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The production performance benefits from JIT implementation

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Abstract

The intense competition in the current marketplace has forced firms to reexamine their methods of doing business. The US manufacturers have struggled with growing trade deficits and outsourced operations, while strong market competitors have emerged, using superior manufacturing practices in the form of just-in-time (JIT) and continuous process improvement. Although proponents cite the many benefits of JIT adoption, its implementation rate in the US has been relatively conservative. This study uses survey responses from executives at 95 JIT-practicing firms to better understand the benefits that firms have experienced through JIT adoption, and whether a more comprehensive implementation is worthwhile. The research results demonstrate that implementing the quality, continuous improvement, and waste reduction practices embodied in the JIT philosophy can enhance firm competitiveness. JIT implementation improves performance through lower inventory levels, reduced quality costs, and greater customer responsiveness. This study indicates that JIT is a vital manufacturing strategy to build and sustain competitive advantage. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

The globalization and intense competitiveness of the current marketplace has forced firms to reexamine their methods of doing business. Despite an abundance of both natural and economic resources, the US manufacturers have struggled with growing trade deficits and outsourced operations. With fewer available natural resources, strong market competitors have emerged, specifically in the Pacific Rim, using superior manufacturing practices in the form of just-in-time (JIT) and continuous process improvement (CPI) (Cammarano, 1996). JIT is a manufacturing philosophy that emphasizes achieving excellence through the principles of continuous improvement and waste reduction. Some of its purported benefits include higher quality production, lower inventory levels, improved throughput times, and shortened customer response times. In the US, JIT has been both praised and criticized for its effectiveness, accounting, in part, for its relatively conservative adoption rate (Bowman, 1998; Clode, 1993; Milligan, 1999; White et al., 1999). This study has two principal objectives: first, it investigates the benefits received from the implementation of JIT; second, it examines the dependence of these benefits upon the level of commitment in adopting specific JIT practices.

This paper contributes to the JIT literature by providing a better understanding of why firms consider JIT adoption to be beneficial. Improvements resulting from reduced inventory levels are documented in several JIT studies. However, limited empirical evidence

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exists concerning other benefits received from investing in JIT. Most evidence consists of case studies of individual firms or descriptive statistics of small samples (Ellis and Conlon, 1992; Kalagnanam and Lindsay, 1998; Orth et al., 1990; Pandya and Boyd, 1995; Patell, 1987). This study focuses on the survey responses from executives at 95 manufacturing firms that have formally adopted JIT. The level of JIT implementation is measured by responses to Likert-scaled questions and partitioned into low and high levels. One-way analysis of variance (ANOVA) tests are performed to ascertain if there are differences in the perceived benefits of JIT between the low and high adopters.

2. JIT review

JIT is a Japanese-developed manufacturing philosophy that represents "an aesthetic ideal, a natural state of simplicity" in production efficiency (Zipkin, 1991, p. 42). Although precisely defining JIT continues to be perplexing (Mia, 2000; White and Ruch, 1990), JIT production is generally referred to as a manufacturing system for achieving excellence through continuous improvements in productivity and elimination of waste (Crawford and Cox, 1990; Lummus and Duclos-Wilson, 1992; Orth et al., 1990; Suzaki, 1987). A more specific definition is provided by Calvasina et al. (1989, p. 41):

> "JIT is a system of production control that seeks to minimize raw materials and WIP inventories; control (eliminate) defects; stabilize production; continuously simplify the production process; and create a flexible, multi-skilled work force."

According to Schonberger (1987, p. 5), JIT is the "most important productivity enhancing management innovation since the turn of the century." Gleckman et al. (1994) stated that "JIT has come of age," and is recognized as a legitimate management philosophy. "The concept of JIT has completed its evolution from a manufacturing technique to a much broader philosophy of improvement" (Vokurka and Davis, 1996, p. 58) that can help the US manufacturers regain and maintain a competitive advantage in the global market (Yasin et al., 1997).

2.1. JIT objectives

JIT looks beyond the short run to the long-term optimization of the entire production/distribution network (Jones, 1991). Successful JIT implementation should accomplish two major objectives: improve quality and control the timeliness of the production and delivery of products (Davy et al., 1992; Monden, 1981; Walleigh, 1986). By concentrating on quality, companies should experience less scrap and rework and more effective communication among departments and employees. In addition, long-term commitments with fewer suppliers should result in fewer inspections. The achievement of these results requires an even production flow of small lot size, schedule stability, product quality, short setup times, preventive maintenance, and efficient process layout (Chapman and Carter, 1990; Foster and Horngren, 1987; Hall and Jackson, 1992).

2.2. JIT implementation benefits

By 1982, only three English-authored publications related to JIT were available (Schonberger, 1982a). Subsequently, growing interest in JIT has led to a proliferation of articles. Field studies of companies that have had success with JIT adoption comprise much of the published research. Most survey studies examining the benefits from JIT adoption have reported only descriptive statistics. The sample sizes are generally quite small because of the difficulty in effectively identifying JIT firms and collecting survey responses. The most consistent benefit from JIT adoption found in the empirical studies is a reduction in inventory levels and/or an increase in inventory turns (Balakrishnan et al., 1996; Billesbach, 1991; Billesbach and Hayen, 1994; Celley et al., 1986; Crawford and Cox, 1990; Droge and Germain, 1998; Gilbert, 1990; Huson and Nanda, 1995; Im and Lee, 1989; Norris et al., 1994; Ockree, 1993).

