FMS Implementation Management: Promise and Performance

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Published in:
International Journal of Operations and Production Management

Publication date:
1990

Received January 1989
Revised April 1989

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Introduction

At the present time, industry is confronted with ever-increasing customer demand for a wider diversity of products, faster product innovation, shorter delivery times and higher delivery reliability. Flexible Manufacturing Systems (FMS) are widely regarded as a major technological response to this need for increased flexibility. Since the development of the first FMS in 1962, a few hundred FMS have been installed worldwide. The number of companies that have experience in operating an FMS over a long period is very much smaller, so it is hardly known whether, and under what circumstances, the promises of FMS can be achieved. In this article a tentative answer to this question is provided, based on seven case studies of FMS implementation, for which operational experience varied between three and six years.

Before the account of this survey, however, some general remarks will be made on the supposed benefits of FMS, and factors that might promote or inhibit these benefits. After a brief description of the research design employed and the companies studied, extensive attention is paid to the goals defined by the companies when introducing FMS. The extent to which these goals were realised is described and then explained, by showing the effects of organisational measures that have or have not been taken, and the influence of other factors, such as technical problems, market changes during the FMS implementation process, and FMS design characteristics. Some recommendations for FMS implementation management conclude this article.

Flexible Manufacturing Systems

Definition

A Flexible Manufacturing System (FMS) is a group of NC machines or other automated workstations which are interconnected by a materials handling system. The system is controlled by computer and can work on several different workpieces simultaneously [1].

Advantages
FMS are designed to fill the gap between high production transfer lines and low volume stand-alone NC machines, thus supposedly providing adopters with the opportunity to meet demands for flexibility, quality and cost effectiveness simultaneously. Many publications highlight the strategic or marketing advantages of FMS. This is not surprising considering the manufacturing strategy "crusade" by authors such as Skinner [2], Hayes and Wheelwright [3] and Hill [4], who have advocated a more prominent role of manufacturing in corporate strategy. Krabbendam [5], on the other hand, suggests a more differentiated approach pointing out that organisations adopting FMS need not necessarily pursue market advantages, but may "just" be aiming at reduced costs of operations, improved production management, and other operational advantages. However, by adopting FMS, companies may achieve a wide set of (interdependent) goals [1,5,6,7], namely:

(1) *Improved market performance:* a more adequate and rapid response to market demand for product diversity, product innovation, customer responsiveness and aggregate volume; lower sales prices; shorter delivery times; higher delivery reliability; improved product quality.

(2) *Reduced cost of operations:* reduced direct labour or even unmanned operation; reduced indirect labour, overhead costs and floorspace; shorter processing, set-up and manufacturing lead times; reduced batch sizes and work-in-progress; increased machine utilisation.

(3) *Improved operations management:* linking of production control and automated manufacture; fewer human errors; increased scheduling flexibility; JIT manufacture; improved and consistent quality and productivity.

(4) *Spin-offs:* standardisation of product designs, tools and fixtures; more knowledge of AMT; improved logistics and quality management.

(5) *Other aims:* a step towards integrated manufacture and computer-aided design and manufacture (CAD/CAM); an improved company image.

Achievement of FMS Advantages
A few papers that have addressed success and failure of FMS implementations leave some doubt as to how the promises of FMS are realised in practice. Some authors conclude that market advantages arising from reduced changeover times, such as numerous product options and frequent modification, are difficult to achieve. Jaikumar [8], for example, reports that most FMS installed in the US show an astonishing lack of flexibility, and are used for high-volume production. Tombak and De Meyer [9] go even further by concluding that European and US firms are not adopting FMS to rapidly change their product designs, but to standardise their product lines, using FMS to reduce the effects of variability in demand on input requirements. Other authors, like Bessant and Haywood [7], however, report that many of the operational benefits of FMS, as well as market advantages such as shorter lead times and improved product quality, may indeed be obtained.

