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Capital Budgeting with Technology Choice and Demand Fluctuations in a Simple Manufacturing Model: Sample Calculations and Observations on Output Flexibility

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In capital budgeting with technology choice and demand fluctuations errors can arise if managers unitize fixed costs and do not make proper allowance for expected idle capacity. In a standard-cost system, managers and accountants should use as the standard cost E(AC), the expected average cost, employing a procedure shown in the paper. Managers should compare E(AC) and the short-run-average-cost minimum, an output-flexibility indicator proposed by the author. The more output flexible is the equipment, the less of an increase in costs to a firm if there are wider fluctuations in output rates than planned.

INTRODUCTION

Technology choice arises in many plant and equipment investment decisions and refers to alternative ways to manufacture the same product. In technology choice, managers need to be especially careful with a product facing wide fluctuations in demand, and will likely make better technology choice decisions if they use capital budgeting techniques as outlined in cost accounting, finance, and economics textbooks. The basic advice of this paper is a reaffirmation of the principle that managers should try to maximize net present values by looking at after-tax cash flows for each of the different possible sizes of investment for each technology. Errors can arise if managers unitize fixed costs and do not make a proper allowance for expected idle capacity.

Different technologies have different degrees of output flexibility in the sense of ease of handling changes in the rate of output. Economists define output flexibility as the relative flatness of the short-run average cost (SRAC) curve. An output-flexible technology has a flat SRAC curve, while on output-rigid technology has a steeply U-shaped one.

Figure 1 is taken from a classic article by George J. Stigler showing SRAC curves of two types of plant producing the same product. The dashed SRAC curve represents output-flexible technology and the solid SRAC curve output-rigid technology (Stigler, 1939, p. 317). In Stigler's illustration, if output rates were to fluctuate between points W and Z, then the output-rigid technology would produce at lower costs, while if they were to fluctuate between points A and K, then the output-flexible technology would produce at lower costs.

Figures 2 and 3 are taken from Aranoff (1989, p. 147). These show the SRTC (short-run total cost), SRAC, and SRMC (short-run marginal cost) curves of two plants, each of a different technology, technology$_K$ (output rigid) and technology$_L$ (output flexible), that can produce the same product in accordance with: (1) b, the per unit variable operating cost; (2) q, the maximum operating rate; and (3) β, the average fixed costs per unit at maximum operating rate.

In Aranoff (1989) it is shown, under simplifying assumptions of competitive manufacturing, that the conditions of economic indifference between two

