Perspectives on Operations Strategy and Economics

by

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Perspectives on Operations Strategy and Economics

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Abstract:  Economics provides a foundation for scientists and managers to understand business strategy. This paper shows how economics can aid teaching of operations strategy. A definition of operations strategy is offered along with some examples of operations papers that use economic ideas to illuminate strategy. I present detailed descriptions of several strategic topics that I teach to MBA students. Examples include the interaction of plant location and pricing policy, designing service networks, capital budgeting for major operations investments, operations organization and time based competition.
1. What is Operations Strategy?

"Strategy" is a term often used by academics and consultants to attract a business audience's attention. "Strategy" carries the connotation of plans and actions taken at the highest levels in an organization by enterprise leaders. The implication is that of important activities involving significant sums and important outcomes. The decisions are those made by resource-allocators, not managers of the day-to-day activities. Audiences (particularly MBA students) quickly imagine themselves in the attractive role of the ultimate decision maker (or, highly paid consultant-advisor). Business school faculty, not immune to such crowd-affecting devices, use "strategy" as a indicator that what is to follow is not mundane, detailed, or specialized but instead is of general value, broad utility and universal business interest.

Operations management faculty, too, resort to this approach, describing many issues as "operations strategy." Qualification is unchallenged so long as the issue is not too closely aligned with the day-to-day. Even so, there is some confusion as to what constitutes strategy and what does not. Hill (1989) provides a useful insight to this definitional issue. He describes (manufacturing) strategy as encompassing operations activities that can provide the product an advantage in the marketplace. In Hill's book, topics falling into this category include: process choice, focus, experience effects, manufacturing infrastructure and capital investment. Likewise, other authorities, including Sasser et al. (1982), describe strategy as long term decisions made in support of corporate strategy. Specifically cited are those decisions concerning facilities, processes, capacity, vertical integration, infrastructure and interfaces with other functions. Many other issues of current topical interest such as product design, time-based competition and quality can be forced into either of these definitions without too much trouble.

I choose to define operations strategy a bit more operationally: It encompasses all decisions made in the operations function that affect the long term cost or demand of a firm's products. (In the non-profit sector I would amend the end of this sentence to be
"the long term cost or value of the outputs"). I like this definition for two reasons. First, it decomposes any strategic issue into two important subproblems of cost and demand effects. Second, it suggests powerful methodologies for analysis for which there is a considerable knowledge base, namely operations research and microeconomic theory.

Much of the traditional operations strategy literature is based upon OR models using cost minimization as the objective. However, there are many problems of operations interest where long term demand or revenue effects are important. This last point in no way surrenders the discipline to economists. Operations professionals and academics have specific knowledge of operations technology that must be known in order to sort out the demand (and cost effects). Indeed, modern mathematical microeconomic analysis is often framed using the most general models possible. Specializing such models to much more specific situations allows stronger, sharper results about cost and demand in operations.

Many types of methodologies and modes of analysis can be used in operation strategy analysis. Analysis need not necessarily be mathematical, game theoretic or especially complex, but there must be a link between operations and long term cost or demand. Tools of OR, empirical analysis and economics all lend themselves to the task.

Although OR models of strategic cost analysis are well established, economics based models that consider the demand side of strategy are relatively rare. There are a large number of economics models that are well suited to study operations strategy. To cite a few examples:

Competitive economic theory can be used to analyze the relationship between operations technology and firm performance. Any change in the production possibility set (what economists call the "production function") can be analyzed in terms of changes in cost and revenue. Applications include changes in firm performance due to lower cost or higher quality, or the effects of vertical integration decisions on firm performance. This area is particularly
wide open for study. Many OR models of cost performance (such as provided by queuing theory) are available to be used to model the production function. Examples include Harker (1986), Lieberman (1989), Karmarkar and Pitbladdo (1994), and de Groote (1994).

Option theory can be used to analyze the value of real production options as hedges against uncertainty. Relevant applications are the value of foreign plants as currency hedges, and the value of excess production capacity to facilitate quick introduction of new products when faced with demand uncertainty. Demonstrations of this approach are Andreou (1990), and Huchzermeier and Cohen (1996).

Agency theory models can be used to analyze the cost and benefits of different ways of organizing operations. Applications include firm performance if operations is organized as a cost center (or profit center), and the effect of new technologies on the control of operations. Porteus and Whang (1991) uses these ideas.

