

INCLUDING EQUIPMENT FLEXIBILITY IN BREAK-EVEN ANALYSIS: TWO EXAMPLES

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Much more than in the past, today's manufacturers may find themselves faced with competition that is highly flexible, thus able to meet a wide array of customer requirements in a very cost-effective fashion. As manufacturers strive to meet such competitive challenges in the market place, they are confronted with a wide array of process technology alternatives. As such, decision makers typically look for a quick, logical, and easily communicated model to help make initial economic comparisons between the alternatives. In the past, if cost was a major factor, then flexibility typically was not. In such cases, the widely recognized model cost-volume break-even analysis (CVBA) may have been sufficient to make an initial screening between mutually exclusive manufacturing systems and equipment alternatives. Unfortunately, CVBA is blind to manufacturing flexibility. The result of making choices when relying on CVBA alone is often the hindrance of attempts to enhance competitiveness through increased flexibility.

Alternatives to CVBA which might be used in the selection of manufacturing systems and technology might include linear programming, goal programming, or other more complex operations research/management science techniques. While these approaches may include considerations of both volume- and flexibility-related issues, managers, however, prefer simple tools and are more likely to use them—especially for the initial screening of technology alternatives.

In this article we describe the experiences of a medium-sized facility designed specifically to produce a wide variety of customized low-volume parts for a large midwestern manufacturer of hydraulic fittings. In addition, we will use their situation to illustrate the simple decision-making tool called cost-volume-flexibility break-even analysis (CVFBA) [1]. CVFBA explicitly considers manufacturing flexibility and provides a mechanism by which the trade-offs between cost advantages and flexibility advantages can easily be considered and communicated. Indeed, as in the cases described here, we believe that CVFBA would be a more appropriate tool than CVBA for those manufacturers with a strategic commitment to the en-

hancement of manufacturing flexibility accompanied by a desire to control manufacturing costs.

ORGANIZING FOR MANUFACTURING FLEXIBILITY

According to Swamidass [2], "Manufacturing flexibility refers to the capacity of a manufacturing system to adapt successfully to changing environmental conditions and process requirements. It refers to the ability of the production system to cope with the instability induced by the environment." Manufacturing flexibility is also an offensive weapon. A firm with a large degree of manufacturing flexibility is capable of providing the customer with a greater amount of product choice within a limited time frame.

It was with this in mind that a large midwestern manufacturer of hydraulic fittings attempted to improve the way its facilities could respond to a growing segment of its business. An increasing percentage of its production requirements called for small runs of often customized and widely variable parts. Since the company was traditionally cost and volume oriented, existing performance measures and controls were not effective for this new business. While existing processes had sufficient technical capability to handle this new demand in most cases, inventory levels, manufacturing lead times, and overall responsiveness to demand for both high- and low-volume parts suffered.

It became clear that specific process technology is only one factor among many that determine a facility's overall manufacturing flexibility. According to Swamidass, **machine-level** flexibility is predominantly technology based, while **plant-level** manufacturing flexibility is a complex blend of several ingredients including technology [2]. Attempts to compete through both cost effectiveness and increased manufacturing flexibility are likely to fall if the distinction between machine-level flexibility and manufacturing flexibility is not recognized. Simply inserting machine-level flexibility in a system that is governed and dominated by volume cost-efficiency-driven decision

mechanisms is likely to result in little enhanced manufacturing flexibility.

As a result, a new "focused factory" was built specifically to handle the low-volume, high-variety production requirements. In the new factory, appropriate process technologies were matched with a more consistent set of infrastructures and people systems to maximize overall plant-level manufacturing flexibility. This new factory's processes are continually being improved and upgraded. This additional machine level flexibility does have a cost, and capital expenditures must be approved in this plant as in any other. However, the volume cost-efficiency-based tool, CVBA, used to make initial distinctions between technology alternatives in the original facility, is not adequate and is inappropriate in this situation. Managers in this new facility found themselves trying to gain upper management support for process improvements they instinctively felt necessary using standard techniques that, at best, considered only part of the benefits potentially available.

Managers in this facility, as in many others, need a technique for comparison of technology options which considers both volume cost-efficiency and flexibility cost-efficiency. The technique needs to be simple, capable of quick sensitivity analysis, and easily communicable, especially to higher level managers. The extension of CVBA used by this company was CVFBA, and was found to be helpful in this regard.

