Division of Research
Graduate School of Business Administration

REVISED May 1987

STRATEGIC DEPLOYMENT OF FMS IN DOMESTIC PLANTS: WHAT WE ARE LEARNING IN THE 1980's

Working Paper #515

John E. Ettlie
University of Michigan

Stephen A. Rosenthal
Boston University

Strategic Deployment of FMS in Domestic Plants:
What We are Learning in the 1980s[@]

April 1987
revised May 1987

Stephen A. Rosenthal
School of Management
Boston University
621 Commonwealth Avenue
Boston, Massachusetts 02215
(617) 353-4288

and

John E. Ettlie
School of Business Administration
The University of Michigan
Ann Arbor, Michigan 48109
(313) 936-2835

[@]Presented at the National Joint Meeting of The Institute of Management Sciences and the Operations Research Society of America (TIMS/ORSA), New Orleans, LA, May 4-6, 1987. Work in this area was supported by the National Science Foundation. The opinions herein are those of the authors and do not necessarily reflect the official position of the National Science Foundation.

Strategic Deployment of FMS in Domestic Plants:
What We are Learning in the 1980s

INTRODUCTION

At a time when flexible manufacturing systems (FMS) are being hailed as a solution to manufacturer's inability to compete, evidence is accumulating that the strategic deployment of FMS is likely to follow a rocky road. This paper explores some of the most significant contours of this managerial terrain by drawing on the findings from recently completed research by the authors, e.g., Graham and Rosenthal (1986, 1986a), and Ettlie (1987). Common emergent patterns in the findings of these two studies suggest that certain critical managerial roles are underplayed in the deployment of FMS. Furthermore, these managerial gaps lead to predictable shortcomings in developing and introducing FMS with the result that this new technology often does not have the intended impact on manufacturing performance. We believe that an enhanced sensitivity to the radical implications of FMS technology leads companies to adopt more appropriate, though more complex, deployment strategies and that in so doing they will obtain a better design for the FMS itself as well as for the production organization within which it will be embedded. Such insights are more operational than the findings of earlier studies which established the important, though more general, principle that moving toward the "factory of the future" is more a managerial challenge than a technical one (Rosenthal, 1984).

Our interest in this paper centers on a critical though largely neglected stage of new process innovation in manufacturing: one which is subsequent to the initial expression of interest and awareness in the new technology, yet preceding its installation and operational use. Included in this stage, which we call "deployment" is the formulation of a posture on flexible automation and a strategy for developing the desired capability. While the cases we have studied concentrate on FMS systems for machining metal parts, our discussion of deployment is also relevant to related flexible technologies at the cell (rather than sets of cells) level or in assembly (in addition to machining) operations.

Our purpose, in short, is to identify some constructive trends in the ways that U.S. companies are deploying flexible automation with an eye towards administrative reform associated with technological innovations of this type. This paper argues that it is important for management to pay attention to the dynamic requirements of introducing advanced manufacturing technology regardless of whether or not their organization seeks to achieve a complete computer integrated manufacturing (CIM) capability. This is especially true when companies simultaneously pursue other initiatives, besides automation, that are also intended as responses to international or domestic competitive pressures.

We begin by arguing that several traditional axioms for automating plants seem to be refuted by emerging evidence from recent deployments of computer based automation technology. We then move on to present highlights of why and how U.S. manufacturers approach these deployment programs. We conclude with a discussion of implications for management.

MODERNIZATION MYTHS

One of the exciting and challenging aspects of the evolving, globally oriented manufacturing strategies of this decade is that they attempt to exploit all of a firm's strengths. This typically means that both new technology and new administrative practices are being simultaneously installed in about half of these domestic modernizing plants. But the fine grain examination of these approaches reveals that it is by no means a matter of common sense or use of warmed over practices from earlier generations of management. In recent years there has emerged a widespread enthusiasm among U.S. manufacturers for experimentation with new technology and new organizational forms. In order to illustrate the counter-intuitive nature of this trend, four widely held "truisms" about automating are briefly examined below, and contrasted with the evidence that we have collected.

Myth #1: "High Tech is Likely to Fail"

One rather widely held belief about automation is that if you choose the high technology option in new manufacturing technology, you are likely to fail. That fancy robots with vision or complicated software for control or scheduling never work is, we have found, only a myth.