Modern finance theory can be used to study the relationship between operations decisions and firm risk. This theory provides models for firm valuation and risk adjustment. Applications are the analysis of how new manufacturing technologies affect the way a firm will finance itself and how different inventory holding policies affect firm risk. Some applications include Fine and Freund (1990), Singhal and Raturi (1990), and Hodder (1984).

Game theory studies competition between a few firms. Many firms operate in oligopolistic markets, and operations decisions are often crucial competitive choices. Applications include how capacity and technology decisions between firms interact. Some papers that use game theory in operations environments are Tombak (1990), Hobbs and Kelly (1990), and Li and Lee (1994).
It is my view that continuing research using economic methodologies will lead to exciting breakthroughs in operations strategy.

The purpose of this note is to present some models of operations strategy that I have used in MBA teaching. All of the models are drawn from my research and use economics ideas. My intent is not to provide an in-depth survey of teaching materials that are available, nor a complete scholarly discussion of the issues. Instead I want to illuminate and demonstrate what has worked for me, and point to some new directions for teaching and research.

This note is organized as follows: I continue with separate sections on operations problems that benefit from economic modeling: firm location, network design, evaluation of new manufacturing technologies, operations organization and time-based competition.

2. Economic Models in Operations Strategy

2.1 Competitive Firm Location and Pricing

Facility location is one of the "classical" problems of strategic operations planning. Traditional operations models formulate a firm's problem as that of locating to minimize production and transportation cost, often imposing service constraints or ignoring service altogether. On the other hand, economics models study the effect of location on demand, profits and, sometimes, prices. Due to the complexity of the problem, most competitive location models assume overly simple environments, such as only two firms with identical costs, linear markets, etc. Operations details such as the effect of location on production cost are always ignored.

An important empirical observation is that firms with high transportation costs use delivered prices, that is, absorb freight charges. For example Greenhut, Greenhut and Li (1980)
shows that most American firms (even with relatively small transportation costs) do not use mill prices. It is remarkable that this empirical observation greatly simplifies the analysis and conclusions. Analysis shows that complex location problems that simultaneously examine demand, pricing and firms' operations decisions can be analyzed quite easily. These results are found in Hurter and Lederer (1986), and Lederer and Hurter (1986). Problems with location in arbitrary dimensional space (such as product positioning problems), asymmetric firm costs, non uniform customer distributions and delivered prices can be studied. Full examination of the firm's production problem can be accomplished using some easily described models. These models combine game theoretic arguments along with the cost minimization paradigm.

The main result of these papers is that a firm's profit increases when it locates to minimize total industry cost, not firm cost. Thus, the traditional objective of minimizing production and transportation cost does not necessarily lead a firm to an optimum. The argument is very simple. Consider the situation in Figure 1. Two firms A and B located, as indicated, compete for customers located on the line. Suppose for simplicity that demand is inelastic with respect to price. Each firm's marginal delivered cost is as shown. With any fixed locations, the equilibrium price in the market is as shown; each firm reduces its price so that the other cannot undercut its price profitably. Then, firm A's profit contribution is the shaded region. This region is the reduction in cost to the industry that firm A's presence contributes. Now consider firm A's location problem: its profit rises when it maximizes the cost reduction it contributes. This is equivalent to firm A minimizing both firms' costs of serving customers. When both firms are located so as to globally minimize both firms' costs, then the firms are in location equilibrium; that is neither can unilaterally improve its profits by changing its prices or location. This result holds for generalization with fixed cost, location dependent production cost and non constant marginal cost. (See Lederer 1994 for this generalization).

Many firms compete in markets with these characteristics. A typical situation is that of a firm that produces near commodity products. One example is found in the Carborundum Inc. case
(found in Sasser et al., 1982), where an abrasives manufacturer seeks to locate a new facility to meet growing demand. The case states that Carborundum prices to undercut competing firms. This creates pricing profiles like that shown here. Strategic location decisions are analyzed by considering total industry cost and finding locations that minimize industry efficiency. In short, Carborundum should locate its new facility to minimize total industry cost.

2.1 Firm Location and Pricing Policies

Anytime a firm's facility location affects the demand generated for the firm, there is a clear interaction between facility location, pricing and demand. The assumption of delivered pricing of the last model allowed very simple analysis of this interaction.

However, some firms cannot use delivered pricing because of arbitrage opportunities of its customers or enforcement of anti-trust law. Instead, these firms use other pricing policies such as f.o.b. pricing (where customers pay a price at the shipping point plus the exact transportation cost) or uniform pricing (where customers pay the same delivered price independent of location).

