Issues in Economic Justification for Flexible Manufacturing Systems and Some Guidelines for Managers

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Information technology has enabled substantial automation of manufacturing functions by way of computer integrated manufacturing and flexible manufacturing systems. These systems offer many benefits but also require substantial long term capital investment. Traditional cost accounting and capital budgeting techniques fail to fully justify installation of these systems. A substantial quantity of literature in this field is reviewed to come up with the existing state of affairs in manufacturing automation and economic justification of flexible manufacturing systems. Economic justification of flexible manufacturing systems on broader basis than provided by traditional methods appears to be not only desirable but also imperative for manufacturing firms going in for them. Based on literature review, some guidelines have been culled for managers to enable them to invest in these systems on a more rational basis and with more confidence. A bibliography of articles and research papers provides further references and readings to practitioners in this area.

In the beginning of this century, manufacturing was revolutionized with the introduction of “transfer line” technology for mass production where, basic inputs are processed in a fixed sequence of steps using equipment specifically designed to produce a single standardized product in extremely large quantities for extended periods of time. In the late twentieth century, there is again a revolution in manufacturing. The specialized, single-purpose equipment that characterized transfer lines is being replaced by flexible machine tools and programmable, multi-task production equipment. These systems provide a wide range of benefits including great improvements in quality, customization of products, extremely high output efficiencies of production in very small batches, etc. At the same time, these systems are expensive and require a commitment of sizable funds for a long time to implement them. The question of economic justification of these systems assumes importance in this context.

Flexible Manufacturing System (FMS) is an integrated system of machine tools and material-handling equipment designed to manufacture a variety of parts at low or medium volumes. It can also be viewed as an integrated system for automatic random processing of work units through various workstations in the system. FMS actually is an umbrella term, which in turn refers to flexible assembly, fabrication, machine and welding systems. An FMS is characterized by its ability to process many variations within a single-product family as well as ability to make rapid extensions of an existing product line.

There are many motivations for adopting FMS. These are:

• Cost Reasons
• Lower inventory levels
• Reduced labor costs
• Reduced scrap and rework
• Reduced floor space requirements
• Reduced information tracking costs
• Time Reasons
• Sizable reductions in production-cycle times due to:
  • The ability to route around bottlenecks and machine
breakdowns
• Lower set up times
• Reduction in fixture and tooling errors
• Reduced human intervention in all phases of manufacturing
• Marketing Reasons
• Shorter delivery times
• Ability to maintain production of low-volume products
• Ability to make rapid changes in product mix and volume to accommodate market shifts
• Quicker introduction of new and modified products
• Quality Reasons
• Very high first-time-through quality levels
• Maintain high consistency levels with which parts are processed
• Technology Reasons
• Creates or maintains a competitive advantage
• Desire to experiment with new technology
• Desire to be on the technology frontier

Different firms acquire FMS for different reasons. Usually, a common reason is competition from other firms. With increased customization of products, the firms which can deliver the desired product to customers at the right time, in the right quantity and at the right price turn out to be winners. Time, quality and meeting customer requirements are the main reasons for adopting FMS.

There are a number of positive consequences as also a few negative consequences associated with adopting FMS. Based on a survey of twenty US firms (Forster and Horngren, 1988.), these consequences are:

• Positive consequences of adopting FMS:
• Reductions in direct labor ranging from 50 percent to 88 percent;
• Increase in machinery efficiency ranging from 15 percent to 90 percent;
• Reductions in production-cycle time ranging from 30 percent to 90 percent and;
• Reductions in floor space ranging from 30 percent to 80 percent

A survey of thirty UK engineering companies reported the following (Forster and Horngren, 1988):

• Mean reduction in work in process of 68 percent; and
• Mean increase in machine use from 40-50 percent with conventional machine tools to over 90 percent with FMS.

