
Employee reactions to JIT manufacturing practices: a two-phase investigation

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Introduction

It is widely suggested that the adoption of just-in-time (JIT) leads to marked improvements in an organization's competitiveness and ability to respond to rapid fluctuations in market demand. JIT incorporates a variety of manufacturing practices that involve fundamental changes to the nature and management of shopfloor work. The implications of these changes for production employees are currently a matter of considerable controversy. In this article we examine these implications, and describe an empirical investigation, carried out within an electronics company in the East Midlands (UK), of the effects of a two-phase introduction of JIT manufacturing practices on the perceptions of changes in the content of work and psychological wellbeing of shopfloor employees.

JIT manufacturing practices

JIT is an approach to manufacturing based on waste reduction and rapid response to customer demand. Unlike traditional forms of manufacturing, where fabrication or assembly takes place on the basis of materials availability, JIT is a "pull" system of manufacturing where production only takes place when there are requirements from downstream operations and specific demands from external customers. Thus, a major aim of JIT is to "produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies, and purchased materials just in time to be transformed into fabricated parts"[1].

Core elements of JIT focus on streamlining production flow, and eliminating waste in materials and labour through substantial reductions in work in process (WIP), standardization of work methods and elimination of all forms of non-value added operator activities, such as rework, end-of-line quality inspection and unnecessary material handling.

One consequence of the core JIT practice of lowering WIP is a greater vulnerability of the production process to quality problems. In order to overcome this vulnerability JIT has become strongly interlinked with *kaizen*[2], total quality control (TQC)[3] and total quality management (TQM)[4]. Principles and tools of *kaizen*, TQC and TQM help employees identify and eliminate root causes of problems, and stimulate process improvement

activities. Thus, whereas WIP reduction creates uncertainty in the production process, quality control practices serve to monitor that uncertainty, regulate it, eliminate it and stimulate action to prevent it[5].

Other JIT manufacturing practices which help reduce production uncertainty and eliminate it at source include product-based manufacturing (PBM), cellular manufacturing (CM)[6,7] and teamworking[8]. Product-based manufacturing (PBM) is a form of manufacturing organization that organizes production around single products, or sets of related products. In PBM systems, different employees within each department are allocated responsibility for an individual product or set of related products. In this way employees within different departments share ownership and responsibility for the same products. Thus, the manufacturing orientation becomes geared towards a product-focus in contrast to a process-focus. Where this approach involves changes in shopfloor layout, to enable employees with shared ownership to work together in the same location, it is more commonly known as cellular manufacturing (CM).

CM involves the creation of “mini-factories”, or manufacturing “cells”, that bring to the same location the full range of machines and processes required to complete a whole product. CM systems are often arranged in a U-shaped layout, to aid material through the cell and facilitate reduced WIP. Within one factory there may be several such cells operating relatively independently of each other. Such mini-factories are also known by a variety of other names, which include “product lines”, “modular systems” and “product-based” or “product-oriented” cells. Because of their design, CM systems are particularly suited to semi-autonomous teamworking, since they require multi-skilled, flexible employees able to work on different processes in the cell. Semi-autonomous teamworking is similarly suited to JIT because it enables employees to eliminate production variances effectively at their source.

Effects on shopfloor work

Over the past decade there have been strong and widely divergent claims concerning the potential of JIT and lean manufacturing to meet employee needs for enriched and challenging work. Strong advocates of JIT, such as Hay[9], Womack *et al.*[10], Schonberger [11] and Monden [12], argue that teamworking, multi-skilling and job rotation under JIT systems create conditions for job enrichment and job enlargement, while at the same time catering for employees' social needs. Additionally, the generation of production uncertainty through WIP reduction is regarded as providing employees with enhanced opportunities for problem solving, greater challenge, and more involvement in the production process. In their view, JIT produces a climate of continual challenge and creative tension which can “develop the skill of the mind”[11] and “increase respect for humanity”[12]. Many would agree with these views to the extent that traditional notions of teamworking (heavily inspired by the early work on socio-technical systems[13,14]) provide increased opportunity for skill use, variety,

challenge, enhanced wellbeing and improved social relationships on the shopfloor [15].

Critics of JIT and lean manufacturing initiatives, on the other hand, believe that the focus on multi-skilling and elimination of waste in the production process can have seriously deleterious impacts on the quality of working life experienced by production employees. Turnbull[16], for instance, believes that JIT is a “highly developed form of work intensification which belies any notion of job enrichment” (p. 8) and that “job rotation, teamworking, flexibility and the like are the very tools of work intensification under the JIT system” (p.8). According to this view, job rotation, teamworking and multi-skilling under JIT simply serve as systems that intensify workload and peer pressure in the service of maximizing the output of direct labour.

