THE EFFECTS OF BACK ORDERING ON PERFORMANCE: MARKETING AND PRODUCTION COOPERATION IN SUPPLY CHAIN MANAGEMENT

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This paper examines the performance of back orders in a manufacturing operation which utilizes the management and scheduling techniques of material requirements planning (MRP) and just in time (JIT). The topic is concerned with the impact of supply chain management and marketing actions such as back orders on customer service, sales, and the production system. The interjection of back orders within the time fence of the master production schedule will reduce sales, revenue and customer service up through the supply chain, while the total system cost associated with these back orders and service levels would increase.

INTRODUCTION

Back ordering is a marketing action that is most likely to impact many parts of the supply chain, customer services, sales, and the production system performance. Previously, it was felt that increases in sales and revenues more than offset the additional production costs caused by back orders. This paper shows that this argument might be valid when back orders are scheduled beyond the time fence of the master production schedule. However, interjecting these back orders within the time fence of the master production schedule is certain to reduce sales, revenue and customer service, while the total system cost associated with these back orders and service levels increases up the supply chain. In other words, when the back orders are injected into the master production schedule within the time fence or the total offset lead time, the resultant disruption of current sales orders and production rescheduling, and the total disregard for shop floor capacity within the offset lead time, will result in production inefficiencies and loss of productivity. The rescheduling of disrupted production schedules will then cause the same kinds of late order difficulties in the near future with production schedules for the next planning period.

Marketing

The marketing concept implies that the logistics activity, along with other marketing mix variables, should be adjusted.
to customer demand, thus creating customer satisfaction and, in turn, generating revenue, while tacitly assuming complete flexibility of order production. What effect does this concept have on the production process? If an organization truly adheres to the marketing concept, will sales increase; or, more importantly, will profits increase in both the short and long term? In order to answer these questions it is necessary to examine that part of the supply chain which is related to the marketing-production interface; and it is at this interface that production and marketing are entering a newly defined conflict position with respect to the management of inventory. The marketing-production interface becomes most pronounced with the firm’s customer service policy which has a direct effect on the production system, the timely delivery of goods and, consequently, customer satisfaction.

“Good customer service depends on effective use of the master production schedule (MPS) to establish delivery dates a firm can meet. Thus, a key interface between marketing and manufacturing develops through the MPS since it links customer service directly to efficient use of production resources” (McClelland 1988). This brings us to the new “player” in this field: supply chain management. Supply chain management is a combination of those activities that procure raw materials, transform those materials into intermediate goods and final products, and deliver products to ultimate users through a distribution system (Render and Heizer 1997; Copacino 1998; Nichols 1998).

This paper examines a very important element of the supply chain, the marketing-production interface through customer service. The first part of the paper discusses stockouts, back orders and plant layout, while the second portion reviews customer service. The third section of the paper discusses the responsibilities and objectives of both the marketing and the production functions as aspects of the supply chain and the corresponding interface between the two. The research design is described in the fourth section, where the results of a large scale factory computer simulation model are presented to demonstrate one alternative to customer service and its effects on the production system and on total system sales. Finally, in the last section, the results and recommendations are presented, and conclusions are drawn regarding the marketing-production interface. The focus is on those parts of the supply chain represented by the marketing alternative, the management and production scheduling of back orders, and the subsequent effects on customer service, sales, and the production system performance.

**BACK ORDERS AND PRODUCTION FACILITIES**

A back order occurs when the product is not available to meet the customer’s demand today and the producing firm places an order on future capacity to produce today’s demand. This situation can exist when both producer and customer agree to placement of the back order. Obviously, to produce a product for customers who will not wait for the back order would be unwise. In many situations, a back order can be for a “special design” which may be any out-of-stock variation or option of the standard product (Ritzman & King 1991). In marketing, the primary customer service concern is the availability of the product. If the product is not available for the customer to purchase, then there is a lost sale and, therefore, a corresponding loss of revenue. When a stockout situation occurs, the marketing personnel, with the agreement of the customer, will most likely place a back order into the system without concern as to the additional production costs associated with this back order (Gue 1991). The theory is that by satisfying the customer through a back order, the company will not lose the sale.