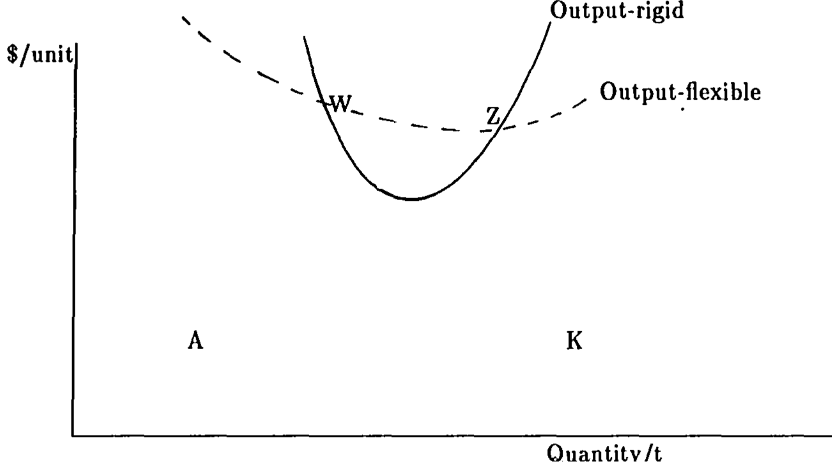

Figure 1. Short-run average cost curves of two technologies

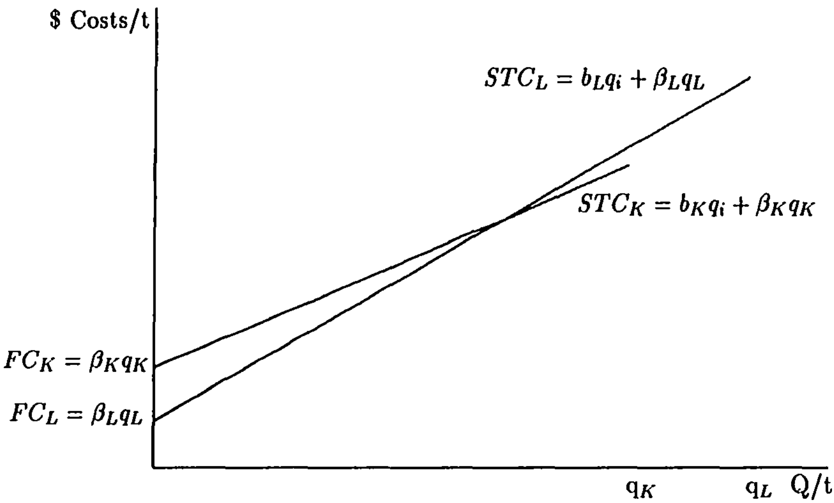

Figure 2. Short-run total cost curves of two plants

hypothetical plants that an investor can choose are that one plant be more static efficient and the other more output flexible. Technology$_K$ is more static efficient because it has a lower SRAC minimum, since $b_L + \beta_L > b_K + \beta_K$ (see Fig. 3). Technology$_L$ is more output flexible in the Stigler sense of having flatter SRAC and SRMC curves even though a discontinuity exists in the slopes of the SRAC and SRMC curves because plant$_L$ has a higher q and a higher b. In Fig. 3, $q_L > q_K$ *and* $b_L > b_K$; SRMC$_L$ can be considered flatter bottomed than SRMC$_K$ because it has the same zero slope for a greater range of outputs.

Even dropping the simplifying assumptions of linearity and rigid capacity limits, the two conditions of indifference between two plants of two

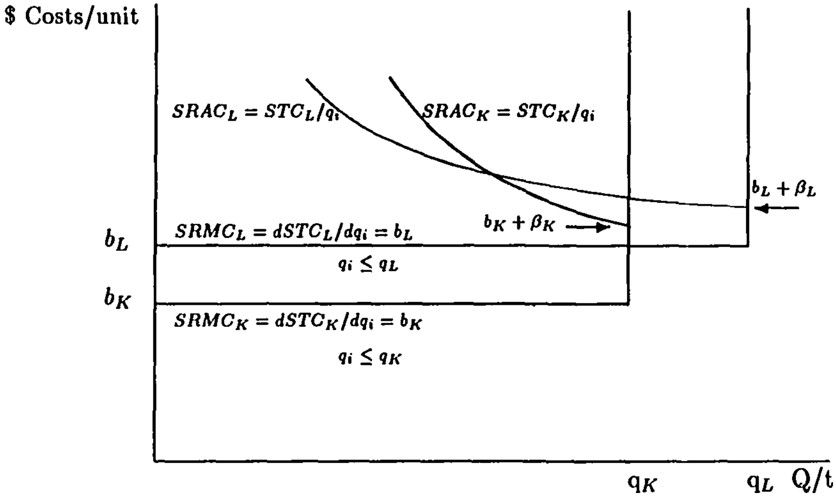

Figure 3. Short-run average and marginal cost curves of two plants

technologies 'should be' the same under common conditions in manufacturing today. Stigler's diagram, (Fig. 1) was drawn that way.[1] The output-rigid technology has a lower SRAC minimum while the output-flexible technology has a higher 'capacity', with capacity defined as the output rate for the SRAC minimum.

Output flexibility is helpful where the operations have widely varying operating rates. Companies could reduce widely varying output rates by building up inventories during slow periods for later sales in high-demand ones. Also, use of 'flexible manufacturing' equipment, as defined in recent cost literature,[2] will reduce widely varying operating rates, since with such equipment a firm can make individual product changes at a low cost.

Output flexibility is a different concept from flexible manufacturing for highly automated systems. Flexible manufacturing has the implication of being able to make product changes at a low cost and output flexibility of being able to operate economically far from SRAC and SRMC minimum operating rates. With output-flexible technology the average cost per unit and marginal cost per unit are close to their minima even when operating rates are far from the optimum rates—this is the meaning of flat SRAC and SRMC curves.

Much of this research is based on the writings of John M. Clark (1923), who wrote extensively on the economics of fixed costs, which he called 'overhead costs'.[3] Clark stresses the importance of the economies of fuller utilization which refer to the shape of the SRAC and SRMC curves. To get higher average operating rates and achieve economies of fuller utilization Clark argues for price cuts during slow periods and for reductions to customers when these do not compete with regular sales. As Clark eloquently states (1923, p. 416):

> If one had to choose a motto of six words expressing the most central economic consequence of overhead costs, the first choice might fall upon some such phrase as: 'Full utilization is worth the cost,' but a close second would be: 'Discrimination is the secret of efficiency.' This last, to be sure, needs to be taken with a proviso: one must know where to stop.

Assuming certain economic conditions explained in the next section, this article suggests how managers can make better capital budgeting decisions with technology choice and demand fluctuations in a simple manufacturing model. The early sections present the economic environment of a simple manufacturing model and the capital budgeting decisions facing managers. The later ones illustrate sample calculations and make general observations on output flexibility and capital budgeting with technology choice and demand fluctuations.

MAIN ECONOMIC ASSUMPTIONS OF THE MODEL

The following are the main assumptions used in this analysis of capital budgeting with technology choice and demand fluctuations:

(1) The pricing system is a quoted-price one as opposed to supply-and-demand pricing.[4] Under a quoted-price system firms first quote a price and then try to fill orders from inventory, production, or ordering. This is the common situation in manufacturing. Under supply-and-demand pricing firms trade goods on organized commodity exchanges for which they can sell or buy virtually unlimited amounts at the going market price.