Recently, Brown and Mitchell[17] have noted that many of the conclusions that have been reached about JIT have “been based almost entirely on anecdotal evidence” (p. 906). Given the multifaceted nature of JIT and the variety of different production environments into which it has been introduced, it is likely that different applications will vary considerably. Thus many of the claims about JIT may constitute unjustifiable generalizations. One response which research must take is to use appropriate measurement to evaluate systematically how different aspects of shopfloor jobs and employee wellbeing can be affected by JIT practices.

Specific effects on shopfloor work

In examining the literature on JIT one can identify four key aspects of shopfloor jobs about which the controversy over the impact of JIT revolves. These are: employee autonomy, job demands, social climate, and psychological wellbeing. With regard to the first, autonomy, many commentators have argued that JIT can lead to significant reductions. Klein[18], for instance, suggests that “process controls tend to limit discretion over pace and work methods” (p. 36) and the “attack on waste ... inevitably means more and more strictures on a worker’s time and action”[19, p. 60]. She believes that JIT’s emphasis on reducing slack in the process creates increased interdependency between adjacent workstations, or work groups, leading to a decrease in operator or group discretion over the timing and pace of their activities. Delbridge and Turnbull [20] argue that when JIT is used in cases of machine-minding it can lead to operators being assigned extra machines which “removes any ‘free time’ the worker may have previously enjoyed while the machine ran through its cycle” (p. 66). JIT’s further emphasis on strict adherence to quality specifications and standardization of work methods is also argued to result in reduced operator control over the methods used to carry out production tasks[18, 20].

Thus, two aspects of autonomy may be affected by JIT: timing control and method control. In Klein’s view, however, this loss of control may be more evident at the level of an individual’s discretion over task execution than task design. It is in the latter aspect that Klein sees opportunities for more collective or collaborative forms of autonomy[18].

Given these arguments, a conflict arises when one considers that multi-skilling and job rotation in product-based teamworking (often espoused as an integral part of JIT) may give rise to perceptions of enhanced employee autonomy. Further, increases in responsibility over vertical tasks, and broader roles, often associated with the creation of product-based teams, may add to a perception of increased control. At present, however, quantitative research into the effects of JIT manufacturing practices on job control is still in its infancy. A recent empirical study by Jackson and Martin[21], however, did observe reductions in timing control following the introduction of JIT in an electronics company. However, aspects of group level autonomy were not measured.

The second aspect over which there is current dispute is JIT's effects on job demands. Statements in the literature regarding JIT's impact on job demands are rather general. Klein[19], for instance, states that, when taken to extremes, JIT "can turn workers into extensions of a system no less demanding than a busy assembly line" (p. 61). Delbridge and Turnbull[20], in referring to the aims of some JIT applications to increase the value associated with every second of an operator's actions, believe that JIT is a tool designed "to maximise the output of human resources ... whereby ... the work routine is continually intensified" (p. 66). Many of these statements imply an assumption that lowering WIP results in an increase in the pace of work and levels of production pressure. However, Young[22] has argued that low levels of WIP may not necessarily lead to an increase in the pace of work. Rather, he argues that the enhanced visibility associated with low inventory may result in increased perceptions of responsibility and pressure to get things "right-first-time". If so, then levels of attentional demands and perceptions of responsibility for production errors may be more pronounced under JIT.

It has also been argued that problem-solving demands are likely to increase under JIT. One consequence of lowering levels of WIP in JIT systems is the exposure of production problems. Given the increasing emphasis that the JIT culture places on employee ownership and responsibility for the identification, intervention and rectification of problems, it may be expected that levels of problem-solving demands will be far greater in JIT systems compared to traditional manufacturing systems, where buffer stocks serve to conceal problems. To some extent, many of the advocates of JIT agree that levels of problem-solving demands will increase. However, they regard such demands as leading to an increase in the challenge and creative tension of the job, a view which contrasts starkly with the more negative outcomes that many critics propose.

The third aspect of shopfloor work over which there is dispute is the effect of JIT on social climate. Traditionally, teamworking has been regarded as a form of work organization where social needs can be fulfilled and where co-operation, trust, and general *esprit de corps* can flourish. Indeed, the sharing of common goals and involvement in collective decision-making processes, as well as the sense of mutual indebtedness and dependency that can develop between group members, may give rise to greater social cohesion, and higher levels of

trust between group members under a JIT system. Harrison[5] believes that layout changes associated with JIT are likely to lead to “improved human relations resulting from the team spirit which develops within the cell setting” (p. 134). The JIT culture of teamworking, participation and involvement is thus regarded by many as fostering shared values that engender mutual trust and support.