USING CVFBA

Though many different factors may influence the cost of manufacturing flexibility, the requirement for small lot sizes and customized parts made setup costs a key element to incorporate in evaluating equipment alternatives at the new manufacturing facility. In fact, two specific cases where small lot sizes made setup costs very important to the decision-making process are illustrated below. In each case, traditional CVBA was inadequate to model the available alternatives that were identified. However, by extending traditional CVBA analysis to include setup costs, this was remedied without significant loss of simplicity.

In both cases, description of the specific costs involved have been modified for confidentiality, though for illustrative purposes, the relative comparisons were not changed significantly.

Where More Flexibility Paid Off

In one situation, an identification number unique to each batch of a given part type needed to be im-

printed on each part. Two options were identified. In one case, an existing stamping machine could be modified with little capital expense (primarily tooling), thereby only slightly increasing the annual fixed cost of the technology. The second alternative would be to purchase a computer-controlled bar marking machine. While resulting in somewhat higher annual fixed costs, this alternative would result in somewhat reduced variable operating costs and would also reduce setup costs by 85%. See Table 1 for the specific costs and demand requirements.

As can be seen in Equation (1) and Figure 1, using simple CVBA, the combined fixed and variable costs of each technology are set equal to each other in order to determine the break-even volume (v). This, however, does not capture the real reason for considering the computer-controlled bar marker, that of setup cost reduction. Production of 500,000 units is required to break even using the computer-controlled bar marker when considering only the reduction in variable operating costs. Given that annual volume is estimated at just under 21,000 units, the existing stamping machine looks more attractive.

$$2500 + .0038v = 600 + .0076v$$

$$v = 500,000 \quad (1)$$

While such analysis may have been helpful in quickly estimating the cost-effectiveness of each alternative given the higher volume production of a narrower product mix in this company's other facilities, it was misleading in this case. By including the setup costs (s) in Equation (2), the combined costs of each technology can be set equal to one another and solved for volume. The resulting relationship is plotted in Figure 2. This line represents the various combinations of annual volume and number of setups (3) where the combined cost of using either alternative would

TABLE 1: Cost and Demand Summary: Stamping Machine vs. Computer-Controlled Bar Marker

<i>Manufacturing Option</i>	<i>Fixed Costs (\$/year)</i>	<i>Variable Costs (\$/unit)</i>	<i>Setup Costs (\$/setup)</i>
Stamping machine	600	0.0076	40
Computer-controlled bar marker	2,500	0.0038	6
Annual Demand = 20,880 units Setups/year = 696			

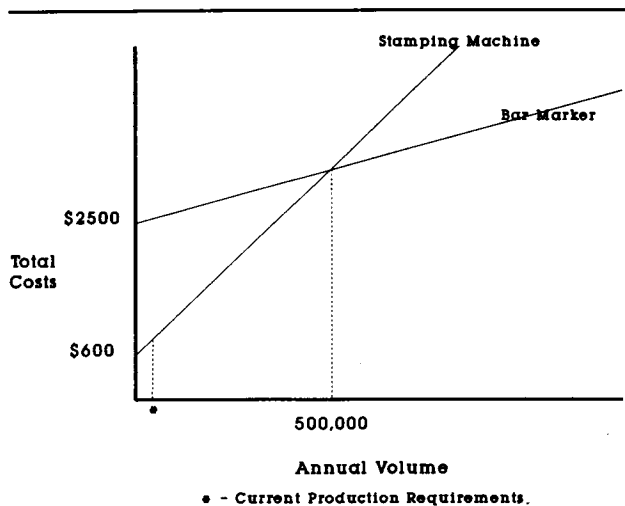


FIGURE 1: CVBA—Stamping machine vs. bar marker

be the same. When estimated production requirements are described by points above the line, the computer-controlled alternative would be more cost-effective. Production requirements described by points below the line would be more cost-effectively met using the existing stamping machine. Figure 2 shows that reaching an annual volume in excess of 500,000 units regardless of the number of setups or requiring more than 55 setups annually regardless of volume would make the computer-controlled bar marking alternative more attractive.