When held up to the light of evidence, there is simply no consistent relationship between the degree of sophistication in a new technology system and the overall success of a project. **It is true** that high technology projects require more preparation for things like new technical skills and, even more importantly, more creative management practices like effective ways to implement concurrent engineering with a team approach. However, we have found that high uptime, high cycle time, and low personnel turnover during modernization result from new administrative practices carefully installed and acclimated to evolving plant culture.

Myth "2: "Commitment to Training is the Solution"

Folk wisdom tells us that new technology fails because people weren't trained. However true, this wisdom is flawed in a number of important ways and needs significant qualification before it becomes part of a modernization strategy.

First of all, training does not in itself guarantee success. Ettlie (1983-1986) found that firms reporting high commitment to training for new technology deployment are also <u>less</u> likely to report that CAD/CAM integration is in their 5-year plan. This suggests that training is not a strategic modernization issue. What is more, implementation group members report higher stress in firms more committed to training. Perhaps this is because everyone is not trained equally. We have found that engineers and skilled trades are typically trained directly by technology vendors, while operators and supervisors are not. This is not an attempt to discourage training as part of a modernization strategy but to put substance in the fine-tuning of a human resource policy in transition firms. The source and type of training can be more important than the simple fact that "training has been provided." In addition, more than just training is needed. Management typically depends too much on training as a catch-all for all implementation problems.

In fairness, firms committed to training do report lower unexpected expenses with their new projects. This is most likely because when they do train these plants have fewer surprises, and, therefore, fewer budget overruns. When firms budget less than 10% of their modernization budget for training they jeopardize the program. Training is essential, but it has to be placed in an overall human resource development policy for modernization.

Myth #3: "There is one Best way to Modernize

Another myth of modernization is that there is one best way to do it. Platitudes like top down planning and bottom up implementation are typical of this thinking. We have found no relationship, per se, between the approach taken to decision making for modernization and ultimate outcomes. Rather, it seems necessary to tailor the decision making approach to the organization's history and context. Firms that take a conservative "cover all bases" approach (such as documenting needed tolerances, uptime, and physical part properties) typically have less experience with these technologies. Firms taking a calculated risk approach on the other hand, are more likely to have a group technology program in place, and understand integration of islands of automation in their modernization effort. In the short run, both approaches may have an equal chance of success, but in the long run, the actual targets for improved quality, cost, delivery and flexibility have to be taken into account. With few exceptions (e.g., use group technology, inventory control and design for manufacturing) there are very few recommendations we can make that are not contingent on the circumstances that a firm finds itself in as it begins to modernize.

The message is clear. If you are taking a risk with new technology (e.g., your first FMS), you will require a new strategy for modernization. If it's off-the-shelf automation, with the exception of a very large project, business as usual (i.e., no new strategy) is the rule-of-thumb. Most importantly, when the technology is new to the firm or, especially to the industry, new administrative practices are called for. The most common in the domestic plant studies (Ettlie, 1986; Graham and Rosenthal, 1986) is the use of engineer--blue collar teams and concurrent engineering teams comprised of representations from design and manufacturing. But the range of administrative experiments for modernization has also been impressive. Examples include quality circles for FMS design, compensation experiments rewarding cell managers and operators for uptime, exploitation of flexible assembly for Just-in-time (JIT) manufacturing and supplier qualification programs. All of these successful administrative experiments tend to be matched with the technology in terms of their degree of radicalness and tailored to the plant situation for installation.

Myth #4: "FMS is Flexible and Strategic"

The most overused and confused term in the world of advanced manufacturing technology is "flexibility." Many manufacturing managers use this term as if it meant "something valuable that is easily achieved by deploying an FMS." In fact, flexibility is an outcome of a large number of specific design choices and their is considerable confusion as to what types of flexibility are most appropriate for different companies to pursue (Graham and Rosenthal, 1986).