On the other hand, some commentators have argued that JIT’s emphasis on providing upstream operations with perfect quality at all times, and the consequent accountability of employees to other group members, may create increased interpersonal and social tension. According to this view, resentment within teams may set in when group members find themselves having to fill in for other members who do not pull their weight, do not work to specification or are absent from work. Thus, the social climate under JIT is perceived by its critics as being characterized by “peer pressure” and “management by compliance”[20], characteristics much less conducive to mutual trust and social cohesion.

The final aspect we examine is JIT’s potential effects on the psychological wellbeing of production employees. Again, many general statements have been made in the literature concerning the effects of JIT on employee strain. Briggs[23], for instance, believes that psychological strain is a major concomitant of working under Japanese working practices: “It seems that the Japanese often feel nervous, or tense at work ... Absenteeism is usually low, but when it does occur it is often attributed to stress” (p. 26). Turnbull[16], believes that “added stress ... is endemic in the system” (p. 18) and Klein[19], argues that the demands that JIT can impose “can push workers to the wall” (p. 64). Many of these claims, however, are not explicitly tied to impacts of JIT on specific aspects of shopfloor jobs.

Many of the potential effects of JIT on jobs, described above, have implications for psychological wellbeing. The most significant effect may be attributable to the potential of JIT to reduce employee autonomy. According to Delbridge and Turnbull[20], “The loss of collective and individual control over the work process, combined with ‘flexible work intensification’, produces high levels of stress” (p. 67). Such ideas are entirely consistent with research which examines the impact of control on psychological wellbeing[24]. One may also expect negative effects on wellbeing if JIT affects job demands in a negative fashion. There is very little empirical research that has examined whether reductions in employee wellbeing arise following the introduction of JIT. One recent empirical study has shown a reduction in levels of job satisfaction following JIT, although no effects were observed on an additional measure of general strain[21].

To date, very few studies exist which assess employee reactions, and there is very little systematic examination of the ways in which different elements of JIT manufacturing affect specific aspects of shopfloor work. This has led to a recent call by Oliver[25] for “careful empirical investigation” (p. 26) and more “systematic studies of shopfloor activities before and after the implementation

of JIT” (p. 26). In this article we describe an empirical investigation of the effects of JIT manufacturing on the above four aspects of working life. The study is based within a batch manufacturing environment of an electronics company manufacturing control equipment for the process control industry. The company studied had taken a two-phase approach towards JIT production, in which product-based manufacturing and training in total quality methods preceded the later introduction of CM and core JIT practices. One advantage in this approach is that it enables an evaluation, over time, of different aspects of organizational change that are often introduced simultaneously.

Method

The company setting

Company F is an East Midlands enterprise that designs, manufactures and installs equipment to measure, regulate and control operations in process control plants. During the period of this research the workforce comprised some 400 employees. Our study was based within the product assembly area, which employed 70 people who were responsible for the production of 209 different printed circuit boards (PCBs) and standard process-control sub-assemblies. Production was characterized by small batch and high variety. Once combined in sub-assemblies, these products were shipped world-wide to operations staff who installed the equipment on customer sites.

The company took a two-phase approach to major organizational change. This was in response to poor quality yields and long lead times that were associated with the existing functionally-based production organization. Other problems also experienced related to low ownership of problems, “passing the buck”, excessive materials handling and large amounts of WIP.

The introduction of Phase 1, in early 1991, involved the introduction of product-based manufacturing and total quality training. Layout changes during this phase were minimal. Instead, individuals within different functional departments were each allocated responsibility for a family of related PCBs. Although team members still worked in different areas on the shopfloor, all shared responsibility for the production of the same boards. Team members met regularly to discuss the daily and weekly master production schedules for their particular family of PCBs and to discuss staff development. Skill matrices were introduced to help the teams in the development of this latter aspect. Additional meetings took place as necessary, to discuss quality problems relevant to the groups’ products.

All team members received formal, two-day, in-house training in total quality management techniques, based largely on the work of Deming[26] and incorporating elements of statistical quality control. These were run by managers who had attended courses organized by a non-profit making organization in the USA. Additional training in technical skills, such as basic electronics and static electricity, was also provided to all team members. As the teams developed, members were encouraged to become more flexible by rotating responsibility for different tasks. Team members were also encouraged

by first-line management to assume increased ownership and responsibility for creating and achieving weekly production schedules, ensuring high quality, and checking that materials requirements were met.

The second major phase, the formation of CM systems and introduction of core JIT practices, began in June 1992 (18 months following the start of Phase 1). In Phase 2, major changes were made in the physical layout of the assembly areas, and core elements of JIT were introduced. U-shaped assembly areas were formed, with minimum inventory stored at point of use. A kanban system of production control was also introduced, which served to reduce production batch sizes from up to 60 PCBs to ten. These systems resulted in significant enhancements to the streamlining of process flow. Visual “end of line” performance charts and skill matrices were also displayed, these being prepared and regularly up-dated by team members. Additional training was provided in basic preventive maintenance for machines for which the teams were responsible. Operators were also given far greater responsibility for direct liaison with external customers.