When these pricing policies are considered, how should a firm coordinate its price and location plans? Assuming a fixed demand distribution, location decisions can be made to minimize firm costs. However, in general, changes in location invite reoptimization of prices, which then changes the demand pattern. Now location decisions can be reoptimized to minimize cost, but this allows repricing to raise profits, etc. Clearly this can be modeled as a fixed point problem. We conclude that these two decisions cannot be made separately by marketing and operations. But are there any insights to be gained about the interaction of pricing policy and facility location?

Very few analytic models exist with general results. However, it can be shown that the interaction of facility location and firm pricing policy greatly affects location decisions and profit. As an example of this situation, consider the case of Zodiac Brothers Toys Inc. (Harvard Business
School case #9-764-104). Zodiac produces toys from its plants in Wisconsin and needs to add capacity. Zodiac prices using f.o.b. prices from Wisconsin. As is reported in the case, its demand pattern is highly skewed to the northeast United States.

As a classroom exercise, I make a myriad of assumptions about Zodiac's transportation and facility cost which are described in Figure 2a. A key issue in the case is, Where should Zodiac place a new plant? By assuming fixed demand and modeling Zodiac's problem as a cost minimization problem, an MBA student can solve the problem using spreadsheet software such as Microsoft Excel Solver. However, this ignores the interaction of pricing with location. I use the case to estimate demand as a linear function of delivered price. In class we consider two pricing policies: set an f.o.b. price from the factories or set a uniform price throughout the US. A surprising, counter intuitive result occurs; the optimal decision by Zodiac is to use uniform prices! The summary of the analysis is found in Figure 2b. This policy tends to equalize the demand pattern and spread out the factories. The superiority of uniform pricing when firms have multiple facilities has not been generally recognized, but many industries use such a policy. From private communications with firms in the processed food industry, uniform pricing is used in the following food categories: laundry cleaners, coffee, juice, shortening and oils, baking mixes, cereal and many others. Some results are presented in Lederer and Nanda (1995).

2.2 Competitive Network Design

The service sector dominates the United States economy. Many service industries provide their services using networks. (I use the term network in the usual topological sense). Two prominent examples of industries where the operational design involves choice of networks are the transportation and telecommunications industries. It is easy to demonstrate that the design of networks captures the full complexity of operations strategy. Despite this complexity, insights are forthcoming about real situations.
The model found in figure 3 helps understand the tradeoffs in network problems. The choice of network affects both the attributes of service quality and provider cost. Service quality, in turn, affects demand. Then again, the pricing strategy the firm uses should consider both the attractiveness of the product and the cost of service. Optimizing profits requires an understanding of how network design and consumer choice interact.

Generally, the network design problem in real networks is complex. However, some recent papers provide insights. The hub and spoke is the dominant passenger airline design in the US. However, in recent years the most profitable American airline has been a direct carrier, Southwest Airlines. Not only has Southwest been very profitable, it has the highest schedule reliability of any major carrier. The paper, Lederer and Nambimadom (1993), develops a model to study the effect of these networks on an airline's cost and passengers' service level. The model explains both the dominance of hub and spoke designs, and why direct carriers can be very profitable in niche markets and have high schedule reliability.

A straightforward economic argument shows that the airline maximizes its profit by choosing its network so as to minimize its own cost plus convenience related costs of its customers. If the network does not have the “minimization” property, the airline could change its network design, adjust prices so that customer's utility remains constant, and raise its profits. It is easy to demonstrate that airline cost (consisting of flight related cost as well as fixed cost) is minimized by hub systems, while passenger related cost (due to travel time, late arrival and schedule delay - the difference between ideal and actual departure time) is minimized by direct service. Many factors drive which component dominates, but in many circumstances the significant economies of scale of airline cost drives the solution to the hub configuration. Further results helps explain when direct systems will dominate hubs: for medium sized cities that are not far apart and whose demand levels don't favor the hub's economies of scale. An insight is gained after realizing that such markets tend to have high demand elasticity compared to hub markets.
serving far away cities; thus, direct carriers will price low to stimulate demand and reduce average cost. Finally, schedule reliability of direct flights is expected to be greater than hub flights because the amount of time necessary to guarantee any reliability level is much smaller. These insights about the interaction of pricing, network design and cost structure can be explained to the master's student.