While most FMS users cite the importance of strategic dimensions of flexibility (product change and reuse of capital), this is rarely achieved. Instead, most FMS projects focus on achieving a different objective: the development of complex software and systems to enhance "defensive" forms of flexibility (being able to react to unanticipated changes in product mix, routing or volume). Achieving strategic manufacturing flexibility may be achieved through careful planning and design during the deployment of an FMS. It is also likely to require other simultaneous administrative initiatives. In many cases, deploying an FMS is not even the proper way to pursue strategic manufacturing flexibility. What's more, there are any number of other, more focused and specialized new manufacturing technologies (e.g., lost foam casting, near-net shape, etc.) that actually might return more on the manufacturing R&D investment. FMS has to be viewed as part of the total strategic investment equation of a business unit.

WHY DO COMPANIES PURSUE FMS?

Why do firms purchase new, often more flexible, manufacturing technology systems? In the domestic plant study (Ettlie, 1987) we asked key respondents this question at 39 locations where new, mostly FMS, systems had been recently installed or were being delivered. We repeated the question on two separate occasions of plants visits approximately one year apart. Answers were content analyzed and are summarized in Table 1 below. It should be kept in mind that these are preliminary results and not all the longitudinal data have been collected in these developing cases.

Table 1

The most frequently reported first or emphasized purchase rationale was PRODUCTIVITY ENHANCEMENT mentioned by 13 (33%) of the plant or firm representatives. This included reduction of labor costs, general cost control or productivity improvement. Even with the combination and pooling of several types of answers into this category, this most frequent response still falls short of even a simple majority. This coupled with the fact that 35 of these plants reported multiple reasons for adoption of these new technology manufacturing systems suggests a complex purchase decision process. For example, inventory reduction was mentioned in 8 cases at some point in the rationale for buying the new technology manufacturing system.

Tied for the second most frequent reported important reason for new processing technology adoption were LEARNING ABOUT NEW TECHNOLOGY and QUALITY with 7 mentions each or about 18% of the plants. In the former case, the majority of company representatives indicated the importance of manufacturing R&D or the equivalent in the decision making process. In the latter case of quality, most respondents said that quality was a driver for cost reduction which begins to hint at a causal model for modernization justification.

Tied for third as most important reason for adoption of new processing technology was the introduction of a NEW PRODUCT and COMPETITION with five (13%) mentions each. These reports of general reasons or rationales for new technology adoption are remarkably like dimensions typically recounted for measuring organizational effectiveness, which is not surprising.

BUSINESS UNIT CHARACTERISTICS AND DEPLOYMENT RATIONALE

There is no reason to believe that there is a direct and simple relationship between the adoption process and ultimate performance of new technology systems, or ultimate organizational effectiveness. Rather, it is assumed that there is a sequence of causality that spans the adoption process to the routinization process for significant modernization programs in manufacturing and planned organizational change in general. Data from the domestic plant study on firm and system characteristics were correlated with adoption rationales.

There appears to be a relationship between the rationale for adoption of advanced, flexible manufacturing technology and the type of firm deploying the new technology. Although these trends should be taken as preliminary, and there were some surprises, they confirm some earlier case history and empirical findings on modernization.

Productivity Rationale: A Problem

Although productivity enhancement is the most common rationale for new manufacturing technology adoption, it should be recalled that it is NOT reported in even a simple majority of Ettlie's current cases of modernization. Only about one-third of these cases emphasize it as an adoption reason. The report of this rationale tends to be associated with indicators of the quick-fix method of organizational change (e.g., higher unanticipated expenses, less through put time reduction, and lack of attention to CAD/CAM integration). Much more than productivity enhancement is at the core of recent attempts at strategic deployment of flexible automation in domestic plants.

Quality Enhancement is Strategic

Quality enhancement rationales, in contrast to the productivity focused change, tend to be associated with a long-range perspective on modernization and suggest a more thorough understanding of the relationship between cost, quality, and reduction in inventory. U.S. manufacturing managers are seeing FMS deployment as one approach to acquiring cost-effective quality enhancement. What's more, firms that understand the quality-cost relationship are significantly more likely to invest in a more radical new production technology and have a better working relationship with their technology vendor(s).

Come Back Strategies: Products and Competitors

Both new product launch and competitor driven modernization seem typical of firms mounting a comeback campaign in their industries using technology as a focus for change. Furthermore, it can be a mistake to think of FMS as being of interest for just one of these strategic reasons: when multiple strategies coalesce around the justification for expensive automation, a particularly persuasive case can be made for its deployment.