There is more agreement about the problems which may delay or even prevent the full benefits of FMS. These problems seem to fall in three broad categories, namely economic, technical and organisational [10,11,12]. The main economic problem is to financially appraise FMS, which are expensive. Some of the anticipated benefits and implementation costs are readily quantifiable in advance, but others are difficult to estimate; whilst conventional investment selection methods [13] and costing systems are often not capable of accurately assessing such factors [14]. Furthermore, the costs of operating FMS are difficult to determine, as standard costs of machining have traditionally been expressed in terms of direct labour hours rather than machining hours [10]. As a result, this lack of accurate data and the slow emergence of suitable financial justification methods, cause FMS adopters to continue to use reduced direct labour, floor space and work-in-progress, in formal financial appraisal, because they represent a familiar basis on which to make calculations [15], although they may not be objectives *per se*. In addition, many adopters' efforts seem to be aimed at meeting these goals, rather than pursuing the main issue, i.e. using the FMS to improve the company's market performance.

According to the literature, most of the technical problems are related to the immaturity and complexity of FMS, as it is a new, developing combination of different technologies, in which formerly separate items of hardware are put together and integrated with software applications and controls. Integration, though, is impeded by low levels of standardisation and lack of software protocols. Problems of compatibility, interfacing and standardisation in hardware and software may also arise well into the operating life of an FMS [11]. In addition, adopters often lack the technological knowledge to specify the most suitable system for their situation and to operate and maintain the system after installation.

Most of the benefits of and implementation problems with FMS seem to arise from the new type of organisation which FMS requires, rather than the technology itself. The introduction of FMS often causes a mismatch between technology and organisation [10], which, however, is often noticed only after implementation [7, 12]. In the literature, the use of just-in-time (JIT), total quality control (TQC) and preventative maintenance, CAD and computer-aided process planning (CAPP), Group Technology, and multi-skilled operators, besides changes in product and process design and in management attitudes, are recommended to reduce this mismatch [16]. The validity of some of these recommendations is supported by contingency theories [5].

So, by adopting FMS many advantages may be achieved, although economic, technical and organisational problems and prerequisites may prevent or delay the full benefits. A question which is left virtually unanswered in the literature, however, is how to manage the adoption of FMS in such a manner that implementation problems are prevented. In other words: what are the organisational measures that FMS adopters may take in order not only to achieve the goals set, but also to obtain them on time?

Using the cases described below, tentative answers to these questions will be provided by investigating the FMS-related goals pursued by the companies involved in this research, and the extent to which they were attained. An explanation as to why, or why not, companies succeeded in achieving the goals will provide the basis for some preliminary recommendations for the effective management of FMS implementation.

Research Design and Method

This article presents an extension of previous research into the introduction and operation of FMS. Earlier reports have described the anticipated advantages and future role of FMS [14], organisational consequences of introducing and operating FMS [17], organisational measures required to achieve goals set [5], and the progress and management of the FMS implementation process [12].

In this present research, data have been collected from 1984-88 to provide longitudinal case studies on the introduction and operation of FMS in three British, one Belgian and three Dutch companies. The main characteristics of these companies (size, products, markets) and the FMS which they selected, are shown in Table I.

The main research tool used in these companies was semi-structured interviews with manufacturing, process planning, production planning, quality control and maintenance managers; some of their subordinates; (future) FMS operators; and FMS project managers. Among the topics covered in the interviews were:

- general information about the company and its markets;
- quantitative and qualitative information about the manufacturing and other processes affected by operating an FMS, and the people involved in these processes;
- anticipated and realised consequences of the FMS for these processes and personnel;
- the goals set and the extent of goal achievement;
- features and management of the implementation process, including problems encountered.

Further, document studies (project reports, minutes of meetings) and participant observation (membership of project teams) were used, together with individual data feedback to the interviewees, and conferences to confront the Dutch and Belgian sample firms with each other's experience.

Goals, Priorities and Achievement

Within an organisation, opinions usually differ on the goals to be pursued when adopting a new technology and the relative priorities of these goals. As we felt that the FMS project leaders would be the "dominant coalition" [18] influencing the topics covered by this research, we mainly relied on their opinions about the goals and their relative priorities. These goals are summarised in Table II, together with the extent to which they were achieved.