2.3 Evaluation and Justification of New Manufacturing Technologies

A completely different use of economics is analysis of the capital budgeting problems. Many of my MBA students have interest in finance, accounting or general management. Operations faculty must clearly communicate to this important audience in terms that they appreciate. The message I seek to deliver is that knowledge of operations is necessary to apply their disciplines. Specifically, operations decisions affect the risk of the firm as well as future cash flows, and these, in turn, affect the firm's valuation of investments and how it will finance these investments.

In my own classes I discuss the interaction of operations decisions and capital budgeting. The main ideas that I use are found in Lederer and Singhal (1988). This paper uses empirical data from public sources and a case study to compare the cost structure of new and conventional technologies (such as FMS and older, labor intensive technologies such as a traditional job shop). The data shows that new technologies have lower unit variable costs and period fixed costs but require higher initial investment than conventional technologies. I point out that the different cost structures imply different risks and different discount rates. I use the capital asset pricing model (CAPM) to estimate the appropriate discount rate to use. The CAPM implies that new technologies actually have lower systematic risk than conventional technologies. A worked example that demonstrates this result is shown in Table 1. Thus, cash flows from such projects should be evaluated at a lower discount rate than conventional technologies. Another point I make is that the
CAPM shows that investments justified on the basis of cost savings should be evaluated at lower discount rates than investments justified by both revenue and cost. Further results in Singhal and Lederer (1994) study the effect of technology choice on financing decisions. The main point is that different cost structures imply different capital structures. The case study of the previous paper shows that new manufacturing technologies have cash flows that stochastically dominate those from conventional technologies. This implies that the value added by financing is greater with new technologies compared with conventional ones. It is easy to demonstrate that technology choice may change if the value added due to financing decisions is ignored. Another corollary is that product flexibility can increase the firm's ability to finance with debt.

Both of these discussions yield a significant conclusion: to maximize firm value, technology choice and financing decisions should be made jointly. Thus, a general manager needs to understand both finance and operations to make financing decisions.

2.4 The Organization of Operation and Interactions With The Firm

How the operations function is organized, evaluated and controlled often has a large impact on firm profitability. Operations performance is often assessed using accounting and non financial data. Operations also has significant formalized interactions with other functions such as marketing and information systems that need to be monitored and controlled. Because operations consumes a very large percentage of a firm's expenditures and assets, major organizational changes and improvement programs such as JIT or TQM can have a large impact on firm performance. Economics based models can be useful in exploring these issues. In my own classes I discuss the choice of operations performance measurement systems and total quality management programs.
Teaching about operations performance measurement can be difficult because there is little data as to what measures are actually used to control and monitor operations performance. The paper Karmarkar, Lederer and Zimmerman (1990) may be useful; it reports the use of different operations measures using a survey and five case studies.

The cost center organization has become the most common one for manufacturing operations. Recently, quick customer response is becoming increasingly important to firms. Therefore, it is valuable for students to understand cost center performance evaluation when long lead time increases production cost or reduces demand. In addition, I teach about how operations managers ought to be evaluated when there are agency costs due to manager's effort and control costs due to inaccurate marginal cost estimates. This analysis is found in Lederer and Rhee (1996). An interesting finding is that lead time generates overhead costs which add to the firm's fixed cost. Most often, firms use average cost to estimate marginal cost. Thus, it can be shown that more accurate marginal cost estimates (and better production decisions) occur when lead time is removed from the production process. Thus, two benefits of just-in-time (JIT) and business process reengineering (BPR) that are not usually recognized are accurate estimates of marginal cost and superior general manager decisions.

Recently, quality management has become a significant issue for American industry. Research is required to understand the economic basis of TQM so that rational business decisions can be made. Although many state that “quality is free,” my own view is that quite often “quality is a positive NPV project.” This emphasizes that any improvement program has costs as well as benefits. It is helpful to teach students what the costs and benefits of these programs are. A good survey of benefits is found in Kolesar (1990). However, economic models are effective in translating these benefits to bottom line impact.

To this end, Lederer and Rhee (1995) presents two models of the economic impact of total quality management. In the first, quality management is viewed as a technological innovation that
requires investment. The effect of quality on market competition is studied. I demonstrate to my students that when all firms quickly adopt quality technology, returns of such investments are normal, that is, have a zero net present value. However, firms that do not invest in quality are forced from the market. On the other hand, a firm that is faced by competitors slow to adopt quality technology can earn positive returns by early adoption. This firm invests more in quality and produces higher quality products, charges a higher price and earns higher profits than competitors. Evidence shows that these advantages persist over time. The results are confirmed in an empirical study by Easton and Jarrell (1995). Another benefit of TQM is elimination of incentives for “functional silos.” In the second model, I show that firm value increases by aligning incentives when customer satisfaction is used as an objective. This explains the common use of customer satisfaction measures in TQM programs.