Inventory Reduction and Innovation Approaches

Firms that explicitly include inventory reduction in their rationale, regardless of priority, tend to take more risks with new technology, but are also more likely to use new organizational structures to implement change. Perhaps as many as 20% of our cases include inventory reduction as part of the backbone rationale for flexible automation, and the number appears to be growing rapidly.

Now let us turn from questions of why companies deploy FMS to those of how they do it.

INVESTMENT IN THE PLANNING PROCESS

A typical "lesson learned" that is reported by most firm representatives after the initial FMS experience is invest more in planning. This is a reminiscent echo of lessons learned from firms installing material requirements planning (MRP) systems in earlier decades. However, just investing more in planning is hardly a useful recommendation to inform a modernization strategy. What do we know specifically about planning for FMS?

In the Ettlie (1987) survey, firm representatives were asked how much was invested in up front planning for flexible automation. The average reported investment, as a percentage of the initial cost of the system was 5.3% with a standard deviation of 6.9% for 28 reporting cases. But the range was substantial. The lowest investment in planning was 1% and highest was 30% of the cost of the system! (It is not clear if this reported investment includes the technology vendor's engineering costs, but it is likely that it is limited to just the user's portion of the planning investment).

There were some significant correlates of investment in modernization planning. Firms using the greenfield approach were more likely to invest substantially in planning. One unexpected but positive outcome for a more limited number of reporting cases (16) was lower stress among team members in plants that invested more in the planning process.

The average system purchased in the Ettlie (1983-1986) study cost $3 million, so the average user planning investment was estimated to be $150,000, or about 5%. It is likely that if vendor planning and engineering were included, that this figure would double, so the investment in time, human and managerial effort is not insignificant for these projects in the 1980's.

The Graham and Rosenthal (1986) study of FMS procurement did not try to measure investment in the planning process that proceeded procurement of the new technology. However, during their in-depth case studies certain impressions were gathered on this subject. First, consistent with Ettlie's statistics on investment in planning, there is very likely to be great variability from company to company on the extent and type of planning that is performed.

For example, companies that saw the FMS procurement as an incremental step in their historical attempt to be at the forefront of such manufacturing technology tended to invest very little up front in planning related activities. A typical scenario here is that a trusted manufacturing engineer is asked to do a rather traditional cost-benefit analysis of the deployment of an FMS in comparison with more conventional equipment options. In such a situation the engineer would likely draw on existing plans for new product launches and projections of the demand for existing products that would need to be converted to production on the new FMS. In retrospect, one might criticize such companies for not taking the planning function more seriously, since those in smokestack industries turned out not to have begun to anticipate the severe downturn in their international businesses in the early 1980s and the resultant costs of getting committed to an expensive (over $10 millions) integrated system of manufacture premised on excessive estimates of required production capacities.

Alternatively, Graham and Rosenthal found instances where planning efforts, involved a considerable amount of time (more than a year) to capture and fully appreciate the strategic implications of a new FMS and what this would mean in terms of functional specifications for the technology and the manufacturing organization within which the FMS would be embedded. While such planning efforts were not always "costed out" it is clear that they were non-trivial (even in comparison with the procurement cost of the FMS) for they involved management at all levels and functions in the organizations, as well as staff specialists and others more attuned to the inherent operational issues arising from the introduction of an FMS.

Regardless of the level of planning for FMS deployment, we believe that two common shortcomings arose, one dealing with the elapsed time allowed for planning, the other with the range of assumptions explored in the planning process. First, we noted that senior management, having become supportive of the concept of FMS acquisition early on, tended to push their subordinates to shorten the planning period and move to the procurement stage by an artificially mandated time. This is an example of how the conventional wisdom to "seek top management support early" can backfire: cutting corners in the planning stage can incur very high costs when avoidable problems arise during procurement, installation or subsequent implementation. Second, we noted a tendency for planning teams to underestimate the human resource orchestration issues associated with FMS deployment. Recognition that the successful the deployment of flexible manufacturing systems requires advance consideration of new middle and lower level roles for workers has direct implications for the membership of planning teams and for their agenda. (Graham and Rosenthal, 1986a).

