The Effects of Low Inventory on the Development of Productivity Norms

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Low inventory, a crucial part of just-in-time (JIT) manufacturing systems, enjoys increasing application worldwide, yet the behavioral effects of such systems remain largely unexplored. Operations research (OR) models of low-inventory systems typically use a simplifying assumption that processing times of individual workers are independent random variables. This leads to predictions that low-inventory systems will exhibit production interruptions leading to lower productivity. Yet empirical results suggest that low-inventory systems do not exhibit the predicted productivity losses. This paper develops a model integrating feedback, goal setting, group cohesiveness, task norms, and peer pressure to predict how individual behavior may adjust to alleviate production interruptions in low-inventory systems. In doing so we integrate previous research on the development of task norms. Operations research models are used to show how norms can significantly improve throughput by decreasing variance and increasing the speed of the slowest workers, even if accompanied by decreases in speed of the fastest workers. Findings suggest that low-inventory systems induce individual and group responses that cause behavioral changes that mitigate production interruptions.
(*Group Norms*; *Work Teams*; *Job Design*; *JIT*; *Cohesiveness*; *Feedback*; *Peer Pressure*)

Introduction

One technique commonly used to improve manufacturing competitiveness is the reduction of inventory, a crucial element of just-in-time manufacturing systems (JIT). Current operations research (OR) models suggest that reductions in inventory reduce inventory costs, but also increase interference within the manufacturing line. This interference causes idle time which reduces line efficiency and throughput. Yet many firms have experienced increases in profit when changing to low-inventory systems. Proponents of low-inventory argue that this apparent contradiction is explained by savings elsewhere in the system (e.g., lower holding or obsolescence costs) and improvements in production quality and response time.

We propose that this is only part of the story. There are behavioral benefits to low-inventory systems that, when ignored, would cause OR models to consistently overstate the amount of interference and idle time in certain circumstances. By encouraging the development of productivity norms, low-inventory systems decrease variability and increase the speed of the slowest workers. This enhances throughput even if accompanied by a slower pace by the faster workers on the line. Understanding these effects is important to manufacturers who are constantly trying to balance the benefits of lower inventory against the costs of increased idle time. Such understanding requires research that integrates behavioral theory from applied psychology with OR models.

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There is value in integrating the literature in the fields of operations research and industrial/organizational psychology (I/O). Operations research models generally assume that changes made in the amount of inventory in a manufacturing line do not affect the behavior of the workers. Almost all models use the assumption of independent machine processing times. For example, the speed of a co-worker and the amount of inventory in the system do not affect an individual's work speed. Yet goal theory suggests that increased feedback, such as that available in low-inventory systems, can lead to increased goal achievement (Latham and Locke 1991). The increased interdependence among workers, which accompanies the reduction of inventory, can also have consequences for the dynamics of groups and the motivation of group members (Guzzo and Shea 1992). Thus, behavioral theory suggests that processing times may not be independent of the amount of inventory.

OR research can also inform behavioral theory, which generally focuses on changes in the average work pace of all workers. While Steiner (1972) recognized that most assembly tasks are conjunctive and therefore limited by the pace of the slowest worker, he did not discuss variability. The principle of buffers, from the OR literature, shows that the *variance* of task times, both within and between workers, can have significant effects on throughput in low-inventory situations. We propose to integrate behavioral theory with operations research models to expand our knowledge of the effects of job design on work behavior.

This paper has two goals. First, we use I/O theory to model and predict the effects different inventory policies may have on the behavior of manufacturing workers. Second, we propose a set of relationships between job design and group productivity norms and test them experimentally using different inventory policies. We start by examining the fundamental differences between low- and high-inventory systems and use behavioral theory to explain the possible effects of these differences on worker motivation and group dynamics. We then describe an experiment to gather processing time and questionnaire data to test our predictions. The results of our experiment are used to explore the interrelationships among work interdependence, feedback, group cohesion, group norms, and work speed to further refine both OR and behavioral theory.

