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The relationship between JIT practices and type of production system

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Abstract

After World War II, the Japanese incrementally applied new management practices to improve their global competitiveness. With refinement and systematic integration of these new practices the Japanese achieved a new manufacturing paradigm and, by the 1970s, a competitive superiority in the marketplace. In an effort to emulate the success achieved by Japanese manufacturers, US managers began to apply these new management practices in their organizations. These management practices were introduced as just-in-time (JIT) manufacturing. US managers have progressed through a series of trial and error efforts to apply these new management practices and still do not understand many of the issues associated with JIT implementations. This study attempts to address some of the misunderstandings associated with JIT implementations. A systems approach is utilized for collecting data and analyzing pertinent relationships associated with JIT implementations in US manufacturers. Findings from the study suggest that an association exists between implemented JIT practices and type of production system. In addition, this is the first study to show the benefits attributed to JIT implementation as a function of implementation status of specific JIT management practices and type of production system. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: JIT; Japanese management practices; Production processes; Lean manufacturing; US manufacturers

1. Introduction

Japanese management practices have been the focus of US managers' efforts to adopt different approaches that provide the same or higher output levels for their organizations with fewer resources for more than a decade. These Japanese management practices, introduced to US manufacturers as just-in-time (JIT) manufacturing, were presented using a variety of descriptions in the early literature [1–4]. Later descriptions of this organizational phenomenon [5] generally involve broad-based production systems that consist of various management practices associated with efficient material flow, improved quality, and increased employee involvement systems [6–10]. However, the names used for these management practices were not consistent, i.e., just-in-time manufacturing, total enterprise manufacturing, world class manufacturing, and lean production [6,10–12]. In reference to the names used for JIT, Hall [7] states "None of the names often used for this philosophy suggest its total power and scope … and none are universally used" (p. 23). JIT is a misused term that is less than adequate to describe this broad production system, but it is still the best term available because it is a more universally accepted term than any of the alternatives. Therefore, JIT is used throughout this paper to describe a broad-based production system that strives to achieve excellence. Unfortunately, some confusion about JIT still exists and unanswered questions remain about implementation issues associated with JIT systems [13–15].

In this study we investigate JIT implementations in US manufacturers. JIT manufacturing is defined as a system composed of various management practices. Next, the methodology employed for investigating JIT implementations is presented. We assess the individual practices

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associated with JIT, then by aggregating the knowledge gained about the practices (system components) and their interrelationships, a comprehensive understanding of JIT implementations is achieved. The relationships are analyzed and the results of the study are discussed. Finally, the findings of the study are summarized and the study's contribution to understanding JIT implementations in US manufacturers is discussed.

2. Just-in-time manufacturing

The overall objective of a JIT system is to continuously improve the organization's productivity, quality, and flexibility [6,7,10,11]. Each element of a JIT system provides some benefit for a manufacturer, but the application of each element potentially involves only certain areas in the organization, and unless a systems perspective is employed, the areas optimize locally, rather than at the organization level [8]. Consequently, the potential synergic benefits are not fully realized until all elements of a JIT system are integrated [18,19].

In a related survey study, White et al. [16] collected data from large and small manufacturers to investigate JIT implementations. The instrument used to collect the data measured a set of 10 JIT management practices (representing a holistic understanding of JIT systems) and associated implementation variables. The 10 JIT management practices examined in the study include the following: focused factory, reduced setup times, group technology, total preventive maintenance, multifunction employees, uniform workloads, Kanban, total quality control, quality circles, and JIT purchasing.

In a separate survey study, a different survey instrument centered around the 10 JIT management practices identified by White et al. [16] was used to collect data for modeling JIT systems [17]. Ten subscales were developed (one for each of the 10 JIT practices) in the instrument and subsequently, data were collected from three professional organizations. Upon modeling the data, Davy et al. [17] suggested that the results represented the systems perspective and integrative thinking associated with JIT. Systematic integration of the 10 JIT management practices (presented previously) represents holistic JIT systems as presented throughout this paper.

3. JIT implementations and US manufacturers

3.1. JIT implementations

Implementations of JIT in US manufacturers often involve adopting just a few of the management practices associated with JIT [18–21]. As a result of this selective process the frequencies of JIT practices implemented by US manufacturers often differ among the various JIT practices [22–25]. In addition, researchers suggest the practices implemented are typically the ones easiest to implement, but not necessarily the ones that provide the greatest benefits [22,23]. The piece-meal approach to adopting JIT used by US manufacturers occurs despite research findings that suggest the synergic benefits desired by US manufacturers cannot be fully realized until all JIT practices are integrated into a holistic management system [5,8,18,19].