Some survey studies examining the relationship between JIT practices and firm performance, as measured by productivity, lead-time, and quality, have failed to find a significant relationship (Flynn et al., 1995; Sakakibara et al., 1997; Dean and Snell, 1996). However, both Kim and Takeda (1996) and Nakamura et al. (1998) reported an improvement in several production performance measures subsequent to JIT adoption. In a comparison study of JIT and non-JIT

Canadian electronic firms, Brox and Fader (1997) found JIT firms to be more cost efficient. A few studies have examined specifically the effects of JIT implementation on traditional financial performance measures, with inconsistent results (Balakrishnan et al., 1996; Fullerton and McWatters, 1999b; Huson and Nanda, 1995; Inman and Mehra, 1993; Mia, 2000; Ockree, 1993).

Although reducing inventories may not be the primary purpose for implementing JIT, it is a natural consequence (Green et al., 1992). As opposed to the traditional "push" approach, JIT "pulls" inventory through production only as orders are demanded. With work-in-process inventories kept at a minimum, production can respond more quickly to errors and changes in demand. Throughput time is reduced along with non-value-added (NVA) activities such as wait, move, and inspection time, which can comprise up to 95% of product costs (Foster and Horngren, 1987; Peters, 1990).

2.3. JIT implementation rates

The implementation of JIT by the US firms has been in a relatively slow and ad hoc manner, despite growing awareness of its purported benefits (Clode, 1993; Gilbert, 1990; Goyal and Deshmukh, 1992). One reason for a firm's reluctance to adopt JIT is its resistance to change (Golhar and Deshpande, 1993; King, 1988). The implementation lag has been attributed to a number of other factors, including a lack of understanding of JIT methods, an incompatible workforce and workplace environment, non-supportive suppliers (Majchrzak, 1988; Snell and Dean, 1992; Wafa and Yasin, 1998), and an inadequate performance measurement and incentive system (Fullerton and McWatters, 1999a). Evidence also exists that JIT may not be appropriate and has not been successful for all firms (Golhar and Deshpande, 1993; Inman and Brandon, 1992; Milligan, 1999).

Studies have found that each company undertaking JIT implementation develops its own set of JIT practices, as it tries to eliminate NVA activities (Lubben, 1988; Schonberger, 1982b). "The greatest benefits to be achieved by an organization adopting JIT may result from the synergistic gains of the JIT techniques operating as a system" (White and Ruch, 1990). A piecemeal implementation approach has led to mixed results, often creating negative assessments of JIT's potential (Clode, 1993; Gilbert, 1990; Milligan, 1999).

3. Research proposition

JIT is not a new, "mysterious, oriental ritual, but a way of operating with a higher priority on time than we have ever experienced before" (White and Ruch, 1990). Blackburn (1991) contended that time compression in manufacturing originated with JIT. Bowman (1996, p. 39) stated that "JIT is a lead-time reduction program, not an inventory reduction program." Flynn et al. (1995) used a reduction in throughput time as a measure of JIT effectiveness. They further explained how the basic tenets of JIT production improve customer response times. Shorter setup times reduce the time required to change machines to work on different parts and also allow for smaller lot sizes. With lot sizes decreased, inventory levels are lowered, production flexibility is increased, and faster feedback on quality is obtained. The more rapid detection of problems leads to better quality, with less scrap and rework (Hall, 1987; Hay, 1988).

JIT empowers employees by using their input in decision making and broadening their workplace skills (Banker et al., 1993a; Hall, 1987; Johnston, 1989; Kalagnanam and Lindsay, 1998; Schonberger, 1982a). Workers must be trained to be flexible and given authority to make day-to-day production decisions, so that they can react appropriately. Cross training of workers is considered critical to the success of JIT (Epps, 1995; Inman and Mehra, 1993; Spencer and Guide, 1995). Working effectively in teams is also important for problem solving in a JIT environment (Banker et al., 1993b). Im and Lee (1989) declared teamwork essential for JIT implementation.

The general consensus is that accounting practices should be streamlined in a JIT environment (Banker et al., 1993a; Bhimani and Bromwich, 1991; Durden et al., 1999; McNair et al., 1990; Sakakibara et al., 1993; Schonberger, 1986; Swenson and Cassidy, 1993). However, studies examining the actual changes in accounting practices with the adoption of JIT report mixed results (Fullerton, 1998; Patell, 1987; Sillince and Sykes, 1995).

Managers will be reluctant to implement JIT, if they are not convinced that JIT will enhance overall firm performance. Therefore, a firm's investment in JIT practices should be reflected in its profitability measures. Much of the extant research has suggested that JIT leads to improved profitability, but few studies have tested this relationship empirically. Inman and Mehra (1993) stated that their research study was the first to directly link JIT to bottom-line improvements. A later empirical study by Balakrishnan et al. (1996) found no differences in return on assets (ROA) between JIT and non-JIT firms until firms were grouped into those with high or low customer concentrations and different cost structures. Other empirical studies have demonstrated a significant relationship between JIT implementation and firm profitability (Fullerton and McWatters, 1999b; Huson and Nanda, 1995; Mia, 2000).