Research design and survey administration

Figure 1 shows the study design in relation to the company’s change strategy. Opinion surveys were administered to groups of employees on four occasions. These took place in: February 1990 (T1: one year prior to Phase 1); January 1991 (T2: one month prior to Phase 1); May 1992 (T3: 15 months following Phase 1, and one month prior to the introduction of JIT, Phase 2); and November 1992 (T4: five months following the introduction of JIT, Phase 2).

The same procedure for administering opinion surveys to employees was followed on each measurement occasion. This involved a briefing to respondents concerning the nature of the survey. Confidentiality was assured

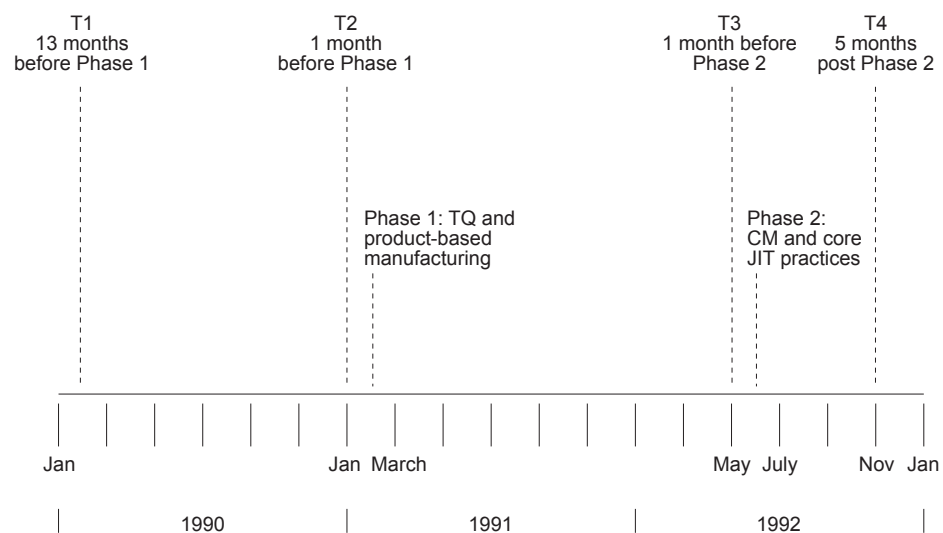


Figure 1.
Study design in relation
to company F's change
strategy

(although respondents were asked to give their names so that measurements on more than one occasion could be matched) and all respondents received a guarantee that feedback would be provided following the results of each survey. All questionnaires were filled in during working hours by groups of between five and 18 employees.

As a result of staff turnover, 65 people completed three surveys, and the number of operators present on all four occasions was 32. As a result, sample characteristics differ somewhat between the separate measurement occasions.

Measures

Five sets of measures were used in the study. These were designed to measure employee perceptions of individual autonomy, group autonomy, job demands, group climate and psychological wellbeing.

Individual autonomy. Individual autonomy was assessed using three measures: timing control, method control (whose psychometric properties are described in detail in Jackson *et al.*[27] and Wall *et al.*[28]) and finally, boundary control. Timing control consisted of a four-item measure which taps the extent to which operators have control over the initiation, completion and pace of operations (e.g. "To what extent do you set your own pace of working?"). Method control is a six-item measure of the degree to which operators have discretion concerning how they carry out their work (e.g. "To what extent can you choose the methods to use in carrying out your work?").

Our third measure of autonomy, boundary control, is a seven-item scale which measures the extent of vertical role integration[29] within production jobs. This scale taps the extent to which operators are involved in a variety of activities that are associated with traditional supervisory or first-line management activities. The seven items in this scale consist of: "To what extent"; "do you carry out your own routine maintenance?"; "do you inspect the quality of your own work?"; "do you call out engineers yourself when there is a machine problem?"; "do you fetch your own kits from store?"; "do you help train other people?"; "do you set up your own equipment?"; "do you control the detailed scheduling of your own work?"

All three individual autonomy measures used a five-point response scale, with response alternatives labelled not at all (1), just a little (2), a moderate amount (3), quite a lot (4), and a great deal (5).

Group autonomy. At the T3 and T4 surveys, additional timing and method control measures were added which allowed respondents to report the extent of collective autonomy experienced by their team; these scales are referred to below as team timing control and team method control. The items were adapted from individual timing control and method control, substituting "your team" for "you". The scaling of these measures is identical to the scales used for the existing measures of control.