**Plant Layout and Production Volume**

One can view manufacturing facilities as being on a continuum varying from the extremes of a pure job shop to that of a pure flow shop (Hayes & Wheelwright 1979; Schmenner 1984; Krajewski & Ritzman 1990) and any combination in between. In the case of a pure job shop, or “one-of-a-kind,” make-to-order, custom shop, all orders are indeed back orders, and customer service and uncertain demand are provided for by having extra, flexible capacity, flexible product designs and a raw material inventory. McClelland (1988) and Ragatz & Mabert (1988) have conducted back order research in the make-to-order factory, and it is obvious that the back order alternative is the only feasible strategy for a job shop. At the other extreme is the pure flow shop where there is one common, high volume product which is made to stock inventory on specialized production processes, and demand is met from finished goods inventory. Unique orders, both in terms of design and production lead time, are considered only at the beginning of the production line.

Back ordering does not work well in the make-to-stock or “flow shop” factory (Raturi & Hill 1988; Sridharan, Berry, and Udayabhanu 1988; Ritzman & King 1991). The introduction of a back order in this situation is the same as treating the factory as if it were, indeed, a “job shop” (McClelland 1988; Ragatz & Mabert 1988). Thus, the master production schedule has regular orders with all appropriate lead times and component parts considered; and “mixed” in are the new “special orders” which do not consider the total offset lead times for components and subassemblies.

Back orders can be produced or filled in several ways such as overtime or subcontracting, safety stock, excess capacity, worker flexibility (Ritzman et al. 1984), and can be eliminated by better forecasting (Ritzman & King 1991).
Additionally, the back order can be introduced as part of the forecast demand in a time period beyond the time fence of the master production schedule. Of course, this strategy may lead to a loss of some customers due to their unwillingness to wait.

An example of the use of back ordering is television marketing with the familiar disclaimer to allow six to eight weeks for delivery. In fact, the six to eight week time period is to allow for the accumulation of enough orders for an economical production lot as well as the production time itself.

The back order production scheduling which is most commonly used in the make-to-stock factory (Ritzman & King 1991) is the interjection of the current back order into the master production schedule. This unanticipated demand is then added to gross requirements for the next production period. But, what happens to the production system when a back order is introduced? What happens to stockouts and, in turn, overall customer service? Are sales increased through the use of back orders? This paper attempts to explore these questions through a factory simulation model.

CUSTOMER SERVICE

The limited amount of available literature forms a consensus in suggesting that many firms have not usually developed an integrated corporate philosophy of customer service because of the difficulty of doing so (LaLonde, Cooper and Noordewier 1988; Krajewski & Ritzman 1990). However, there is agreement from both the production and marketing elements that customer service is of strategic importance (LaLonde and Zinszer 1975, Skinner 1986, LaLonde, et al/1988) and that its importance will only increase in the future as noted by the development of supply chain management (Fox 1998; Helming and Misty 1998). Perhaps the most definitive statement to date is, "Customer service is a key factor in the mix of values that suppliers offer customers to secure their patronage" (Ballou 1987). Customers are demanding heightened service performance - that is, shorter lead times, more frequent deliveries, and elimination of stockouts (Copacino 1997; Bendliner 1998).

Impact On Sales

The evaluation of the effect of different customer service levels on sales has generally focused attention on the effects of product stockouts on sales, with more recent focus being on the effects of stockouts as seen by those who have the responsibility for supply chain management (Copacino 1997; Pooler & Pooler 1997; Render & Heizer 1997). Shycon and Speague (1975) performed an analysis on the number of days that a firm remained in a stockout situation, and determined that the more prolonged and extensive the stockouts, the more business was lost. Conversely, Burgin (1970) determined that any demand not immediately satisfied may be lost, but customers may be prepared to postpone purchase to a later date. His goal was to allow an empirical relationship between the time out of stock and the amount of back ordering to be built into the inventory model.

Perreault and Russ (1974) demonstrate that past physical distribution difficulties had the effect of causing purchasers to evaluate customer service as an important factor in purchase decisions, and these criteria appear in the literature related to supplier performance evaluation long before supply chain management. Also, in instances where customer service was viewed as important, frequent stockouts caused canceled orders; hence, lost sales. Schary & Becker (1978) demonstrated that stockouts have a temporal effect on market share, and the decision to be made is determining the inventory necessary to ensure a market position.