Literature Review of Low-Inventory Systems

Many researchers, in both the fields of operations research and behavioral theory, have looked at low-inventory production systems. Much of this literature has been related to the use of just-in-time production techniques. The OR literature predicts that low inventory will lead to lower productivity. When higher productivity results they understand the result as savings elsewhere in the system and do not look for a behavioral explanation. Behavioral researchers, when considering JIT, have looked at implementation issues and the increase in management control. The question of the motivational effects of low inventory has not previously been considered. In this section we review those streams of literature. We use this literature to highlight the fundamental differences between low- and high-inventory systems that could have behavioral consequences.

Operations Research Literature

Operations research models have investigated the dynamics of serial production lines for over 40 years. Low inventory in a line is maintained by restricting the size of the inventory buffers between parts of the line. The general conclusion is that low-inventory production lines, with machines in series and random processing times, will experience more idle time than similar lines with higher inventory (Dallery and Gershwin 1992). Idle time results when the buffer is empty because the next process has nothing to work on. Idle time results when the buffer is full because the previous process has no place to put its output. We will call this the "Principle of Small Buffers." However, there are many anecdotal examples of productivity increasing when inventory has been reduced. The traditional explanation is that savings elsewhere overcome productivity losses due to idle time.

The principle of small buffers assumes that individual worker processing times are independent of the amount of inventory in the system, and unaffected by the speed of neighboring machines. With this assumption, and others concerning the processing time distribution, it has been proven that the rate of production of a manufacturing line is a nondecreasing function of the buffer capacity (for example, see Shanthikumar and Yao 1989). If buffer capacity is a resource then artificial limits on this resource should hurt, or at least not improve, the production rate of the line. While most modelers would quickly agree that these assumptions may not hold in some cases, no one has demonstrated a systemic error related to their use.

Yet errors in this assumption can lead to large and systemic errors in model predictions. Schultz et al. (1998) showed that the consequences are significant, amounting to a difference of 19% between predicted and actual results. If processing time distributions are the same in high- and low-inventory, then workers in low-inventory would have been idle, on the average, 17% of the time. In fact they were idle only 9% of the time and, because average processing times were faster, the output of the two lines differed by only 0.7%. As we shall show, and as Schultz et al. (1998) noted, most of the increase in speed was seen in the slowest worker on each processing line, those who are the cause of bottlenecks.

Schultz et al. (1998) focused on the effects when workers do not act in accordance with the independence assumption. This paper attempts to explain why. Using data from the same experiment and behavioral theory we show how the differences between high- and low-inventory can cause differences in worker behavior. We use these results to increase our understanding of low-inventory systems, and to improve our theories of job design and group motivation.

Behavioral Theory and Low Inventory

Very few researchers have used behavioral theory to explain the increased productivity associated with low inventory. Most of the behavioral research on low inventory has focused either on the implementation of JIT systems (see, for example, Arogyaswamy and Simmons 1991, Sevier 1992) or recommendations for HRM practices (see, for example, Huber and Brown 1991, Snell and Dean 1992). These studies made little attempt to explain the effects of low inventory on work behavior and productivity.

Those articles that have considered the motivational effects of low inventory usually focus on management uses of JIT to coerce workers into higher levels of effort. Parker and Slaughter (1988) attributed the productivity increases to speedup and tighter management control. Sewell and Wilkinson (1992) likened JIT factories to optimally designed prisons. They argued that JIT regimes "both create and demand systems of surveillance which improve on those of the traditional bureaucracy in instilling discipline," thereby "consolidating central control and making it more efficient" (p. 277). Delbridge et al. (1992) thought that JIT intensifies work as "a result of increased surveillance and monitoring of workers' activities, heightened accountability, the harnessing of peer pressure . . ." (p. 97). Prior research mentions peer pressure, but no attempt was made to measure the effects, or to relate them to current theory. These papers made valuable insights and observations, but they were anecdotal and descriptive. They implied that JIT increases the available information which management uses coercively to decrease shirking, but they did not test this hypothesis.

These differences in available information are critical to our understanding of the motivational differences. Low-inventory systems intrinsically provide more task-related information to workers than high-inventory systems. A change from two to three items in a buffer can be noticed with a glance while it takes more effort to notice a change from 2000 to 2001 items. These changes provide immediate information on the worker's relative speed. If the inventory in the output buffer goes up, the worker is processing faster than the next worker. If it goes down (s)he is slower. In the same way inventory in the input buffer signals differences in speed with previous workers. We have already discussed how this information can lead to greater management control but it is also available to anyone who can see the buffer, most notably the workers on the line.