Other benefits of adopting FMS are:
• The ability to produce a wide variety of products in a wide range of volumes.
• The ability to respond quickly to customer demands and product design changes.
• The ease of adding new members to a product line and accommodating a change in volume in existing products.
• Vastly improved product quality; almost zero defect in some cases.
• Less setup time because of better computer scheduling and setups performed at the load/unload station instead of at each machine.
• Better information on production, system utilization, tooling, maintenance and the like.
• Negative consequences of adopting FMS.

Four main classes of negative experiences have been reported:

• Cost related. This class includes dramatic underestimation of the cost of installing the FMS, not being able to eliminate the labor time predicted in the proposal, and not achieving the planned machine use.
• Time related. Long delays in making the FMS operational have been reported by several firms.
• Technology related. This class includes break-downs in hardware (e.g. automated guided vehicles, machines, and tools) or software (e.g. tool record programs and system supervisory programs).
• Labor related. Problems with labor unions have been reported at many firms.

Usually protracted negotiations over labor issues delay the implementation of FMS. Because of so many benefits of having FMS, a number of firms have adopted and are in the process of adopting them. As reported by Ranta and Tchijov (1990), FMS can be divided into two categories: compact systems costing less than US $4 million and high-efficiency systems costing more than US $5 million. A typical compact system consists of 2-4 CNC-tool or machining centers, conveyor and/or automatic storage and retrieval systems and two robots for material handling and a programmable controller for systems control. A typical large scale system consists of 15-30 CNC-tools, automated guided vehicles and an automated storage and retrieval system for material handling, a local area network and distributed microcomputer based cell and machine control systems and usually two VAX-type computers for coordination, scheduling and database management. It usually has a backup computer system and a software system for the coordination of the systems. According to this study in spring 1989 there were around 1200 flexible systems worldwide and at least a 15% annual growth rate of FMS population is predicted for the rest of this century. The number of implemented FMS and estimated numbers in future is given in Table 1.

Based on 293 documented cases, Table 2 shows the FMS distribution over investment (Ranta and Tchijov, 1990).

In 1985, there were approximately 50 fully computerized FMS installations in the United States. By 1990, close to 300 complete FMS installations were expected to be operative. In
addition, 250 flexible manufacturing cells (compact systems) were in operation in 1985 and their number was expected to rise to 1900 by 1990. The major U.S. users of FMS are the automotive, aerospace, defense, and construction industries (Bennett and Hendricks, 1987). Investment in automation by American manufacturers has been on the rise. In 1987, this investment went up by $17 billion (Forster and Horngren, 1988). In 1964 there were fewer than 100 graphics terminal installations in the United States. By the end of 1985, the level had reached 8.8 millions with an annual growth rate of 30%. In 1987 there were about 6000 CAD/CAM systems and more than 80,000 workstations in operation (Bennett and Hendricks, 1987). As reported in Ranta (1990), the growth rate in new installations has been 20%-25% towards the end of 1980s and even after considering a saturation of the diffusion process as well as application barriers, the growth rate is expected to be at least 15% through the end of this century. The main reason behind adoption of automated manufacturing systems has been to boost productivity and to remain competitive in the world market.

**Economic Justification: Traditional Methods**

One major problem associated with the adoption of FMS has been their economic justification. Traditional cost accounting methods are either inadequate or fail completely when used for accounting for FMS. In one instance when the traditional cost accounting methods were used, the company found that it was beneficial for it to farm out certain parts and retain the others. In actuality, it should have been just the opposite (Bennett and Hendricks, 1987). When a traditional cost-benefit analysis is done for FMSs, these systems are doubly disadvantaged: while calculating the cash outflows and inflows, discounted cash flow technique unduly penalizes these long-term projects and at the same time major benefits of adopting these systems like flexibility of switching from one product to another, improved quality, reduced throughput and lead-times, etc. are not considered.