2.5 Time-Based Competition

Response time is an increasingly valuable strategic weapon in the arena of global competition and has become a standard topic in operations strategy. Many companies seek to introduce products quickly and to respond to customers in minimum time. Some relatively simple models such as Lederer and Li (1997) can provide insights about when a firm ought to adopt a quick response strategy. Economic models can capture the effect of responsiveness on prices, customer demands and firm profit. Results counter to conventional thinking are easily seen. For example, a firm may use its ability for fast production to operate at high capacity utilization, lengthening its response time but reducing its costs! This is a basic point that is often ignored in the strategic literature by time based competition “gurus.” I also explain why firms that jointly serve several types of customers tend to match prices and delivery times for each type.
3. Conclusions:

This paper has described several economics related models that can be used in operations management teaching. Although my discussion is largely limited to my own work, I hope that these examples illustrate how economics models can bring new ideas into the operations classroom.

Although I have focused on economics, I wish to emphasize that many other disciplines are necessary for a full understanding of operations strategy. The other business functions, especially finance, marketing, accounting and human resources, are necessary to understand business impacts of long term operations decisions. This knowledge, combined with an understanding of cost modeling (using OR) and market impacts (using economics), will reveal the true effect of operations decisions.
4.0 References


Figure 1: Assume that firm A and B's locations are fixed and that they compete in price. In equilibrium, Firm A will set its delivered price as shown. Its profit contribution is the shaded region, which is the amount by which its presence reduces the total cost of both firms of serving the market.
Data:

\[ D_j = \text{Demand requirement for customer } j \]
\[ S_i = \text{Capacity of Plant } i \]
\[ c_{ij} = \text{Cost/unit supplied to customer } j \text{ from plant } i. \]

Decision variables:

\[ x_{ij} = \text{amount of product supplied by plant } i \text{ to customer } j \]
\[ y_i = 0 \text{ or } 1 \text{ depending if plant } i \text{ is open or not.} \]

Three Facilities Sites: West Bend (i=1); Winchester (i=2); and Baraboo (i = 3)

Five Customer Regions \( j = 1, 2, 3, 4, 5 \), with representative cities, Fresno, St. Louis, Dallas, Pittsburgh and Savannah, respectively.

Problem: \[ \text{Min } \sum_{i=1}^{3} \sum_{j=1}^{5} c_{ij}x_{ij} + \sum_{i=1}^{3} F_i y_i \]
subject to

\[ \sum_{i=1}^{3} x_{ij} = D_j \text{ for all } j = 1, \ldots, 5 \text{ and } \sum_{j=1}^{5} x_{ij} \leq y_i S_i \text{ for all } i = 1, 2, 3 \]
\[ x_{ij} \leq D_j y_i \text{ for all } i = 1, 2, 3 \text{ and } j = 1, \ldots, 5 \]
\[ x_{ij} \geq 0 \text{ for all } i = 1, 2, 3 \text{ and } j = 1, \ldots, 5 \]
\[ y_i = 0 \text{ or } 1 \text{ for } j = 1, \ldots, 5. \]

Estimated transportation Costs; \( c_{ij} \) to typical location in each of the 5 regions:

<table>
<thead>
<tr>
<th>Facility</th>
<th>Fresno, CA</th>
<th>St. Louis</th>
<th>Dallas, TX</th>
<th>Pittsburgh, PA</th>
<th>Savannah, GA</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Bend</td>
<td>$30.48</td>
<td>5.31</td>
<td>14.00</td>
<td>17.08</td>
<td>16.49</td>
</tr>
<tr>
<td>Winchester</td>
<td>34.11</td>
<td>4.83</td>
<td>12.35</td>
<td>13.92</td>
<td>8.28</td>
</tr>
<tr>
<td>Baraboo</td>
<td>31.17</td>
<td>6.00</td>
<td>14.69</td>
<td>17.77</td>
<td>17.18</td>
</tr>
</tbody>
</table>

| %Total Demand | 14.5% | 25.7% | 6.6% | 41.1% | 12.1% |
| % of US Pop.  | 17%   | 18%   | 9.5% | 33%   | 21%   |
| Demand/Region | $34.8 M | 61.68M | 15.84M | 98.64M | 29.04M |