Rogers, et al., (1982) showed that by adjusting three elements of the customer service mix (order cycle time, variability of order cycle time, and communication time), a firm could increase its profits. These research findings and others (Gustafson & Richard 1964; Mueller 1968; LaLonde & Zinszer 1975; Walter & Grabner 1975; Uhr et al. 1980; Blumenfeld et al. 1985; LaLonde et al. 1988) document the effect of customer service on sales.

All of these studies address customer service from a marketing perspective, and have not considered the marketing-production interface. Ritzman et al. (1984) note that cutting down on risk orders, with the subsequent reliance on safety stock, causes an increase of inventories from 79% to 121%, but that it also improves customer service by lowering the number of late deliveries from 170% to 29%. Part of the problem is that U.S. managers "jealously guard their 'flexibility' and reaction time..." (Hayes 1991) when, in fact, manufacturing management should be "involved" up front in major marketing and engineering decisions (and vice versa)" (Wheelwright & Hayes 1985). The historical perspective of purchasing management has been that purchasing was "in charge of outside manufacturing," and placing a greater emphasis on this activity has resulted in part the evolution of the management philosophy of supply chain management (Render & Heizer 1997). A firm practicing supply chain management may be expected to delve into many more areas of the management of a supplier firm than has previously been the custom (Fox 1998)

MARKETING AND PRODUCTION INTERFACES

It is the responsibility of the production function to manage the transformation process while marketing's primary objective is to match the goods and services of a company with target customers. The marketing concept certainly
seems logical, but it has to be applied in a rather one-sided manner at times, particularly when the production function is ignored.

Marketing and production interface in the subset of activities traditionally known as logistics, where logistics, from a marketing perspective, provides the product for the customer at the right place, at the right time (Ballou 1987). In so doing, the traditional view has been that long production runs at all levels of production with correspondingly large inventory levels were best for the production function for economies of scale, (and that the inventory at all levels was safety stock for uncertain demand, uncertain delivery dates, uncertain quality, and uncertain production quantities).

The Management of Inventories and Back Orders

There is a great amount of literature (Chase & Aquilano 1989; Krajewski & Ritzman 1990; Render & Heizer 1997) explaining the functions of inventories in relation to the production operations, and explaining that safety stock inventory is needed because of uncertainties.

In many instances, the pooling of physical inventories from different locations of a business allows a particular inventory to fill several of the above needs. The inventories at the intermediate production levels, if pooled, also serve multiple purposes by providing a secondary level of protection from the uncertainties of demand at the finished goods level. When there is not enough finished goods inventory to meet unanticipated demand, and a back order is scheduled into the master production schedule, the underlying components and subassemblies are usually in abundant supply from these intermediate levels of inventory or work in process, allowing rather rapid completion of the back orders. This position is coincidental with the marketing need for large inventories in which inventories of finished goods, as noted above, are the cushion for forecast errors in immediate demand (Zimm & Marmorstein 1990), and work in process (WIP) is a further cushion for back orders.

Historically, then, production management and marketing management each has had its respective use for larger inventories; and the only resistance to large inventories was from those responsible for the financial investment and the cost of carrying the inventory. This resistance was weak in most cases because it was thought the carrying cost of inventory was fairly low, but these managerial attitudes and philosophies have changed drastically with the adoption of Just-In-Time (JIT).

Just-In-Time

With the resurgence of interest in manufacturing management came an awareness, adopted from the Japanese, that the cost of carrying inventory may be exorbitant. This awareness has caused great pressure for the production function to find other alternatives to the ubiquitous use of inventory as managerial slack (Biggs, Long and Fraedrich 1991). This has led to the implementation of scheduling techniques such as MRP and JIT and a renewed interest in other management technologies such as total quality management (TQM).

These new methods of production management, particularly JIT, have decreased much of the production uncertainties mentioned above and have caused machine setup times to be decreased. They have also allowed a substantial decrease in the size of inventories needed to support the production function, without providing any matching decrease in the amount of inventory needed to support the traditional marketing activities such as customer service. This, of course, has led to a greater dependence (rightly or wrongly) on whatever managerial alternatives may be at hand, which, in many situations, is the innocent, indiscriminate use of back orders by marketing and the innocent, unmanaged scheduling of back orders by production. Therein lies a possible source of conflict between the marketing function and the production function. Prior to these developments there was agreement; and now, when others are advocating a greater coordination between functions (Skinner 1969, 1986; Hayes 1991; Helming & Mistry 1998), neither marketing nor production management is quite aware of all the interdependencies or total costs of these activities. However, there is some current interest in related problems such as late orders, and concern that JIT will affect scheduling strategies used to produce and distribute goods (Blumenfeld, Burns, and Diltz 1985; Blumenfield and Burns 1991).