Goyal and Deshmukh [18] state that most of the JIT literatures confirms that understanding the concept of JIT requires a systems perspective. Benefits attributed to implementing JIT typically include reduced throughput time [22,23,26], improved internal quality [27,28], improved external quality [27,29,30], improved labor productivity [22,29,31], reduced inventory levels [32–34], and lower unit cost [35–37]. Moreover, the findings of JIT research generally suggest the longer the JIT system is in place the greater the benefits achieved [38], and the greater the extent of JIT implementation the greater the success achieved [35,39–41].

3.2. US production systems

The framework for understanding JIT implementations in US manufacturers draws from Thompson's [42] concept of traditional US organizations and Hayes and Wheelwright's [43] continuum of production processes. Thompson [42] posits that US manufacturers have traditionally used buffers or inventories to reduce the effects of uncertainties on the organization's internal core (technological activities). Buffers between the internal core and the external core (input and output activities) allow for developing greater efficiencies among the activities within the internal core; this is achieved by increasing the level of interdependence across the activities in the internal core. A reclassification of the ends of Hayes and Wheelwright's [43] continuum of production processes (project/job shop and assembly line/continuous flow) provides a clearer distinction of processes and associated characteristics that support Thompson's [42] concept. For example, with movement from one end of Hayes and Wheelwright's [43] continuum (project/job shop) to the other end (assembly line/continuous flow) increasingly higher levels of raw materials and finished goods exist to protect the internal core and increasing lower levels of work-in-process inventories exist among the activities of the internal core. At the project/job shop end, high levels of work-in-process inventories exist to buffer among the technological activities and lower levels of inventories exist to buffer the internal core from the input and output activities (see Fig. 1). Batch, the production process that falls in the middle, in a sense, is a hybrid of the revised processes on the ends of the continuum. Since batch does not provide a clear distinction for differentiating from either of the ends, it is not included as a classification of production processes in this study.

Traditional nonrepetitive production systems (project/job shop) are capable of producing a high variety of products; however, the high levels of WIP inventories (see Fig. 1)

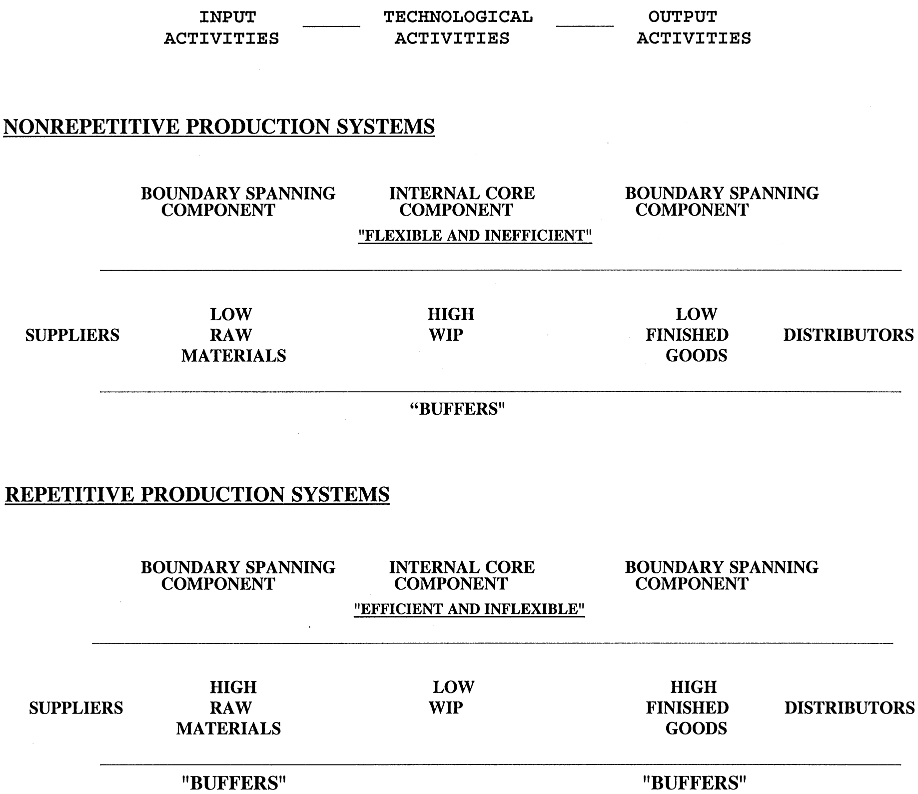

Fig. 1. Traditional inventory buffers in US manufacturers.

associated with nonrepetitive production suggest that inefficiency exists among the technological activities [42]. In contrast to nonrepetitive production systems, repetitive production systems (assembly line/continuous flow) are typically efficient, but lack the flexibility to produce a high variety of products. In repetitive production systems, inventories are used as buffers between input activities and the technological activities, and the technological activities and output activities; this allows for developing efficiency among the technological activities [42]. Other characteristics of the revised extremes of Hayes and Wheelwright's [43] continuum are presented in Table 1.