(2) Durable and specific assets. *Durable* implies that productive assets are economically useful for many years. *Specific* indicates that the assets are specialized for the manufacture of a single product and cannot be adapted to manufacture a different product without incurring a high conversion cost. Thus, the assets are not the 'flexible manufacturing' type cited earlier. Durable and specific assets create a long-term economic commitment to the manufacture of the particular product. Even if prices fall below average total costs, production will continue while prices are above-average variable costs, the shut-down point. Owners may sell their ownership interest but the assets will continue to produce the same product. An example would be a cement kiln that should last at least 50 years and has a high cost to relocate or to convert to another use.

(3) Demand fluctuations. Demand fluctuations, where the assets are durable and specific and the pricing system is the quoted-price system, lead to a condition where some idle capacity is a normal and desirable situation most of the time.[5] In periods of idle capacity, if management cannot find temporary alternative use of the assets, the opportunity cost of the idle assets is zero.

Cost accounting distinguishes between:

(a) *Idle capacity*, which arises from capacity to handle peak or projected future growth in demand, and

(b) *Excess capacity*, which arises from an error in judgment in the original investment. As Polimeni *et al.* (1986, p. 145) note: '. . . The cost of unused capacity should be separated into the cost of *excess capacity* and the cost of *idle capacity*.'

The cost of excess capacity is a period cost. The accounting procedure that charges the cost of excess capacity to a loss account rather than to a product cost account makes management aware that something should be done to reduce existing facilities that are more than what the sales department can ever hope to sell.

The cost of idle capacity, however, is a product cost. Existing facilities will be temporarily unused due to seasonal and cyclical variations in customer demand. This is an unavoidable cost of providing a normal level of productive capacity. Good accounting procedure requires charging the cost of idle capacity to a product or inventory account.

(4) Technology choice. Assume two technologies are available to produce the same product, technology$_K$ and technology$_L$. Intuitively, one can think of the two technologies as the same except in a decision of make or buy of a part or subcomponent needed for the final product: technology$_K$ opts for making the part and technology$_L$ for buying the part from suppliers. Technology$_K$ becomes capital intensive (expensive to build and cheap to operate) because of the machinery needed to manufacture the part, while technology$_L$ is labor or energy intensive (cheap to build and expensive to operate) because of the reduced need for this machinery. Variable operating costs per unit will be lower for technology$_K$ due to the presumably lower variable manufacturing cost per unit to make the part than the cost to buy the part. The make-or-buy decision will be treated here as part of a long-run decision to buy specialized equipment to make a part in the spirit of Coda and King, who note (1989, p. 23):

> Contrary to what one would expect from reading textbook discussions, make versus buy decisions at the firms we visited are rarely treated as incremental decisions made on the basis of differential costing techniques. In the short term, firms apparently buy because they do not have the ability to make. In the long term, they decide whether or not they want to be in a particular business. The decision becomes an investment decision rather than a make/buy decision.

One could also think of an example of old versus new cement kilns, where new kilns have lower per unit operating costs due to, say, a recent improvement in cement kilns. Assume that a firm can get any size of old or new kiln. The cost per unit capacity of the old kilns would have to fall for old kilns to be competitive with new ones. This is much like prices on existing long-term bonds falling if yields on new issues rise.

(5) Plant or equipment of each technology has a certain practical capacity, that is, an operating rate that minimizes total costs per unit. A manager can run the plant or equipment beyond its capacity, to a degree, but only by paying an overload or overtime premium. Perhaps firms have to pay direct labor time and a half for overtime and this can be done only to a limited extent.

(6) Production costs fall into the following groups:

(a) A constant per unit variable operating cost;
(b) A constant per year fixed capacity cost;
(c) A constant per unit overload or overtime premium cost when operating rates are above practical capacity.

(7) Perishable or semi-perishable product. This separates the inventory-level problem from the capital budgeting problem. Including inventory adds a complication without contributing to the points studied. Building up inventories during slow periods is one way to accommodate fluctuations in demand, but inventory holding has costs for such items as interest, insurance, warehousing and supervision. Thus, managers still need the ability to operate at varying output rates, that is, output flexibility.

(8) The basic variables facing managers in their capital budgeting decisions are the following:

(a) Technology choice which may be new versus used equipment, or the choice of making a part versus buying one, or mixtures, such as a certain amount of new and of used equipment. In the model of this paper managers face the choice of technology$_K$ or technology$_L$, or a mixture;

(b) The size of the investment. More investment in the same technology gives more capacity. Since the cost per unit capacity is lower for technology$_L$, a given amount of investment in technology$_L$ will allow more capacity than the same investment in technology$_K$.