Master Production Scheduling (MPS)

When implementing production planning and control techniques such as material requirements planning (MRP) and just-in-time (JIT), along with the new insistence on higher quality at all levels of production, the current view is that the production function wants firm, planned orders to extend beyond the total offset lead time to insure production schedule stability (Sridharan et al. 1988).

Prior to this time, in the textbook analyses of buffer stock, there has been some mention of the cost of stockouts versus the cost of carrying buffer stock, but there was little early research into or managerial concern for the scheduling of back orders. For the reasons given above, stockouts were not recognized as a problem. But, as noted above, the research results reported herein will demonstrate adequate reasons why the scheduling of back orders should be more carefully managed.

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RESEARCH DESIGN

The research design consists of a complete factorial design with two factors. The primary factor is back order level (11 levels) and the secondary factor is forecast error bias (5 levels), thus creating an experimental design of 55 cells (see Table 1). The number of levels and forecast error was determined as that which would adequately bracket the targeted phenomenon.

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<tr>
<th>TABLE I</th>
<th>RESEARCH DESIGN</th>
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Five replications per cell, each with a different starting value. All replications were run for a 48-week year, producing 240 data points per cell.

The back order level refers to the amount of stockouts the researcher will allow to be "back ordered" by being inserted in the master production schedule. In most instances, not all customers are willing to wait; thus, it would be worthwhile to back order only for those customers who will wait. The reason for back orders, as has already been noted, is primarily due to demand uncertainty at the finished product level. This research is conducted using biased error forecasting (Biggs & Campion 1982; Ritzman & King 1991) as a factor to determine if there is any support for the notion that biased forecasting could help the demand uncertainty back order situation and to determine if greater amounts of forecast error contribute to the managerial problems.

The sample size consisted of five replications for each combination which amounts to 5 replications by 11 back order levels by 5 forecast error levels, producing a 275-year run of the simulation model. To ensure the validity of the model, a substantial number of computer runs were examined week by week and variable by variable. The difference between replications within each combination is in the demand of the 10 final products. To avoid the possibility of over- or under-loading the system, a small change in demand between replications is achieved by randomly generating the demand with a different starting value before the start of a simulation run for each replication. In order to be sure that the data collected is representative of the system, the simulation has to be initialized until a steady state is reached. In this model, the simulated factory is given a set of starting conditions and then run for 12 weeks before data collection is commenced. The 12-week period was determined as sufficient to reach a steady state condition for the purpose of analyzing the performance outcomes produced by the iterations of simulation under various conditions.

For purposes of definition, forecast error is said to be the difference between the calculated or projected forecast and the actual demand at a future point in time. Forecast variability is defined as the difference between the forecast and the mean or trend line. Thus, forecast variability and forecast error are not used synonymously.

The experimental design entailed examining the marketing performance criteria of customer service and total system sales and the production performance criteria of manpower levels, departmental staffing changes, inventory, and setups for different back order and forecast error levels.

As shown in Table 1, a reasonable range of operating parameters, or experimental levels, was tested for both back orders and forecast biased error. In a practical sense, a constraint on capacity exists and is reflected in the simulation by establishing limits on the size of the labor force, as noted above. Obviously, many unrealistic, "out-of-control" situations could have been generated using other labor levels. Therefore, only those situations that were measurable and germane were included in this paper. The performance measurements recorded can be used as indications of what could happen in other situations.

In calculating the performance outputs of the mean and standard deviation in each cell, all 48 weeks (one year) of each replication were used, thus creating a sample size of 5 years by 48 weeks, or 240 time periods. Then the mean and standard deviation were calculated from these 240 data points for each cell, reducing the total number of observations to 55; that is, one observation for each experimental level of back order and forecast error, respectively. The means and standard deviations of the observations regarding the six aforementioned performance criteria are graphed in Figures 2 - 7.
A limitation of this study is that the week-to-week samples within one year are not statistically independent, resulting in some serial correlation between samples of any one year. Differences between replications were generated by using a different random number seed for each replication. As noted, this caused the demands for each product for each replication to vary differently about the average or mean demand for that particular product. Since this was a controlled simulation, it was possible to control the forecast error for each product. Therefore, the forecast error was predetermined and did not vary between cells, giving each cell an identical pattern.