Job demands. A total of four measures of job demands were used in this study. Three of these, monitoring demand, problem-solving demands and production responsibility, were included in all four surveys. Full descriptions of these

measures are contained in Jackson *et al.*[27] and Wall *et al.*[28]. A fourth measure (production pressure) was included in the T3 and T4 surveys.

Monitoring demands (four items) measures the extent of undivided attention, vigilance and active monitoring required in a job (e.g. “to what extent do you have to concentrate all the time to watch for things going wrong?”); problem-solving demands (three items) measures the frequency, novelty and difficulty of problems an employee feels their job confronts them with (e.g. “to what extent do you have to solve problems which have no obvious correct answer?”); and production responsibility (five items), which taps employee perceptions of the degree to which their alertness and behaviour can prevent costly disruption to production and machinery (e.g. “to what extent, if you failed to notice a problem, would it result in a costly loss of production?”).

Production pressure, used in the T3 and T4 surveys, consisted of a three-item scale tapping the extent to which JIT resulted in perceptions of work intensification. The three items in this scale consist of “to what extent do you find yourself working faster than you would like in order to complete your work?”, “are you under constant pressure at work?”, “do you find that work piles up faster than you can complete it?”. All measures of job demands used a five-point response scale with response options labelled from not at all (1) to a great deal (5).

Group climate. Three aspects of group climate were measured: co-worker support (five items) assessed levels of adaptive and instrumental support in the workplace, and was adapted from earlier research on university students[30] and unemployed adults[31], e.g. “to what extent do you feel that you can talk to your colleagues about a personal problem?”. Items in this measure used a five-point scale with response alternatives labelled from not at all (1) to a great deal (5). Team cohesiveness (four items) measured the extent to which respondents felt that team members worked well together. Items in this measure consisted of statements with which respondents either disagreed or agreed on a five-point scale from strongly disagree (1) to strongly agree (5). Examples of items in this measure include: “The team-members I work with cooperate to get things done”; “there are often arguments among team-members in my team”.

An additional measure of group climate was included in the T3 and T4 surveys: trust in co-workers[32] (seven items), which assessed levels of self-reported trust in and reliability of co-workers, e.g. “I can rely on other team-members not to make my job more difficult by careless work”. A five-point scale was used with response alternatives from strongly disagree (1) to strongly agree (5).

Psychological wellbeing. Four aspects of psychological wellbeing were assessed. General strain was assessed using the widely known 12-item version of the general health questionnaire (GHQ)[33]. Items in this measure ask how much within the past month respondents have experienced problems with such things as their confidence, concentration, ability to sleep, ability to face up to problems, and ability to make decisions capably. Items are scored on a four-

point scale ranging from 0 to 3. Individuals' overall scores were taken as the mean score based on responses to a minimum of ten items. Low scores indicate positive psychological wellbeing. The GHQ has been shown to be a sensitive measure of individual strain in organizational settings[34].

Job satisfaction was measured using an established 15-item scale measuring extent of satisfaction with a variety of intrinsic factors (e.g. opportunity to use abilities; amount of variety in work) and extrinsic factors (e.g. physical working conditions; rate of pay) in the workplace[35]. This measure used a seven-point response scale with response alternatives labelled extremely dissatisfied (1), very dissatisfied (2), moderately dissatisfied (3), not sure (4), moderately satisfied (5), very satisfied (6) and extremely satisfied (7).

Job-related strain was assessed using two measures adapted from Warr[36]. Items were preceded by the question, "During the last month, how much of the time has your job made you feel each of the following?" Job-related anxiety was measured using five adjectives: tense, worried, contented, calm and relaxed. Job-related depression was measured using four adjectives: miserable, depressed, optimistic, and enthusiastic. Response alternatives for both measures were labelled never (1), occasionally (2), some of the time (3), most of the time (4), and all of the time (5). Positively worded items in both measures were reverse scored so that high scores indicated high job related strain.

Analysis

Data were analysed in two steps. Step 1 was designed to assess the changes in jobs arising from Phase 1, the creation of product-based manufacturing and the introduction of TQ training. In this step, a series of repeated measures analysis of variance tests was carried out for each of the measures using data from subjects present for the first (T1) and third (T3) opinion surveys (a maximum of 56 subjects). This analysis provides us with an evaluation of the effects of Phase 1 changes on each of the study variables and an insight into the work culture into which further JIT practices were introduced.

Step 2 of our analysis tested for changes arising following Phase 2, the introduction of CM and core JIT practices. For this step, a further series of repeated measures one-way analyses of variance was carried out. These analyses were based on data from individuals who participated in the third and fourth surveys (a maximum of 49 subjects). This enabled us to evaluate perceived changes in work content and psychological wellbeing associated with the introduction of Phase 2.