As with Thompson's [42] concept, Arogyaswamy and Simmons [44] suggest that the key in implementing JIT is to increase the intensity of interdependence between operations while emphasizing global rather than local optimization. According to Arogyaswamy and Simmons the first step in the implementation process is to make the interdependence between operations obvious. This should be accomplished by introducing the pull system in the following sequence of JIT practices: cellular layout (an aspect of group technology), reduced setup times, Kanban and uniform workload. Since the levels of buffers vary between nonrepetitive and repetitive processes [43], the assumption is that the value of implementing specific JIT management practices for increasing interdependencies may differ dependent upon whether the process is nonrepetitive or repetitive.

3.3. Association between JIT implementations and US production systems

Shingo [1] suggested that the Toyota Production System (JIT) is applicable to all factories, but warned that the system should be adapted to the characteristics of each particular plant. Research in this area provides some evidence that the JIT practices implemented is influenced by type of production system [1,25,38,45].

Each type of production system may have characteristics that are the same or similar to characteristics conducive for implementing certain JIT management practices. However, when JIT practices deviate substantially from existing production system characteristics, opportunities for improvement may be greater because of the substantial change that occurs with implementation. For example, with the high worker skill level and large worker job content typically associated with nonrepetitive production systems, it would seem easier to implement the JIT practice of multifunction employees in nonrepetitive than in repetitive production systems. Because the employees in nonrepetitive production systems are generally of higher skill level

Table 1
Characteristics of production processes[a]

Characteristics	Production processes	
	Nonrepetitive	Repetitive
Variety of products	Customized	Standardized
Material requirements	Difficult to predict	Very predictable
Scheduling	Uncertain, frequent changes	Fixed schedule, inflexible
Production runs	Short	Long
Setups	Different every job	Very few and costly
Type of equipment utilized	General purpose	Special purpose
Worker job content (scope)	Large	Small
Worker skill level	High	Low
Control over suppliers	Low	High
Inventory levels		
Raw	Low	High
WIP	High	Low
Finished goods	Low	High

[a] Source: Adapted from Hayes and Wheelwright [43].

initially, the benefit for the system may not be as great as that in a repetitive production system. Based on the evidence presented, supported with the characteristics of production systems derived from Hayes and Wheelwright [43], the reasoning leads to the first hypothesis (null form):

Hypothesis $H_0 1$: No association exists between the JIT practices implemented and type of production system.

3.4. JIT practices and associated benefits in US production systems

JIT researchers suggest that certain production systems allow for easier and lower cost implementation of some JIT management practices compared to other JIT practices [22,32,46]; accordingly, certain production systems offer greater opportunities for improvement from implementing some JIT practices compared to other JIT practices [22,27,28,46]. The second hypothesis (null form) is based on these findings and the characteristics of production systems derived from Hayes and Wheelwright's [43] work.

Hypothesis $H_0 2$: The relative benefit from each JIT practice is the same regardless of type of production system.

Though numerous other variables may influence the relationships investigated in this study, this work is focused on the association between JIT systems and type of production system. Consistent with the focus of this work the relationship between JIT and other variables was not explored.

4. Methodology

This research involves a cross-sectional field study using survey methodology in different manufacturing environments across a variety of US manufacturing organizations. Unfortunately, most organizations are prone to publicize and perhaps exaggerate examples of successful implementation while downplaying or hiding instances of failure. Therefore, to avoid bias about the success of implementing specific JIT management practices we surveyed well-informed middle- and upper-level managers with hands-on experience with JIT manufacturing. These respondents were sought because of their broad perspective of the organization's activities and because of their knowledge of associated implementation issues.

4.1. Target population

The data analyzed in this study were collected from members of the Association for Manufacturing Excellence (AME). AME members represent all types of production processes and all functions within those operations. In this study we investigate JIT implementations in US manufacturers. The methodology for this work overlaps the one used by White et al. [16] because the data analyzed for this study used the same respondents. However, the data in this study constituted a distinct and different data set because the variables selected were different.