Computer Simulation

A large-scale computer simulation model was used to model the complex relationships involved in a multi-department, multistage, production system. This particular computer simulation model uses material requirements planning, as do many real world companies (Raturi & Hill 1988; Ritzman & King 1991; Sprague et al. 1990) for production planning and record keeping (Biggs et al. 1980; Biggs & Campion 1982). The overall scheduling and capacity management techniques used are strongly based on the principles of just-in-time (JIT) (Goddard 1986; Chase & Aquilano 1989). The factory operations involve three production levels and one purchasing level, with a total of 10 finished goods, 7 subassemblies, 15 component parts, and 8 raw materials. With this model, the researcher has the capability of forecasting sales, scheduling back orders, making aggregate and detailed planning decisions, and collecting data for report generation on a timely basis. Short discrete time periods of one week for updating or making decisions are used, which agrees with the JIT philosophy. Figure 1 summarizes the characteristics of input, process, and output of the simulation model for this study.

![Input Variables Diagram](image)

**FIGURE 1**

**FACTORY SIMULATION**

- 10 Finished products
- 7 Subassemblies
- 15 Components
- 8 Raw materials
- 3 Departments (final assembly, subassembly, component manufacturing)
- 1 Purchasing function

**Transformation Process**

- Average weekly service level
- Average weekly sales
- Average weekly setups
- Average weekly stockouts

**Output Variables**

- 471 Persons in the labor force
- 5 Forecast error levels
- 11 Backorder levels

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Assumptions

As with any simulation, this analysis contains necessary simplification that helps to focus the results:

1. The average demand is constant for each final product but is different between products. The demand level for each product is normally distributed with a range of 10% of the average demand over the 48-week period. This is consistent with the level loading aspect of JIT (Goddard 1986; Chase & Aquilano 1989; Ritzman et al. 1984).

2. The capacity level is determined by the number of workers available, and all workers have uniform ability.

3. The scheduling rule used was the critical ratio rule. Each lot, once started, must be completed if component parts or raw materials are available, and all production and purchasing requirements are scheduled to meet the needs of the next level, just-in-time.

4. The machine setup and operation time for each product or operation is known and constant, and not sequence dependent.

Capacity

In practice, the capacity of a JIT production system is predetermined at the beginning of a planning period and it is not intended to be changed for that period. Most firms have found it more advantageous to have a level production capacity over a planning period, and this is the manner in which capacity is managed for the duration of the simulation. In preliminary runs of the simulation a level of capacity was determined which was adequate as long as the system did not have difficulties such as machine breakdown, nor tried to meet some unexpected and unplanned production requirement. This level of capacity, which was determined to be 471 employees, was low enough to avoid the effect of having infinite capacity with no production scheduling problems, which would also incur an infinite cost, yet was high enough that the system had level capacity that was only slightly more than enough to stay out of trouble if operating under stable conditions. Of course, if unplanned production difficulties arose, the production system could recover, but only over several time periods because the capacity available in any one period is only slightly greater than that needed for planned production. If there were too much excess capacity cushion, it would act as a buffer to system problems (Ritzman & King 1991). This, too, is in agreement with JIT with respect to having a well-maintained capacity that is only some small percentage larger than demand.

Marketing Performance Criteria

The performance criteria for the marketing function were service level and total sales. The reasons for selecting these criteria are:

1. Service level—Service level is the ratio of end item sales to end item demand and, consequently, measures the overall effects of various marketing-production systems planning strategies. As noted above, service level gives an indication of customer satisfaction.

2. Sales—Sales is a direct measure of revenue generated by the marketing-production system. However, traditionally revenue generation has been the responsibility of the marketing function only.