There are a number of reasons why traditional cost accounting methods fail when applied to FMS. The principles of current cost-management systems were laid down soon after the Securities Exchange Act of 1934 in an era when labor was the chief variable cost. Then mass production was the theme and Frederick W. Taylor’s time and motion studies were the paradigm of efficiency. That system served its purpose fully and the U.S. industry came up at the top in the world. Now the scene has made a U-turn. Automation has brought direct labor down to 8% to 12% of total production costs at an average. It is much less in electronics, which is America’s fastest growing and third-largest industry. This trend is demonstrated by a company like the Beckman Instruments Inc. which has eliminated labor as a separate cost category and merged it with other overheads (Bennett and Hendricks, 1987). Apart from its emphasis on allocating overheads based on direct labor, traditional cost accounting methods are inadequate to account for FMS because of their inability to fully or even partially account for some major benefits of FMS like reduced inventory levels, reduced floor space requirements, reduced scrap and rework, flexibility, improved quality and reduced throughput and lead times. There is every indication that as manufacturing becomes more and more automated, these benefits will become more pronounced and will provide vital competitive advantage to firms. These traditional financial evaluation models are more suited to short-term profitability goals rather than long-term strategic goals (Miltonburg, 1987).

Another issue related to economic justification of FMS is product costing. These systems, as has been pointed out, are characterized by their capability to produce diverse products and in small lot sizes. Traditional product costing systems allocate overheads on some direct basis like direct labor, machine hours or material dollars. This cost accounting system works well for machine systems that produce a single product in large quantities. For multiple product-low volume systems, such a costing system returns highly distorted product costs. Traditional or volume based costing, in fact over-costs high-volume products and under-costs low volume products (Cooper, 1988). Obviously, such a distortion works against economic justification of FMS which specialize in diverse and low volume products. This aberration in product costing can be corrected by resorting to an Activity Based Costing System (ABCS). Activity Based Costing Systems focus on activities rather than products. They use secondary bases other than direct labor, machine hours or material dollars for allocation of overheads. These bases include setup hours, number of setups, material handling hours and the like. Consumption of these bases varies directly with the number of items produced and

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**Table 1: Implemented and estimated FMSs**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total No.</th>
<th>Compact Systems</th>
<th>High-efficiency Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>80</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>1988</td>
<td>1000</td>
<td>800</td>
<td>200</td>
</tr>
<tr>
<td>2000</td>
<td>3000</td>
<td>1600</td>
<td>1400</td>
</tr>
</tbody>
</table>

**Table 2: FMS Distribution Over Investments**

<table>
<thead>
<tr>
<th>Investment (Million US dollars)</th>
<th>No. of FMS</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>188</td>
<td>64%</td>
</tr>
<tr>
<td>5-10</td>
<td>68</td>
<td>23%</td>
</tr>
<tr>
<td>10-15</td>
<td>17</td>
<td>6%</td>
</tr>
<tr>
<td>15-20</td>
<td>17</td>
<td>4%</td>
</tr>
<tr>
<td>&gt;30</td>
<td>9</td>
<td>3%</td>
</tr>
</tbody>
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thereby returns much accurate product costs.

The traditional cost accounting practices have their basis in discounting procedure for evaluating investments in long-lived assets. These procedures became widely adopted in corporations during the mid-1950s. There are many reasons to believe that discounted cash flow (DCF) techniques may not be fully adequate to evaluate important corporate investments like in FMS. Some of the principal reasons why DCF techniques may not be fully adequate to justify investment in FMS are:

1. **Inaccurate Cash Flows:** Any alternative to new investment assumes that the present cash flows can be maintained with no investment in new technology. A better way of looking at this situation will be that if a new investment is made in technology now, the future cash flows will be improved due to lower labor, material or energy costs, better quality, etc.