4.2. Questionnaire

The Total Design Method [47] for writing questions and constructing the questionnaire was followed for developing the survey instrument. The items in the questionnaire were structured as close-ended questions with ordered choices. The structure of the questions used to collect information on each of the key variables assessed in this study included production systems, implementation status of JIT practices, and benefits associated with JIT implementations.

Production systems. Items used to collect information for type of production system consisted of percentage measures of annual sales produced by type of production process. Definitions of types of production processes based on Hayes and Wheelwright's [43] classification of manufacturing processes (project, job shop, batch, assembly line, and continuous flow) were included in the questionnaire.

Implementation status of JIT practices. Each of the 10 JIT practices that represent the holistic understanding of JIT systems formed an item used to collect information on implementation status of JIT practices. Definitions for each of these JIT management practices were used in data collection to reduce any misunderstandings that may exist (see [16] for these definitions). The data for the practices were scored based on the midpoint of the assessment scale: not implemented (scored "0"), implementation started within the last year (scored "0.5"), implementation started 1–3 years ago (scored "2"), implementation started 3–5 years ago (scored "4"), and implementation started more than 5 years ago (scored "6").

Benefits associated with JIT implementations. Data were collected on six benefits associated with JIT systems: throughput time (lead time — includes time from order release to job completion), internal quality (defects, rework, etc.), external quality (warranties, returns, etc.), labor productivity, inventory levels, and unit cost. The data on four on these benefits (throughput time, internal quality, external quality, and labor productivity) were collected as "better" or "not better". The data of the other two benefits (inventory levels and unit cost) were collected as "lower" or "not lower".

Validation. Focus groups consisting of experts in the areas, a pretest, and a pilot study were used to clarify items on the questionnaire and further develop the comprehensiveness of the instrument (for further details see [16]). In addition, follow-up interviews with the respondents from the pretest allowed for additional clarification of ambiguous items. Follow-up interviews of the respondents allowed for feedback which was reviewed and necessary revisions were made to the questionnaire prior to data collection.

4.3. Data collection, review and reclassification

The data collection process consisted of two mailings. Approximately 5 weeks after the initial mailing a follow-up mailing was performed. Of the 2640 surveys initially mailed a total of 1165 surveys were completed and returned for an overall response rate of 44.1%.

A review of the data allowed for identification of data omitted from the final sample for the following: completed surveys that were from multiple respondents of the same organization, academicians and/or consultants ($N = 70$); completed surveys from respondents' whose organizations had not implemented any of the JIT practices ($N = 34$); and completed surveys that had incomplete data pertaining to any of the key variables assessed in this study ($N = 144$). Since the focus of the study was on manufacturers, 76 cases were omitted because less than 75% of the firm's sales were generated from manufacturing.

The data for project and job shop production processes were combined to form a revised classification representing nonrepetitive production systems. Assembly-line and continuous flow data were combined to form a second reclassification representing repetitive production systems. To qualify as primarily having a nonrepetitive or repetitive production system, a manufacturer had to generate at least 70% of its sales from either of the reclassified production processes. Subsequently, the data collected on the middle production process (batch) were omitted from the sample for this study ($N = 126$). In addition, another 221 cases where a combination of processes used to generate sales were omitted from the final sample. Throughout the rest of this study the term "production system" is used to refer to these production systems (nonrepetitive and/or repetitive). Ultimately, the effective sample for this study is 494 responses, of which 191 represent manufacturers with nonrepetitive production systems and 303 represent manufacturers with repetitive production systems.

5. Results and analysis

A wide variety of industries was represented by the organizations included in the sample data. Seven categories of industries accounted for greater than 69% of those industries represented in the sample. The highest percent (39.0) of organizations represented in the sample was in the electronic/electric industry category. Other industries in the sample include metals, transportation equipment, machinery — except electric, medical components, rubber/plastics, and furniture represented by 9.1, 6.9, 4.3, 3.9, 3.9, and 2.4 percent of the organizations, respectively. Several other industries collectively accounted for 30.5% of the remaining manufacturers in the sample.

5.1. Implementation status of JIT practices

Sample statistics for implementation status of specific JIT practices by production system are presented in Table 2. The data indicate quality circles, total quality control and reduced setup times have the largest means for implementation status in repetitive production systems, with 2.47, 2.26, and 2.20, respectively. Total productive maintenance had the smallest mean (1.29) for implementation status in repetitive production systems. Multifunction employees and quality circles had the largest means for implementation status in nonrepetitive production systems, with 1.73 and 1.72, respectively. Uniform workload had the smallest mean (0.78) in nonrepetitive production systems.

