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Requirements And Benefits Of Implementing Just-In-Time Manufacturing For Small-Firm Manufacturers

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ABSTRACT

This study explores the applicability of Just-In-Time (JIT) manufacturing elements for small-firm manufacturers. A survey of small-firm electronic firms was undertaken to identify and document the level of JIT implementation already underway. Integrating concepts necessary for successful JIT implementation along with the benefits of JIT are also discussed. It is suggested that JIT manufacturing is a viable and useful strategy to enhance the competitive position of small manufacturing firms.

INTRODUCTION

Responding to the intensification of competitive pressure that has occurred in the past 10 years, many of America's top manufacturing companies have adopted Just-In-Time (JIT) manufacturing practices. Led by the auto industry and electronics firms including Hewlett Packard and Texas Instruments, these typically large manufacturers of repetitive products have turned their attention to JIT manufacturing in their efforts to raise productivity and improve their competitive position vis-a-vis world class manufacturers. Although these efforts to duplicate the production practices of successful Japanese manufacturers have met with mixed results, JIT is now recognized as a manufacturing system with significant potential to enhance the competitiveness of manufacturers of high-volume, repetitive products (26).

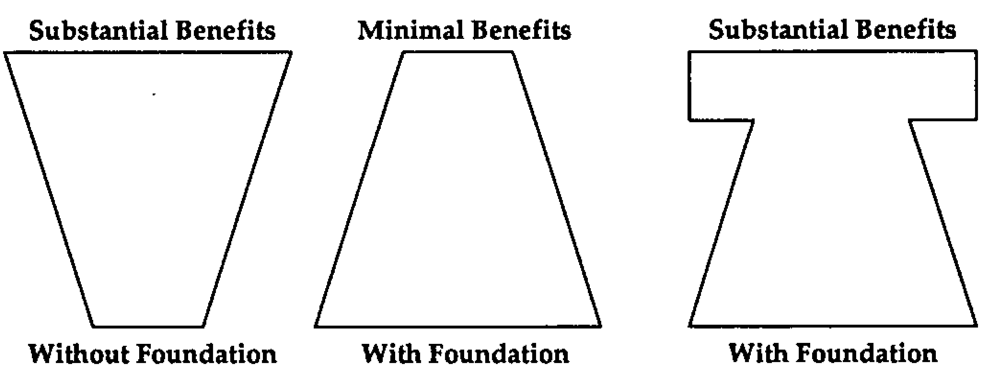
Even as JIT has become popular among many of America's largest and most progressive manufacturers, its applicability to non-repetitive manufacturing settings including those found among the majority of small-firm manufacturers has been questioned. Surprisingly, despite the vast literature that has emerged in the past decade concerning JIT, relatively little research has been performed on the requirements and benefits of implementing JIT in the small-firm manufacturing setting (5). This tendency to overlook the small-firm setting is unfortunate not only because much of America's industrial base is made up of small-firm manufacturers but also because a large number of small manufacturers could potentially benefit from the adoption of certain JIT practices.

Further, as implementation efforts in the large repetitive manufacturers have progressed, it has become evident that many added benefits can be achieved by promoting JIT implementation throughout the logistics supply chain. This realization has led to a dramatic increase in JIT purchasing and JIT transportation practices. As a result, many small-firm manufacturers that act as suppliers to the larger implementors of JIT are faced with the often difficult prospect of adapting to the demands of a JIT environment. Ultimately, to provide the responsive customer service that is required by their JIT buyers, small-firm manufacturers are forced either to carry the inventories that were previously carried by the buyer or to become JIT producers themselves.

The difficulties encountered by small-firm manufacturers in implementing JIT begin with the nature of the small-firm manufacturing setting. Small-firm manufacturers typically do not operate in the uniform-volume, repetitive manufacturing environment that is most often associated with successful JIT manufacturing. This difficulty is often exacerbated by the fact that many small-firm manufacturers lack the resources that facilitate JIT implementation. That is, efforts to implement any new management system are often more difficult for the small-firm manufacturer because of limited capital availability, constrained managerial and human resources, and a lack of leverage with other firms in the supply chain. Thus, the issue of whether JIT practices can successfully be implemented in the small-firm setting is founded both on the characteristics of JIT and on the nature of the small-firm setting.

Fortunately, many of the elements of JIT production can successfully be applied to a small-firm manufacturing environment if the application is selective (5). However, despite the evidence supporting JIT implementation, a perplexing lack of understanding pertaining to JIT continues to prevail among many smaller manufacturing firms. Too frequently, the failure to completely understand the role, the benefits, and the requirements of JIT implementation has led smaller manufacturers to "misread" JIT, resulting in two significant negative occurrences. First, many small manufacturers have attempted to implement JIT without adequately planning for or supporting JIT operations. This occurrence most often leads to work stoppage, frustration, and ultimately, to a return to "business as usual." Second, other companies that could benefit through the implementation of JIT have overlooked this approach to competitiveness because the visible benefits are not attractive enough for a company to go to the effort and expense to implement JIT in a supposedly "non-JIT" environment. Only when the requirements and benefits of JIT implementation are jointly understood does it make sense and is it possible to successfully implement JIT (see Figure 1).