SIGNIFICANCE OF THE EXPERIENCE FACTOR

Technical experience is, of course, an important determinant of a company's decisions regarding the deployment of flexible manufacturing systems. To begin, the more "technical experience" senior management perceives the company to have, the more comfortable they will be in aggressively pursuing FMS as part of a competitive strategy. The reasoning here is quite simple: solid in-house technical experience is seen as a partial guarantee that the company can "make it happen", even though senior management lacks their own sense of the issues inherent in the deployment of FMS. Such trust in the organization's ability, based on prior successes, to introduce new process technology can strongly influence the decision to go ahead. (Graham and Rosenthal, 1986).

But how reliable are such judgments about the experience factor? Our research leads us to believe that particularly in the early-to-mid 1980s senior management of domestic firms could easily misjudge the relevance of their own company's experience for the pursuit of FMS. The reason, in short, was that much of what could easily pass for proven experience fell far short of what is really needed to strategically deploy FMS. Senior management could very easily come to believe that since their company had a long history of bringing numerical control (NC) and then computer numerical control (CNC) into their plants, that FMS represented the next incremental step in the evolution of flexible automation. It turns out, however, that FMS involves a significant leap ahead in technological terms and raises new challenges in areas such as materials handling, material consistency, job scheduling and routing, and the integration of information systems. It is relatively easy for senior management not to appreciate the gaps in prior technical experience when confronted with these types of challenges inherent in FMS technology. Chronic software maintenance problems are typical of almost every flexible system we have studied.

Another related type of misjudgment could arise even in the most sophisticated organizations. These firms may have understood that there was a need for a combination of automation skills and computer-related skills to successfully deploy FMS, but in some companies, senior management can commit a "fallacy of aggregation." Just because the company was strong in both automation on the shop floor and in all kinds of business data processing, it did not necessarily mean that they had adequate prior experience working together on complex problems of systems design and development. (This finding was also reported by Rosenthal and Ward (1985) in an exploratory study of issues in the pursuit of computer integrated manufacturing (CIM)). In summary, with an overly-simplified notion of relevant technical experience, senior management in leading-edge U.S. manufacturing companies launched many FMS projects without a realistic sense of the risks they were taking.

Ettlie (1987) found that firms reporting more experience with numerical control (NC) and computer numerical control (CNC) were much more likely to adopt FMS in order to expand capacity, and emphasized flexibility in the systems they purchased. Firms with this experience factor ultimately attained higher uptime on their new systems, but this was not automatic. These firms usually took a more calculated risk approach to modernization, and often used greenfield plants to install FMS, but they also took much longer to install their new systems. Firms with more experience with NC were more committed to training for modernization and invested more per plant employee on new technology systems. In short, these successful firms took more chances but ultimately tried to lower their risk by taking action to exploit their previous experience and learn more from deployment of this new generation of technology.

Subsequent to the strategic decision to pursue FMS technology, the experience factor arises, in another form. In the Graham and Rosenthal (1986) study, the importance of the concept of "usable experience" was identified. The point here is that while it is necessary for a company to have the right kinds, (both numbers and levels) of technical expertise, these conditions are not a sufficient condition for successful deployment of FMS. The FMS deployment effort also must have adequate access to these people at the right time and with the right level of intensity and interaction. The notion of access to technical expertise is not new; nor is it particularly profound. Yet we believe that more companies pursuing FMS have not come to appreciate the subtleties of usable experience. Manufacturing management needs to work harder to appreciate the difference between cosmetic and truly substantive interdisciplinary efforts at process innovation that are needed to get a synergy of planning impact. A minimum amount of cross-training and education is a must to accomplish multidisciplinary team management, but firms rarely prepare their people in this way.

Even when a company is relying heavily on an outside vendor to supply a FMS, there is an ongoing need, from the initial conception of the FMS through to its design and development, for technical work on the part of the manufacturer making this purchase. In the vast majority of the FMS installations that we studied, such internal technical efforts could be seen, in retrospect, as inadequate. What was most disappointing is that in most of these cases, the manufacturer had much more technical expertise available throughout the corporation than was constructively brought to bear on the procurement effort. When such experience was harnessed, it was often lost due to bumping, turnover or promotion. In other words, there was often the simple failure to value experience enough to make arrangements to hold onto it. For example, why is marketing so frequently excluded from this planning for flexibility?