Abundant research evidence is available attesting to inventory reductions subsequent to the adoption of JIT (i.e. Balakrishnan et al., 1996; Billesbach and Hayen, 1994; Droge and Germain, 1998; Gilbert, 1990; Huson and Nanda, 1995; Im and Lee, 1989; Norris et al., 1994). Droge and Germain (1998) extensively examined the relationship between JIT and inventory levels and found a significant inverse correlation in every organizational context between the levels of JIT implementation and total inventory. The individual relationships of raw materials (RM), work in process (WIP), and finished goods (FG) inventories to JIT have also been examined (Balakrishnan et al., 1996; Golhar et al., 1990; Nakamura et al., 1998; Patell, 1987).

As noted, several studies have explored different aspects of what constitutes JIT and what benefits should be expected from its implementation. Utilizing broadly-based measures, this study extends prior JIT research by examining the benefits from the adoption of specific and integrative JIT practices. The following research proposition is examined: firms that make a higher level of commitment in adopting a more comprehensive array of JIT practices experience greater benefits in (1) quality improvement; (2) time-based responses; (3) employee flexibility; (4) accounting simplification; (5) financial performance; and (6) inventory reduction than firms with lower levels of commitment and fewer JIT practices in place.

4. Research method

A subset of data obtained from a detailed, five-page survey instrument was used to explore the research proposition. The survey instrument was evaluated in a limited pretest by several business professors and managers from five manufacturing firms for readability, completeness, and clarity. Appropriate changes were made as per their comments and suggestions. The survey questions applicable to this research are interval Likert scales. Factor analysis combined the Likert-scaled questions related to JIT practices into three independent measures for testing the research proposition.

4.1. Sample firms

An extensive literature search was done to identify all of the US manufacturing firms known to be formally practicing JIT. A sample size of 169 JIT firms was initially identified. For inclusion in the study, a firm must have a primary two-digit SIC code within the manufacturing ranges of 20 and 39, have sales between US$ 2 billion and 2 million, and be included on the COMPUSTAT database. Using these criteria, the final sample size of “known” JIT firms was reduced to 89. To select additional sample firms (either JIT or non-JIT), an initial search was done on Compaq Disclosure to identify the potential pool of the US manufacturing firms that met the set criteria. There were 3266 records available. A random selection of 600 firms was chosen. Randomly selected firms were eliminated from this sample due to duplication, inadequate COMPUSTAT information, addresses outside of the US, or non-applicable manufacturing operations. As a result, manufacturing executives at 447 firms were faxed or mailed the survey packet.

Following a maximum of three contacts, 254 out of the 447 firms surveyed completed and returned the survey instruments, for an overall response rate of 56.8%. One of the returned surveys was unusable. Respondents had titles equivalent to the Vice President of Operations, the Director of Manufacturing, or the Plant Manager. They had an average of 17 years of management experience, including nine years in management with their current firm. The data of only the JIT sample firms add another year to both measures of management experience. An ANOVA test shows the differences in the means for responding (US$ 404 million) and non-responding (US$ 380 million) firm sales are not statistically significant. Thus, a response bias related to firm size is not evident.

Table 1
Distribution of two-digit SIC codes for sample firms

Industry	JIT firms frequency	JIT firms percent	Sample frequency	Sample percent
20 — Food	1	1.0	7	2.8
22 — Textiles	2	2.1	5	2.0
25 — Furniture and fixtures	5	5.3	6	2.4
26 — Paper and allied products	1	1.0	2	0.8
27 — Printing/publishing	1	1.0	1	0.4
28 — Chemicals and allied products	4	4.2	24	9.5
30 — Rubber products	3	3.2	5	2.0
33 — Primary metals	3	3.2	15	5.9
34 — Fabricated metals	7	7.4	14	5.5
35 — Industrial machinery	17	17.9	41	16.2
36 — Electronics	24	25.3	61	24.1
37 — Motor vehicles and accessories	6	6.3	11	4.3
38 — Instrumentation	20	21.2	55	21.7
39 — Other manufacturing	1	1.0	6	2.3
Totals	95	100.0	253	100.0

The majority of the sample firms classified themselves as non-JIT firms (138). Twenty other respondent firms that are also classified as non-JIT firms in this study either left this question blank, or indicated they were contemplating or just beginning to implement JIT. Ninety-five of the responding firms (37.5%) indicated on the survey that they had formally implemented JIT. However, the total sample size is reduced to 91 firms for the data analyses, as four of the JIT firms did not respond to the questions related to post-JIT implementation.