Figure 1. Alternative Views of JIT Implementation



	Without Foundation	With Foundation	With Foundation
Decision:	Worth Doing	Not Worth Doing	Worth Doing
Outcome:	Attempt, But Fail	Maintain Status Quo	Attemp and Succeed

Therefore, although it is increasingly accepted that JIT is an appropriate approach to attaining manufacturing excellence, the applicability of its basic precepts and practices to the small-firm environment needs to be clarified. This paper addresses this need by briefly looking at the foundations of the JIT concept and by evaluating the applicability of JIT's identified components to the small-firm manufacturing setting. The paper also discusses the findings of a survey of small electronic manufacturers and draws some conclusions about the underlying requirements of JIT production along with the numerous benefits that small manufacturers can achieve through JIT implementation. This approach will show that although the individual components of JIT are not equally applicable to all manufacturing settings, the foundations of JIT are readily applicable to a wide variety of manufacturing environments and many of the benefits of JIT can be attained by small-firm manufacturers.

THE FOUNDATIONS OF THE JIT CONCEPT

For most of the 20th century, mass production on assembly lines was believed to be the most efficient approach to the manufacture of high-volume, repetitive products. However, as the Japanese reindustrialization took hold in the 1960's, many Japanese companies, particularly Toyota, realized that improvements could be made in the standard assembly-line approach to manufacturing. Production in the process industries where continuous production is used was viewed to be more efficient. Therefore, an attempt was made to alter the production process so that it would resemble, as closely as possible, that found in the process industries. The result was Just-In-Time Manufacturing (JIT).

Although the objective of JIT is the same as that of other production systems—the on-time production of low-cost, high-quality products—the JIT approach to manufacturing represents a different way to think about the entire scope of manufacturing (2; 7; 20). Much of the difference in the JIT approach to manufacturing stems from the fact that the JIT concept emerged from the experience of the Japanese re-industrialization. In fact, many of the foundations on which JIT is built represent the formalization of the lessons Japanese manufacturers learned during the re-industrialization process (see Table 1). This statement holds especially true for the two most frequently cited JIT concepts—people as problem solvers and elimination of waste (24).

Table 1. The Foundations of JIT

JIT actively pursues an integrative approach to competition, emphasizing manufacturing competence.

JIT undertakes extensive training and human resource development in an effort to integrate workers more fully into all aspects of the manufacturing process.

JIT focuses on getting the most out of all inputs through an emphasis of waste elimination.

JIT is extremely dedicated to developing a competitive advantage based on superior-qualityproducts.

JIT relentlessly pursues continual improvement in both process and product. Constantimprovement is considered fundamental to building a sustainable competitive advantage.

JIT emphasizes long-term considerations over short-term profitability.

Perhaps the foremost of these "lessons of re-industrialization" is the importance of the human resource in developing a competitive edge. Since Japan has always been a relatively resource-poor island dependent on imports for many of its productive inputs, Japanese manufacturers found that they had to take full advantage of their one major resource—the Japanese worker. Thus, extensive training and the integration of workers into all aspects of the manufacturing process became a fundamental aspect of JIT. Similarly, because critical manufacturing resources including materials, energy, and land were all relatively scarce during the re-industrialization, emphasis was naturally placed on getting the most out of all inputs. Thus, the attention devoted to waste elimination.

A third important lesson was the notion that the production of high-quality products is essential to competing successfully in world markets. This realization came only after initial attempts to capture world market share met resistance because Japanese products were perceived to be of inferior quality. However, by importing quality expertise from Deming and Juran and striving diligently to improve quality over several years, Japanese industry overcame its "quality problems" (9; 10). The emphasis on building quality into both the product and the production process has since been formalized within the concept of Total Quality Control. A fourth closely related lesson of considerable impact, the concept of continual and endless improvement, also developed from Japan's prolonged and constant effort to become competitive in world trade. Success had not come easily, but had come only as a result of continued effort and an incremental approach to improvement. Today, the concept of continual improvement provides JIT manufacturers with one of their most potent competitive weapons.

A final lesson learned during the revitalization of Japanese industry is that long-term competitiveness is more important than short-term profit. Not only was Japan's economy forced to rely on exports in order to develop a positive balance of payments, but domestic competition in Japan has always been intense, and only those companies that survive the rigor of domestic competition are around long enough to export to the U.S. In this environment where the primary goal is to assure long-term survival against both tough domestic and global competitors, the focus switches from who can grow the fastest or show the highest return on equity to who is going to still be in business in a year or two. The requirements of survival therefore often dictate modest returns be accepted over several years if necessary in order to build a strong, long-term foundation for success.