CAPITAL BUDGETING WITH TECHNOLOGY CHOICE AND DEMAND FLUCTUATIONS

The procedures outlined in leading cost accounting, finance, and economics texts for capital budgeting decision making apply to technology choice and demand fluctuations. The manager's aim should be to choose the course of action that will yield the greatest increase in the company's net present value (NPV). Admittedly, judging alternative investment decisions by immediate profit calculations might tempt managers, but a course of action with less immediate profit is better for a company if future profits are so much greater that the NPV of the company increases.

As affirmed in articles in recent years, managers should use incremental after-tax cash flows analysis in investment decisions.[6] The discount rate should be the company's weighted-average cost of capital, or possibly a slightly higher rate to compensate for omissions and unforseen contingencies or a slightly lower one to compensate for hard-to-quantify benefits of new technology.

The basic capital expenditure decision variables facing managers in this model are the technology choice and the size of the investment. The manager should start with one technology and do incremental after-tax cash flow analysis to find the level of investment that yields the highest NPV. Then the manager should try an alternative technology and carry out a similar analysis to assess the level of investment with that technology that yields the highest NPV. Managers should also try mixtures of technologies, and should select the technology or the mixture of technology and the level of investment that gives the highest NPV.

This is a correct approach and it is not so obvious, because one might erroneously think that managers should consider all possible arrangements of technology choice and size of investment and choose that which produces zero NPV. Managers must seek maximum NPV, not zero NPV. They do attempt zero *incremental* NPV on *incremental* investment, but this procedure achieves maximum NPV and not zero NPV.

When facing a decision involving size of investment, some writers suggest focusing on *incremental* investment levels,[7] and in that framework the guiding rule is (Morse, 1981, pp. 714–15): '. . . Profits are maximized at the point where the incremental present value of subsequent net cash inflows equals the incremental investment.'

Under demand fluctuations, however, the approach outlined by Morse may be confusing and error prone because of the difficulty of isolating incremental investment and incremental revenues. The method proposed in this paper is a total approach and is the general one used on any capital expenditure project. Admittedly, managers would need to calculate extensively because many arrangements are typically possible, but with a computer spreadsheet program managers can do the necessary calculations.

ILLUSTRATION OF CALCULATIONS NECESSARY

This section illustrates the necessary calculations using a modification of a capital budgeting problem from Louderback and Hirsch (1982, p. 628). The product is tonnage of goods hauled on waterways via a barge. The firm can select new or used barges of any size, or possibly different models of barges of any size, where each model has varying degrees of automation or other technical differences. The decision maker should start with a particular technology, such as a certain model of new barge and a particular level of investment that would give a specific level of practical capacity.

For illustrative purposes, assume a level of investment of $1 million for a barge with the capacity and cost characteristics as shown in Table 1. The practical capacity of the barge is 268 750 tons per year as in the Louderback and Hirsch example. Carrying tonnage (or production) above this amount can be done but at an increased cost, such as by overtime pay, slower travel, higher accident and spoilage rates, and some subcontracting. The ideal rate, where unit costs would be the least, would be at the practical capacity of 268 750 annual tonnage rate. A manager would have to estimate the likely pattern of output rate fluctuations. From US Federal Reserve Board statistics on percentage capacity utilization, an approximate 80% weighted average rate is common in manufacturing. This could arise by assuming the discrete probability distribution of Clark (1923, p. 185) shown in Table 2.

Table 1. Illustrated barge

Practical capacity	268 750 tons per year which can be exceeded by overload to 322 500 rate
Cost of barge	$1 million
Variable operating cost	$0.66 per ton
Fixed operating costs	$660 000 per year $610 000/yr cash fixed costs $50 000 depreciation (straight-line)
Overload premium	$0.46 per ton
Economic life of barge	20 years
Tax bracket	34%
Tax life (MACRS)	10 years
Weighted average cost of capital	10%
Price/ton of output	$4.67

Table 2. Assumed Discrete Probability Distribution

Frequencies or probabilities	Tonnage rate of practical capacity (%)
1/9	0
2/9	60
2/9	80
2/9	100
2/9	120

The expected tonnage rate is the weighted average where the weightings are the frequencies. This value is 80% $(1/9 \times 0 + 2/9 \times 60 + 2/9 \times 80 + 2/9 \times 100 + 2/9 \times 120 = 80)$. The next step is the development of a flexible budget, which Clark (1923, p. 184) calls '. . . a series of simplified budgets showing what happens to each main item, from a state of temporary shutdown up to a state of 20 percent overload'. This flexible budget forms the basis of the cost per unit and profit and NPV calculations. Table 3 illustrates the flexible budget and cost-per-unit calculations. The assumptions are that variable costs (VC) for oil, wages, etc. are $0.66 per ton; fixed costs (FC) are $660 000 per year (made up to $610 000/yr for cash items such as basic salaries, maintenance, and insurance and $50 000/yr straight-line depreciation); and the overload premium is $0.46 per ton for all tons when shipments are above the practical capacity. The popular convention is to omit interest costs—but, interestingly, Clark (1923, p. 185) includes interest and returns to equity owners as elements of fixed cost.