Table 2
Mean implementation status and number of production systems with JIT practices implemented

JIT management practices	Production system[a]	Implementation status		Number of production systems with practices		Percent with practices implemented
		Mean	SD	Implemented/not implemented		
Quality circles	Non	1.72	2.12	113	78	59.2
	Rep	2.47	2.29	223	80	73.6
Total quality control	Non	1.69	1.62	161	30	84.3
	Rep	2.26	1.88	268	35	88.4
Focused factory	Non	1.20	1.51	122	69	63.9
	Rep	1.83	1.76	228	75	75.2
Total productive maintenance	Non	0.83	1.40	101	90	52.9
	Rep	1.29	1.55	199	104	65.7
Reduced setup times	Non	1.51	1.42	157	34	82.2
	Rep	2.20	1.74	269	34	88.8
Group technology	Non	1.35	1.66	121	70	63.3
	Rep	1.74	1.80	213	90	70.3
Uniform workload	Non	0.78	1.25	87	104	45.5
	Rep	1.55	1.82	203	100	67.0
Multifunction employees	Non	1.73	1.65	157	34	82.2
	Rep	2.01	1.86	248	55	81.8
Kanban	Non	0.96	1.31	115	76	60.2
	Rep	1.92	1.85	220	83	72.6
Just-in-time purchasing	Non	1.22	1.32	138	53	72.3
	Rep	1.82	1.73	247	56	81.5

[a]Non = nonrepetitive production system ($N = 191$), Rep = repetitive production system ($N = 303$).

5.2. Implemented JIT practices

To provide data for testing association between implemented JIT practices and production system, and comparing results of this study with those of other survey studies [22–24,38], the data for assessing implementation status were recoded with a score of 0 if the respondent checked "not implemented" and 1 if otherwise. This dichotomous coding scheme allows computation and comparison of the frequencies of implementations of the JIT practices across the 10 practices assessed in each production system. A summary of these results is presented in Table 2.

Sample statistics for benefits attributed to JIT implementation are presented in Table 3. Better throughput time was the most frequent benefit cited by the respondents in both nonrepetitive and repetitive production systems 86.9 and 89.1%, respectively. The second most frequent benefit cited by the respondents was better internal quality with 80.1 and 88.4% for nonrepetitive and repetitive systems, respectively. Lower unit cost was the benefit least frequently cited by both nonrepetitive and repetitive systems with 56.0 and 68.6%, respectively. The second least frequently cited benefit attributed to JIT was better external quality with 65.9 and 71.0% for nonrepetitive and repetitive production systems, respectively.

5.3. Odds ratio

The odds ratio of JIT practices (implemented vs. not implemented) were constructed to examine the association between implemented and production system for each JIT practice (Table 4). The odds ratio is defined as the ratio of the odds for $x = 1$ (implemented) to the odds for $x = 0$ (not implemented). In other words, the odds ratio is a measure of association that approximates how likely (or unlikely) is an outcome ($x = 1$) versus the absence of that outcome ($x = 0$). A significant negative association (odds ratio < 1.000) was indicated between nonrepetitive production systems and implemented for seven of the JIT practices (quality circles, focused factory, total productive maintenance, reduced setup times, uniform workload, Kanban, and JIT purchasing). The negative association for each of these practices suggests nonrepetitive production systems are less likely to implement JIT practices than repetitive production systems. No significant association between production systems and implemented was indicated for total quality control, group technology or multifunction employees. Thus, the evidence

Table 3
Benefits attributed to JIT implementation

Benefits	Production system[a]	Cases indicating Not better/better		Percent better
Throughput time	Non	25	166	86.9
	Rep	33	270	89.1
Internal quality	Non	38	153	80.1
	Rep	35	268	88.4
External quality	Non	65	126	65.9
	Rep	88	215	71.0
Labor productivity	Non	59	132	69.1
	Rep	63	240	79.2
		Cases indicating Not lower/lower		Percent lower
Inventory levels	Non	43	148	77.5
	Rep	38	265	87.5
Unit cost	Non	84	107	56.0
	Rep	95	208	68.6

[a]Non = nonrepetitive production system ($N = 191$), Rep = repetitive production system ($N = 303$).