The information presented in this table shows that market advantages have been the prime motive for investing in FMS for companies A and D only. Company C felt it could best achieve its main goals, namely cost reduction and JIT

Table I.
Details of FMS Installations Included in Survey

Company Designation	Company Size	Products	Market Demands	Type of FMS and Date of Installation	FMS Capabilities
Company A (UK)	1,900 employees	Coal mining equipment	Product quality and delivery time	Six CNC machines and AGV for component transport. Installed in 1984.	Production of 1,000 parts per year (mainly major castings), in 30 variants. Replaces 16 conventional machine tools and 2 CNC machining centres.
Company B (UK)	200 employees	Hydraulic systems	Price, delivery time and product modification	Two cells linked by conveyor and comprising: (a) 3 CNC machining centres; 1 CNC co-ordinate measuring machine, 1 washing station, one 5-axes robot for materials handling in cell (a) and inter-cell parts transfer; (b) pressing and drilling equipment, one 4-axes robot for materials handling in the cell. Installed in 1984.	Production of 100,000 sets of parts per year for 2 main types of pump. Conventional manufacture of these components would have required about 9 machines.

Continued

Table I *(continued)*. Details of FMS Installations Included in Survey

Company Designation	Company Size	Products	Market Demands	Type of FMS and Date of Installation	FMS Capabilities
Company C (UK)	1,050 employees	Engines	Price, product quality and delivery time	Three CNC machining centres and AGV. Installed in 1985.	Forecast output of 35,000 (mainly manifolds and thermostat housings). 3 main types and 200 variants. Replaces 12 conventional drilling, boring and milling machines.
Company D (Netherlands)	400 employees	Compressors and air conditioners for industrial refrigerating systems	Product modification, price and delivery time	Two CNC machining centres each having a pallet carousel. Installed in 1983.	Anticipated production of 36,000 parts per year (mainly major parts for a family of compressors). Replaced 10 conventional drilling, boring and milling machines.
Company E (Netherlands)	700 employees	Printing and finishing systems for textile, wallpaper and floor covering industries	Product innovation and quality	Two CNC machining centres interconnected by a railcar (AGV). Installed in 1985.	Forecast output of 42,000 components per year (mainly cubic in shape) in 315 variants. Replaced 4 CNC machining centres and 1 CNC milling machine.

Continued

Table I *(continued)*. Details of FMS Installations Included in Survey

Company Designation	Company Size	Products	Market Demands	Type of FMS and Date of Installation	FMS Capabilities
Company F (Belgian subsidiary of Dutch company)	400 employees	Truck axles	Delivery time and product modification	Two CNC machining centres. Installed in 1985.	Designed to produce 180 rear axle bodies per year, in 6 types and 64 variants. Replaces 20 conventional machine tools.
Company G (Netherlands)	400 employees	Truck engines	Delivery time and product modification	Six CNC machining centres, interconnected by an AGV. Installed in 1985.	Designed to manufacture 30,000 cylinder blocks and heads per year, in 4 main types. Replaces 4 conventional transfer lines, containing 100 machining stations in total.

Notes: (a) All of the systems listed above, with the exception of that installed in company D, are controlled by a designated FMS computer. In the case of company D, the system is linked to the company's central computer.
(b) All of the listed FMS capabilities were those intended at the time. See text for capabilities achieved in practice.