$$2500 + .0038v + 6s = 600 + .0076v + 40s \quad (2)$$

$$v = 500,000 - 8947s$$

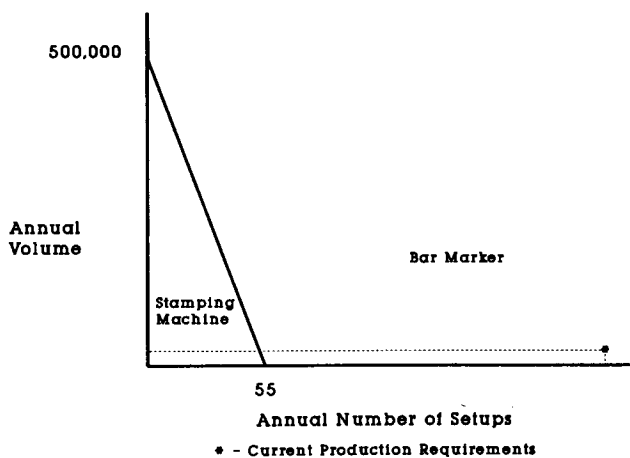


FIGURE 2: CVFBA—Stamping machine vs. bar marker

While current volume requirements alone were clearly insufficient to justify the investment, it is obvious that when the combined benefits of both variable operating cost reduction (though in this case small) and setup cost reduction are considered, the computer-controlled bar marker is expected to be the more cost-effective alternative. In this case, CVFBA provided managers at the new facility with a way to communicate more of the trade-offs relevant to their situation (based upon both current and potential future production requirements) when discussing the initial comparison of the competing technology options with upper management. Purchase of the bar marker has now been approved.

Where the Most Flexible Equipment Wasn't Needed

In a second situation, three technology alternatives had been identified to perform a similar marking function. Existing stamping machines could perform the operation with no additional capital investment, however, variable operating costs and setup costs would be substantial. As a result, alternatives were investigated. An etching machine would increase fixed costs but would reduce variable costs by 25% and setup costs by 69%. A third alternative would be to invest in a laser marking machine that, while greatly increasing fixed costs, would reduce variable operating costs by 55% and setup costs by 81% over the existing technology option. See Table 2 for the specific costs and demand requirements.

As was the case in the first example, simple CVBA does not adequately model this situation since it fails to capture the impact of setup costs. Equation (3) determines a volume of 36,000 units would be required to justify the etching machine when compared to the existing stamping machine. Equation (4) determines a volume of 120,000 units would be required to justify the laser marking machine when compared to the

TABLE 2: Cost and Demand Summary: Stamping Machine vs. Etcher vs. Laser Bar Marker

Manufacturing Option	Fixed Costs (\$/year)	Variable Costs (\$/unit)	Setup Costs (\$/setup)
Stamping machine	0	.20	32
Etcher	1,800	.15	10
Laser bar marker	9,000	.09	6

Annual Demand = 7,317 units
Setups/year = 192

etching machine. These points, based upon only reductions in variable operating costs, are illustrated in Figure 3.

$$\begin{aligned} .20v &= 1,800 + .15v \\ v &= 36,000 \end{aligned} \quad (3)$$

$$\begin{aligned} 1,800 + .15v &= 9,000 + .09v \\ v &= 120,000 \end{aligned} \quad (4)$$

As Figure 3 indicates, the relatively low volume of parts requiring this type of marking would seem to rule out anything other than the existing technology. However, managers of the facility concerned by the substantial setup costs associated with the existing equipment were still left without a way to objectively include that consideration in the decision-making process.

Extending Equations (3-4) to include setup costs, Equation (5) uses CVFBA to compare the existing equipment to the etching machine alternative, while Equation (6) uses CVFBA to compare the etching machine alternative to the laser technology. The resulting relationships are plotted in Figure 4 and define the annual volume and setup requirements where each equipment alternative would be the most attractive. When estimated production requirements are described by points in the region closest to the origin, then the stamping machine would be most cost-effective. The middle region describes the combination of parameters where the etching machine would be most cost-effective. The outer region describes the combi-