The information available with low inventory has important features that influence behavior. First, it is evaluative data; the worker is processing items faster or slower than some standard. Second, it allows role comparisons; the worker is processing faster or slower than a particular coworker. Third, it has a direct interpersonal consequence; a worker's processing speed may cause a co-worker to be idle.

Brown and Mitchell (1991) analyzed perceptions of the effects of low inventory. They surveyed direct labor employees at a manufacturing firm switching to a JIT system over a period of 18 months. Focusing particularly on performance obstacles in JIT, they considered the interdependence of work in low-inventory settings and the possibility of slower workers restricting output. They found that JIT was associated with a significant increase in perceived problems in the areas of "Schedules and Assignments" and "Reliance on Coworkers." The paper did not postulate any systematic change in worker behavior associated with low-inventory systems. It did demonstrate, however, the importance of worker interdependence and that workers in JIT perceive performance obstacles related to peer pressure and co-worker work pace.

Brown and Mitchell highlight another fundamental difference between low- and high-inventory situations: The interdependence among workers. With high inventory, people work essentially as individuals, independent of each other. The very reason for having inventory buffers between machines is to isolate the workstations. With low inventory, workers are interdependent. A slower pace by any worker causes an immediate disruption of work over the entire line. Anyone working faster will be constrained by the buffer limits. Also, with much less inventory, the work area becomes less cluttered and it is easier to see the entire work process.

To our knowledge only one paper measured differential work speed between low- and high-inventory settings. Doerr et al. (1996) looked at the interaction of different types of goals and buffer sizes on work speed in a fish packing plant. They observed no significant difference in overall throughput between these systems, despite higher levels of idle time in the low-inventory systems. While spending more time idle, workers in low-inventory worked faster when work was available. Doerr et al. (1996) hypothesized that short breaks of idle time might allow increased effort during work periods. Unfortunately this was not the focus of their paper, and they were unable to test this hypothesis. Moreover they did not provide a theory-based framework to explain different behaviors in low-inventory systems. We now develop such a framework.

Hypothesis Development

We now use behavioral theory to show how the increases in information and interdependence associated with low inventory affect worker behavior in low-inventory manufacturing. We proceed by discussing the behavioral implications of feedback, cohesiveness, and norms.

Feedback is Provided with Low-Inventory

The information available in low-inventory systems corresponds to the concept of feedback first defined by Wiener (1954) as "performance-related information used to control a system." It has many of the qualities of good goal feedback by being specific, timely, and frequent (Nadler 1979). The feedback from low-inventory is specific as it relates exactly to the speed of the worker relative to the speed of the rest of the line. It is timely, being immediately available by glancing at the buffer. It is frequent in that it occurs upon completion of every item. All these qualities increase the impact of the feedback available in low-inventory systems. Thus,

Hypothesis 1. *Subjects in a low-inventory work system will perceive more task feedback than those in a high-inventory system.*

Feedback in Low-Inventory Suggests Goals, Allows Role Modeling, and Reduces Social Loafing

Goal Theory, Role Theory, and Social Loafing Theory explain feedback's effects on performance. All of these theories predict that feedback available to the workers in low-inventory systems will encourage the slower workers to speed up and the faster workers to slow down.

The effectiveness of goal setting increases with task-related feedback and the combination of both goals and feedback leads to performance benefits (Erez 1977). However, even feedback not accompanied by goals can improve performance if it suggests self-setting improvement goals (Latham and Locke 1991). Thus, if the feedback available in low-inventory is matched with, or suggestive of, task-related goals then it should induce a worker to work at a different speed than he or she would in a high-inventory system.

Low-inventory feedback tells a worker when he or she is about to disrupt the flow of work or is about to be forced to stop work. Both may be undesirable outcomes that can lead to setting goals to avoid those situations. Feedback indicating that performance is below the standard can increase the motivation to work harder. A worker who is the slowest in the group causes idle time, restricts the overall output of the group, and is demonstrated to be less capable than other group members. This person has incentives to speed up, which may lead to setting internal goals to work faster.