Table II.
Comparison between Intended and Achieved Goals

Goals	Companies A	B	C	D	E	F	G
Market Advantages							
— ease of product replacement			(*)				
— ease of product modification			(*)				(+)
— improved product quality	*[4]	+	(*)	+			
— shorter delivery time	0[1]	+[2]	0[3]	+[1]	0[2]		
— reduced sales price		0					
Operational Advantages							
Reduced costs/times							
— unmanned manufacturing			*[1]	*	*		
— reduced direct labour	*	+[3]	+[1]	*[3]	+[2]	+[2]	0[3]
— reduced overhead costs		(–)					
— reduced transport/handling		+		(*)		+	*
— higher machine utilisation	0	0	*	*	*		+
— fewer machines			+				
— higher output rate	–	–					
— shorter processing times		*	+				
— shorter set-up times	+	+	+[1]	*	*	*	0
— shorter lead times	+[1]	+	+[2]	+	0	–	–
— smaller batch sizes	(+)		(+)			*	
— lower stocks/work-in-progress	+[2]		+[1]	+[2]	0[2]	–[2]	–[2]
— reduced scrap and rework	+[4]	+	(+)				
— reduced floor space			(+)	(*)		+	
Improved operations management							
— JIT production			+[2]		0		
— constant/predictable quality	+		(+)	+			
— fewer human mistakes				+			
— flexibility of scheduling	+[3]		+				
— production in sets/manufacturing for assembly	0	+		(*)			
Other objectives/anticipated spin-offs							
— more knowledge of AMT					+		+
— standardisation of design/tools/fixtures	(+)	+		+	+		
— reduced cost of tools/fixtures		*					
— improved logistics management				(*)			
— application of latest technology/technological image	+	+	+				
— step towards further automation				0	*		
— new product launch		+[1]				+[1]	+[1]
— technical obsolescence of existing machines				+	+[1]	+[1]	

Key to Symbols

+ intended and achieved
* intended and partially achieved
0 intended and not achieved
– intended and not achieved, and the defined factor was worse than before FMS
(+) not intended, yet achieved (unanticipated spin-offs)
(*) not intended, yet partially achieved
(–) not intended but the defined factor became worse than before the FMS

[1,2,3,4] denote the importance attached to the above goals (e.g. shorter delivery time and lead times were the most important; and improved product quality and reduced scrap and rework the least important to company A).

delivery to assembly, by using FMS. For companies B, F and G, the prime motive was the launch of a new range of products which could be produced most cost effectively using an FMS. In company F, replacement of facilities was also necessary for technical reasons. This also applied to company E, which regarded FMS as the most cost-effective alternative. The emphasis on using an FMS simply to replace facilities that were technically obsolescent and/or unsuitable for the manufacture of a new range of products does not mean that market advantages cannot be eventually obtained. However, most companies involved in the research initially had to deal with other problems before achieving their prime goals, as discussed below.

Though most of the companies felt that the decision to invest in FMS had been the right one, Table III shows that none of them obtained all of the goals pursued. Companies B and C were the most successful firms in the sample, companies A, D and F were about half-way to goal achievement, whereas companies E and G still had a long way to go. Such a simplistic assessment, however, does not show *why* they had only partially succeeded, nor whether, and how, the expected benefits of FMS may be achieved eventually.

Barriers to achieving the goals set appear to fall into three categories, namely: technical problems, changes in the marketplace, and organisational bottlenecks. These barriers are described in more detail below, and analysed to form a basis for recommendations for FMS implementation management. Six of the companies reported that the problems impeded the achievement of return on investment (ROI) by the required time, and for most top managements ROI was the major criterion for deciding whether or not to purchase FMS.

Barriers to Goal Achievement

Technical Problems

At the end of the longitudinal study discussed in this article, most of the sample of companies were encountering technical problems which were significant barriers to goal achievement. Company A was operating part of its FMS in CNC mode because of faults in the construction of one of the machining centres. This machine, the bottleneck in the parts flow through the system, needed full-time attention, so anticipated reduction of direct labour had been achieved only partially. Due to still unresolved software bugs, company B had not finally accepted its system. Company D experienced all the problems one can think of in relation to a first generation manufacturing system, which has now been

Companies	A	B	C	D	E	F	G
Goal achievement (%)	54[1]	69	75	62	33	56	38

[1] i.e. Company A pursued 13 different goals, of which 7 goals (54%) have been achieved, not counting unanticipated spin-offs. The other goals have not been achieved as yet, or only partially achieved.