Assumed Fixed Facility Costs:

<table>
<thead>
<tr>
<th>Facility</th>
<th>Capacity/Shift</th>
<th>NPV Fixed Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Bend</td>
<td>1.02 M pallets</td>
<td>0</td>
</tr>
<tr>
<td>Winchester</td>
<td>.523 M pallets</td>
<td>$5.5M</td>
</tr>
<tr>
<td>Baraboo</td>
<td>.525 M pallets</td>
<td>$6.2M</td>
</tr>
</tbody>
</table>
Figure 2a: Math Program for Zodiac's Problem
In Zodiac:
Assume that total demand per year is given by

\[ \text{Demand} = 7392 - 43.27 \text{ Delivered Price} \]

This was estimated from the actual demand data by region.

Assume, with delivered price held fixed, demand is proportional to population.

**Zodiac Demand and Profit as a Function of Pricing Policy and Price**

<table>
<thead>
<tr>
<th>Pricing Policy</th>
<th>Pallets Sold/Year (Thousands)</th>
<th>Profit NPV (Thousand $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform Price ($/pallet)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$90</td>
<td>3895</td>
<td>$628</td>
</tr>
<tr>
<td>100</td>
<td>3018</td>
<td>1059</td>
</tr>
<tr>
<td><strong>110</strong></td>
<td><strong>2591</strong></td>
<td><strong>1392</strong></td>
</tr>
<tr>
<td>120</td>
<td>2164</td>
<td>1204</td>
</tr>
<tr>
<td>130</td>
<td>1740</td>
<td>1145</td>
</tr>
<tr>
<td>FOB Price from Warehouse ($/pallet)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$80</td>
<td>3231</td>
<td>$961</td>
</tr>
<tr>
<td><strong>90</strong></td>
<td><strong>2803</strong></td>
<td><strong>1224</strong></td>
</tr>
<tr>
<td>100</td>
<td>2377</td>
<td>1196</td>
</tr>
<tr>
<td>110</td>
<td>1950</td>
<td>1182</td>
</tr>
</tbody>
</table>

Figure 2b: Comparing FOB and Uniform Pricing for Zodiac. The analysis shows that profits are maximized using uniform prices of $110/pallet.
Figure 2: In any service system, the design of the delivery system affects the firm's costs and demand. This is particularly important in network based services.
<table>
<thead>
<tr>
<th>Beta of Demand</th>
<th>Conventional Technology (%)</th>
<th>FMS (%)</th>
<th>Conventional Technology (%)</th>
<th>FMS (%)</th>
<th>Conventional Technology (%)</th>
<th>FMS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>11.2</td>
<td>7.5</td>
<td>8.9</td>
<td>7.3</td>
<td>8.2</td>
<td>7.3</td>
</tr>
<tr>
<td>0.2</td>
<td>17.0</td>
<td>9.0</td>
<td>12.0</td>
<td>8.7</td>
<td>10.5</td>
<td>8.5</td>
</tr>
<tr>
<td>0.3</td>
<td>23.0</td>
<td>10.5</td>
<td>15.1</td>
<td>10.1</td>
<td>12.8</td>
<td>9.8</td>
</tr>
<tr>
<td>0.4</td>
<td>30.0</td>
<td>12.0</td>
<td>18.4</td>
<td>11.4</td>
<td>15.2</td>
<td>11.1</td>
</tr>
<tr>
<td>0.5</td>
<td>37.5</td>
<td>13.5</td>
<td>22.0</td>
<td>12.8</td>
<td>17.7</td>
<td>12.4</td>
</tr>
<tr>
<td>Breakeven Point</td>
<td>83.0</td>
<td>44.0</td>
<td>70.0</td>
<td>38.0</td>
<td>61.0</td>
<td>33.0</td>
</tr>
</tbody>
</table>

Breakeven point is expressed as a percentage of the average demand of 440,000 pieces per year.

Table 1. Comparison of the Discount Rates for Evaluating the Conventional Technology and the Flexible Manufacturing System (FMS) for Various Values of Beta of Demand and Selling Prices of Output. Note that FMS always has the lower discount rate, independent of the beta of demand (which measures demand uncertainty) and the price of output. Source: Lederer and Singhal, 1989.