Table 4
Odds ratio for JIT practices (implemented vs. not implemented) in nonrepetitive and repetitive production systems

JIT practices	Production system[a]	Number of systems with practices implemented/not implemented		Odds ratio	95% confidence interval	Significance
Quality circles	Non	113	78	0.520	(0.354, 0.764)	Yes
	Rep	223	80			
Total quality control	Non	161	30	0.701	(0.415, 1.185)	No
	Rep	268	35			
Focused factory	Non	122	69	0.582	(0.392, 0.863)	Yes
	Rep	228	75			
Total productive maintenance	Non	101	90	0.587	(0.405, 0.849)	Yes
	Rep	199	104			
Reduced setup times	Non	157	34	0.584	(0.349, 0.976)	Yes
	Rep	269	34			
Group technology	Non	121	70	0.730	(0.498, 1.072)	No
	Rep	213	90			
Uniform workload	Non	87	104	0.412	(0.284, 0.598)	Yes
	Rep	203	100			
Multifunction employees	Non	157	34	1.024	(0.639, 1.642)	No
	Rep	248	55			
Kanban	Non	115	76	0.571	(0.389, 0.838)	Yes
	Rep	220	83			
Just-in-time purchasing	Non	138	53	0.590	(0.384, 0.907)	Yes
	Rep	247	56			

[a]Non = nonrepetitive production system ($N = 191$), Rep = repetitive production system ($N = 303$).

Table 5
Fitted logistic regression models for benefits associated with JIT practices in nonrepetitive production systems[a]

Independent variables	Response variables					
Coefficients (SE)	Better throughput time	Better internal quality	Better external quality	Better labor productivity	Lower inventory levels	Lower unit cost
Constant	0.948[b] (0.308)	0.931[b] (0.275)			0.830[b] (0.211)	
QC						
TQC			0.413[b] (0.130)			
FF		0.519[c] (0.202)				
TPM	−0.523[c] (0.206)					
SU						
GT	0.979[b] (0.356)					0.463[b] (0.116)
UW			0.413[c] (0.189)			
MFE				0.215[c] (0.107)		
KAN	1.437[c] (0.581)	0.722[b] (0.263)			0.557[b] (0.212)	
JITP		−0.420[c] (0.188)				
−2 log likelihood	116.576	169.801	221.897	231.723	193.947	241.576

[a]Implementation Status: QC = quality circles, TQC = total quality control, FF = focused factory, TPM = total productive maintenance, SU = reduced setup times, GT = group technology, UW = uniform workload, MFE = multi-function employees, KAN = Kanban, and JITP = Just-in-time purchasing, $N = 191$.
[b] $p \leqslant 0.01$.
[c] $p \leqslant 0.05$.

supports rejection of the null hypothesis ($H_0 1$) and acceptance of the alternative hypothesis that an association exists between the JIT practices implemented and type of production system.

5.4. Logistic regression models

5.4.1. Implementation status of JIT practices and benefits

Logistic regression models are appropriate to examine how benefits attributed to JIT implementation are affected by the implementation status of each of the 10 JIT management practices in repetitive and nonrepetitive production systems. In each logistic model, implementation status of each of the 10 JIT management practices (ordinal scale) represent the explanatory variables and the binary response variable is the benefit (six assessed in this study) attributed to JIT implementation. The regression coefficients estimate the impact of the independent variables on the probability of achieving a benefit (better throughput time, internal quality level, external quality level, labor productivity, and lower inventory levels, unit cost). Thus, there are six models for repetitive production systems and six models for nonrepetitive systems. Each of the models has 11 parameters.

The results obtained from the fit of these logistic regression models for nonrepetitive and repetitive production systems are summarized in Tables 5 and 6, respectively. The columns in each table contain the coefficients for each logistic model for the implementation status of the indicated JIT management practice. A positive coefficient indicates increasing the implementation status for that JIT practice tends to increase the probability of achieving the benefit. A negative coefficient indicates the opposite effect. All nonsignificant parameter estimates ($p \geqslant 0.05$) in the fitted models were omitted from the reported tables.