Production Performance Criteria

A simulation model is by nature a fiction, which the researcher hopes will in some useful part mimic a real world system, and the better the mimicking the more globally applicable are the results of the research. The use of cost or profit values as output performance criteria is an additional step removed from the reality of the real world for the simulation, and their use would limit the applicability of the results to a smaller set of the real world. Thus, the more the performance criteria are limited to the basic outputs of the simulation, the more likely it is that the practitioner will be able to match some portion of the research to a real world system. For this reason the performance criteria for the production function were: 1) average machine setups and purchase orders (setups); 2) average stockouts at all levels; 3) average inventory; and 4) average desired labor force. The reasons for selecting these criteria are:

1. Setups—In effect, setups occupy economic resources causing them to be "idle." Another aspect is that those economic resources are part of the overall capacity of the system, and inefficient scheduling of setup time will use up capacity without producing profitable products, even in a JIT system where setup time has been decreased by significant amounts. Conversely, the efficient scheduling of setups can "free up" capacity. This, of course, is nothing more than the traditional economies of scale; but, at the practical level, the efficient scheduling of setups can free up unproductive scarce capacity.

2. Stockouts—Stockouts at all levels were used because not only are stockouts at the finished goods level a measure of lost profits and service level, but stockouts at the dependent stages of production are a measure of chaos in the system that, in an actual situation, would cause excess expediting and other rush activities. Stockouts

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also cause work in process inventories to increase, all of which cause increased costs.

3. Average inventory--The use of average inventory as a performance measure is, of course, because of the large cost burden inventory imposes on the operation of the system.

4. Labor force desired--The labor force requirement is the level of labor the system would like to have if the supply were infinitely flexible. The production system has the given level labor force as described above, and this labor force is slightly more than needed if the production requirements are level. But when there are problems and the system is trying to recover, a measure of the problem is difficulty is the amount of capacity or labor, which the system would like to have to recover. Thus, the labor force in this scenario can be used quite well as a surrogate measure for desired capacity. Both labor and machine capacity fluctuations are expensive to make; and although the labor force is usually easier to change or manipulate than the machine or process capacity, anyone involved with the personnel function would soon demonstrate that hiring and firing can also contribute to high costs.

**FINDINGS**

It must be recognized that a simulation merely attempts to model an ideal situation or simply reflect the real world. No attempt was made to optimize the operation of the computer model since the intent was to represent natural conditions that might be found in a real-world situation. As a result, it was possible to evaluate the performance variables with a minimum of external and potentially contaminating controls.

An analysis of variance of the performance variables produced significant results over all back order levels and most forecast error levels. As noted earlier the forecast error levels were secondary and were included primarily to enlarge the operating response area in the experimental design.

**Marketing Performance**

The marketing performance criteria of customer service and sales were evaluated separately as dependent variables. The treatment variables that were simultaneously considered in the analysis of variance were back order and forecast error

**FIGURE 2**

Average service-level based on the weekly averages of the ratio of sales to demand at the end item level

- F-E = 0.96
- F-E = 0.98
- F-E = 1.00
- F-E = 1.02
- F-E = 1.04

*** Analysis of variance indicates that the differences in average service-level among the backorder levels and among the forecast error levels are significant at the p<0.001 level.
levels. As can be seen from Figure 2 and Figure 3, both service-level and sales decrease as the percentage of allowable back orders going into the production system increases. These rather striking results are counter-intuitive to the obvious conventional marketing wisdom, but indeed are due to rather common actions between the marketing and production functions. The production system is in such a chaotic state that what is being produced is either the incorrect component needed at the next level or is in incorrect volume to complete the production order at the next level of Production Performance.

Similarly, the production performance criteria of setups, stockouts, inventory, and labor force were evaluated separately as dependent variables. The treatment variables that were simultaneously considered in the analysis of variance were back order and forecast error levels. As shown in Figure 4, as the percentage of allowable back orders going into the production system increases, the number of setups decreases. As the system incurs greater difficulty, it requests greater lot sizes, thus causing fewer setups. This phenomenon, although freeing up more capacity, does not free up enough to make a significant difference.

From the examination of Figures 5, 6, and 7, respectively, stockouts, inventory, and labor force levels as measures of production system difficulty clearly indicate that as the percentage of allowable back orders going into the production system increases, the level of production difficulty increases. These difficulties will show up as work in process.
schedule disruptions or increased work in process inventories of the wrong parts; and these, in turn, will act as bottlenecks to put the total production system in a state of "gridlock" until there is enough capacity to produce them. This extra capacity will have to be available from the top down.