2. **Piecemeal Development:** The capital approval process for many companies specifies different levels of authorization as a function of the size of the request. This creates an incentive for managers to propose a series of small projects instead of going in for a major investment in technology. Because of this the division or the company never gets the full benefit from a completely redesigned and re-equipped plant. As an alternative to this piecemeal approach, the company should forecast the remaining technological life of the plant and then accept any process improvements that will not be repaid within this period. At the end of the specified period, the old facility would be scrapped and replaced with the new one with latest technology. It is possible that the collection of incremental decisions could have a lower net present value than the alternative of deferring most investment during a terminal period, earning interest on the unexpended funds, and then replacing the plant.

3. **Quality Benefits:** It is necessary to measure all the benefits from the new process. It is especially necessary to measure the benefits mentioned earlier and which are not tracked well by the traditional cost accounting and project appraisal systems. Benefits accruing out of reduced inventory levels and reduced floor space are comparatively easy to measure. Quality improvements, which are a major source of tangible benefits from new technology investments are not so easy to measure. The opportunities for savings in quality can be estimated by first collecting information on how much the company is currently spending on producing, repairing, replacing, and discarding poor-quality items.

4. **Level of Precision:** Another point which has to be kept in mind while quantifying benefits mentioned above is that these savings can not be estimated with the customary precision from the financial and cost accounting systems. But this should not be construed to mean that difficult-to-estimate benefits are zero. For purposes of financial justification, less rigorous precision could be considered. This will be better than ignoring such benefits altogether.

5. **Flexibility Benefits:** Computer based process technologies provide very great flexibility in accommodating changes in product specifications, process improvements, schedule changes and implementing new products and variants on existing equipment. Such a capability permits efficient manufacturing at much smaller scale than before and even batch sizes of one can be run efficiently. The flexibility in FMS equipment gives it useful life beyond the life cycle of the product for which it was purchased. These benefits should be accounted for while justifying investment.

6. **Benefits Due To Reduced Throughput Time:** Successful adoption of FMS technology results in great reductions in throughput processing times. In some cases the processing times have been reduced to one or two days for products that formerly took months to process. Besides these dramatic reductions in some cases, other installations have reported time savings ranging from 50% to 95%. The obvious benefit of such a reduction in throughput processing time is by way of greatly reduced inventory. Other benefits are: (a) ability to meet customer demands with much shorter lead times and (b) an ability to respond quickly to changes in market demands. Both these factors will provide major marketing advantage to the company and the benefits flowing from that should be considered in any justification decision.

7. **Organizational Learning:** Another benefit of investing in new-process technologies which is ignored is opportunity afforded to the entire organization to learn about the capabilities of such processes. Thus, many of the start-up costs of any new project will eventually be shared by other projects which use similar technologies. An investment in
the training of employees in new technologies also gives the organization an opportunity to participate in future enhancements.

**Economic Justification: Alternative Methods**

Many organizations have realized the limitations of traditional accounting and capital budgeting methods, especially DCF method, in justifying investments in FMS. According to a Management Accounting survey (Hendricks, 1988), the alternatives and extensions to DCF and other guidelines which are considered by managers while accounting for FMS are:

1. Investments in FMS should be made in the belief that if the right strategic decisions are made, the future will be as good as the past.
2. Intangible benefits should also be taken into account and managers should try to quantify these benefits as much as possible. An educated guess about the value of these benefits is better than leaving them out altogether.
3. In conjunction with a DCF primary capital budgeting technique, payback may be a useful secondary technique because it indicates how long it will take to recover the initial outlay. The primary and secondary capital budgeting techniques used by the survey respondents to justify expenditures for factory automation are shown in Figure 1.

Some salient points which emerge from the above study are:

(a) Only about two-thirds of the respondents now use a DCF technique as a primary technique in justifying expenditure for factory automation and 14% do not use a DCF technique as either a primary or secondary technique.

(b) About one half of the respondents use payback as a secondary evaluation technique. Also, about one-half use subjective evaluation as a secondary technique in conjunction with a quantitative primary technique; the reason being that they may not be comfortable with their quantification of the more intangible benefits.