The industry distributions of the self-identified JIT and total sample firms are presented in Table 1. The majority (64%) of the respondent firms are from three industries: industrial machinery (SIC-35), electronics (SIC-36), and instrumentation (SIC-38). The industry distribution for the non-JIT firms is similar to the JIT firm distribution, except for chemicals and allied products (SIC-28). The industry distribution for the total respondent firms is similar to the total sample industry distribution. Seventy percent of the firms sampled were from the same largest represented industries: SIC codes of 28, 35, 36, and 38. The distribution of non-responders by industry was also similar to the distribution of the total sample size. There was a slightly higher percentage of non-responders in motor vehicles and a slightly lower percentage of non-responders in fabricated metals, but neither of these industries was significantly represented in any kind of sample partitioning.

4.2. *Measuring the degree of JIT implementation*

The measurement of JIT implementation levels and benefits required a representative set of JIT manufacturing practices. These measures were established from prior research (e.g. Banker et al., 1993a,b; Flynn et al., 1995; Mehra and Inman, 1992; Moshavi, 1990; Spencer and Guide, 1995; White and Ruch, 1990). The ten JIT elements described in the White and Ruch (1990) literature review and used in an empirical study by White et al. (1999) are presented as eleven six-point Likert-scaled questions on the survey instrument to measure the extent to which firms have adopted JIT: focused factory, group technology, reduced setup times, total productive maintenance, multi-function employees, uniform workload, *kanban*, JIT purchasing, total quality control (process and product), and quality circles. Each of the JIT practices was measured by a single question on the survey instrument. Multiple measures for each JIT characteristic, as used in other studies (Flynn et al., 1995; Sakakibara et al., 1993, 1997) would have been beneficial. However, the benefits from an expanded questionnaire were determined to be less than those received from a higher response rate. A glossary defining the JIT terms was attached to the survey packet to provide a clearer understanding of the 11 JIT terms found on the survey, similar to the approach of White et al. (1999) (for further explanation of the determination of the JIT measures, see Fullerton and McWatters, 1999a).

4.2.1. Factors for JIT determinants

Using the principal components method, JIT measures were subjected to an exploratory factor analysis. Three components of JIT with eigenvalues >1.0 were extracted from the analysis, representing 64% of the total variance in the data. All of the 11 elements loaded >0.5 onto one of the three constructs except for *quality circles*, which was eliminated from further testing. The first factor is a manufacturing component that explains the extent to which companies have implemented general manufacturing techniques associated with JIT, such as focused factory, group technology, uniform work loads, and multi-function employees (JITMANUF). Collectively, these techniques represent elements of a JIT manufacturing system, although individually these practices may be adopted by any high technology manufacturing firm.

The second JIT factor is a quality component that examines the extent to which companies have implemented procedures for improving product and process quality (JITQLTY). Total quality management (TQM) and JIT are associated through their common continuous improvement goals. Although TQM can be adopted without implementing JIT, it is unlikely that a JIT manufacturing system can succeed without incorporating the underpinning tenets of TQM. Good quality management is frequently referred to as the cornerstone of JIT and key to its survival (Banker et al., 1993a; Imai, 1998; Sim and Killough, 1998; Swanson and Lankford, 1998; Young et al., 1988).

The third JIT factor identified is one of uniquely JIT practices that describe the extent to which companies have implemented JIT purchasing and *kanban* (JITUNIQUE). Unlike the other JIT practices, these practices are associated more specifically with JIT. Thus, firms that have adopted these practices would more likely perceive themselves as fully committed to JIT (refer to Table 2 for results of the factor analysis).

4.3. Construct validity and reliability analysis

"Factor analysis is considered one of the most powerful methods of construct validation, as it allows an examination of the overall measure" (Gupta and Somers, 1992, p. 173). The factor solutions for the defined constructs support the construct validity of the survey instrument. Convergent validity is demonstrated by each factor having multiple-question loadings in excess of 0.5 (see Bagozzi and Yi, 1988). In addition, discriminant validity is supported, since none of the questions in the factor analyses have loadings in excess of 0.4 on more than one factor. In order to further test the construct validity of the resulting constructs, the factor structures were cross validated through the use of the total sample. Similar loadings in the cross-validation total sample verified the initial underlying patterns.

Firms reported on the survey instrument whether or not they had formally implemented JIT. Gupta and Somers (1992) indicate that a large correlation between two somewhat different measures of the same construct can be used to provide further evi-

Table 2
Factor analysis (VARIMAX rotation) factor loadings for JIT variables[a]

Chronbach's alpha	Factor 1 (JITMANUF 0.831)	Factor 2 (JITQLTY 0.946)	Factor 3 (JITUNIQUE 0.684)
Focused factory	0.662		
Group technology	0.719		
Reduced setup times	0.732		
Productive maintenance	0.729		
Multi-function employees	0.537		
Uniform work load	0.750		
Product quality improvement		0.928	
Process quality improvement		0.940	
Kanban system			0.732
JIT purchasing			0.797

[a] All loadings in excess of 0.40 are shown ($n = 95$).

dence of the construct validity of the instrument. A correlation matrix showed significant correlations between all of the JIT constructs used in this study and the JIT/non-JIT response. In addition, an ANOVA test was run comparing the means of the self-identified JIT and non-JIT sample firms for the three JIT factors (JITMANUF, JITQLTY, and JITUNIQUE) and a JIT measure representing a complete set of JIT elements (JITCOMB) that is the average of the three specific JIT factors. All of these JIT constructs have highly significant means differences between JIT and non-JIT firms (for further explanation, see Fullerton and McWatters, 1999a).