Tables I and II present the means and standard deviations of study variables across the four surveys, and the results of one-way analyses of variance in Step 1 and Step 2 analyses. It will be noted that T3 data means differ between Tables I and II. This arose as a result of company turnover affecting differences in the samples on which the repeated measures analyses within each step were based. Further differences in sample sizes between analyses within Steps 1 and 2 arose as a result of missing data.

		Phase 1 – Product-based manufacturing and TQ			
		<i>N</i>	T1	T3	<i>F</i>
<i>Individual job control</i>					
	Individual timing control	48	3.15 (0.90)	3.66 (0.93)	6.40*
	Individual method control	48	3.59 (0.86)	3.94 (0.76)	6.35*
	Boundary control	46	2.97 (0.69)	3.38 (0.81)	11.97**
<i>Job demands</i>					
	Monitoring demands	48	3.26 (0.72)	3.80 (0.87)	12.11**
	Problem-solving demands	40	2.89 (0.82)	3.10 (0.76)	2.02
	Production responsibility	44	3.14 (1.10)	3.43 (1.08)	3.24 †
<i>Group climate</i>					
	Co-worker support	40	2.86 (0.67)	3.10 (0.84)	2.40
	Group cohesiveness	35	3.86 (0.61)	3.78 (0.80)	0.18
<i>Wellbeing</i>					
	GHQ	56	0.83 (0.35)	0.83 (0.35)	0.00
	Job satisfaction	39	4.80 (0.71)	4.76 (0.78)	0.08
	Job-related anxiety	33	2.78 (0.62)	2.96 (0.66)	1.51
	Job-related depression	35	2.52 (0.53)	2.78 (0.79)	0.18
<i>Note.</i> * $p < 0.05$; ** $p < 0.01$; † $p < 0.10$					

Table I.
Means, SDs (in parentheses) and *F*-ratios for repeated-measures oneway ANOVAs across: T1 and T3 measurement occasions

Results

Phase 1 – product-based manufacturing and total quality

From Table I it can be seen that the introduction of Phase 1 changes between T1 and T3 were associated with statistically significant increases in perceived levels of individual timing control, individual method control, and boundary control. Thus, employees saw themselves as having greater discretion concerning the order and pacing of work activities, and increased control over the methods used for carrying them out. The most statistically significant effect emerges in relation to boundary control, which showed that employees perceived themselves as having a much broader range of tasks involving greater levels of responsibility, following Phase 1.

With regard to job demands, one measure (monitoring demand) showed a statistically significant increase, indicating that employees perceived their work as requiring higher levels of undivided attention and concentration compared to levels before the introduction of product-based manufacturing and total quality practices. There was also some indication of an increase in levels of production responsibility shown by the marginally statistically significant result for this variable.

The changes brought about by Phase 1 were not associated with significant changes in the two group climate measures of co-worker support and group cohesiveness. Levels of group cohesiveness, however, were already quite high.

	<i>N</i>	Phase 2 – CM and core JIT practices		<i>F</i>	Employee reactions to JIT manufacturing
		T3	T4		
<i>Individual autonomy</i>					
Individual timing control	48	3.63 (0.88)	3.70 (0.85)	0.19	
Individual method control	47	3.89 (0.84)	3.81 (0.86)	0.58	
Boundary control	48	3.42 (0.79)	3.50 (0.65)	0.79	
<i>Team autonomy</i>					
Team timing control	49	3.72 (0.81)	4.08 (0.80)	11.23**	
Team method control	49	4.00 (0.66)	4.07 (0.80)	0.42	
<i>Job demands</i>					
Monitoring demands	47	3.71 (0.87)	3.47 (0.88)	2.92†	
Problem-solving demands	45	3.06 (0.62)	2.92 (0.72)	1.61	
Production responsibility	44	3.49 (1.06)	3.39 (0.96)	0.61	
Production pressure	48	2.99 (0.95)	2.74 (0.89)	1.80	
<i>Group climate</i>					
Co-worker support	49	3.08 (0.74)	3.37 (0.80)	7.40**	
Group cohesiveness	48	3.50 (0.77)	3.81 (0.70)	6.92**	
Trust in co-workers	48	3.81 (0.48)	3.91 (0.59)	1.99	
<i>Psychological wellbeing</i>					
General strain (GHQ)	46	0.82 (0.34)	0.79 (0.35)	0.42	
Job satisfaction	48	4.74 (0.83)	4.96 (0.81)	6.05*	
Job-related anxiety	45	2.74 (0.59)	2.61 (0.57)	1.51	
Job-related depression	46	2.50 (0.70)	2.41 (0.59)	1.04	

Note. * $p < 0.05$; ** $p < 0.01$; † $p < 0.10$

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Table II.
Means, SDs (in parentheses) and *F*-ratios for repeated-measures analyses of variance across T3 and T4 (Phase 2 changes introduced after T3)

Levels of psychological wellbeing, as measured by GHQ, job satisfaction, job-related anxiety and job-related depression, were generally positive in this company and showed no change following the introduction of product-based teamworking.

