on financial data input. The long and wide-ranging discussions which are used in Japanese decision making allow these benefits to be considered without precise quantification and to be tested against a wide range of managerial experiences."

Bromwich and Bhimani propose a framework that explicitly considers strategic benefits which can be derived from AMT investments, both within the firm and externally in its market positioning:

- Internal Strategies
  - Cost advantages
  - More control of production systems
  - Improved organization
  - Beneficial interactions

- Market Strategies
  - Diversification
    - Expanded product portfolio
    - New products with new skills
    - New skills in new areas
  - Enhancement of existing products
    - Enhanced corporate image

Response to fluctuating demand
Lower cost of meeting demand
Improved quality
Risk reduction
Stronger skill base
Better control
Better planning
Reduced working capital
More flexible responses

Figure 1 is an example of a strategic investment appraisal matrix designed to reflect the blending of financial quantification and qualitative strategic analysis that Bromwich and Bhimani recommend.

Bromwich and Bhimani are correct in their assessment that an explicit blending of financial analysis and nonfinancial strategic considerations deserves careful consideration. Neither approach alone is as strong as a blending of the two. However, they have not pushed these ideas far enough to explain *how* to structure the strategic assessment phase. More can be applied across all firms to focus the strategic evaluation of technology change investments. Since the previously described approaches for evaluating investments in technological change are inadequate in important ways, we suggest here a different method that addresses those limitations.

The Strategic Cost Management Framework

The SCM perspective, suggested by Shank, involves three key themes that are taken from the strategic management literature:[12]

1. Value Chain Analysis
2. Cost Driver Analysis
3. Competitive Advantage Analysis

Each of the three represents a stream of research and analysis about strategy in which cost information is viewed differently from the way it is viewed in conventional management accounting. Blending the three themes represents the most powerful way to focus cost analysis for strategic choices — Strategic Cost Manage-ment. Each is a *necessary* component of the SCM analysis, but a *sufficient* analysis must involve all three.

We illustrate the application of the SCM framework in analyzing technology investments by using a disguised example of a large forest products company that is evaluating a proposal for a major technological innovation.

The SCM Perspective on Technology Costing

Yakima-Olympia Corporation, a multibillion-dollar, highly vertically integrated forest products company, must choose equipment for logging operations in its Virginia timberlands. The prevailing technology for logging is clear cutting by using "feller-bunchers," which are similar to large farm tractors and have heavy-duty scissors attached at the front to shear off standing trees at ground level. These tractors also have large clamps that can hold several tree trunks upright at one time so that the tractor can shear them off before stopping to dump the load on the ground. The machine literally fells trees in bunches. After felling, the bunches of trees are dragged (skidded) to a roadside staging area (the deck) by another variety of tractor called a skidder. The feller-bunchers and skidders leave no trees standing as they move through a wood lot. At the deck, workers use hand-held chain saws to delimb the trees as best they can, usually leaving many short limbs on the log. Cranes then load the logs onto flatbed trucks for transport to wood yards, where the logs are sorted and cut into segments for sawmills, plywood mills, or pulp mills, depending on the quality and species of the trees.

The tempo and pace of this process can best be described as pandemonium. There is no sophistication involved, only brute force applied in an environment that is hot, insect-ridden, snake-infested, and alternately thick with dust or deep in mud. This process represents the latest technological stage in the evolution of a process geared to cut down and move as many trees as possible in as short a time as possible. The methods achieve high-volume throughput but also seriously damage the trees and the land and cause great discomfort and danger for the workers.

The alternative technology, widely used in northern Europe but, in 1990, virtually unknown in the United States, involves sophisticated computerized machines that resemble *Star Wars* robots. A worker in a harvester, a closed-cab tractor that uses computer programs, moves carefully through the woods, selecting individual trees for cutting based on current needs in the processing mills. The machine fells each tree with a smooth saw cut (as opposed to scissors cut), precisely delimbs each log flush to the stem, cuts the stem into sections of predetermined lengths, and gently drops the sections in neat piles. A forwarder then picks up the logs according to computer-programmed sequences and carries them gently to the roadside. Later the forwarder will load the cut logs onto trucks destined directly for specific processing mills, bypassing the wood yard step altogether. In this system, the wood lot is not clear-cut. Only the fully mature trees whose size and species meet current processing mills' needs are harvested.