Overall, the results of the fitted logistic models suggest that implementation status of specific JIT management

Table 6
Fitted logistic regression models for benefits associated with JIT practices in repetitive production systems[a]

Independent variables	Response variables					
Coefficients (SE)	Better throughput time	Better internal quality	Better external quality	Better labor productivity	Lower inventory levels	Lower unit cost
Constant		1.135[b] (0.223)			0.785[b] (0.276)	
QC						
TQC			0.439[b] (0.097)	0.275[b] (0.100)	0.383[b] (0.142)	
FF						0.396[b] (0.100)
TPM						
SU						
GT						
UW						
MFE	0.582[b] (0.198)		0.221[b] (0.085)	0.292[b] (0.103)		
KAN	0.899[b] (0.252)	0.788[b] (0.192)				0.323[b] (0.090)
JITP					0.376[c] (0.156)	
−2 log likelihood	158.938	187.374	321.125	283.768	204.389	327.429

[a]Implementation status: QC = quality circles, TQC = total quality control, FF = focused factory, TPM = total productive maintenance, SU = reduced setup times, GT = group technology, UW = uniform workload, MFE = multi-function employees, KAN = Kanban, and JITP = just-in-time purchasing, $N = 303$.
[b]$p \leqslant 0.01$.
[c]$p \leqslant 0.05$.

practices and production system affect benefits attributed to JIT implementation and differences exist in the relationships between the explanatory variables and the response variable in the logistic models for nonrepetitive production systems compared to those for repetitive production systems. Moreover, the results indicate implementation status of three JIT practices, total quality control (TQC), multifunction employees (MFE), and Kanban (KAN), have similar relationships (significant and positive) in four of the logistic regression models (total quality control (TQC) and better external quality, multifunction employees (MFE) and better labor productivity, Kanban (KAN) and better throughput time, and Kanban (KAN) and better internal quality) in both nonrepetitive and repetitive production systems.

The fitted models suggest that benefits are affected differently by implementation status of the JIT practices in nonrepetitive and repetitive production systems with seven of the 10 practices. Therefore, the second hypothesis (H_02) is rejected and the alternative hypothesis, the relative benefit from each JIT practice is not the same regardless of type of production system, is supported.

6. Discussion

The JIT manufacturing concept was defined in this study as a system of management practices, any of which could be adopted in a US manufacturing environment and would contribute to benefits for the organization. Overall, repetitive production systems appear to be more progressive in their utilization of JIT practices than nonrepetitive production systems. They have a higher utilization of each of the JIT practices compared to nonrepetitive systems. The results of the odds ratios indicate there is an association between the implemented JIT management practices and type of production system with seven of the practices investigated (quality circles, focused factory, total productive maintenance, reduced setup times, uniform workload, Kanban, and JIT purchasing). With each of the seven practices, the results suggest that nonrepetitive production systems are less likely to implement than repetitive production systems. This general bias for repetitive production systems was expected because JIT was designed in and had its roots in a repetitive production system, Toyota. In addition, early researchers promoted JIT applications in repetitive systems [1,48,49]. For example, Shingo [1], in his description of the Toyota Production System, suggested that Kanban was applicable to repetitive production systems. Im and Schonberger [48] suggest that Kanban is good practice to implement in a repetitive production process; it provides the pull system for linking the production activities and a level production schedule (uniform workload) gives a stable environment for introducing Kanban. In addition, initial implementations of JIT in the US started in repetitive production systems, e.g., the automotive industry.

Greater than 50% utilization of each of the 10 JIT practices existed in both production systems, except for the uniform workload practice in nonrepetitive production systems. Only 45.5% of the organizations with nonrepetitive production systems utilized uniform workload whereas 67% in repetitive productive systems utilized uniform workload. In addition, a significant relationship existed between implementation of uniform workload and type of production system.

Implementation of uniform workload in a nonrepetitive production system appears counter to the traditional approach of manufacturing in nonrepetitive production systems. However, it does not involve building high levels of raw materials and finished goods in order to develop efficiencies in the internal operations, but initially involves implementing group technology (cellular layout) and reduced setup times. This allows a nonrepetitive manufacturer to level production schedules through responsiveness and adapting to fluctuations by changing the product mix. It is the responsiveness of the production system that dictates the organization's effectiveness for satisfying customers' needs and adapting to disruption in supply, and minimizes the adverse effects from fluctuations in customer requirements and disruption in supply on the organization's internal operating efficiency. In addition, leveling an organization's production schedule involves smoothing demand fluctuations by working with downstream activities (working more closely with the customers), and upstream activities (working more closely with suppliers).