Senior management was seldom aware of this knowledge shortcoming since such project management considerations were left to middle management after the go ahead decision had been made. In some cases, middle management did not recognize this problem because on paper the project team seemed to include the right mix of experts. Yet, the timing and nature of their varied inputs was often left to chance. (Team building ability was found to be the single best indicator of FMS project team manager performance by Ettlie.) Only after an in-depth investigation do some of the real shortcomings become apparent, such as the fact that large projects are not necessarily better than smaller ones (less substantive participation by more people). Furthermore, one of the apparent ingredients for successful procurement is a meaningful inter-disciplinary perspective to deal with a variety of hardware, facility, human resources and software considerations.

All of these observations lead us to caution management that the critical success variable is "usable experience" in the procurement project, rather than a more primitive accounting of technical expertise existing in the company. In particular, we believe that middle, rather than senior management is the proper audience to deal with this aspect of the experience factor. Fewer, smarter, better prepared middle managers are the key to successful manufacturing organizations of the future. Finding, assigning, and developing these people is a major challenge in the 1980's and 1990's. In firms moving toward further integration, these new middle managers will be much better prepared for general management, as well as for senior manufacturing management in the decade to come. (Lund, Rosenthal, and Wachtell, 1986).

Inappropriate images of relevant experience were also apparent in the selection of FMS vendors and supervisors. Vendors were frequently chosen based on their familiarity to the manufacturer ("We're worked with them for many years" or "We have lots of their machine tools in our plants and we're very satisfied so far".) rather with their existing skills at FMS development and installation. Supervisors, the first-line persons in charge of the FMS, were frequently chosen for their machining skills rather than for their computer literacy or worse, for political or seniority reasons. In both of these examples the confusion over the assessment of experience stems from treating

FMS as an incremental extension of conventional manufacturing technology, rather than as a radically new technology with significantly heightened prerequisites for success.

HOW WELL ARE WE DOING WITH FMS?

There is a fairly wide-spread belief that FMS has been a failure in the U.S. This may have been true in the more easily documented cases of the 1970's, but domestic firms have learned alot with their first efforts and we are now in a much better position to evaluate the outcomes of more recent efforts.

First, we have done much better with FMS in this decade than with stand alone automation, using almost every measure known to management. A recent survey of 20 FMS systems in the U.S. found that switching to FMS resulted in a direct labor saving of 50-88%, an increase in machine efficiency of 15-90%, and reductions in product cost of 25-75% (Manufacturing Engineering, March 1987). Ettlie found in two earlier studies of stand alone numerical control (NC) and computer numerical control (CNC) in the late 1960's and early 1970's that average utilization (time producing parts on a two-shift basis) ranged from 54-57%. Whereas in the most recent study of flexible automation (Ettlie, 1987) average utilization was 65% to 70% in preliminary data returns. More recent data shows this sample of plants doing even better, including improvements on measures of uptime, cycle time, quality and less rework and scrap. Throughput time reductions averaged about 40% on these flexible systems.

Yet, there is room for improvement. Jaikumar (1986) reports that Japan averages 85% utilization on FMS (two-shift basis), which is a goal for most FMS installations in the U.S. rather than a current reality. What's more, even when those levels are reached, total integration has yet to be achieved. Many managers are asking questions like how should a successful FMS be integrated into the plant work flow? Or, how can a FMS be utilized as a business unit? In one recent case of an FMS familiar to the authors, a post audit on the project revealed a return-on-investment well in excess of 40% but the firm is still very concerned about integrating design and manufacturing in their plant. There is still much to be done in flexible domestic manufacturing.

IMPLICATIONS FOR MANAGEMENT

Using Organizational Structure to Facilitate Successful FMS Deployment

The deployment of advanced manufacturing technology will be greatly facilitated by recent trends towards flattened organizational hierarchies. The existence of fewer levels separating the Vice President of manufacturing from those who work on the shop floor will facilitate the approaches to FMS planning and deployment that we found to be most successful. In other words, the reduction of administrative and staff personnel that accompanies recent attempts to make many U.S. manufacturers more responsive and more cost-competitive should also allow managers in these organizations to see more clearly how to better deploy new flexible process technologies. Yet, above all, it should be remembered that what people do in these newly created roles is far more important than how many jobs or levels exist in a unit.