Figure 1 Strategic Planning Matrix

Strategies/ Benefits	Improved Revenues	Lower costs	Higher reliability	Better supply response	Meeting customer requirements	Fit with other products	Enhanced image	New skills	Better information	Risks of not investing	Costs of investment	Costs of operation	Organizational plans	Totals
Product enhancement	X*						X**							
New products	X*			X*			X**	X**						
Risk reduction				X**										
Cost advantages		X*		X										
Improved organization structure														
Companywide impact														
Monetary items														
Items which can be expressed in monetary terms*														
Scored items**														
TOTALS														

* Items which can be converted into monetary terms.

** Items which can be expressed in monetary terms scored on a single 'points' scale (1 to 10).

Source: M. Bromwich and A. Bhimani, "Strategic Investment Appraisal," *Management Accounting*, March 1991, p. 48.
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In terms of tempo and pace, the harvester-forwarder system resembles ballet dancers performing an elegant pas de deux in the woods. It represents the latest technological stage in the evolution of a process in which the logger sees each individual tree as a precious object and takes full responsibility to deliver clean, undamaged, sorted, and cut logs to specific processing mills, based on their current needs, while doing minimal damage to the land. The work is performed safely and cleanly from air-conditioned cabs.

How these two approaches to logging developed in such dramatically different ways in Northern Europe and the United States is beyond the scope of this paper. In 1990, the issue for Virginia loggers was whether to stay with feller-buncher/skidder technology or switch to harvester/forwarder (H/F) technology for Yakima-

Olympia's 450,000 acres of timberland in the Tidewater region.

Yakima-Olympia (Y-O), like many major forest products companies, was vertically integrated from research-intensive farms that developed and planted genetically improved seedlings to wholesale and retail distribution of paper and solid wood products. The only step in this chain in which Y-O did not participate was logging. Primarily for cost reasons (nonunion wages and work practices), most of the forest products firms had long ago exited the business of cutting their own trees. Y-O hired private logging contractors to cut the mature trees from its lands and transport them to Y-O's processing mills. How Y-O should evaluate a proposal to switch logging technologies is the subject of our field study.

Three Components of the SCM Perspective

We will consider in turn each of the three components of the SCM perspective as it applies to the choice of logging technology, starting with the value chain component.

Value Chain Analysis. In the SCM framework, managing costs effectively requires a broad focus, external to the firm. Porter has termed this perspective the value chain.[13] The value chain for any firm in any business is the linked set of value-creating activities from basic raw materials (starting ultimately with the periodic table of the elements) through to component suppliers, to the ultimate end-use product delivered to the consumers, and perhaps through recycling to the beginning of a new value chain cycle. The external focus sees each firm in the context of the overall chain of value-creating activities of which it is only a part. We are aware of no firms that span the entire value chain in which they participate. Value chain analysis is contrasted with value-added analysis, which starts with payments to suppliers (purchases) and stops with charges to customers (sales), while focusing on maximizing the difference, the value added (sales minus purchases) for the firm.

Value-added analysis is far too narrow a view because it misses the importance of linkages upstream and downstream in the value chain.[14] In the CIM context, the principal benefits of new investment may well fall elsewhere in the value chain than where the investment itself takes place, as the logging example illustrates.

The power of the value chain perspective for this situation is highlighted by its contrast with a conventional, project level, value-added analysis. Table 1 shows the conventional analysis for a logging contractor comparing the two alternative logging systems. From the logger's perspective, the return is virtually identical for the two options. Given the comparable economic returns, the logger currently using feller-buncher technology is not inclined to switch. The new technology involves a significantly larger investment for a small business, a much heavier reliance on highly skilled labor (versus low-wage, day-rate laborers for conventional logging), much more complex maintenance issues, and a much more complex job task than the old technology.

Y-O experimented with the new technology at test

Table 1 NPV Comparison of Feller-Buncher/Skidder Technology versus Harvester/Forwarder Technology for Virginia Logging*

Capital Cost

A One harvester/forwarder pair = $608,000.
Can work two shifts with lights on the equipment.