Table 3. Flexible Budget and Cost Per Unit Calculation

	Practical capacity (%) 0%	60%	80%	100%	120%	Expected values
Production (tons), ann. rates	0	161 250	215 000	268 750	322 500	215 000
Frequencies or prob.	1/9	2/9	2/9	2/9	2/9	
VC/ton	$0.66	$0.66	$0.66	$0.66	$0.66	
Total VC	0	$106 425	$141 900	$177 375	$212 850	$141 900
FC, annual	$660 000	$660 000	$660 000	$660 000	$660 000	$660 000
Overload premium/ton					$0.46	
Total overload premium					$148 350	$32 967
TC = VC + FC + Overload	$660 000	$766 425	$801 900	$837 375	$1 021 200	$834 867
Cost/unit = TC/prod.	Undefined	$4.75	$3.73	$3.12	$3.17	$3.8831

In this illustration we assume production = sales (perishable or semi-perishable inventory assumption), because complications from introducing inventory and backlog levels would not add to the points studied. Managers could certainly accommodate widely varying demand for many products by building up inventory levels in slow periods to meet peak demands, or by creating order backlog during high-demand times for delivery in slower periods. They would then have to add as a separate element of FC an inventory holding cost or an order backlog cost (due to possible lost revenues).

One can calculate the expected NPV of the project as shown in Table 4. For simplification purposes, this illustration assumes a 10% weighted-average cost of capital, a 20-year economic life of the barge, zero salvage value, a 34% tax bracket, depreciation for tax purposes under MACRS with a 10-year life, and the initial investment $1 million. The illustration assumes a price/ton of $4.67 as in the Louderback and Hirsch example.

With this same technology the manager should then try alternative levels of investment to see if the expected NPV increases, and for each level of investment there should be a chart similar to Table 1. The manager should then make the same calculation for alternative technologies, which may be old versus new barges, or they may be different model barges, or different mixtures of technologies such as some old and some new. A computer spreadsheet program, which can easily duplicate analyses with slight changes in assumptions, would be essential.

Managers can also experiment in their calculations with alternate patterns of output rate fluctuations to see if the recommended technology selection and capacity level would change for alternate assumptions. They would then be carrying out sensitivity analysis and critical-value thinking.

Table 4(a). Calculation of Expected NPV ($) Using One Technology and Investment of $1 million

Annual expected revenues	1 004 050
Annual expected variable costs	141 900
Annual expected cash fixed costs	610 000
Annual expected overload costs	32 967
Annual pretax cash flow from operations	219 183
Annual after-tax flow (1 − 0.34)	144 661
Present value of after-tax cash flow at 10%	1 231 579
Present value of tax shield from depreciation	224 611
Initial investment	1 000 000
Expected net present value	456 190

Table 4(b). Present Value of Tax Shield from Depreciation

Year	Rate (%)	Depr'n ($)	Tax shield (0.34 × depr'n) $	PV at 10% ($)
1	10.00	100 000	34 000	30 909
2	18.00	180 000	61 200	50 579
3	15.00	150 000	51 000	38 317
4	12.00	120 000	40 800	27 867
5	9.00	90 000	30 600	19 000
6	8.00	80 000	27 200	15 354
7	7.00	70 000	23 800	12 213
8	7.00	70 000	23 800	11 103
9	7.00	70 000	23 800	10 094
10	7.00	70 000	23 800	9 176
Sum	100.00	1 000 000	340 000	224 611

The procedure in this section should improve capital budgeting decision making with technology choice and demand fluctuations. The approach outlined here is similar to that in problems that systematically or implicitly review all possible arrangements or eliminate nonoptimal solutions. This is frequently done, for example, in a linear programming problem, as when firms are trying to determine how much of different products to manufacture given a fixed plant capacity.

A SHORT-RUN AVERAGE COST CURVE

Managers should draw (by using their computer and spreadsheet program) a SRAC curve for each investment possibility. This paper focuses on the shape of the SRAC and the importance of knowing its shape in capital budgeting decisions.

Figure 4 is a representation of the SRAC curve for the barge illustrated in Table 1. The cost per unit is undefined at 0% capacity utilization, \$4.75 at 60%, \$3.73 at 80%, \$3.12 at 100%, and \$3.17 at 120% as calculated in Table 3. This is a discrete (as opposed to a continuous) SRAC curve. It is useful to draw this graph and to connect the points to show visually how cost per unit varies as output rates vary.

Incidentally, one cannot calculate expected average cost E(AC), by weighting the cost per unit at different output rates since cost per unit at 0% capacity utilization (temporary shut-down) is undefined. The correct way to calculate E(AC), as shown in Table 3, is by dividing expected total costs by expected output.[8]

OUTPUT-FLEXIBILITY INDICATOR

It is useful to look at the difference of the SRAC minimum (\$3.12 in the illustration) and the E(AC) (\$3.88 in the illustration). Clark (1923, p. 188) calls this number '. . . a specific allowance for wastes of partial utilization'. One can also call it a cost of idle capacity. It is a product cost that managers should monitor, as they do with other product costs. Leaving out this cost element would overstate expected NPV of a proposed project, as would be the case if managers omitted any other ordinary and necessary cost element. Managers should be able to explain differences between actual and planned cost of idle capacity as they do between actual and planned cost of other cost elements. They should explore ways to reduce this cost—for example, through salesmanship, marketing, price cuts, or product changes that would increase sales in slow periods.