The important point to be made here is that none of the foundations of JIT are intrinsically the domain of the large-firm, repetitive manufacturing setting (13). Rather, they not only represent sound practices that play a vital role in the success of manufacturing firm but their evolution also points out many similarities between JIT's early environment and that of the typical small-firm manufacturer. For example, to be successful, smaller firms must take full advantage of their limited workforce while seeking to get the most out of all productive resources. Likewise, small-firm manufacturers often rely on a process of small, incremental improvements to their products and production processes since they lack the financial resources to do otherwise. An emphasis on quality is also essential for the small manufacturer to remain competitive and differentiate its products in very competitive markets. Finally, small-firms typically must look to the long term, emphasizing survival over short-term profits

JLT'S APPLICABILITY TO SMALL MANUFACTURERS

In the early 1980's, most discussions concerning JIT centered on inventory reduction. In fact, the term JIT was frequently considered to be synonymous with zero inventories. However, as more experience with the JIT philosophy has been gained, a better understanding of the elements that make JIT successful has emerged. The once central issue of inventory reduction is now viewed as a catalyst in the process of continual improvement, and several components or elements have appeared in the literature as comprising the JIT concept (5) (see Table 2). These basic elements, by themselves and as part of JIT, have recently received tremendous attention because of their perceived value in improving the manufacturing firm's competitive position. Yet, their applicability to the small-firm manufacturer has received only superficial treatment. The following paragraphs discuss these elements as they apply to the small-firm manufacturer.

Table 2. The Elements of JIT

Cross-Trained Employees
Focused Factory
Group Technology
JIT Purchasing
Reduced Set-up Time
Synchronized Manufacturing
Total Preventive Maintenance
Total Quality Control
Uniform Workloads

Cross-Trained Employees

Getting the most out of the manufacturing system begins with the development of the human resource. To achieve this goal the workforce must be viewed as a asset equal in value to the plant and equipment. Only then does it make economic sense to train workers in the appropriate skills. As this happens, the workforce becomes a valuable competitive weapon capable of assuming greater responsibility for the success of the organization. The cross-training of employees is critical in this process and is one of the foundation elements of JIT. The often cited example of General Motor's joint-venture with Toyota demonstrates the value of cross-training—job classifications were reduced from over 200 to 3 so that workers could be cross trained and more fully integrated into the manufacturing process (3; 11). Cross-training allowed the role of the worker to expand from operating a single machine to performing routine maintenance, assuring quality, and becoming involved in both product and system design. Similar approaches to cross-training employees have been adopted recently by Ford in the development of the 1991 Escort and GM in its Saturn project (25). Cross-training's impact on the firm comes from its ability to allow workers to become a vital part of the manufacturing system.

The small-firm manufacturer frequently has two advantages over larger firms with respect to the cross-training of employees. First, smaller manufacturing firms often do not have to deal with the restrictive work rules and narrow job descriptions that inhibit the cross training of employees in larger manufacturing settings. Second, employees in small-firm settings are usually expected to be more flexible and often are already trained on more than one machine simply because small manufacturers do not have sufficient personnel for each individual to focus on a specialized job or task. Further, workers in the small-firm setting frequently must operate multiple machines to compensate for erratic demand and absenteeism. In this sense, cross-training is already common in many small firms. The challenge facing these firms is thus to formalize their efforts to cross-train employees, expanding the role of the workers into assuring quality, performing routine maintenance, and participating in the continual improvement of both the product and process designs.

Focused Factory

The focused factory concept emerged in the mid 1970's as manufacturers attempted to deal with increasing complexity on the production floor (22). The objective was to focus the facility's resources either by producing a single product or a group of similar products or by using a single production process within each facility. By so doing, the conflicting objectives that develop when multiple products are produced using more than one major process type can be eliminated. Focusing the factory thus not only leads to production efficiencies but increases the facility's effectiveness by reducing confusion and allowing a more targeted set of production goals. The direction and simplicity that derives from a focused factory is very important to the implementation of JIT (21).

The fact that small manufacturers are small and therefore often offer a limited product line requiring only one or two major production process types is a definite advantage in developing a focused factory. Indeed, many small-firm manufacturers already operate focused factories. However, a rigorous review of operating practices can often help the small firm improve its overall focus. For example, a small manufacturer of industrial vehicles reviewed its production process and found that it could separate out two types of operations: the fabrication of metal parts and the assembly of the final product. By dividing its facility into two sections—one for fabrication and one for assembly—the firm was able to enhance its focus, reducing confusion and streamlining the production process. The key for the small firm is to avoid taking focus for granted and to consciously and continuously seek to attain the benefits available from focused operations.