B One feller-buncher with two skidders and one crane = $370,000.
Can work only one shift.

Running two shifts, A processes 17,600 cunits of wood in one year, which is equal to what B can process working one shift.

Financial summary

	A	B
Capital cost	$608,000	$370,000
Cash operating costs		
Labor	94,000	105,000
Fuel	15,000	75,000
Supplies, repair, and maintenance	91,000	91,000
Insurance and taxes	3,000	3,000
Supervision	50,000	35,000
Total	253,000	309,000
Depreciation (five years)	122,000	74,000
Salvage value (after year five)	60,000	18,000
Assume 36% combined tax rate		
Processing revenue (for 17,600 cunits)	407,000	407,000
Five-year NPV (at 12%)	(70,000)	(42,000)
Five-year internal rate of return	7.4%	7.3%

* For purposes of this example, the comparison is framed in internal rate of return (IRR) terms rather than net present value (NPV) to avoid the issue of risk-class comparability between two options. The well-known caveats about ranking projects in IRR terms are acknowledged, but are not a concern in this context.

sites. Senior management at Y-O knows that the logger does not really stand to gain directly from any of the potential benefits. From this perspective, there is really no way to encourage the logger's technological innovation. Table 2 summarizes the anticipated financial returns from the new technology, broken down by where in the value chain they are realized. As shown, although the switch to harvester/forwarder logging technology could save Y-O an estimated $33.6 million per year in just one of its several timberland regions, none of the gains are realized at the stage of the value chain where the investment must be made. Applying a value-added perspective in a project evaluation mode at the logging stage will never lead to the change. Applying a value chain perspective in a business unit evaluation mode reveals the tremendous potential benefits from the change.

Cost Driver Analysis. In conventional management accounting, cost behavior is seen largely as a function of volume. Examples of management accounting concepts that hinge on volume as the cost driver include fixed versus variable cost, average versus marginal cost, cost-volume-profit analysis, break-even analysis, flexible budgets, and contribution margin, to name a few. In SCM, output volume per se is seen to capture very little of the richness of cost "behavior." In this regard, SCM draws much less on the simple models of basic microeconomics and much more on the richer models of industrial organization economics.

There are structural cost drivers that relate to the firm's explicit strategic choices regarding economic structure such as scale, product-line complexity, scope of operations (vertical integration), or experience.[15] Technology investments also represent structural choices about how to compete.

There are also executional cost drivers that are major determinants of a firm's cost position and hinge on its ability to execute successfully within the economic structure it chooses.[16] Whereas structural cost drivers are not monotonically scaled with performance, executional cost drivers typically are. That is, for each of the structural drivers, more is not always better. There are potential diseconomies of scale and vertical scope, as well as potential economies. A more complex product line is not necessarily better or worse than a less complex line. Too much experience can be as bad as too little in a dynamic environment. For example, Texas Instruments emphasized the learning curve and became the world's lowest-cost producer of obsolete 8K microchips! Technological leadership versus followership is a legitimate choice for most firms.

Table 2 A Value Chain Perspective

Annual returns from switching to harvester/forwarders from feller-buncher/skidders for Y-O's 450,000 acres (about 15,000 acres harvested each year).

Returns to the landowner	
Improved product mix selection	$ 2.6 million
Saved stem damage waste (saw cut is better than shear cut)	.3 million
Saved cost for site repair (H/F does much less damage to the residual land)	.2 million
	$ 3.1 million
Returns to the logger	
Virtually none!	$ 0.0
Returns to the processing mills	
For pulp mill wood supply:	
Saved processing cost from precise sorting classification	$26.0 million
For solid wood supply (sawmills and plywood mills):	
At the wood yard:	
Saved cost of sawing trees to logs in the wood yard	$ .5 million
Saved trim loss in the wood yards	1.6 million
Saved cost from logs misapplied by the saw operators in the wood yard	.5 million
Saved wood loss from wood yard saw spacing	.3 million
	$ 2.9 million
At the processing mills:	
Kiln drying savings from more precise sorting	.2 million
Savings by using lighter duty debarkers	.1 million
Savings from double handling of off-grade logs in the plywood mills and sawmills	1.3 million
	$ 1.6 million

In contrast, for each of the executional drivers, more is almost always better. The list of potentially important executional drivers includes at least these:

- Workforce involvement (participative management).
- Workforce commitment to continuous improvement (*kaizen*).
- Adherence to Total Quality Management concepts.
- Utilization of effective capacity (given the scale choices on plant construction).
- Efficiency of production flow layout.
- Effectiveness of product design or formulation.
- Exploiting linkages with suppliers and customers all along the value chain.