Ideally, all expected benefits and costs should be quantified and included in a DCF model when evaluating capital expenditures for factory automation. The benefits that survey respondents quantify and those they consider qualitative only are shown in the Figure 2.

**Quantification of Intangible Benefits:**

Most companies quantify the first five benefits listed in figure 2 because they are more tangible and easy to quantify. While justifying investment in FMS, first easily quantifiable benefits like reductions in labor, rework, material and inventory levels, cycle time, and capacity are considered only.

![Figure 1: Capital Budgeting Techniques (Source: Management Accounting, December, 1988, p. 25)](image1)

![Figure 2: Benefits of FMS (Source: Management Accounting, December 1988, p. 26)](image2)
tory costs need to be considered. If investment in FMS can be justified on the basis of these benefits alone, the management should go for it with confidence as many benefits ranging from reduced cycle time to improved quality have not yet been taken into account. However, if the project cannot be justified on the basis of easily quantifiable benefits alone, then other benefits should be evaluated before making a decision on rejecting the project. In conjunction with a discounted cash flow primary capital budgeting technique, payback may be a useful secondary technique as it indicates the time in which initial outlay will be recovered. Methods which need to be tried at this second stage of evaluating FMS make use of heuristics where experienced managers try to assign weights and valued to likely benefits. Use of probability factors for cash flows, sensitivity analysis, or other risk analysis techniques can be employed. Another rigorous evaluation method is the modeling method (Miltenburg, 1987). This method develops mathematical models for each manufacturing system. These models consist of both stochastic and deterministic variables and capture the important flexibility components for the particular problem. Simulation is another powerful method to study the cash flows and the effects of variables on the NPV of a firm, etc.

Based on the above discussion, steps needed for justifying investment in automated equipment can be summarized as follows:

1. The firm must consider its products, markets, customer demands, and domestic and foreign competition. This will help the company to determine its long-term strategic goals and the manufacturing strategy to achieve these goals. This strategy may or may not require investment in automated equipment.

2. If the firm comes to a conclusion that it is desirable to acquire automated equipment, the second step consists of listing all expected benefits and costs associated with the automated equipment.

3. The third step is to quantify those items listed in step 2 that can be estimated with a reasonable degree of accuracy, for example the first five benefits shown in Figure 2.

4. The fourth step is calculating internal rate of return or net present value and payback for those items quantified in step 3. These calculations may justify acquisition. If not, the next step should be considered.

5. Quantify the remaining benefits and costs using a team approach and risk analysis. Calculate internal rate of return or net present value and payback to determine if project is now financially acceptable.

These steps are shown in the flow chart in Figure 3.

**Conclusions**

1. Flexible Manufacturing Systems offer unprecedented promise in manufacturing discrete parts in mid-volume range.
These systems have grown at a fast pace all over the industrialized world and will continue to grow in the years to come. With increased customization and competition, these systems are expected to provide vital competitive advantage to manufacturing firms.

2. These systems are expensive and require long-term capital commitment. The benefits deriving out of the implementation of these systems are not easily quantifiable. This makes economic justification of these systems difficult. The popular DCF capital budgeting technique may not favor investment in FMS. This method needs to be extended or modified to fully justify investment in FMS.

3. Apart from the DCF capital budgeting techniques being unfavorable to adoption of FMS, traditional volume-based product costing techniques return distorted (lower) product costs for systems which produce multiple products and in small lot sizes. This can be corrected by switching over to Activity Based Costing Systems to get accurate product costs. Organizations which are considering adoption of FMS or already have one in place, should look at their product costing system and assess if they need to switch to an Activity Based Costing System. A series of four articles referenced in Journal of Cost Management (Cooper, 1988; Cooper, 1989) provide a good starting point for such an evaluation.

4. It is recommended that some of the techniques outlined in this paper and the literature should be applied to fully justify investment in flexible manufacturing systems.

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