Group Technology

Group technology (GT) seeks to take advantage of similarities among products and processing techniques to enhance firm productivity. Two elements comprise the concept of group technology: 1) the physical arrangement of machines into manufacturing cells used to process a family of like products and 2) the development of a computerized classification and coding system capable of identifying similarities among products and processes. Both aspects of group technology are designed to exploit commonalities in the production process.

Schonberger describes a GT layout as "... a cell with a maximum of five manned work stations arranged into a U-shaped configuration.... At the limit a single worker handles all five machines, which are conveniently grouped into a U—like an efficiency kitchen (21). The benefits of this type of layout include a reduction in setup times, simplified materials handling, decreased work-in-process inventories, reduced throughout times, simplified production control, and an enhanced ability to efficiently produce a large variety of small-volume products. Additional benefits including a reduction in part numbers and improved product design accrue from the development of the computerized classification and coding system.

The layout aspects of group technology often occur naturally in the small-firm setting. Finch and Cox note that in the absence of diversification strategies, "many small manufacturers have naturally organized their shop on the basis of similarity of parts produced rather than on the function of the machines," (5). Most small manufacturers that are not organized according to GT cells possess the flexibility to rearrange the physical layout of their machines. Further, the lack of shop floor unions and the natural cross training of workers in the small-firm environment have a tendency to reduce worker resistance to the behavioral modifications required when a GT layout is adopted. However, developing the computerized data base that frequently accompanies the adoption of a GT layout can be costly and is often difficult for the small firm. Fortunately, the operations in many small firms are not so complex as to require the computerized classification system allowing the small firm to take advantage of the benefits of a GT layout.

JIT Purchasing

As JIT practices have increased in popularity on the production floor, many efforts have been directed toward utilizing a JIT approach throughout the entire supply chain. This systems view of JIT extends the just-in-time philosophy of small lot sizes to purchased parts, requiring frequent deliveries of small order quantities directly to the area of the production floor where they are to be used. JIT purchasing arrangements are typically characterized by the integration of buyer/supplier activities and require a great deal of cooperation and communication between the two. The degree of integration and the specific arrangements depend on the strength of the buyer/supplier relationship. However, the following characteristics are common in JIT purchasing.

1. The buyer frequently represents a large portion of the supplier's business. This assures a high level of service responsiveness.
2. The buyer often reduces its supply base utilizing sole sourcing from certified suppliers whenever possible.
3. Long-term relationships are established allowing for an increased use of blanket contracts and the sharing of production schedules.
4. Performance specifications replace specific design specifications allowing the supplier to better use its expertise.
5. Joint problem solving efforts are undertaken to improve product quality and supply dependability. The buyer works closely with the supplier, providing quality control and process engineering support.
6. Critical performance criteria are focused on product quality and delivery dependability. Lowest ultimate cost is emphasized over low price (6).

The tightly coupled buyer /supplier relationships that are established through JIT purchasing practices provide many benefits to both the buyer and the supplier. Buyer benefits include a reduction in administrative costs, greater responsiveness from its preferred suppliers, higher quality inputs, reduced inspection costs, improved product design, and an assured source of supply. Supplier benefits include a more stable operating environment, greater production volume, lowered production costs, improved communication, access to the buyer's process engineering and quality control personnel, and the opportunity to make more definite long-term financial decisions (e.g. in R&D).

Implementation of JIT purchasing is often difficult for the small-firm manufacturer. Because the orders placed by smaller firms are generally small in comparison to those placed by large manufacturers, smaller firms frequently lack the leverage or clout necessary to establish JIT purchasing agreements. This lack of negotiating power can make it difficult for the small firm to obtain the attention, cooperation, and responsiveness from its suppliers that are typically required in order to make JIT purchasing work effectively. Small manufacturers also often lack the managerial resources (quality control and engineering) needed to help develop other and frequently smaller suppliers into reliable partners. Even so, small-firm manufacturers should attempt to find responsive suppliers, seeking to develop cooperative relationships. As JIT purchasing practices become more widely accepted, the challenges smaller manufacturers face in adopting JIT purchasing will diminish.

Set-up Time Reduction

The use of process development to substantially reduce set-up times makes short production runs practical and JIT economically feasible (17; 18; 23). Likewise, through extensive process development, variability in the production system can be diminished (in some cases eliminated) reducing the need for inventory. Process development's principal ingredient is process engineering, which works to modify existing equipment so that set ups are easier and quicker and so that process yields are stabilized. The goal in JIT is to achieve a "single setup" of 10 minutes or less. In many cases, complex setups have been simplified to take less than one minute—a "one-touch setup." Process engineering is also used to design specialized equipment. This equipment tends to be smaller and less expensive than the large "super" machines designed by commercial equipment makers and is designed for reliability and ease of maintenance. In addition to developing specialized—often proprietary—equipment, in-house design often results in lower costs and shorter delivery lead times.