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**TABLE 5**
AVERAGE STOCKOUTS BASED ON THE WEEKLY AVERAGES OF STOCKOUT UNITS AT ALL LEVELS

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*** Analysis of variance indicates that the differences in average stockouts among the backorder levels are significant at the $p<0.001$ level whereas those among the forecast error levels are not significant.

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FIGURE 6
AVERAGE INVENTORY BASED ON THE WEEKLY AVERAGES OF THE UNITS ON HAND AT ALL LEVELS

*** Analysis of variance indicates that the differences in average inventory among the backorder levels and among the forecast error levels are significant at the $p<0.001$ level.

FIGURE 7
AVERAGE LABOR FORCE BASED ON THE WEEKLY AVERAGES OF THE NUMBER OF WORKERS AT ALL DEPARTMENTS

*** Analysis of variance indicates that the differences in average labor force among the backorder levels are significant at the $p<0.001$ level whereas those among the forecast error levels are not significant.
Please note, the reason that stockouts and inventory are positively correlated is that both are related to work in process, and there is a mismatch between needs and availability. Thus, finished goods are still in process and not completed.

Forecast Error Bias

It is apparent from examining Figures 2 to 7 that back orders cause problems at all levels of forecast error bias. There is some indication that the factory performs better at the over forecast level of 1.02, when the over forecast seems to cause an unplanned safety stock. These results are supported by Figures 2, 3, and 6. Figures 2 and 3 show greater service level and higher sales for the 1.02 level in most instances, and Figure 6 shows that in most instances the 1.02 level has a higher inventory level than do all others except the 1.04 forecast error bias. The logic for these occurrences is that the 1.02 level causes slightly more production in each period than is thought to be needed. This extra production tends to act as a safety stock for all levels for subsequent periods. But at the 1.04 forecast error level, this additional demand only adds to the system's problems. Reviewing the overall performance over the range of forecast error, the better performance is at the lower levels of forecast error. One could probably safely speculate that the system performance would deteriorate over greater ranges of forecast error.

Marketing-Production Interface

In comparing Figures 2 and 3 with Figures 4 through 7, it is apparent that as the percentage of allowable back orders going into the production system increases, the marketing performance and the production performance deteriorate. Prior thought has been that back ordering with some attendant form of expediting (Gue 1991) would not cause the production system to lose overall productivity, but would increase total volume produced. However, the results show that the interjection of back orders above some very small number into the system reduces sales revenue and customer service, while the total system cost associated with these back orders and service levels increases. The primary reason for this phenomenon is that the insertion of back orders as a form of unanticipated demand severely disrupts the production schedule to such an extent as to decrease the total amount of production achieved.

CONCLUSIONS AND RECOMMENDATIONS

Since the ideal situation of zero backorders with exact forecast demand and infinitely adjustable production capacity is not possible, the intent of this paper was to examine back ordering within the supply chain as part of the marketing-production interface in a make-to-stock production system managed with current techniques such as Material Requirements Planning and Just-in-Time. This was accomplished by comparing marketing performance criteria and production performance criteria with the use of back orders as the common denominator. Widespread thinking prior to this study, using the revenue - cost = profit equation, was that back orders may cause an increase in production costs; but these additional costs were more than offset by corresponding increases in revenues (LaLonde et al. 1988; Gue 1991; Tyworth 1991). In light of the above results, it is obvious that the production costs increase significantly more than anticipated. Furthermore, revenue and customer service, rather than increasing as expected, had a dramatic decline. Instead of having a small-loss large-gain situation, the result is two large losses.

The two major conclusions that result from this study are:

1. For both the marketing and production functions, the back ordering within the time fence of the master production schedule is not a good alternative for stockouts and, therefore, not a good alternative for satisfying customer service levels or increasing sales. Other alternatives within the supply chain need to be explored to satisfy customer demand, such as using safety stock, excess capacity, worker flexibility (Ritzman et al. 1984), subcontracting, or overtime—even, perhaps, referring the customer to a competitor in order to satisfy the need for a product.

2. For the production function, back ordering should be included in the master production schedule only beyond the total offset lead-time fencing, and then only if the customer is willing to wait the extra time. In a just-in-time production environment, the study results demonstrate that the unmanaged use of back orders leads to production schedule disruptions, severely cripples any hope for productivity, and, in the real world, would have a serious effect on total quality management. Disruptive phenomena have been documented by others (McClelland et al. 1988; Raturi & Hill 1988; Sridharan et al. 1988; Sprague et al. 1990; Geigle 1991; Ritzman & King 1991), but this is the first focused on the disruption caused by back ordering.