Cronbach's alpha is used as the coefficient of reliability for testing the internal consistency of the constructs validated by the factor analysis. The alpha coefficients for JITMANUF and JITQLTY are 0.831 and 0.946, respectively; the coefficient falls to 0.684 for JITUNIQUE (the alpha coefficients are shown in Table 2). The Chronbach's alpha of the reliability for the combined JIT measure (JITCOMB) is 0.864. According to Nunnally (1978), alpha coefficients of 0.50–0.60 are acceptable for exploratory research. Overall, these tests support the validity of the measures representing the constructs used in this study.

5. Research results and discussion

The respondents who indicated that they had formally adopted JIT were asked to identify the extent of operational change that occurred post-JIT adoption in the following areas: quality, production timeliness, employee utilization, accounting, firm profitability, and inventory reduction. They were given five choices for the level of change: significant increase, moderate increase, little or no change, moderate decrease, or significant decrease. The number of answers given in each category for each level of change is shown in Table 3. Approximately, 28% of the responses indicate that firms have had *significant* improvements in their operations since implementing JIT. More than 61% of the responses are positive, whereas only 5% of the responses are negative with respect to changes after adopting JIT. When examining only inventory effects, over three-fourths of the respondents report declines in total inventory.

5.1. ANOVA comparisons

One reason suggested for the limited success from JIT implementation is the piece-meal approach that

Table 3
Responses to changes in production operations after JIT implementation[a]

	Significant increase	Moderate increase	No change	Moderate decrease	Significant decrease	Percentage improved
Scrap		2	35	33	21	59.3
Rework		3	38	31	19	54.9
Inspections	2	7	37	24	21	49.5
Setup times		9	31	25	26	56.0
Queue times		2	20	37	32	75.8
Move times		3	33	28	27	60.4
Machine downtime		5	54	17	15	35.2
Lot sizes	1	7	25	28	30	63.7
Throughput time		12	18	31	30	67.0
Customer response time		2	27	35	27	68.1
Worker flexibility[b]	20	37	29	5		62.6
Teamwork[b]	24	41	23	3		71.4
Accounting simplification[b]	4	22	59	6		28.6
Firm profitability[b]	19	37	31	4		61.5
Inventory reduction						
Raw materials		2	15	39	35	81.3
Work in process		3	14	29	45	81.3
Finished goods		3	29	23	36	64.8

[a] $n = 91$.
[b] Increases in these categories reflect improvements in operations.

companies use in its adoption (Clode, 1993; Daniel and Reitsperger, 1991; Gilbert, 1990; Goyal and Deshmukh, 1992). To better understand which elements of JIT affect improvements in firm operations, four JIT factors are examined. Three individual factors, representing three different implementation perspectives of JIT (a manufacturing component, a quality component, and a unique JIT practices component), are used to assess the perceived benefits of JIT practices. In addition, the average score of the three JIT factors facilitates the assessment of JIT benefits resulting from the implementation of a comprehensive array of JIT applications.

Each of the JIT factors is separated into low and high levels of implementation. Respondents were asked to indicate to what extent their firm had implemented individual JIT techniques per the following categories — 1: no intention; 2: considering; 3: beginning; 4: partially; 5: substantially; 6: fully. Mean responses for the JIT factors that are ≥ 5 are classified as high adopters. Mean responses for the three JIT factors that are >2 and <5 are classified as low adopters. Mean responses outside this range are not used in the analyses, because no judgment of the change effects from JIT adoption can logically be made when responses indicate that these measures have not yet been implemented.

The combined JIT measure adds the three individual factors together and averages them. This result is then sectioned into high and low JIT adopters, providing a more comprehensive perspective of JIT. This measure examines more than the sum of the individual factors, since a high adopter on one or even two individual factors might be classified as a low adopter overall. The distribution of low and high adopters is different for each of the four JIT measures. Table 5 indicates that all of the categories except JITQLTY have almost twice as many low as high adopters. JITQLTY has approximately three times as many high as low adopters, supporting the importance of quality maintenance in a JIT environment.

After partitioning the four JIT factors into the two high/low classification levels, an ANOVA was run to determine if a higher level of JIT implementation contributes to greater improvements in inventory levels, quality, timeliness, worker flexibility, and profitability. Other complex, interactive interrelationships that affect production improvements may exist beyond those resulting from JIT implementation. However, this study focuses specifically on JIT, recognizing implicitly thereby the trade-off in model testing between generalizability and simplicity (Weick, 1976). The ANOVA results demonstrate whether firms more extensively committed to the implementation of specific JIT practices receive greater benefits from their implementation efforts. The results for production operations are shown in Table 5 and for inventory reductions in Table 4. In addition, the means for each JIT level, along with the total sample are given.