Another emerging trend in organizational structure is the intentional destruction of traditional boundaries between the product design and manufacturing functions of a firm. The current impetus for such structural innovations is to achieve more communication between these functions, thereby enhancing the producibility of new products and effective procedures for the modification of existing products. The eventual advent of integrated design and manufacturing capabilities will require stronger working relationships between those on both sides of this traditional organizational fence. Even before then, however, the deployment of FMS will benefit from these new organizational arrangement as they facilitate the types of strategic planning and project management efforts that we have found to be essential yet so elusive at present.

Within a plant, organizational structure is also important. We found that FMS had the greatest chance of success if it could be supported with its own dedicated or partially dedicated services (e.g., maintenance, programming). This often represents a change from more centralized groupings of support services, but it recognizes the huge penalties incurred when a highly automated facility is down while waiting for the allocation of scarce support services. An alternative or parallel strategy for achieving this support is to upgrade operator and supervisor positions.

Acquiring and Using Critical Expertise for FMS Deployment

An obvious technical gap in most manufacturing organizations is the software and systems expertise needed to develop and support flexible manufacturing. Even if a manufacturer wishes to buy a "turn-key" FMS, internal expertise is necessary to develop its specifications, to monitor the vendor's progress and (most likely) to modify the software some time after installation. While hardware components are generally well developed and understood, knowledge about the integration of such components under computer control is usually lacking. Underestimating the need for in-house software and systems expertise has been a common lesson from FMS deployment to date in the U.S. in the first half of the 1980's. Since such expertise is both scarce and expensive there is no easy solution. Keeping experienced talent in this field from leaving the company for greener pastures may be even more difficult challenge to management than finding appropriate new recruits.

Another staffing implication of our studies is the increasing significance of engineering generalists, people who have experience both in product design and in manufacturing engineering. The strategic deployment of FMS depends directly on using manufacturing as a competitive weapon through the timely introduction of product changes and new products. The design of an FMS must reflect the specific kinds of flexibility that the company will need to accommodate such product modifications. For example, companies usually underestimate the software requirements of FMSs that will perform with the desired degree of flexibility. Communication on such matters, when limited to traditional specialists in either product design or manufacturing processes, is open to much more confusion and misinterpretation than if conducted by engineers with more generic backgrounds.

Individuals who have acquired project management experience in the deployment of FMSs are valuable human resources. Companies have to be more creative in finding ways to reward and retain such people, despite the lure of employment either with other manufacturers launching similar projects or with FMS vendors seeking to strengthen their own user orientation. Furthermore, beyond retaining project management expertise in-house, companies must find ways to effectively use such resources in planning and deploying future FMSs. While it seems logical that this would occur, there is frequently little evidence that an FMS user has successfully transfered technological know-how about FMS from one facility to another or even within that same facility in the same company. It appears that the more decentralized the company, the greater the likelihood of underutilized FMS project management experience.

Our studies point also to implications for the skill level of workers. The use of low skill operators who are given limited discretion in affecting the FMS calls for very elaborate software, thereby introducing new risks of failure and limitations on both the enhancement maintenance of the software. While many companies pursue FMS explicitly to take control away from touch labor, evidence is now emerging that flexible manufacturing systems require flexible people (Graham and Rosenthal, 1986a). Developing job specifications, selection mechanisms, training programs and promotion plans for such individuals represents a tremendous challenge in both union and nonunion environments. Team-based incentive approaches, particularly promising though potentially problematic, require special attention. We have found that each plant implements the team concept in its own unique way.

Finally our investigations lead us to emphasize the radical nature of change inherent in the successful deployment of advanced manufacturing technology. We concur with Jaikumar (1986) that modernization in an era of "post industrial manufacturing" is essentially a matter of planning and managing complex projects.