This number might be called an 'output-flexibility indicator', because it can test which of two technologies is more output flexible in the sense of Stigler's diagram in Fig. 1. This indicator gives a measure of risk of each technology. The more output flexible is a technology, the less will be the difference between E(AC) and SRAC minimum and the less of an increase in costs to a firm if fluctuations in output rates are wider than planned. In the illustration of this paper the output-flexibility indicator would be 3.88–3.12 = 0.76. One can look at it in absolute terms or in percentages: \$0.76 absolute cost/unit or 20% (0.76/3.88 = 20%). This might

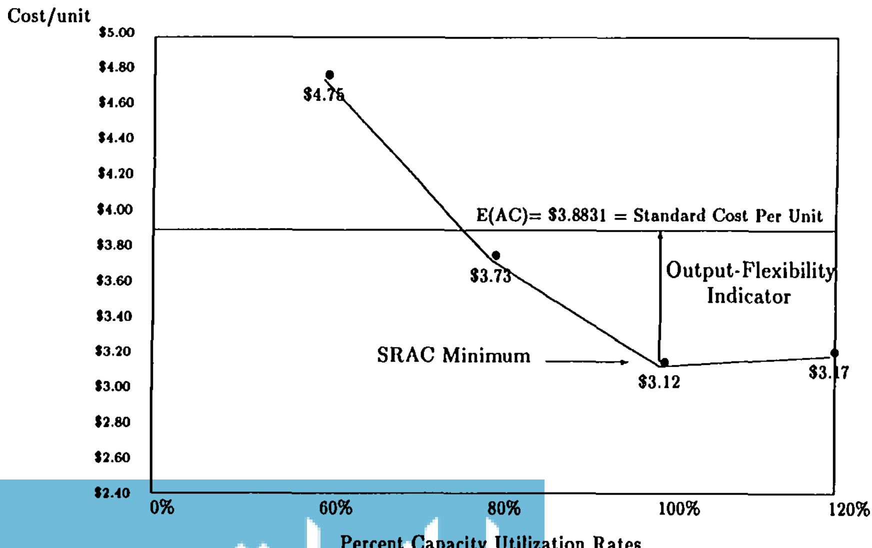

Figure 4. Short-run average cost curve: \$1 million investment in one technology

be a satisfactory number for many types of investment.

To test which of two technologies is more output flexible, for each technology, we need to calculate the E(AC) *using the same pattern of output rate fluctuations* such as the discrete probability distribution of Table 2, and then compare this to the SRAC minimum. Often managers should expect that new (instead of used) equipment or equipment requiring parts to be made (instead of buying them) would be justifiable only if it is expected to operate at a high average-percentage capacity utilization rate throughout the year. This would be true unless the new equipment or that requiring parts to be made have such large economies that the used equipment, or that which requires parts to be bought, is virtually obsolete. Obsolete equipment should be scrapped. As Clark (1961, p. 189n) writes on obsolescence: '. . . due to inferior performance and increased cost of maintenance, its [the obsolete equipment's] net earning capacity before depreciation would have a present worth less than salvage value, in hypothetical competition with new equipment of identical sort . . .'[9]

In the illustration, managers might recommend new barges if they can operate them at their practical capacity or higher for all but temporary shutdown periods. They could recommend used barges (that are not obsolete) if they expect to operate them only when demand exceeds the physical limits of the new barges. The result might be as shown in Table 5, assuming the demand pattern of Table 2.

The new barges would operate 1/9th at 0%, 2/9ths at 100% and 6/9ths at 120% to give a weighted average of 102%, while used barges would operate 5/9ths at 0%, 2/9ths at 100% and 2/9ths at 120% to give a weighted average of 49%. The approximate result would be that the new barges would operate between points W and Z in Fig. 1 and the used ones between points A and K in Fig. 1.

Table 5. Old and New Barges Available

Periods	Frequencies	Barges used
1	1/9	Temporary shutdown
2	2/9	New barges only at 100% capacity
3	2/9	New barges only at 120% capacity
4	2/9	New barges at 120% capacity and old barges at 100% capacity
5	2/9	New barges at 120% capacity and old barges at 120% capacity

Thus, managers should consider that with equipment of different technology the plan may be to operate it at a different output rate pattern—with the output-flexible technology operating at a wider pattern than the output-rigid technology, as in Table 5. This is an unavoidable complication of the capital budgeting decision process because one must assign a discrete probability distribution of expected use of equipment for each technology.