Table III. Achieved Objectives as a Percentage of Intended Objectives replaced by a completely new, third generation system, obtained from the same supplier. To date it is still not clear whether or not the technical problems are finally solved. Company E had software problems too, and decided to solve these problems first, before trying to further improve the system's performance.

It should be borne in mind, however, that the companies involved were relatively early adopters of FMS, and therefore among the first to deal with all kinds of technical problems related to the use of an immature technology. As FMS technology is now much more mature, future adopters will probably have far fewer problems of this nature. Yet, most FMS contain customised, one-off elements which are the most likely source of technical problems.

Changes in the Marketplace

Variations in market demand between FMS specification and implementation had significant effects on the utilisation of the company's advanced manufacturing systems. Companies A and B achieved only 50 and 20 per cent of anticipated output, respectively, as their market collapsed during the implementation process. Company A is still programming alternative products, but company B had not found alternative products by mid-1988 but was operating its FMS for one shift only, instead of the anticipated three shifts. Finding new products will remain a problem as this FMS has been designed for a relatively narrow envelope of components, and flexible manufacture of parts outside this envelope would require a virtually new FMS.

Companies C, F and G have encountered a higher demand than forecast, causing capacity constraint problems as the companies had aimed at a system utilisation of about 70-80 per cent. Moreover, in company F, set-up times appeared to be higher than specified, which accounted for a longer cycle time and a further reduced machining capacity. Company C was looking for possibilities to manufacture high-volume parts conventionally, thus giving up JIT delivery to assembly for these parts. Companies F and G were operating major parts of their old production lines to cope with their capacity problems, even though this increased lead times and work-in-progress, due to problems of integration between the existing facilities and the FMS. Annual volume of company G had reached a level at which conventional, dedicated manufacture was probably cheaper than using an FMS, so the company was considering the use of its FMS for manufacturing low-volume parts and start-up production of new variants only.

The findings indicate that the volume flexibility of FMS is limited, and depends on the extent to which the adopter allows for investment in overcapacity, on the one hand, and product flexibility, on the other. Many companies, and not only the ones in the sample, still retain the conventional manufacturing wisdom that machine utilisation should be as high as possible [16]. In itself this is not surprising, considering the high investment costs of FMS, which urge companies to make the best use of available capacity. Our impression is that in most companies a high level of machine utilisation is the overriding goal, and usually at the expense of flexibility. The risks that go with this attitude are very high if the company has difficulties in reacting to changing or slackening market demand by using the system to produce a wider range of parts; or if sales exceed available machining capacity, and the provision of additional resources is difficult, or entails great expense.

Organisational Barriers

The data previously presented in Table II show that the first concern of all companies was to pay back the expensive investment in FMS by pursuing *operational* advantages. These advantages, however, can only be achieved *partially* by implementing an FMS, and using the characteristics that distinguish FMS from conventional manufacturing equipment. Specific features of FMS are their technical flexibility (the ability to quickly change mix, routing and sequence of operations within the parts envelope), and complexity resulting from the integration, mechanisation, and re-programmable control of operations (parts machining, material handling and tool change). But, on the basis of contingency theories, Krabbendam [5] has shown that many organisational adaptations are required in order to fully obtain the operational advantages of FMS. The exact measures required depend on the technological characteristics mentioned above, the goals set, and characteristics of the adopting organisation. All of these variables may differ case by case. As will be shown below, in all of the cases encountered in this current study, full achievement of the original goals was delayed, as none of the companies had implemented prior to installation all of the organisational measures required to operate FMS effectively.

Figure 1 illustrates some of the interdependences between technological characteristics, organisational measures (including those of other technologies) and goals pursued. Reduced direct labour (especially if operations are unmanned) and increased utilisation of capacity, require optimised loading schedules, and smooth input and transformation processes, besides an integration and mechanisation of operations. This means that machine breakdowns need to be prevented, emphasising preventative, rather than curative, maintenance. If any breakdowns do occur they need to be solved quickly. Furthermore, the right amount of raw material, tools and NC part programmes need to be in place when operations are to start. To ensure that these inputs meet the required (usually high) quality standards, TQC-type systems must be applied.