Feedback indicating that performance is consistently above the level of one's peers can lead to the setting of lower goals (Bandura and Jourden's study as cited in Latham and Locke 1991). A worker who is the fastest in the group spends the most amount of time stopped or about to be stopped. This feedback, that they consistently outperform the goal, can lead to the setting of lower goals. They might gain the impression that they have worked harder than necessary and may be seen unfavorably by their coworkers. Therefore the incentive for the fast worker may be to slow down. Thus, for both faster and slower workers, low-inventory provides feedback to support and encourage goals of "don't cause idle time."

Role models also help to influence goal behavior to the extent they increase co-workers' self-efficacy, the belief that they are capable of achieving the goal (Bandura and Cervone 1983). In experiments by Lichtman and Lane (1983) and Earley and Kanfer (1985) performance was affected in the direction of a role model. Peer and role-based influence is also higher in low-inventory situations. Role models are more easily observed, the slowest worker in a group notices others who are working faster, and may be influenced to work faster themselves. The fastest worker on each team will be exposed to peer models that are performing slower and might, therefore, be influenced to slow down.

The feedback available in low-inventory may also influence social loafing. "Social Loafing refers to the reduction of individual effort exerted when people work in groups compared to when they work alone" (Williams et al. 1981, p. 303). One theory explains this phenomenon as a desire for equity of effort. That is, social loafing may result from individuals assuming, in the absence of identifiable output, that co-workers are working more slowly and they adjust their own pace accordingly (Jackson and Harkins 1985). Social loafing is diminished with feedback to the extent that workers can identify the effort of their teammates who are working faster. Social loafing would thus predict slower workers will speed up and faster workers slow down in low inventory situations.

Our analysis of goal theory, role theory and social loafing theory leads us to predict

Hypothesis 2. *Slower workers will work faster under low-inventory than high-inventory systems.*

Hypothesis 3. *Faster workers will work slower under low-inventory than high-inventory systems.*

Low-Inventory Increases Cohesiveness

Group cohesiveness is defined as the resultant of all forces acting on the members of a group to remain in the group (Festinger 1968). It can be thought of as a measure of the commitment of group members to the group task (Goodman et al. 1987). Many factors can increase group cohesiveness, including task interdependence. Deutsch (1949) showed that cooperatively interdependent tasks build a sense of unity as does a task that requires active participation from all members (Cartwright and Zander 1968, Coch and French 1948). Low-inventory increases interdependence and may also increase participation due to the vivid cues provided by low-inventory buffers. We therefore predict:

Hypothesis 4. *Participants in low-inventory systems will report greater group cohesiveness than those in high-inventory systems.*

While there is no direct relationship between cohesiveness and work speed, cohesiveness can increase the ability of groups to enforce group norms, reducing the variance of performance to a narrower band around the group norm (Guzzo and Shea 1992). Cohesiveness reflects the amount of effort members will allocate to the group, while norms identify the direction of that effort (Goodman et al. 1987). If the group norm encourages conformance to a common work speed then cohesion that helps enforce group norms will decrease imbalance on the line (Seashore 1954). Therefore the overall effect of cohesiveness on average work speed depends entirely upon the norms chosen by the group.

Low-Inventory Encourages the Development of Group Task Norms

The task interdependence associated with low-inventory encourages the development of productivity-related norms. Group norms are defined as sanctioned expectations of member behavior (Goodman et al. 1987). Feldman (1984) argued that norms are stronger when they make important behaviors predictable. The predictability of task behavior is more important in low-inventory situations when the task is interdependent. Wageman (1995) demonstrated a positive relationship between task-related norms and task interdependence in a study involving 152 Xerox maintenance teams. No one yet has directly tested the type of interdependence found in low-inventory systems. Based on this analysis we predict,

Hypothesis 5. *Subjects in the low-inventory treatment will develop stronger task norms.*

Task feedback, especially group task feedback, also encourages the development of task norms by providing information for the enforcement of those norms and by increasing the group's focus on the task. The feedback available with low-inventory allows a worker's speed to be known by his or her peers. For norms to be effective, deviation from those norms must be observable (Goodman et al. 1987). Group feedback also helps to focus the group on the task. Pryer and Bass (1959) observed that groups without feedback exhibited more signs of boredom, were more easily distracted, and discussed the task less frequently. Berkowitz and Levy (1956) noted that discussions during breaks were more frequently related to the task when feedback was given on a group basis. Therefore we expect that the feedback available with low inventory will encourage the development of group task norms.