Those companies that have vigorously applied process engineering to set up reduction have not only experienced a good deal of success but have found that significant improvements can be achieved through relatively simple and inexpensive steps. For example, 3M's Chicago facility used a setup reduction program to reduce the set-up time of an old cutting machine from 222 minutes to 17 minutes. Four "rules of attack" developed from this experience: eliminate unnecessary movement, eliminate nuts and bolts, use block and gauge templates for adjustment, and move mainline setup to off-line preparation (19).

Small firms are often quite successful in their attempts to reduce set-up times, especially when the small manufacturer focuses its efforts on straightforward approaches such as 3M's four rules of attack. Eliminating unnecessary movement and developing block and gauge templates for adjustment frequently require neither extensive or special expertise nor large capital investments. Since adjustments to machines often represent 50 to 70% of the total set-up time, the use of simple adjustment devices can result in dramatic reductions in set-up times. The small manufacturer of industrial vehicles mentioned earlier developed and used very successfully set-up templates in most of its production processes. Further, in many instances, small firms can successfully convert internal set ups to external set ups, reducing changeover costs even further. The greatest challenges for small firms interested in reducing set-up times occur when extensive engineering or capital investment is required. However, the increased use of tightly coupled buyer/supplier relationships often improves the small firm's financial position and provides many smaller firms access to the buyers process engineering capabilities.

Synchronized Manufacturing

Operating a facility with reduced work-in-process inventory (WIP) levels requires a great deal of coordination and discipline to assure the proper and timely flow of materials through the facility. JIT uses a pull system (often referred to as Kanban) to provide this synchronization. The Kanban pull system is a visual system designed to produce only the parts needed in "downstream" work stations as they are needed. Using a pull system helps prevent possible production crises by carefully controlling the amount of inventory on the shop floor and by reducing expediting. Abernathy et al. describe Toyota's Kanban system which exemplifies the workings of a pull system,

> The system is called "Kanban" after the little cards or tickets it uses, operates much like a supermarket and its warehouse. Just as a warehouse manger will forward only those products ordered by the store manager (and only in the quantity ordered), so the

Kanban system requires work centers to make and send parts to each other only as they receive Kanban cards telling them to do so. The rule of thumb for upstream units is, quite simply, make nothing until you get a Kanban and then only in the standard amount; for downstream units, the rule is, do not order parts until you need them and then order only the standard amount (1).

Many small manufacturing firms operate without a formalized scheduling system, relying more on visual and intuitive systems. In this light, it is not surprising that small-firm manufacturers often view Kanban as an unusual scheduling practice that is inappropriate for their operations. The high levels of discipline required for the successful application of Kanban and the often difficult to follow academic discussions of Kanban add to the perception that Kanban is inappropriate for small manufacturers. However, Kanban is successfully used by small manufacturers in Japan, and in its simplest forms, Kanban's visual approach to scheduling has an intuitive appeal that suggests it could easily be adopted by small-firm manufacturers in the U.S.

For example, in a simple two-station system, the worker at Station A produces only enough parts to fill a standardized cart and then ceases production. Parts are not transferred to Station B until a signal is received indicating the parts are needed. The signal can be a small card, an empty cart, or even a colored golf ball. All the signal needs to communicate is the type and quantity of part that is needed. In this example, the signal to transfer parts is the return of an empty cart and thus, the signal to renew production is the transfer of parts from Station A to Station B. Therefore, when the parts are transferred, the worker at Station A starts production and continues until the empty cart is filled. The cycle then repeats. Discipline is critical since if parts are transferred early or if more than the standard number of parts are produced the system overloads and becomes inefficient.

Total Preventive Maintenance

Total preventive maintenance in JIT manufacturing involves a program of rigorous and routinely scheduled maintenance and equipment replacement. Individual machine operators also take on an active and increased responsibility for the daily maintenance of their own work centers. By becoming familiar with the machine's maintenance requirements, line operators are able to perform daily cleanings along with machine adjustments and some minor repairs. They are also able to identify and diagnose problems while they are still small, preventing machine breakdowns that lead to line downtime. In a JIT environment where WIP is minimal and each work center is directly dependent or the preceding operation, avoiding unplanned downtime is essential. Total preventive maintenance thus not only improves machine utilization but helps reduce production costs, enhance quality, and assure flexibility.

Perhaps the two greatest challenges to the small-firm manufacturer in adopting a total preventive maintenance program are 1) the lack of adequate maintenance personnel and 2) the ability to provide the process training that is required for individual workers to assume the higher levels of responsibility for maintaining their own machines. Otherwise, total preventive maintenance programs are readily adoptable by small firms when preventive maintenance is emphasized as a priority by management. This is especially true since the workers in small firms often possess relatively high levels of job flexibility and in some cases already perform some of the basic maintenance on their machines. The keys to implementing preventive maintenance programs for the small firm are to emphasize proactive maintenance over reactive, "after-the-fact" maintenance and to provide maintenance training for individual workers so they can assume responsibility for the daily maintenance of their work centers.