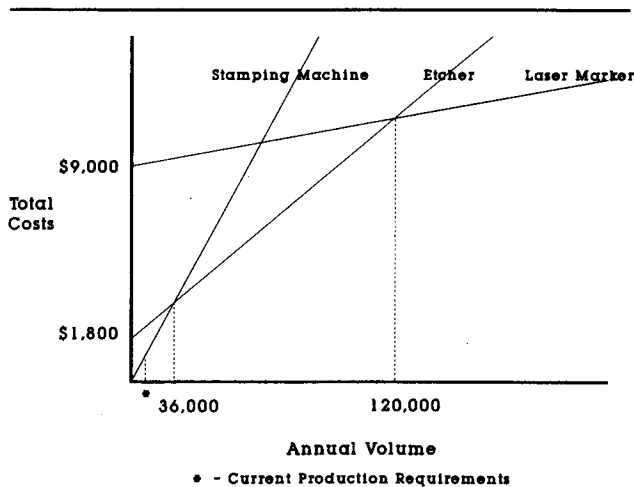


FIGURE 3: CVBA—Stamping machine, etcher, laser marker

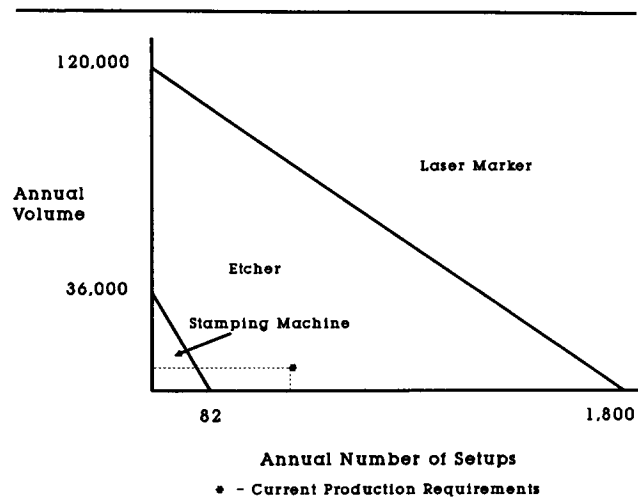


FIGURE 4: CVFBA—Stamping machine, etcher, laser marker

nation of production parameters where the laser bar marker would be most cost-effective.

$$\begin{aligned} .20v + 32s &= 1,800 + .15v + 10s \\ v &= 36,000 - 440s \end{aligned} \quad (5)$$

$$\begin{aligned} 1,800 + .15v + 10s &= 9,000 + .09v + 6s \\ v &= 120,000 - 66.67s \end{aligned} \quad (6)$$

Again, in this case, CVFBA provides a basis for comparing technology options in terms of both volume and flexibility requirements. The initial feeling of the facility's managers was to make a case for the laser marker based upon the facility's focus on high variety and low volume. However, it appears that such an investment may not be the most cost-effective. CVFBA described in Figure 4 suggests that the etching machine may be the most worthwhile alternative based upon current production requirements.

In this situation, CVFBA also helps support planning for future production requirements consistent with the focus of the new facility. Figure 4 illustrates the relative sensitivity of the decision with respect to either the production volume or the number of setups required. Potential changes in total volume required or the demand for flexibility may make the laser marking machine the best solution in the future.

Currently, given this information, manufacturing has asked marketing to estimate the increases in the demand patterns that could be possible given the improved marking flexibility that the laser technology would provide. In general, when current production

requirements are on, or close to, one of the lines representing indifference between alternatives, management should make the choice on the basis of such further considerations. Specifically in this case, even if relatively large growth in demand is the only expected change in the production requirements for the operation, the etching machine may still be the best alternative. If, on the other hand, management has made a commitment to flexibility and expects future competition to be based more upon smaller and more frequent production runs of existing products, or if management anticipates the broadening of product offerings in the future, the laser marker may become the best choice as, under those circumstances, it could offer greater combined flexibility and volume cost-efficiencies.

CONCLUSIONS

As illustrated by the cases described here, CVFBA has several apparent advantages over the CVBA that retains so much popularity. Using CVFBA, managers at this facility were able to make initial comparisons and identify the appropriate manufacturing system

based upon both expected volume and flexibility requirements. The relative sensitivity of their decisions to those estimated requirements is also made very clear using CVFBA. In addition, they were able to easily communicate the rationale for their choices while making the trade-offs between volume cost-efficiency and flexibility cost-efficiency clear through simple graphs such as Figures 2 and 4. Finally, the fact that these advantages are obtained without any substantive loss in the simplicity of the tool is worthy of mention.

Through the real applications presented above, we have illustrated our belief that use of CVFBA can help manufacturing management to make better decisions where cost-efficiency is influenced by both production volume and manufacturing flexibility objectives.

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