Hypothesis 6. *Subjects experiencing greater feedback will develop stronger task norms.*

The effects of task norms on productivity depend on where the norms are set. It is possible for norms to be enforced which encourage the reduction of effort by some workers, especially those who are producing higher than average. However, low inventory systems are constrained in the short run by the pace of the slowest worker. A faster worker who slows down may have no effect on throughput since they do not constrain the system. Thus, with low inventory, task norms can improve throughput even if faster workers slow down as long as slower workers speed up.

The Role of Group Incentive Pay

While our primary purpose is to examine behavioral differences between low- and high-inventory systems our subjects needed to be paid and the opportunity to study effects of pay systems presented itself. We can divide general pay plans in use in JIT environments into two categories, fixed individual pay and incentive group pay. (Individual incentive pay is usually avoided because individual production is constrained, by buffer limitations, to the pace of the slowest worker.) Guzzo and Shea (1992) stressed the importance of matching interdependent pay with interdependent tasks. This relationship is supported by the work of Miller and Hamblin (1963). Drawing on 25 studies, they showed that, with interdependent tasks, productivity increased with interdependent outcomes. DeMatteo et al. (1995), in a review of team reward systems, noted the increasing use of team rewards and attributed it to the increasing interdependence among jobs. However, they found that "the underlying assumption that individuals who work in groups and receive group-level, rather than individually-based, rewards will be more motivated, more cooperative and more productive remains equivocal" (p. 9).

The equivocal link between group incentive pay and productivity may be explained in part by the observation that, in practice, task norms do not always lead to increased productivity. The bank wiring room in the Hawthorne studies had clear norms concerning productivity that were based on a "fair day's work" (Roethlisberger and Dickson 1939). These relationships are consistent with our position that throughput is affected by group cohesiveness directed toward the communication and enforcement of group norms. In a recent paper, Hansen (1997) noted that introduction of a group incentive caused performance to converge toward a standard. Berkowitz (1957) showed how group incentives increased group expectations of group member effort. We interpret this as the communication of group norms. Rosenbaum et al. (1980) found that, with interdependent tasks, feelings of personal attraction for other group members were higher with interdependent rewards. This seems closely related to the concept of cohesiveness. Group pay also serves to legitimize the intervention of one worker in the processing speed of another, for example through advice or peer pressure. Thus, while evidence that group-based incentives raise productivity is equivocal, evidence suggests that group incentive pay increases cohesiveness and encourages group task norms which can lead to changes in group productivity. Thus,

Hypothesis 7. *Subjects receiving group incentive pay will report stronger group task norms.*

Hypothesis 8. *Subjects receiving group incentive pay will report greater group cohesiveness.*

Method

Participants

Subjects were 99 high school students from two central New York high schools. Students were recruited with the help of faculty in the science and physical education departments, and through advertisements and flyers. Ages ranged from 14 to 19 with 96% of the subjects between the ages of 14 and 17. Fifty-five % of the subjects were female. They were randomly assigned to treatments based on the number who showed up for any particular session and to keep the number of runs per treatment level over time. Each subject participated in only one run.

Tasks

Subjects were allowed to choose a computer terminal before the experiment began. Based on their selection they were assigned to teams of three. Treatments were then randomly assigned to teams. Each subject had the task of entering data from a paper form into a computer. The forms allegedly contained order information for an electronics parts supplier. Each page of data consisted of an eight-digit order number and either four or seven lines of parts information. Using a first-in-first-out criterion, subjects selected a booklet of three pages from an input buffer to their left. Turning to the page appropriate for their workstation they used the mouse to select a "begin page" button on the screen. They typed in the order number and selected another button to begin entering the parts data. Each part line had three elements: a part name, a size and a quantity. The words on each line were slightly different at each of the three workstations, but the form, length, and process were the same. Using the mouse, they selected the correct part name from a list of eight, the correct size from a list of six, and then typed in the correct quantity. Upon completion of each line they selected another button on the screen to move on to the next line of data. When they had completed all items on the page, another button on the screen was selected to go to the next order, and they placed the current booklet in an output buffer to their right and began on the next booklet. Workers did an average of 95 pages during an average 90 minutes of work. A Hypercard application was written to record the processing time for each individual for each repetition of each element of the task described above.