Not only has this paper dispelled the myth that back orders are a free and useful alternative for supply chain management, it has also shown that under certain conditions other undesirable and heretofore unrelated conditions result from the use of back orders. In other words, back orders have a negative effect on the production system, customer service, and sales. This paper has also pointed out the interaction and possible conflict situation that may arise between marketing and manufacturing because of the implementation of the newer manufacturing management techniques and philosophies such as JIT. In looking one step further, we
should consider one of the newest developments in production management—the theory that larger volumes of production will allow us to take advantage of traditional economies of scale which we believe are beneficial. Further, these economies of scale will allow improvements in product quality and a decrease in production costs which, in turn, will permit greater inroads into market share. These new developments, using techniques such as group technology (GT), are concerned with "artificially" moving the factory nearer the flow shop end of the continuum (Chase & Aquilano 1988; Krajewski & Ritzman 1990) by grouping products and processes so the factory can perform more nearly like a flow shop. Moreover, these techniques seem very successful from the production point of view. What, then, are the consequences if we try to move manufacturing facilities from the job shop end of the continuum nearer to the flow shop end without also doing something about customer service. The marketing/customer service problem can only get worse because there is a need to achieve these traditional economies of scale and improve quality, but without any growth in the size of inventories to serve uncertain demand. Group technology, by moving the factory toward the flow shop, will cause greater inflexibility in the production system with greater resistance to last minute changes in the production schedule caused by back ordering.

Maybe back orders are, indeed, intended for make-to-order facilities, and not for make-to-stock factories in the supply chain at all. But how, then, is a make-to-stock system to maintain its flexibility and ability to respond to a rapidly changing market? These are all considerations for further research. This paper suggests that future research in both marketing and production should concentrate on the marketing-production interface because cost reduction alone is not the primary source of competitive advantage for the production function (Skinner 1986), nor is back ordering the only alternative to customer service. There are alternatives such as safety stock, safety lead-time, safety capacity, and the old standby, stockout. Perhaps future research can concentrate on the other methods of satisfying customer and sales requirements which may reflect better production system performance and, in turn, better performance of the overall supply chain. One immediate consideration is that improved communication should be implemented so that timely scheduling changes could be considered, to the benefit of the supply chain. Frequently production volumes can be changed instead of complete orders when the total order is not needed immediately such that the timely movement of goods up the supply chain may be maintained with no shortages at any level.

Suggestions for Future Studies

From a marketing standpoint, the problems discussed in this paper will be multiplied because of rapid turnover in product development, and the need to compete by having greater manufacturing flexibility in customizing the products to the customers' needs, all within a much shorter lead than was historically expected. From a production standpoint, the same market phenomenon is causing production problems. The new product development lead time is much faster, requiring a faster response time from the production function, for which these new product designs very frequently require the development and acquisition of new production processes. These new production processes also require the education or reeducation and training of employees, both white collar and blue collar, to the use of the new processes. In addition, within the production function, there has been a constant upheaval and change of management philosophy and managerial methods. Starting with material requirements planning (MRP), and progressing to the use of just in time (JIT) methods of scheduling, and the JIT rationale of decreasing inventories, the managers of the production function have fewer and smaller cushions with which to cope with matters such as uncertainty and managerial errors. The old warehouse full of inventory has been defined away. It is now recognized that inventory has a very high cost, and we are just beginning to learn and identify those managerial changes that will be necessary to manage the supply chain and survive with small amounts of inventory. There is one replacement for inventory, which has been used in the past, and that is excess production capacity and back orders. But we see that in a JIT production system there is only a small amount of extra capacity because it, too, has a rather high cost. The result of all these developments is that the supply chain needs to be managed so that the marketing and production functions work together to develop alternatives to the managerial cushions of excess inventory and production capacity. A recent development in this move to provide alternative management styles to take the place of these traditional managerial cushions is, of course, supply chain management in which the heretofore independent elements of production and distribution are linked and managed.

Future research efforts will have to consider how a firm can operate within these constraints and be competitive, when the traditional managerial supports are being defined as too costly. Other aspects of the marketing and production functions such as back orders and stockouts will have to be examined as possible remedies to support supply chain management.
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