The finding that implementation of quality circles is more likely in a repetitive production system than in a nonrepetitive system was an unexpected result. Compared to employees in repetitive production systems, employees in nonrepetitive systems often are required to perform a variety of tasks and develop necessary skills that allow for effective utilization of labor. Division of labor and specialization of skills, traditionally viewed as opportunities to achieve higher labor efficiency in repetitive productive systems, are contrary to what is expected of employees in quality circles (problem solving skills, decision making, etc.). However, the decision to implement quality circles may have been a rational decision centered around value; this was not given support in the logistic regression models, as no significant relationships existed between quality circles and any of the response variables. Perhaps, the explanation is somewhere between the findings of McLachlin [50] and those of Inman and Boothe [37]. In an empirical study, McLachlin [50] found that organizations do not achieve high levels of JIT flow and high levels of JIT quality without obtaining a high level of employee involvement. Based on the findings of their survey study, Inman and Boothe [37] suggest that quality circles provide a foundation for implementation of JIT. According to Inman and Boothe, "... the use of quality circles could possibly facilitate JIT implementation because a number of QC firms in the study realized better results on some elements of JIT implementation". Perhaps, the managers of these production systems understand this issue associated with employee involvement.

A second unexpected finding involved the multi-function employee practice. There was little difference in the frequency of utilization exhibited with multi-function employees between the two production systems. The cross training of employees on different machines and in different functions (associated with multi-function employees) is contrary to the characteristics of repetitive production systems (i.e., low worker skill level, small worker job content); therefore, implementation of multi-function employees in repetitive production systems is not an easy task. Perhaps, implementation and applicability of multi-function employees may be viewed as infeasible by managers of repetitive production systems and, consequently, implemented relatively less frequently when compared to nonrepetitive production systems.

A third unexpected finding involved the JIT practice of group technology. With this practice, no significant relationship existed between implementation and type of production system. Hall [49] suggests that group technology is a key step for implementation of JIT in job shops. According to Hall, group technology (cellular layout) allows a job shop to convert their operation to more of flow-oriented operation. This is the first step in intensifying the interdependence between operations [44]. However, there are deterrents that job shops have for implementing group technology. For example, a substantial investment may be required for implementing group technology (equipment and facilities) in nonrepetitive production systems. In addition, Gargeya and Thompson [51] suggest that "... the very nature of job shops' intermittent processes creates a resistance to the simplified Kanban production control system" (p. 26). With the deterrents that exist for implementing group technology and finding no significant difference exists between implementation and type of production system, this may suggest the value of group technology as part of JIT implementations in nonrepetitive systems. Further support is provided by the results of logistic regression models. Group technology, in nonrepetitive production system models, was significantly related to better throughput time. No significant relationships existed between group technology and response variables in the repetitive production system models.

Three JIT practices have a similar impact on the benefits investigated in this study in the nonrepetitive and repetitive logistic regression models. Significant and positive relationships existed between total quality control and better external quality, multi-function employees and better labor productivity, and Kanban and better throughput time. These findings suggest that the importance of these JIT practices for obtaining these benefits remains relatively constant regardless of the type of production system. After reviewing the findings of the related study by White et al. [16], it was discovered that the multi-function employees practice had a similar impact (significant and positive) on improving productivity, in nonrepetitive and repetitive production systems, and small and large manufacturers. Perhaps, this suggests that regardless of the organization, if the focus when implementing JIT is to improve productivity, it is important to cross train employees on different machines and different functions.

Generalizations of the findings of this study should be treated with some caution. First, the respondents were not randomly selected, but represented manufacturers that are considered leaders in implementing world-class management practices. Second, only those completed surveys for organizations that had implemented any of the JIT practices were included in the final sample. However the percentage of practices implemented are not unlike those of other studies [22–24,38]. Third, the percentage of electronic/electric manufacturers was 39.0% in the final sample. However, in an effort to address concerns about a potential bias that might be introduced by the large percentage of firms in the electronic/electric manufacturers category we ran all our analysis with only the electronic/electric manufacturers and then again with all other firms excluding the electronic/electric manufacturers. As a result we did find a few variables that were significant in the model using all the data that were significant for only electronic/electric manufactures or alternatively only for the groups excluding the electronic/electric manufactures. We believe that such a finding suggests a sample size issue rather than differences between electronic/electric manufactures and the other manufactures because the direction of the effects were the same but for some variables the significance was only apparent with the larger combined groups.

The traditional view of managing US production systems is difficult to overcome. Understanding the JIT manufacturing concept and philosophy, the role of each practice, their interactions, and their organization is essential for effective implementation of JIT manufacturing. This study has shown that JIT manufacturing is utilized by both repetitive and nonrepetitive production systems. The results of the study suggest there is a difference between nonrepetitive and repetitive production systems in their implementation of JIT practices. It is important to note that 7 of the 10 JIT practices produced significant differences in implemented practices for nonrepetitive compared to repetitive production systems. This does lend support to the premise that much of JIT manufacturing is adaptable and applicable across different production systems.

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