Lead time and work-in-progress are reduced through the integration of operations, but further reductions require shorter set-up times and smaller batch sizes. The former may be easily achieved using the technical flexibility of FMS, but the latter requires the planning system to be able to schedule the supply of raw material according to manufacturing demands, and the manufacture of parts to actual, rather than forecast, assembly orders. Computer-based production planning systems are not always suitable for scheduling small batch manufacture on a day-to-day basis. In many companies, the use of JIT supply to and by the FMS offers more promise.

The complexity of FMS requires other and higher levels of skills since purchasing, operating and maintaining these advanced systems are more difficult compared with conventional machines, and the expertise required includes electronics and software skills, as well as mechanical engineering.

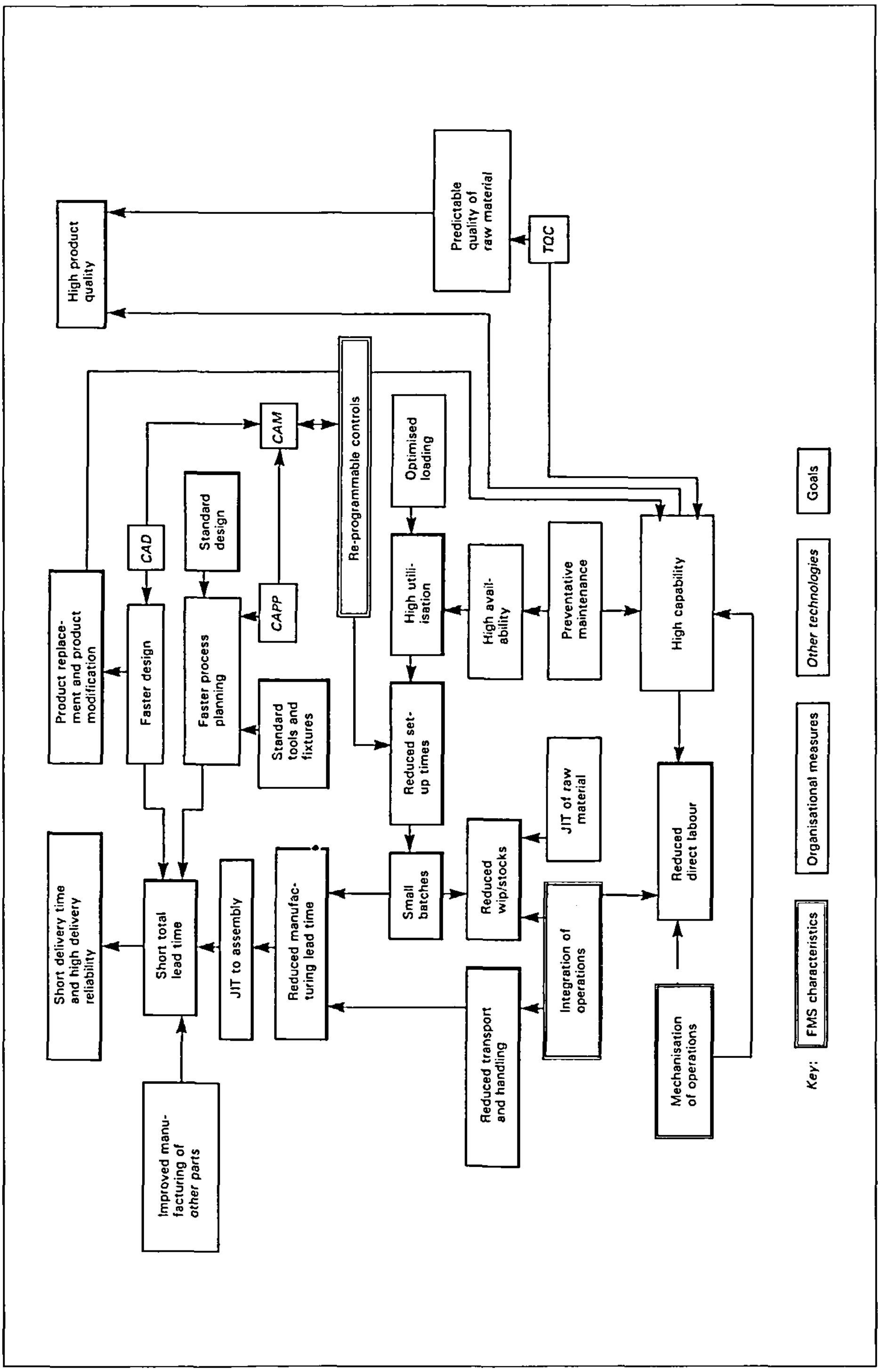

Figure 1.
Some Examples of Interdependences between Technological Characteristics, Organisational Measures, Other Technologies, and Goals Pursued by Introducing FMS

The implementation of all organisational conditions required to obtain the benefits of FMS leads to a very complex working organisation. We consider that the best way of coping with this complexity, while retaining the advantages that the system was purchased for, is the establishment of a semi-autonomous group of well-trained, multi-skilled operators, supported by a multi-functional working group to solve the problems of integration which are encountered. The alternative, in which each of the functional departments involved controls just the aspects for which they are responsible, is much more expensive and time consuming.

None of the companies was sufficiently aware of these prerequisites when they made their investment decision, and the system was perceived to be less complex and more compatible than it eventually turned out to be. The need to adopt FMS was perceived as a technical problem to be solved by process engineers who, in general, had only a narrow understanding of the organisational implications of FMS. The concerted contribution of manufacturing (the shopfloor), production planning, maintenance and quality control is also required in setting realistic operational goals and obtaining the organisational conditions indicated before. But, in most cases, these functions were insufficiently involved in the innovation process, and then too late.