While it may not always be true that a higher level for these executional factors improves cost position, the examples of diseconomies are much less frequent.

The value chain perspective can reveal the critical importance of the logging step in the chain, but value chain importance alone is not a sufficient test of the desirability of changing the logging technology. A second necessary component is that technology choice is an important cost driver at the logging stage. That is, what factors are driving success or failure at the logging stage, and how important is the technology factor compared to other cost drivers? Of the structural drivers, scale does not prove to be very important in this context. Minimum efficient scale for logging is quite small. One or two sets of equipment are adequate to spread the supervision cost element, which is the only cost element with any scale effects. Vertical scope also yields no economies in this context. In fact, because the private logger avoids the union wage rates and work practices in the large forest products firm, there are actually diseconomies of vertical scope. Learning is also not a major cost driver with conventional equipment. Workers learn the job quickly and high labor turnover does not generate a significant cost disadvantage. Learning is a more important issue with H/F equipment because high labor turnover can destroy many of the benefits. However, learning is still not, in itself, a dramatic cost driver — workers with only average intelligence and diligence can learn the job in about twelve months.

Product line complexity is also not an important cost driver since the mix of tree species and sizes is very narrow in the Tidewater region. The area was logged once near the turn of the century and again in the 1950s. Since all the land has already been harvested once or twice in the past seventy-five years, the homogeneity of the forest is enhanced.

As summarized in Table 2, technology choice *is* a critical cost driver in this situation. In fact, our brief overview indicates that of all the structural cost drivers, technology choice is the single most important factor. The next step is to consider the executional drivers to see if they offset or reinforce the structural impact of the technology factor.

Layout of the production process is a neutral factor in this study. It is important because the proximity of the mills to the trees is critical, but it is not a variable in the current context. Similarly, product formulation is also neutral. Developing genetically improved seedlings is an important issue, but it is not a variable in the current context. Capacity utilization is also not a factor since the small scale of operations for any one logger means they are always busy. Chronic oversupply is not nearly as big an issue here as it is for the pulp and paper operations of Y-O.

Participative management, continuous improvement philosophy (*kaizen*), and Total Quality Management are important here, as they almost always are, and they all reinforce the technology factor. The H/F technology is much more amenable to a high-quality/high-commitment workforce management program than is the clear-cutting technology that seems to almost assume and guarantee an alienated workforce.

This leaves the linkages issue, which is of equal importance to the technology issue itself. Unless the contract logger can be induced to see and value the overall benefits across the value chain from the high-tech logging option, there is little hope of achieving the benefits. The linkages between the logger and the landowner and between the logger and the processing mill are dramatically underexploited. Unless Y-O decides to do the logging itself, thus eliminating the need to deal with loggers as independent businesses, some form of gain sharing to induce a tighter linkage along the value chain must be developed. The diseconomies of vertical integration here make Y-O very reluctant to participate in the logging business. In order to make the technology change investment attractive to loggers, it must address the linkage problem by sharing the potential benefits that are likely to accrue ahead of and behind the logger.

An interesting dilemma is how much sharing of potential gains will be necessary to get loggers to switch. Risk avoidance attitudes and overcoming inertia may require more profit sharing than might seem rational in purely financial terms. If Y-O cannot induce the technology change without giving away what it sees as a disproportionate share of the benefits, it may see the diseconomies of vertical scope as less significant after all and reenter the logging business. How overall returns are shared along a value chain is a very complex issue. How enhancements to the overall value created by one player reach an equilibrium distribution across all the players is an equally complex issue.