Table 4
ANOVA analysis of means for changes in inventory for low and high users of JIT practices

Inventory reduction[a]		JITMANUF[b] ($n = 88$)	JITQLTY[b] ($n = 90$)	JITUNIQUE[b] ($n = 90$)	JITCOMB[c] ($n = 91$)
Raw materials	Low	4.098	3.833	3.982	4.048
	High	4.333	4.303	4.471	4.448
	Total	4.171	4.178**	4.167***	4.176**
Work In process	Low	4.230	4.167	4.125	4.129
	High	4.407	4.333	4.500	4.586
	Total	4.284	4.289	4.267**	4.275**
Finished goods	Low	3.967	3.708	3.875	3.919
	High	4.074	4.134	4.206	4.207
	Total	4.000	4.022*	4.000	4.011

[a] Possible responses are:1: significant increase; 2: moderate increase; 3: no change; 4: moderate decrease; 5: significant decrease
[b] The elements for these JIT factors are shown on Table 2.
[c] JITCOMB adds together the three individual JIT factors, averages them, and partitions this answer into high and low overall adopters.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

To determine if the overall means of the sample respondents are significantly different from the neutral point of three (no change), a *t*-test was run for the production and inventory measures with the full sample (both low and high adopters). Every measure was significantly greater than the null hypothesis of no improvement to at least $P < 0.000$. These results reinforce the responses on Table 3 and provide credibility to the tests of significance between the high and low JIT adopters. To check if interactive effects from the combination of the three JIT variables led to different results than the additive effects for JITCOMB in Table 5 , the same ANOVA analyses were performed for the high/low multiplicative product of the three individual JIT factors. The results were similar, with the level of significance reduced somewhat for teamwork and accounting simplification.

5.2. Changes in production operations

Improvements in production operations from the implementation of JIT practices are summarized in Table 5. The quality benefits are measured by the scrap, rework, and inspection variables. Improvements in production timeliness are measured by six variables: queue times, move times, machine downtime, lot sizes, throughput time, and customer response time. Employee flexibility is evaluated by responses to improvements in worker flexibility and teamwork. Benefits related to accounting simplification and financial performance are measured individually.

5.2.1. Quality benefits

The ANOVA analyses show that the level and type of JIT practices in place do affect a firm's quality. Scrap and rework have significant differences between low and high implementers for JITMANUF, JITUNIQUE, and JITCOMB. These results support the findings of earlier survey studies (Im and Lee, 1989; Norris et al., 1994; Swenson and Cassidy, 1993). In a perfect JIT world, inspections would not be necessary, because the quality would be so exceptional that there would be no defects. Inspections during production indicate that less than perfect quality is expected and tolerated (Lubben, 1988, p. 48). Even though a decrease in the number of inspections has one of the lowest positive response rates in this study, there are significant differences between low and high adopters for the JITQLTY and JITCOMB factors. This result provides some evidence that as a more serious commitment is made to JIT and quality practices, managers gain more confidence in reducing the number of inspections.

5.2.2. Time-based benefits

One of the most documented reasons for JIT implementation is the reduction of NVA activities that increase throughput time. The time-consuming, NVA activities examined in this study include queue time, move time, and machine downtime. In addition, small lot sizes contribute to the reduction of these activities, and subsequently, to improved throughput times. The findings in this study demonstrate that JIT can be an effective, time-based manufacturing tool for firms that implement a comprehensive set of JIT practices. Five of the six time-based measures show significantly larger reductions in NVA activities for the high JIT adopters using a complete set of JIT practices.

Arguably, one of the most wasteful manufacturing activities is wait time. A reduction in queue time is the benefit mentioned most frequently by the sample respondents. Along with move time, this measure shows the greatest difference in time-based measures between low and high investments in JIT. In addition, a significant difference in machine downtime between low and high JIT adopters is indicated. However, machine downtime has the lowest average productivity change overall, suggesting that JIT reduces machine downtime, but further improvements are possible. Reduced lot sizes are considered integral to JIT implementation. In this study, a significant difference is found in the change in lot size between those who have adopted different degrees of JITUNIQUE or JITCOMB.

The ultimate goal of reducing NVA activities is to enhance competitive advantage through reduced throughput time. Several studies have found that improved throughput time was the major benefit from JIT adoption (Cobb, 1992; Im and Lee, 1989; Nakamura et al., 1998; White, 1993). The results in this study show that the high adopters who have implemented a full array of JIT practices, have significantly reduced throughput times.

Table 5
ANOVA analysis of means differences in production changes for low and high users of JIT practices