Only after installation, when faced with problems related to the mismatch between organisation and technology, did the companies start to take organisational measures to try and meet the original goals set. All of the companies were implementing elements of TQC and JIT, but finding it difficult to get their suppliers to deliver just-in-time, according to specifications. All companies were adopting preventative maintenance, but found the complexity of FMS leading to very long learning processes. By late 1988, none of the companies had found a satisfactory answer to the question as to who (operators, maintenance engineers, suppliers) should do which maintenance activities, and how often. Changes in planning systems, such as planning the FMS on the basis of realised orders, using zero stock approaches (JIT) and optimised loading schedules to increase utilisation, were applied in companies A, C and D only. None of the FMS was operated by a group of multi-skilled operators, or supported by a multi-functional group of staff specialists. Attempts to improve the systems' performance were hardly co-ordinated, and learning was thinly spread and evolving very slowly. This was partly due to the companies' functional structure, which interfered with integral problem solving. It is not surprising that company C, which involved manufacturing (including the shopfloor), quality assurance, maintenance and production planning in its project team, was the most successful adopter in the sample. Even this company, however, has so far not managed to realise all of the organisational circumstances required to achieve all operational goals set.

For an FMS to contribute to a company's business success, at least two conditions must be met, in addition to operational success. In three cases only (A, B, D) the system is used exclusively to achieve the first condition, namely the reduction of a bottleneck in the production process. In all other cases design, process planning, or manufacture of other parts, were at least equally important with respect to required flexibility, quality, lead time or costs. Implementing an FMS in a non-bottleneck part of a production system may not therefore add to an improved overall market performance. Moreover, by installing an FMS, bottlenecks may move as in company A, where reduced manufacturing lead time was fully absorbed by increased process planning lead time. A second condition for contribution to business success is the the use of other technologies such as CAD, CAPP and CAM (either individually or in combination) in related processes which may significantly help in obtaining the innovation and modification flexibility of FMS, and reduce total lead time. But, whereas most of the companies are using some form of CAD, though in a stand-alone way, companies A, D and E were the only ones which use software in process planning, and none of the companies was using CAM.