For example, a plant with technology$_K$ (such as with all new equipment and all major parts made and not bought) would likely have low output flexibility, that is, it would be output rigid. The SRAC curve for this plant would be steeply U-shaped. If such a plant were to operate at a high percentage capacity utilization rate, the wastage of partial utilization would then be slight. The E(AC) line in Fig. 4 would be close to the SRAC minimum point. A plant with technology$_L$ (such as with old equipment or one that makes a product with parts bought rather than manufactured) would be output flexible. Such a plant would likely be profitable if managers were to operate it under wide changes in output rates, perhaps with temporary shut-downs during all low and moderate demand periods, as the old barges in Table 5.

The optimum arrangement is likely to be a mixture of technology, with technology$_K$ used steadily throughout the year and technology$_L$ used only in high-demand periods. As in modern portfolio theory where firms face investments with differing risk characteristics, a mixture of technology could emerge in an industry by some firms using only technology$_K$ and some only technology$_L$. Mills and Shumann (1985, pp. 758–67) suggest that small firms tend to select labor-intensive technologies such as assembly labor instead of assembly line machinery to compete with large, capital-intensive plants that may have economies of scale. The small plants can compete because they have greater output flexibility, as they can lay off their workers during slow-demand periods and rehire them when demand picks up. The SRAC of the small plants may have a higher SRAC minimum but would be flatter.

JOURNAL ENTRIES IN A STANDARD COST SYSTEM

This section shows that firms facing demand fluctuations in a common manufacturing situation must do the calculations of Table 3 to perform the correct journal entries in a standard cost system. It may surprise managers not familiar with accounting to learn that accountants must also work with assumed discrete probability distributions and calculate unit costs as shown in Table 3. Managers making an investment decision can use a total approach to calculate expected NPV as shown in this paper, and possibly not develop unit costs. Here, we urge managers to develop unit cost (as shown in Table 3) to see the shape of the SRAC curve and the wastage of idle capacity for each different investment possibility. Accountants, however, must develop unit cost figures because the units have a price and are sold individually or in groups, but rarely all at once. They need unit costs because as sales are made, costs of the sales must be determined. In developing the correct standard cost per unit, the accountant should not use the SRAC minimum. The standard cost is E(AC) and *not* the SRAC minimum. In the illustration, for the assumed $1 million investment in a plant of a particular technology, the standard cost per unit would be $3.8831 as developed in Table 3. Variable costs/unit would be $0.66, overtime premium/unit would be $0.1533 (32 967/215 000 = 0.1533), and fixed cost/unit would be $3.0698 (660 000/215 000 = 3.0698).

Table 6. Journal Entries Over the Year

Standard cost/unit:
VC (oil, wages payable, etc.)/unit = $0.66
FC (depreciation, overload, etc.)/unit = $3.2231
TC/unit = $3.8831
Normal capacity = 251 000 (80% of practical)
Practical capacity = 268 750 which can be exceeded by overload to 322 500 rate.

Journal entries	*Debit*	*Cedit*
For the 1/9th of year of 0% practical capacity:		
Work-in-process (1/9 × 0 × 268 750 × 3.8831)	0	
Oil, wages payable, etc. (1/9 × 0 × 268 750 × 0.66)		0
FOH applied (1/9 × 0 × 268 750 × 3.22)		0
FOH control (1/9 × 660 000)	73 333	
Various FOH items (1/9 × 660 000)		73 333
For the 2/9ths of year of 60% practical capacity:		
Work-in-process (2/9 × 0.6 × 268 750 × 3.8831)	139 144	
Oil, wages payable, etc. (2/9 × 0.6 × 268 750 × 0.66)		23 650
FOH applied (2/9 × 0.6 × 268 750 × 3.2231)		115 494
FOH control (2/9 × 660 000)	146 667	
Various FOH items (2/9 × 660 000)		146 667
For the 2/9ths of year of 80% practical capacity:		
Work-in-process (2/9 × 0.8 × 268 750 × 3.8831)	185 526	
Oil, wages payable, etc. (2/9 × 0.8 × 268 750 × 0.66)		31 533
FOH applied (2/9 × 0.8 × 268 750 × 3.2231)		153 993
FOH control (2/9 × 660 000)	146 667	
Various FOH items (2/9 × 660 000)		146 667
For the 2/9ths of year of 100% practical capacity:		
Work-in-process (2/9 × 268 750 × 3.8831)	231 907	
Oil, wages payable, etc. (2/9 × 268 750 × 0.66)		39 417
FOH applied (2/9 × 268 750 × 3.2231)		192 491
FOH control (2/9 × 660 000)	146 667	
Various FOH items (2/9 × 660 000)		146 667
For the 2/9ths of year of 120% practical capacity:		
Work-in-process (2/9 × 1.2 × 268 750 × 3.8831)	278 289	
Oil, wages payable, etc. (2/9 × 1.2 × 268 750 × 0.66)		47 300
FOH applied (2/9 × 1.2 × 268 750 × 3.2231)		230 989
FOH control (2/9 × 660 000)	146 667	
FOH control—overload premium (2/9 × 1.2 × 268 750 × 0.46)	32 967	
Various FOH items (2/9 × 660 000 + 2/9 × 1.2 × 268 750 × 0.46)		179 633
Total of year: FOH control—FOH applied = 0		