Total Quality Control

The ultimate objective of total quality control (TQC) is to make the production of high-quality products automatic. In many respects, the JIT philosophy of continuous improvement is embodied in the TQC concept where constant improvements in quality are sought through the active application of statistical process control throughout the entire supply chain. Targeting defect reduction to parts per million is achieved by shifting the responsibility for quality from the quality control department to each individual involved in the production process. In this manner, quality is controlled at the source—while the work is actually being done. Further, statistical quality control techniques are combined with worker skills and process engineering to seek out and remove the causes of poor quality, which enhances the firm's ability to produce quality products the first time without rework. For TQC to be implemented successfully, quality must be established as the preeminent priority of the firm with all other firm objectives being driven by quality. When this occurs and quality production becomes the driving force, inventories are reduced, productivity is enhanced, and customer satisfaction is typically improved.

Since high-quality production has been the single most important factor in determining long-term competitiveness throughout the past 10 years, the importance of TQC in any JIT production system cannot be understated (15;16). Fortunately, TQC practices are straightforward and equally applicable in a small-firm setting as they are for larger firms. The most substantive problem areas appear to be changing firm culture so that quality becomes the focus and providing the needed training in statistical process and quality control. Intensifying competitive pressure and the trend toward longer-term buyer/seller relationships are providing the incentive for small firms to focus on quality as a necessary ingredient in their competitive positioning. Further, these two trends are also providing many small manufacturing firms with access to the quality expertise of their primary buyers. Indeed, as many larger firms reduce their supply bases, they are establishing supplier qualification programs which place a high emphasis on helping selected suppliers improve their process and product quality.

Uniform Workload

The concept of uniform workload refers to the reduction of demand fluctuations on the production floor. A uniform workload is achieved by matching supply to demand such that the same product mix is produced each day just in time to be sold. This requires very careful master production scheduling coupled with a flexible production system that allows variations in customer demand to be met by changing the frequency of the batches of Individual products that are produced while maintaining overall resource utilization more or less stable. Aggarwal has suggested that JIT works best when production fluctuates less than 10% daily (2).

A uniform workload may be one of the most difficult aspects of JIT for the small manufacturer to adopt successfully. Quite simply, because they lack leverage with larger buying firms, many small manufacturers have little control over demand patterns. That is, the often large orders that are received from a few large buyers come in sporadically creating a lumpy demand pattern which reduces the small firm's ability to maintain a relatively stable production flow. However, with the adoption of JIT by an increasing number of large manufacturers, a greater emphasis is being placed on the production and delivery of smaller lot sizes more frequently. Also, when buyers enter into sole sourcing arrangements, they frequently share vital production information with their key suppliers—often on a daily basis through the use of electronic data interchange (EDI)—further helping small-firm suppliers achieve a stable production flow. In short, the problems faced by the small firm in achieving a uniform workload are often ameliorated by the overall trend toward flexible JIT production.

Integrating Concepts

While the preceding nine elements have been identified in the literature as keys to the JIT approach to manufacturing, two other concepts should be considered by firms as they attempt to adopt JIT manufacturing principles: 1) the role of the manager and 2) the need to have appropriate expectations for the implementation process. First, in JIT manufacturing where worker's are expected to assume responsibility for their own work and actively participate in problem solving, the role of the manager becomes "one of facilitating a team approach" (27). In this setting, the worker-manager relationship is more important than the position of authority the manager holds. Unfortunately, many managers are not comfortable in this managerial setting. Therefore, extra efforts must be made to foster this type of relationship and to replace the familiar worker/management adversarial relationship with a more cooperative relationship focused on improving the company's competitive position. For example, managers must not only develop an understanding of the work that is being done throughout the production process along with the technologies required to do it but they should also become familiar with the "language" of the workers to enhance communication. By so doing, management can attain a credible position with workers from which it can demonstrate its commitment to manufacturing excellence.

Second, by nature JIT requires a long-term perspective. Continual improvement is not achieved in one quarter or in one year, but comes from establishing a manufacturing system that facilitates incremental improvements and from developing an internal attitude of perfection. Each of the JIT elements described above focuses on building either the facilitating system or the attitude of perfection, and all require a constant and sustained effort by top management and worker alike over a long time period to be implemented successfully. For example, inventory cannot be reduced without undertaking the usually long process of reducing set-up times and synchronizing manufacturing. The classic example of modifying Toyota's hood and fender press took five years to design and implement (24). A long-term commitment is equally important in developing the human resource base and worker involvement that are essential to attaining the full benefits of inventory reduction.