To achieve both conditions, an integrated insight into and knowledge of the company's production system and market is required, that goes beyond the scope of traditional, functionally organised, operational management. In addition to the concerted effort of the several operational functions, the involvement of design, marketing and sales is also required, as these functions may help in assessing what production system (including FMS) is most appropriate for the company to improve its market performance. Conversely, there may be a need to adjust the company's market strategy to its new manufacturing potential. However, in none of the companies encountered in this survey were the product design, marketing and sales functions involved in the innovation process. Apparently, many of the top managements of the companies studied did not fully appreciate the required integrated view of the possible market advantages of FMS and the technical and organisational conditions which must be realised in order to achieve these benefits.

Conclusions and Recommendations

This research supports the proposition that technical success is a necessary, though not sufficient, condition for business success [19], when market advantages are being pursued. Only two of the sample companies pursued market advantages, however, whereas the other five companies decided to adopt FMS for the other reasons indicated above. The data suggest that, whatever the prime motives are, most FMS adopters are usually aiming at operational advantages in order to pay back the investment. Using FMS to obtain market advantages is viewed as something to consider later.

It is important to note, therefore, that six of the seven sample companies did not succeed in achieving their operational goals at the time set. Reasons for this were:

(1) technical problems (engineering faults in, and problems with, standardisation and integration of both hardware and software) occurring after installation;

(2) changes in the marketplace during the implementation process (leading to over- or under-capacity);

(3) insufficient knowledge of and attention to the organisational prerequisites for the effective operation of FMS.

Future adopters will probably have fewer technical problems, as FMS is now much more mature than when the systems in these cases were designed. As to the other problems listed above, the research suggests some recommendations for managing FMS implementation processes more effectively. Obviously, implementing FMS and using its technical flexibility and integration, mechanisation, and re-programmable control of operations, do not automatically lead to operational advantages. In order to fully achieve these benefits, many organisational adaptations in production, process planning, production planning, quality control and maintenance are required, dependent on the goals set.

The achievement of market advantages using an FMS depend on whether the FMS is implemented in a "strategic" bottleneck, and on the use of other technologies such as CAD, CAPP and CAM for creating the circumstances in which the flexibilities of FMS can be fully used. However, the implementation of elements of JIT, TQC and preventative maintenance, CAD, CAPP and CAM, and other organisational measures and technologies, are usually protracted processes as well (see for example[20] for the implementation of TQC). It may therefore take many years to fully achieve the operational advantages of FMS, let alone the market advantages, if internally and externally consistent reorganisation are not implemented along with the introductions of FMS[3]. All this means that the effective introduction and operation of FMS requires an integrated approach to the management of innovation.

In any case, the operational and market-oriented functions, mentioned above, need to be involved in deciding on whether or not to adopt FMS, and in setting realistic goals. Throughout installation and operation, the functions affected by FMS need to interface and define and solve the *real* innovation problem. Essentially this requires definition of the technical *and* organisational conditions, implementing these conditions, and maintaining adequate standards after installation. The exact activities to be performed depend on the goals set, and characteristics of the FMS and its adopter (see above for some examples).

In order to achieve these prerequisites for the successful implementation and operation of FMS, top management cannot limit themselves to making go/no go decisions, based simply on quantifiable operational advantages assessed by means of questionable justification methods. Instead, it is top management's responsibility to decide on the role that combinations of FMS, and other computer-aided technologies, together with JIT and TQC, are to play; and the types of new forms of organisation required to establish the link between manufacturing and the company's market strategy. Consequently, it should be top management's decision whether to pursue market advantages, or "just" to aim at improving operations by adopting FMS. Furthermore, they are the only ones able to resource the innovation process appropriately, and to break down the boundaries between functional departments. Only then will organisations experience fewer of the organisational problems frequently encountered during and after installation of the system. A major spin-off of such an approach is increased knowledge of how to tackle process innovation.

In summary, whether market or operational advantages are being pursued by adopting FMS, both can be achieved. The extent and speed of goal achievement, however, depend on company-wide involvement in the management of organisational adaptations and the adoption of other technological and managerial innovations. Like most technologies, FMS promises much in terms of improved manufacturing and consequent market and business success: its performance, however, is dependent upon organisational innovation.

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