We will turn now to a consideration of the third component from the SCM framework for technology costing — competitive positioning analysis. Even if technology choice is an important cost driver for logging and logging is potentially an important step in the value chain, a sufficient test for investing in the new logging technology requires that the benefits achievable are consistent with the competitive positioning strategy adopted by the firm. That is, in more general logical terms, each of the three components is necessary in the analysis, but all three are required for sufficiency.

Competitive Advantage Analysis. In the SCM perspective, understanding the implications of how the firm chooses to compete is fully as important for cost analysis as understanding the value chain and understanding the key strategic cost drivers at critical steps in the chain. As discussed by Porter, the basic choice on how to compete is between cost leadership and differentiation.[17]

1. Low Cost. The primary focus of this strategy is to achieve low cost relative to competitors. Cost leadership can be achieved through approaches such as economies of scale in production, learning curve effects, tight cost control, and cost minimization in areas such as R&D, service, sales force, or advertising. Examples of firms following this strategy include: Texas Instruments in consumer electronics, Emerson Electric in electric motors, Hyundai in automobiles, Briggs & Stratton in gasoline engines, Black & Decker in machine tools, and Commodore in business machines.

2. Differentiation. The primary focus of this strategy is to differentiate the product offering of the business unit, creating something that is perceived by customers as being unique. Approaches to product differentiation include: brand loyalty (Coca-Cola in soft drinks), superior customer service (IBM in computers), dealer network (Caterpillar in construction equipment), product design and product features (Hewlett-Packard in electronics), and product technology (Coleman in camping equipment).

How this choice affects cost management for a firm is discussed by Shank.[18] The relevance for technology costing is illustrated by the logging industry field study.

Y-O has embarked on a differentiation strategy in its solid wood operations for more than twenty years. Its strategy is built around plantation forestry to plant and grow genetically improved trees that will yield a wood mix with a much higher than average value at maturity. With an approximate thirty-five-year growing cycle in the Virginia Tidewater region, the strategy still has about fifteen years to go before it can be fully implemented.

By the year 2000, if conventional logging is used, each year Y-O timberlands will be yielding about 80 percent of the high-grade logs that its expanded set of sawmills and plywood mills will require, up from the 67 percent supplied internally in 1985, but still well below total requirements. The remaining 20 percent will have to be met by outside purchases, as shown here:

Estimated Wood Supply and Demand

Year	Pulp Mills	Sawmills/ Plywood Mills
1985		
Demand	1,500,000 units	300,000 units
Supply from Y-O timberlands	600,000 (40%)	200,000 (67%)
2000		
Demand	1,500,000 units	500,000 units
Supply from Y-O timberlands:		
Using conventional technology	500,000 (33%)	400,000 (80%)
Using H/F technology	500,000 (33%)	450,000 (90%)

If the H/F technology were to be used, the net supply of high-grade logs from the same acreage would increase by 50,000 units each year. This would save the sawmills and plywood mills more than $5 million each year in purchased logs. Thus, adopting the new logging technology moves Y-O substantially closer to self-sufficiency in supplying the high-grade log needs of the expanded set of sawmills and plywood mills it has built as part of its high-value extraction strategy. These savings are in addition to the quality savings shown in Table 2 from stem damage, sorting losses, kiln drying losses, and double handling.

The situation for one of Y-O's major competitors, Marathon Paper Company (disguised), which also owns substantial timberlands in the coastal Southeast, highlights the relevance of the competitive positioning choice to the technology choice. Whereas Y-O's strategy emphasizes "grade extraction" (logs for sawmills and plywood mills) and distribution in global markets, Marathon's strategy emphasizes "fiber extraction" (pulp mill logs) and concentrates primarily on domestic markets. Because Marathon sees its timberlands primarily as a source of low-value pulp logs to supply its pulp mills, it has a much smaller commitment in sawmills and plywood mills and is not nearly as concerned about the problems of conventional logging. Marathon uses a much shorter growing cycle (twenty-two years) and does not spend money each year in its forests (fertilizing, burning, pruning, and thinning) to achieve a high-value wood mix.

It is not necessarily obvious, but growing better trees is only justifiable if there is a strategy for subsequently extracting that extra value in end-product markets.