FINDINGS FROM A SURVEY OF SMALL-FIRM ELECTRONICS MANUFACTURERS

A survey of members of the American Electronics Association was undertaken to identify the utilization of the above discussed JIT manufacturing elements. To collect data concerning the implementation status of each of these JIT elements, a five-point Likert scale was used with response alternatives ranging from used but later rejected to continuous or routine use. The questionnaire was sent to Vice Presidents of those electronic manufacturing firms with 100 to 500 employees. Usable questionnaires were returned by 100 firms for a 30% response rate. The average time in operation for the responding firms was 17.5 years with a range of 6 to 37 years. Revenues ranged from $2 million to over $24 million per year with an average of $14.4 million. Similarly, the average net income before taxes was $970,000 and the average number of employees was 210.

More than half of the respondents (60%) indicated that their firms are actively involved in the implementation of a JIT manufacturing system. This indicates that among this small-firm sample population, JIT is viewed as an appropriate and desirable manufacturing system. In Table 3, a summary mean score is used to gain insight into the appropriateness of each JIT element to the small-firm electronic manufacturer as measured by the actual usage of each element. This mean score was calculated by averaging the responses of the 100 firms providing usage information with a mean score of four or greater indicating a high degree of element appropriateness. As might have been expected, cross-trained employees was by far the most frequently implemented of the individual elements. Total Quality Control, reduced set-up time, and JIT purchasing also had mean scores greater than four. The relatively high score for JIT purchasing indicates that JIT practices are being promulgated through the entire supply chain. Other JIT techniques that were considered to be at least somewhat applicable to small electronics firms include group technology, uniform workloads, and focused factory. Finally, two elements—total preventive maintenance and synchronized manufacturing—had low mean scores. While it was expected that synchronized manufacturing would be viewed by small firms as difficult to implement, the low score for total preventive maintenance is somewhat surprising given this technique is frequently considered to work closely with both cross-trained employees and total quality control.

Table 3. Appropriateness of JIT's Elements to Small Electronics Firms

JIT Element	Mean Score
Cross-Trained Employees	4.43
Total Quality Control	4.12
Reduced Set-up Time	4.11
JIT Purchasing	4.05
Group Technology	3.91
Uniform Workloads	3.88
Focused Factory	3.74
Total Preventive Maintenance	3.50
Synchronized Manufacturing	3.35

Table 4 breaks down the overall applicability scores for each JIT element by focusing on the levels of experimental and routine usage. While these results coincide with those of Table 3, they provide some additional information concerning the state of progress in implementing the various JIT elements. The practice of cross training employees is the most frequently used JIT element based on both routine and overall usage. Group technology and reduced set-up time also have relatively high routine usage levels. This suggests that these elements are viewed as essential starting points for the implementation of JIT. Total Quality Control and JIT purchasing have high experimental usage levels that when summed with their routine usage levels result in high overall usage which indicates that these two elements are also in advanced stages of implementation by small electronics manufacturers. Once again, total preventive maintenance and synchronized manufacturing were the least used elements. However, total preventive maintenance had a moderately high level of experimental usage suggesting perhaps that small electronics firms are paying increased attention to this element. Tables 3 and 4 confirm that JIT elements are suitable for small electronic manufacturing firms. While the usage rate for the individual JIT elements varies, it appears that small electronics firms are making progress in the implementation of JIT manufacturing elements.

Table 4. Percent Usage of JIT's Elements by Small Electronics Manufacturers

JIT Elements	Experimental/ Occasional Use	Routine/ Continuous Use	Overall Use
Cross-Trained Employees	41	53	94
Total Quality Control	42	36	78
JIT Purchasing	41	32	73
Reduced Set-up Time	29	43	72
Group Technology	25	40	65
Uniform Workloads	31	34	65
Focused Factory	28	33	61
Total Preventive Maintenance	31	18	48
Synchronized Manufacturing	20	13	33

Benefits of JIT Implementation

Justification for striving diligently to implement JIT comes from the benefits inherent in achieving manufacturing excellence—enhanced quality both in product and process, reduced manufacturing costs, more responsive lead times and higher delivery performance, improved flexibility, and a more rapid introduction of new products. Further, the interaction among these benefits creates synergies that are important but are difficult to confine to the discussion of any single benefit. By taking advantage of these JIT benefits, the manufacturing firm can enhance its competitive position. These basic benefits of JIT are attainable by small manufacturing firms and will now be briefly discussed.

Enhanced Quality

Quality improves with JIT because inventory is reduced and problems become visible. Defects are spotted much more easily when they are not buried in a stack of inventory. More important, however, is the fact that workers downstream in the production process are motivated to communicate problems back to their source quickly, so they can be eliminated. This motivation comes from the adverse impact defective parts have on the performance of both individual workers and the entire production line. In JIT, each individual's ability to be productive is greatly hindered by detective parts being passed from one work station to the next—a worker cannot produce if no good parts are available to work on. Each individual depends on the previous workers for good parts. This fact, that every person on a production line is the customer of the preceding operation is vigorously stressed in JIT so that each worker's goal becomes to supply the next person on the line with quality parts. Extensive efforts involving statistical analysis and process engineering are also directed at finding and removing the actual sources of the quality problems. Thus, JIT not only increases the entire organization's awareness of problems and their causes but also focuses the appropriate resources so that the causes of problems are removed from the production system.