Production changes[a]	JITMANUF[b] (low = 61, high = 27), $n = 88$	JITQLTY[b] (low = 24, high = 66), $n = 90$	JITUNIQUE[b] (low = 56, high = 34), $n = 90$	JITCOMB[c] (low = 62, high = 29), $n = 91$
Quality benefits				
Scrap				
Low	3.721	3.625	3.643	3.629
High	4.111	3.894	4.088	4.241
Total	3.841**	3.822	3.811**	3.824***
Rework				
Low	3.639	3.542	3.571	3.532
High	4.000	3.803	3.971	4.138
Total	3.750*	3.733	3.722**	3.725***
Inspections				
Low	3.557	3.250	3.464	3.403
High	3.852	3.742	3.824	4.035
Total	3.648	3.611**	3.600	3.604***
Time-based benefits				
Queue times				
Low	4.049	3.917	3.911	3.903
High	4.296	4.167	4.353	4.483
Total	4.125	4.100	4.078**	4.088***
Move times				
Low	3.787	3.750	3.661	3.694
High	4.418	3.924	4.177	4.241
Total	3.898*	3.878	3.856***	3.868***
Machine downtime				
Low	3.443	3.208	3.357	3.307
High	3.556	3.546	3.588	3.793
Total	3.477	3.456*	3.444	3.462***
Lot sizes				
Low	3.803	3.917	3.679	3.726
High	4.111	3.864	4.177	4.172
Total	3.898	3.878	3.867**	3.868**
Throughput time				
Low	3.869	3.625	3.768	3.710
High	4.000	3.970	4.029	4.207
Total	3.909	3.878	3.867	3.868**
Customer response time				
Low	3.984	4.000	3.857	3.919
High	3.963	3.955	4.088	4.035
Total	3.977	3.967	3.811	3.956
Employee flexibility				
Worker flexibility[d]				
Low	3.754	3.500	3.536	3.645
High	3.926	3.909	4.235	4.103
Total	3.807	3.800**	3.800***	3.791**
Teamwork[d]				
Low	3.869	3.750	3.768	3.790
High	4.148	4.015	4.235	4.276
Total	3.955	3.944	3.944***	3.945***

Table 5 (*Continued*)

Production changes[a]	JITMANUF[b] (low = 61, high = 27), $n = 88$	JITQLTY[b] (low = 24, high = 66), $n = 90$	JITUNIQUE[b] (low = 56, high = 34), $n = 90$	JITCOMB[c] (low = 62, high = 29), $n = 91$
Accounting simplification[d]				
Low	3.262	3.292	3.161	3.145
High	3.296	3.258	3.412	3.517
Total	3.273	3.267	3.256*	3.264**
Firm profitability[d]				
Low	3.754	3.417	3.768	3.677
High	3.889	3.909	3.794	4.000
Total	3.796	3.778**	3.778	3.780*

[a] Possible responses are 1: significant increase; 2: moderate increase; 3: no change; 4: moderate decrease; 5: significant decrease.
[b] The elements for these JIT factors are shown on Table 2.
[c] JITCOMB adds together each of the three individual JIT factors, averages them, and partitions this answer into high and low overall adopters.
[d] These items are reverse coded.
* $p < 0.10$ statistical significance of differences in means.
** $p < 0.05$.
*** $p < 0.01$.

5.2.3. Employee flexibility

Human resource issues are critical to the success of JIT. This study demonstrates significant differences between the low and high JIT adopters in teamwork and worker flexibility for the majority of the JIT factors. These results suggest that firms making a greater commitment to JIT implementation reap greater rewards in terms of increased employee flexibility.

5.2.4. Accounting simplification

Along with streamlining their production processes, JIT firms should also streamline their accounting procedures (Bragg, 1996). This study presents some evidence that high JIT adopters are doing a better job of simplifying their accounting systems. Mean differences for JITUNIQUE and JITCOMB are significantly different for high and low JIT adopters. However, the mean for accounting simplification is appreciably lower than the means of all the other measures.

5.2.5. Firm profitability

As noted, several studies have examined production performance benefits of JIT, but there is limited and conflicting evidence of the direct effect of JIT adoption on financial performance. This study indicates that firms that have invested more in quality practices benefit from significantly higher financial rewards. Greater profitability is also observed for those adopting a full complement of JIT practices. External profitability measures were obtained from COMPUSTAT for the sample firms. There is a significant correlation to at least $P < 0.01$ between the respondents' perceived increases in firm profitability and higher external measures of return on assets and return on sales.

5.3. Changes in inventory

The effect on inventory levels has been researched more than any other aspect of JIT implementation. The results consistently demonstrate substantial reductions in inventory levels post-JIT adoption. The firms in this study also show considerable reductions in inventory after adopting JIT (refer to Table 4). Almost half of the respondents indicated that they had a *significant* decrease in WIP since implementing JIT. The WIP mean of 4.6 for the high adopters of JITCOMB, easily the highest average response, is significantly greater than that of the low JIT adopters. RM inventory reductions are also significantly greater for high adopters. However, the results indicate little difference in FG inventory levels between low and high JIT adopters, similar to the results of Balakrishnan et al. (1996) and Patell (1987). Inventory reductions appear to be easier to maintain for WIP than for FG.