Phase 2 – introduction of CM and core JIT practices

Findings relating to the second phase, the introduction of core JIT practices and significant layout changes, are shown in Table II. It can be seen that the levels of all three aspects of individual job control observed following the introduction of Phase 1 remained unaffected by this second change. The second step in our analyses included two new measures of employee autonomy, team timing control and team method control. A statistically significant increase was observed for the measure of team timing control that indicated an increase in perceptions of collective autonomy over decisions regarding production pacing and task scheduling. No changes were observed in relation to team method control.

Analyses for the four types of job demands showed no change in three aspects, production pressure, problem-solving demands and production responsibility, and a marginally statistically significant reduction in perceived levels of monitoring demands.

The most marked changes associated with the introduction of Phase 2 were observed with regard to group climate measures. Whereas the introduction of product-based manufacturing in Phase 1 resulted in no change to levels of co-worker support and group cohesiveness, there were statistically significant increases in these variables following Phase 2 changes. Mean levels of trust in co-workers did increase slightly following Phase 2, although T3 levels of this measure were already quite high.

Levels of general strain, as measured by the GHQ, remained comparable to positive levels observed before and after the introduction of Phase 1 changes. However, statistically significant increases in job satisfaction were associated with changes in Phase 2. These rose to a level higher than those observed for all previous measurement occasions. Finally, Phase 2 changes were not associated with changes in levels of job-related anxiety or job-related depression.

Discussion

In this study we have examined the effects of a two-phase introduction of JIT manufacturing practices on job characteristics and psychological wellbeing. It is clear from the analyses related to Phase 1 changes that jobs became more enriched as a result of the introduction of product-based manufacturing and total quality practices. Employees saw themselves as having greater control related to the timing or pacing of their tasks and the methods used to carry them out. They also saw themselves as having much broader roles, incorporating aspects of indirect functions. These changes reflect the increased emphasis that management placed on the devolution of control and responsibility to shopfloor employees.

Accompanying this increase in individual autonomy was a statistically significant increase in self-reported monitoring demands, and a marginally statistically significant increase in overall perceptions of production responsibility. These changes may reflect a heightened awareness of the need to attend to factors affecting quality and of individual accountability to quality errors. The increases in both autonomy and job demands observed resemble those that would be construed as a shift towards "active work" as defined by the demand-control model developed by Karasek and Theorell[37].

Of interest is the absence of any effects on perceptions of group climate following Phase 1. One possible explanation for this is that while there were significant shifts in allocation of responsibility of employees to specific products, most team members were still not geographically located in the same area of the shopfloor. Thus, although ownership, accountability and goals were shared between team members, opportunity for high levels of day-to-day contact were far less than in CM systems, where PBM is combined with layout changes.

The effects of Phase 1, which show that jobs became more enriched, might be expected to be associated with positive benefits with respect to employee wellbeing. This was not the case in our study. As Table I indicates, however, levels of wellbeing were already high at T1, leaving, perhaps, little room for improvement. An alternative explanation, based on Karasek's model, would argue that any negative effects of job demands on psychological wellbeing may well have been compensated for by the enhancement in employee autonomy.

It will be remembered that Phase 2 involved major changes in the layout of the shopfloor to U-shaped production cells, a lowering of inventories and the introduction of a kanban system of production. These changes did not result in a decrease in any of the measured aspects of individual or collective control, providing little support to suggestions made in the literature that JIT results in reductions in employee autonomy[18,20]. Indeed, perceptions of collective control over the timing of task execution increased during Phase 2. In talking to production employees, it became clear that this change in perception was largely attributable to teams having been given much greater freedom to liaise with customers, enabling them to make regular adjustments to the priorities of their daily and weekly production schedules.

Evidence that the introduction of JIT practices would lead to wholesale intensification of work was also not observed. No increases in problem-solving demands, production responsibility and production pressure resulted from Phase 2 changes and there was a marginal decrease in perceived monitoring demands. These results appear somewhat unexpected, since it has been suggested that reductions in WIP lead to increases in the number of problems generated by the production process. Similarly, it has been suggested that lowering inventories results in an increase in the pace of work under JIT.

One possible explanation for the absence of an increase in job demands relates to the layout changes that resulted in team members being brought together into their own cell. These layout changes may have facilitated more effective and rapid problem solving by team members and increased perceptions of "load-sharing". The fact that the lowering of WIP levels did not lead to increases in perceived levels of production pressure, alongside the fact that levels of timing control did not decrease, may represent one instance where research has shown that reduced inventory did not increase the pace of work.