Reduced Manufacturing Costs

The combined effect of reducing inventories, along with the subsequent improvements in quality, provide many cost benefits. The most obvious of these benefits are the reduction in scrap material costs and a decrease in direct labor spent on rework. In fact, by having individual workers fix their own mistakes, rework stations can be totally eliminated. Inspection costs are also reduced since the workers are responsible for checking their own work. In addition, because inventories are reduced, less investment is needed to purchase them, less space is needed to store them, and less equipment is needed to move them. Finally, the continual improvement of the manufacturing process increases productivity as down time is reduced and process yields increase.

An ancillary benefit of increased productivity results when the lower manufacturing costs are combined with a desire to build market share and long-term profitability. A competitive cycle begins: as costs decrease, lower prices attract customers and market share increases causing productivity improvement to accelerate and costs to decrease further. By keeping the profit margin low enough to offer good-quality products at lower prices than the competition, even greater market share is captured and costs continue to decrease (4). This can be a very advantageous strategy for the small firm.

Responsive Lead Times

Lead time is roughly equivalent to the time it takes to produce the order, which depends directly on the amount of work already on the shop floor waiting to be produced. If there are large WIP inventories waiting at each work area, this time can be quite long and can vary greatly. It has been estimated that of the time an order is in production, up to 90% is queue or wait time. Thus, for every minute of actual production, the item spends an additional nine minutes waiting to be processed. Inter-operation time can represent most of the lead time and accounts for much of the uncertainty associated with lead times. By reducing production lot sizes, the amount of WIP is also greatly reduced. Therefore, not only is the actual processing time for any order reduced directly proportional to the decrease in lot size but inter-operation and other nonproductive times are reduced drastically. When the time-reduction benefits of a smoother flow, shorter travel distances, and less confusion on the shop floor are added, it is not hard to see why lead times are shorter and delivery performance more reliable in a JIT setting. These short lead times mean better and faster market response both for orders of current products and for the introduction of new products.

Improved Flexibility

Many factors work together to provide better flexibility. JIT's direct impact is through the reduction of inventories and the removal of system disruptions, which combine to reduce confusion. Flexibility is difficult to achieve when crises are constantly developing and orders are being expedited. However, by closely controlling the amount of inventory on the floor, stability is achieved and crises avoided. This gives managers and workers the opportunity to focus their attention on more important matters like quality and flexibility (8). Other contributing factors are the use of specialized equipment, preventive maintenance, and the cross training of workers. Flexibility is gained through the use of multiple copies of small, inexpensive, special-purpose machinery that is often designed in-house. In addition, as setup times are reduced, it is much easier to shift production to meet changes in market demand. Further, thorough preventive maintenance reduces machine breakdowns and their disruptive effects on the production process. Finally, when workers are not only trained to perform many different jobs but provided the opportunity to use their training by the elimination of restrictive work rules, flexibility is greatly enhanced.

CONCLUSION

Implementing JIT is seldom easy, especially in the small-firm setting where the production environment is often different from that typically associated with JIT implementation and where financial and managerial resources are frequently limited. However, through total managerial and employee commitment combined with the selective application of JIT techniques, the risks of JIT implementation can be reduced dramatically. Experience has shown that a great deal of time and effort on the part of every individual in a firm is needed to successfully implement JIT. In most manufacturing settings, achievement of this goal requires changes be made in the actual production environment (10; 12; 14). Changing the manufacturing environment rather than optimizing within the existing environment is a new approach to many managers. Even so, when the proper changes in the environment are combined with changes in the role of both managers and workers, the foundation for manufacturing success is established.

Clearly, the successful implementation of JIT elements by small firms requires careful planning and coordination along with sustained managerial and worker commitment. Nevertheless, the results of the survey of small electronics manufacturing firms support the idea that JIT elements are appropriate for small firm manufacturers. The survey findings also suggest that the implementation of JIT by small firms is often seen as an incremental process in which small firms first seek to reduce inventory levels, improve quality, enhance flexibility, and in general reduce overall complexity. Further, the survey data indicate that some of the JIT elements, in particular the cross training of workers, are more widely applicable to a variety of manufacturing environments. Given the level of competition that can be expected through the 1990's, selective adoption of the elements of JIT appears to present a usable and viable strategy for small firms to enhance their competitive position. Indeed, the potential benefits derived through JIT manufacturing—enhanced quality, reduced manufacturing costs, more responsive lead times, improved flexibility, and a more rapid introduction of new products—provide a strong incentive for all firms to seriously consider the implementation of JIT.

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