CONCLUSION

This paper has summarized some of the key related findings and associated implications from the authors' recent studies of the deployment of flexible manufacturing systems. The body of the paper was intentionally limited to discussions of FMS although the authors conducted their research in part to gain insights on the more general topic of computer integrated manufacturing (CIM). One common, broader insight from this work is that, like any precursor to CIM, FMS is highly interdependent with other manufacturing activities and related company functions. Hence the managerial challenges inherent in successfully deploying FMS by itself are compounded with the need to properly merge the FMS initiative with other ongoing reforms, both technological and administrative.

As we have reported above, companies have different rationales for adopting enhanced manufacturing technology. A significant role of senior manufacturing management in the next decade, therefore, will be to orchestrate their own sets of initiatives in combinations that form a coherent, sustainable strategy. Doing so will not be easy since many U.S. manufacturers have not yet learned to think in terms of combining technological and administrative initiatives to reach a planned stage of modernization.

Finally, appreciating connections between strategy and technology also need to be strengthened. In particular, senior management should be more aware of the strategic significance of FMS design decisions. Improved planning processes to avoid inappropriate design specifications requires senior management involvement. For example, as mentioned above, FMS projects are often focused on the development of complex software and systems to enable firms to react to unanticipated changes in product mix, routing or volume. The resources (money and scarce technical time) used to provide such "defensive" types of flexibility often come at the expense of limited attention to acquiring the more strategic types of flexibility (product change and the reuse of capital). We are hopeful, based on research, that increased attention to other managerial initiatives on the human resources side of manufacturing will provide a better foundation for accommodating all types of automation technology with the eventual there will be less need to invest so heavily in defensive forms of automated flexibility.

Successful Strategies for Modernization

Perhaps the most difficult thing a firm has to accomplish strategically is convert an FMS program in to a process for modernization. The most successful cases we have studied are the sustained, strategically oriented efforts where FMS is just one phase of a strategic effort. The failures come when FMS is isolated from strategy and a firm or plant only goes so far with a program to revitalize. The actual system usually performs at about average levels for U.S. manufacturing, and attention is then diverted to the next surprise or crisis. A strategy that matches the radicaliness of administrative practice and technological innovation is the key.

References

Ettlie, J. E., Synchronous Innovation, Forthcoming (San Francisco, Jossey-Bass).

Flynn, Michael, Personal Communication, 1986.

"FMS: Too Much, Too Soon," Manufacturing Engineering, March 1987, 34-38.

Graham, Margaret B. W. and Stephen R. Rosenthal, Institutional Aspects of Process Procurement for Flexible Machining Systems, Manufacturing Roundtable, Boston University, September 1986, 86 pp.

Graham, Margaret B. W. and Stephen R. Rosenthal, "Flexible Manufacturing Systems Require Flexible People," Human Systems Management, Vol. 8, No. 4 (Fall, 1986).

Jaikumar, Ramchandran, "Postindustrial Manufacturing," Harvard Business Review, Nov.-Dec. 1986, pp. 69-76.

Lund, Robert T., Stephen R. Rosenthal and Thomas Wachtell, The Manufacturing Executive in the 1990's: Advanced Technology and Management Skills, Center for Technology and Policy, Boston University, October 1986, 127 pp.

Rosenthal, Stephen R. and Peter Ward, "Technical CIM Issues: An Assessment for Management," CIM REview, Vol. 2, No. 1, Fall 1985, pp. 42-49.

Rosenthal, Stephen R., "Progress Toward the Factory of the Future," Journal of Operations Management, Vol. 4, No. 3, May 1984, pp. 203-229.

Table 1: Why Do Firms Purchase New Manufacturing Technology?

Reported Purchase Reason[#]		f(%)
1. Productivity Enhancement		13 (33%)
2. Learn About New Technology	(tied)	7 (18%)
3. Quality[&]	(tied)	7 (18%)
4. New Product	(tied)	5 (13%)
5. Competition	(tied)	5 (13%)

[#] The first, or most important reason or rationale. Only three of the 39 plant case representatives gave single reasons; 35 gave multiple reasons, and two cases were missing. For example, inventory was mentioned in 8 cases at some point in the response to the question "Why was the system purchased?"

[&] Most people reporting quality as the first or most important reason for purchasing the new technology manufacturing system said that enhanced quality would ultimately drive costs down.