The most marked effects following Phase 2 changes arose in relation to the group climate measures. Here, statistically significant positive changes in the co-worker support and group cohesiveness measures were associated with the "bringing-together" of team members into a single cell. These effects may reflect the positive benefits to social relationships that have been shown to arise as a result of proximity effects and heightened social interaction[38,39]. These results suggest that poorer social relations, management by peer pressure and decreased trust between group members, which have been reported elsewhere in the literature, are not a necessary consequence of JIT.

Given the above changes in social climate and job demands, and lack of changes in autonomy following Phase 2, it is of little surprise that there was no

indication that JIT had any effect on general strain, job-related anxiety and job-related depression. Indeed, it is also unsurprising that job satisfaction increased as a result of Phase 2 changes. In Phase 1, changes made jobs more enriched, active and challenging, and levels of wellbeing were high. In Phase 2, the bringing together of team members into U-shaped assembly areas resulted in marked positive changes in group climate and no negative effects on autonomy and perceived job demands. The absence of negative effects on wellbeing contrasts with much of the existing literature, which suggests that JIT has deleterious effects on employee stress levels, through processes of work intensification, reductions in autonomy, and work simplification[16,19,23].

Our study has shown that the strategy taken by Company F in its implementation of JIT manufacturing has been extremely successful. The effects of Phase 1 and Phase 2 changes suggest that it is possible to introduce a variety of JIT manufacturing practices into a batch production environment without adverse impact on the perceptions of the content of employees' jobs and their psychological wellbeing.

Given that JIT has received so much critical attention, how can we explain the positive outcomes observed at Company F? One reasonable explanation relates to the approach taken to the introduction of JIT manufacturing techniques. In this study, Company F took a highly developmental, human-centred, participatory approach to the introduction of JIT, by ensuring that employees were sufficiently multi-skilled and well-trained in the principles of quality control and team-working, before reducing inventory levels and introducing kanban systems. Indeed, it is possible that the enhancements in the social climate and absence of stress effects following Phase 2 may only have been possible because of the foundations that had been built through the implementation of product-based manufacturing. Other companies, however, have been known to "dive in at the deep end", introducing CM, teamworking, TQ and core JIT practices simultaneously as part of major organizational change. In such cases, it is possible that employees will experience greater difficulties associated with cross-training, human relations, and the greater vulnerability of the process under JIT. Indeed, Brown and Mitchell[17] describe a study where the simultaneous introduction of many of the changes described here led to increased employee perceptions of problems related to training, scheduling and reliance on co-workers. It may be the case, as Jackson and Martin[21] have stated, that "the successful implementation of JIT will depend fundamentally on the thoroughness of the preparatory work and, without such preparation, the chance of great benefits is low".

A second complementary account relates to variation between companies in the purposes to which JIT practices are put. Management at Company F strongly emphasized the devolution of as much control over quality and the management and scheduling of tasks as possible to production employees. Some JIT applications, however, have been criticized for being used in the service of work intensification, employee accountability, and increasing management control over employees and the work process[16, 20]. The success

of JIT, in both productivity and human terms, may thus rest in large part on aspects of organizational choice over how it will be used.

There are, of course, other issues relevant to this study that warrant comment. One issue is the effect of time. There remains the possibility that, with time, the positive effects we have observed may wear off. Further research is required to examine the effects of JIT practices over much longer time periods. Another question relates to the universality of the impact of JIT on different categories of employees. We have described the overall impacts of JIT on direct labour employees in this company. However, as with all major organizational changes there may be winners as well as losers. In the company we studied, for instance, many of the quality control inspectors and test engineers resented the changes taking place and regarded their absorption into product teams as an affront to their status and skills. For many manual assemblers, however, the opportunity to become more skilled in a wider variety of operations was regarded very positively.

Other issues pertain to the effects of JIT manufacturing practices on indirect staff in areas such as manufacturing engineering, planning, purchasing, and product-support. JIT may have fundamental implications for these employees that differ from those of direct labour employees. Future research should focus attention on questions concerned with the effects of JIT manufacturing on different categories of employees.

One final issue relates to the more general question of what changes in job content and group climate predict levels of employee wellbeing during the various phases of JIT implementation. An evaluation of this question relies on using difference scores between survey occasions as predictors of wellbeing in a regression analysis. However, traditional regression methods are precluded in this instance, since listwise deletion of cases results in the loss of a significant number of data points and a very poor ratio of data points to predictors. More fruitful investigation requires the use of statistical techniques that are able to make use of all of the data points. Such analyses are well worth conducting and will form the focus of further articles.

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