Furthermore, whether a high-value timber strategy is superior to a low-value strategy depends on a complex set of assumptions that play out over a twenty-five- to thirty-five-year growth cycle. Various forest products firms have made different choices on this issue.

Conventional logging technology with its emphasis on high-volume (but lower-value) throughput is fully consistent with Marathon's strategy of lower value/low cost. At the same time, Y-O is moving ahead aggressively to find gain-sharing mechanisms to induce its logging contractors to switch to the H/F technology, which represents a much better fit with its strategy of a longer growth cycle with higher cost, but higher value.

To summarize, Yakima-Olympia faced a significant problem in the logging operation stage of the value chain. The prevailing technology for logging was cost effective for firms pursuing a strategy of high-volume/low-value-added wood products. But it was not cost effective for firms pursuing a strategy of differentiation/high-value-added wood products. But, since independent contractors did the logging, there was no direct way for Y-O to control the loggers' choice of technology.

Conventional project-level financial analysis does not suggest to the logger that a change of technology is a good business decision. An expanded financial analysis framework, as recommended by Kaplan, also does not catch the significance of the change. Even from the expanded viewpoint, the benefits from the new technology fall ahead of and behind the logger in the value chain, but the logger must incur the cost and assume the risks. A competitive strategy perspective is required, but the conceptual framework proposed by Porter is not explicit enough on financial analysis to be very helpful. An augmented cost analysis framework, as recommended by Bromwich and Bhimani, also does not capture the significance of the change because they have not pushed strategy and financial analysis ideas far enough. Explicitly considering the strategic issues involved in the technology change from the loggers' perspective does enrich the decision metric. But, again, one will never see the power of the change by focusing solely on the logger, even when using an expanded and augmented cost analysis framework.

Y-O tried to convince the contract loggers it hired to move from feller-buncher technology to harvester/forwarder technology using conventional project-level financial analysis. Its efforts failed to persuade any loggers to change. Even careful attention to intangible factors, coupled with hurdle rate subsidies (investment guarantees) and appeal to long-run declines under current logging methods did not induce contractors to switch. Subsequent attempts to couch the decision in strategic terms, for the loggers, gained somewhat more receptivity to change, but still nowhere near the groundswell Y-O felt it needed.

No real progress was made until Y-O adopted an SCM framework. First, viewing the problem from a value chain perspective clearly reveals the paradox that, although the change involves major financial benefits, the stage in the chain where the investment must be made earns none of the resulting benefits under current pricing regimes. Second, the cost driver perspective shows that technology choice in this situation is indeed a key structural cost factor that is further reinforced by executional cost factors. Third, the competitive positioning perspective reveals that, although this technology change is not compelling under all conceivable strategic postures, it is compelling under the positioning strategy to which Y-O has committed, virtually irrevocably, over the next ten to fifteen years. Each of these three components of the SCM analysis is necessary to establish the rationale for the new investment.

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Whether Y-O can effect a voluntary changeover to H/F logging among its contractors is still not clear. It will certainly be necessary to explicitly consider gain-sharing mechanisms across the supplier-customer linkages to encourage a change in the logging system Y-O believes to be optimal. If the loggers decide that Y-O's incentives are still inadequate, Y-O may be forced to reconsider its decision to exclude the logging step from its vertical integration chain. In SCM terms, Y-O might realize that, given its strategic position, the potential economies from technological change are large enough to offset the diseconomies from vertically integrating at this value chain step if gain-sharing inducements for more explicit customer-supplier linkages are not successful.

Conclusion

The Y-O study represents the limitations of all four of the current approaches for evaluating technology investment opportunities–conventional financial analysis, expanded financial analysis,[19] competitive advantage analysis,[20] and strategically augmented financial analysis.[21] The study is also an excellent example of how the Strategic Cost Management framework provides a more useful way to apply the power of cost analysis concepts to technology investment opportunities within a fully articulated strategic analysis context.

Clearly, one essential step in the effective management of technology change is effective analysis of the investment opportunities. We believe that Strategic Cost Management is a useful way to structure the analysis of such opportunities and thus represents an important component of technology management. ◆

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