If the plant achieved output patterns as planned, then there would be no over- or under-applied fixed factory overhead. Table 6 is an illustration of sample journal entries over a year. This should convince skeptics that \$3.8831 is the correct standard cost per unit as developed in Table 3. The bookkeeper must debit the Work-in-Process account for the output rate achieved times \$3.8831 and credit the various variable costs such as oil and wages payable for oil consumed and wages incurred, which should equal \$0.66 times the output achieved. The bookkeeper must credit the FOH (factory overhead) Applied account for \$3.2231 (3.0698 + 0.1533 = 3.2231) times the output achieved and debit the FOH Control for the actual FOH incurred, which should equal the \$660 000 of annual fixed costs times the fraction of year plus the overload premium of \$0.46 per unit times the units during the overload periods.

The entries would be basically the same if the actual output patterns were different from the planned patterns as shown in Table 2 but still gave an 80% weighted average. If the weighted average were above 80%, a favorable FOH Volume Variance would emerge. If the weighted average were below 80% there would be an unfavorable FOH Volume Variance. Accountants could work with an even more simplified discrete probability distribution of demand than Table 2, as long as they make an estimate of the expected average usage rate, which they call 'normal capacity', the weighted average over a business cycle.

Table 6 assumes 'treatment 1' of three possible treatments of overtime premium in Polimeni *et al.* (1986, pp. 109–10). This allocates the overtime premium to all production during the year rather than to the specific job (treatment 2) or to a loss account (treatment 3). If the firm receives a steady price of \$3.8831 per ton throughout the year, perhaps due to a long-term contract, then total revenues will exactly cover production costs over the year.

For long-run decision-making purposes managers should think of the unit cost as \$3.8831 and not the minimum cost of \$3.12 if the plant could operate at a steady rate throughout the year. The journal entries in Table 6 do not use the information that the SRAC minimum is \$3.12. If the firm receives a steady price of \$4.67 per unit, it will be earning a gross margin of \$0.79 per unit (4.67–3.88 = 0.79) or 17% (0.79/4.67 = 0.17). In a short-run decision framework, say, for a special order that will not affect regular sales, and if production is at less than 100% capacity, the managers can think of the variable cost of \$0.66 as the relevant one.

RECOMMENDATIONS ON CAPITAL BUDGETING WITH TECHNOLOGY CHOICE AND DEMAND FLUCTUATIONS IN A SIMPLE MANUFACTURING MODEL

The recommendation of this paper is that managers systematically consider all reasonable alternative levels of investment and technologies available and use after-tax discounted-cash-flow analysis. They must work with expected values using projections of fluctuations in output rates for each type of plant or equipment. In a standard-cost system, managers and accountants should use E(AC) as the standard cost, employing a procedure as shown in Table 3.

It is useful to compare E(AC) and the SRAC minimum—an output-flexibility indicator (see Fig. 4). As part of operations management, managers should consider the degree of output flexibility in the plant or in an item of equipment, which shows a measure of risk of that plant or equipment. The more output flexible is the plant or equipment, the less of an increase in costs to a firm if there are wider fluctuations in output rates than planned.

One can call the difference between E(AC) and the SRAC minimum the cost of idle capacity and the wastage of partial utilization, and the cost of idle capacity is a true product cost. Managers must include this cost in expected NPV calculations and also monitor it as with other product costs.

NOTES

1. Mills and Schumann (1985, pp. 758–9) also suggest this same tradeoff.
2. See, for example, Foster and Horngren (1988).
3. Spencer *et al.* (1975, p. 221) call Clark's book: '. . . a book which is undoubtedly one of the most important contributions to economic and business literature in the 20th century'.
4. See Clark (1961, pp. 108–10).
5. See Clark (1961, p. 121).
6. See, for example, Primrose and Leonard (1987).
7. For example, Morse (1981, pp. 714–15).
8. The first to show this clearly, to the writer's knowledge, was Clark, (1923, p. 185).

9. Bain (1968, pp. 382–3) argues that obsolete plant should not be counted in measuring industry capacity:

> A second issue concerns the treatment of obsolete capacity. In the usual industry, plant capacity will be of various ages, states of repair, and degrees of technical 'up-to-dateness'. A plant is properly considered *obsolete*, however, only when because of age, old-fashioned technology, or other factors, the cost per unit of output for simply maintaining and operating the existing plant exceeds the alternative cost per unit of output for building as well as operating and maintaining a new plant. Even according to this strict definition, obsolete plant capacity does persist in some industries, though often on a 'standby' nonoperating basis or with a very low rate of utilization. The main question is whether truly obsolete plants should be counted in appraising the desirability of adjustment of capacity to demand. The answer is, generally, 'No'.

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