Table 6
ANOVA analysis of means' differences in firm characteristics for low and high users of JIT practices

	Level of JIT[a]	*n*	Mean	S.D.
Years of JIT experience	Low	61	4.656	4.311
	High	28	6.464	
	Total	89	5.225*	
JIT training hours per year per employee				
Top management	Low	53	14.226	19.044
	High	24	8.000	
	Total	77	12.285	
Middle management	Low	55	28.582	38.255
	High	26	25.192	
	Total	81	27.494	
Line supervisors	Low	54	29.093	38.949
	High	25	26.000	
	Total	79	28.114	
Non management	Low	54	18.593	32.035
	High	25	21.160	
	Total	79	19.415	
Top management commitment[b]	Low	64	3.688	1.036
	High	29	3.931	
	Total	93	3.763	
Innovation leadership[c]	Low	63	3.841	0.698
	High	31	4.140	
	Total	94	3.940*	
Organizational structure[d]	Low	63	3.037	1.008
	High	31	3.151	
	Total	94	3.075	
Repetitive production process[e]	Low	64	0.781	0.402
	High	31	0.839	
	Total	95	0.800	
Firm size (sales)	Low	61	532.058	1332.637
	High	30	1345.147	
	Total	91	800.109***	

[a] JIT is the average of the three individual JIT factors.
[b] Scale for this survey item: Indifferent: 1...2...3...4...5: highly committed.
[c] Scale for this survey item: Follower: 1...2...3...4...5: leader.
[d] Scale for this survey item: Highly Centralized: 1...2...3...4...5: highly decentralized.
[e] Scale for this survey item: 1: repetitive production process; 0: job shop.
* $p < 0.10$.
*** $p < 0.01$.

5.4. Differences in firm characteristics

Table 6 presents ANOVA analyses of the significance in the mean differences of the JIT factors for various characteristics of the responding firms. The results show minimal variation in the characteristics of the low and high JIT adoption firms. Only firm size, as measured by net sales, demonstrates any strong significant difference. Respondent firms that more fully implement JIT are much larger than those which invest fewer resources in JIT. A larger firm likely would have more resources to study the ramifications of JIT and to make the necessary changes for its adoption. The strong association between JIT implementation and firm size has been confirmed in earlier studies (e.g. Ahmed et al., 1991; Fullerton and McWatters, 1999a; Im and Lee, 1989; White et al., 1999).

Two other measures show marginal significance in mean differences of low and high JIT adopters. As expected, the longer a firm has practiced JIT, the higher is its level of adoption. Also, firms that perceive themselves to be more innovative have made a greater commitment to JIT practices. Although 80% of the JIT firms indicated they use a repetitive production process as opposed to a job shop, there is no significant difference between high and low adopters.

6. Conclusions

This study indicates that managers adopting JIT practices have experienced considerable benefits in all of the measured areas: quality improvements, time-based responses, employee flexibility, accounting simplification, firm profitability, and inventory reductions. The managers who reaped the highest rewards were the high adopters of either a complete array of JIT practices or the more unique JIT practices of *kanban* and JIT purchasing. Fourteen of the 16 benefits examined for the combined JIT measure have significant mean differences between low and high JIT adopters. This result provides convincing evidence that the more comprehensive (both in breadth and depth) is the adoption of JIT, the greater are the overall returns.

Both low and high adopters are receiving similar benefits when their focus is restricted to JIT manufacturing practices and quality maintenance. The individual practices associated with JITMANUF and JITQLTY are more general in application, and could be adopted by advanced, quality-oriented manufacturing firms, whether or not they are formally practicing JIT. Thus, differences in benefits achieved from varying implementation levels in these areas may be limited. JITUNIQUE is the only individual JIT factor that has high incidence of significant differences between the means of high and low users, strengthening our premise that a more comprehensive JIT implementation leads to greater benefits. The JIT practices most likely found in firms that have more fully committed to the JIT philosophy are those that are represented in the JITUNIQUE factor.

International competition continues to intensify as firms strive to attain a greater share of the world marketplace. These research results demonstrate that JIT implementation improves competitive performance by lowering inventory levels and reducing quality costs and throughput time. The evidence supports the concept of JIT as a comprehensive, vital manufacturing strategy that can build and sustain competitive advantage.

6.1. Research limitations

Specific research limitations might reduce the generalizability and applicability of the study findings. A necessary assumption in the data collection is that the respondents were sufficiently knowledgeable and answered the questions conscientiously and truthfully. Although the 11 JIT indicators were supported by a thorough study of JIT literature, and an explanation of their meaning was attached to the survey packet, these single measures for the individual JIT practices might not have captured actual company practices. Evaluation of the performance measures was based on management perceptions. This self-reporting may have created bias in the answers, due to a natural tendency of managers to respond favorably concerning the operations of their firm. Finally, the sample selection process was not completely random. In order to obtain an adequate number of responses from firms practicing JIT, a portion of the sample was selected from specific firms identified in the literature review as “JIT firms”. This limitation might lead to response bias and make the test sample non-representative of other US manufacturing firms adopting JIT.

6.2. Future research directions

As JIT practices become more prevalent, in-depth study of individual industries and companies would result in a more refined representation of both its benefits and limitations. Case studies of JIT failures would provide information on the pitfalls of JIT and the necessary conditions for its success. Case studies also would help to uncover the motivation to implement JIT. The increasing economic importance of service industries reinforces the need for complementary research of this sector to determine which JIT concepts could provide competitive advantage in this environment. JIT is not a panacea for all market challenges. Nonetheless, strong evidence of JITs substantial benefits merits its consideration as part of organizational strategy to enhance long-run performance and competitiveness.

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