Treatments

Experimental treatments were conducted in a 3 (inventory policy) by 2 (pay scheme) factorial design. The three inventory treatments consisted of: (a) high inventory (high), (b) high inventory with feedback (HIF), and (c) low inventory (low). The two pay treatments consisted of: (a) fixed pay, and (b) group pay. Twenty-seven subjects were run with group pay for each of the three inventory treatments (nine groups of three subjects for each treatment). Six subjects for each inventory treatment were run with fixed pay (two groups of three subjects each). The data from one subject was lost (group pay, HIF treatment).

In the high-inventory treatment, buffers were not shared. That is, the output buffer for one machine was separate from the input buffer for the next machine. Although the subjects were instructed that each booklet would eventually go to each machine in the series, the transfer of inventory was not done during the course of the experiment. Therefore, each person worked independently using their own stack of papers from their own input buffer and placed their output into their own output buffer. Input buffers began with more work than possibly could be finished during the experiment. Output buffers started with a modest pile of booklets so that workers could not easily gauge their progress by the amount of inventory in the output buffer.

The only difference between the low-inventory (low) and the high treatment was the size of the intermediate buffers. In the low treatment, only the buffers before the first and after last workstation were essentially infinite. Both intermediate buffers were limited to a size of two with blocking after service. That is, a machine was forced to be idle upon completion of the third item if two items were already in the buffer.

The High Inventory Feedback (HIF) treatment was designed to look at the components of feedback intrinsic to the low-inventory situation. It was exactly the same as the high treatment with the addition of some feedback. The feedback provided was designed to resemble the evaluative content of the information available with low inventory, without the social element or consequences. Workers were given an outside reference as to how fast they were working. A box was added to the screen of each computer that showed the worker the difference between a standard rate and how many orders they had actually completed. If they worked faster than the standard rate the feedback box showed positive numbers of increasing magnitude. If they worked slower, the box showed negative numbers. The standard rate was selected from the average rate of the pretest of the experiment.

The two pay treatments are fixed pay and group incentive pay. These two treatments were chosen not to be exhaustive but to represent the range of pay options found in practice. All subjects in the fixed pay treatment were paid $25 for their participation. Participants in the group incentive pay treatment were paid a rate per page completed by the group, multiplied by the product of the percentage correct for each team member. Percentage correct was measured by the computer by comparing data entered against the master list. The rate per page was selected, based on pretest data, to produce an average incentive pay of $25. Actual average incentive pay was $29 per subject.

Procedure

Each run of the experiment consisted of four stages over 4 hours. Stage 1 consisted of welcoming, paperwork, and initial training to familiarize subjects with the task and the computer. Training was conducted from a prepared text with the use of flip chart diagrams. This section ended with individual practice on 10 pages. The next stage was treatment practice. Subjects were trained in inventory handling and, for the HIF treatment, the meaning of the feedback box. This section ended with a practice session and a 15-minute break. The third part consisted of the experimental run. Subjects worked for two periods of approximately 45 minutes each with a 15-minute break in the middle. The last part consisted of an exit questionnaire and payment. Subjects were told the number of pages they had entered correctly at the end of the individual practice, after the treatment practice, and again after the experimental run.

Measures

Processing times were measured by the computers on which the data were entered. Elapsed time between critical events was measured in sixtieths of a second (times in this paper are shown in seconds). Two dependent measures of processing time are used, “Order # Time” and “Line Time.” Order # Time is the time to enter the eight-digit order number at the beginning of each page. Line Time is the amount of time required to enter each line on the order. There were either four or seven lines on each order. Together, these two measures account for most of the work in the experiment. The only time not included in these measures is “end time” and “between time.” End time is a very short period between clicking the button to signal the end of the last line on the page and clicking the button to go to the next order. Between time includes idle time and the time required to pick up the next booklet. By emphasizing these dependent measures we avoid confounding the speed of entering data with the idle time between orders.

Other concepts of interest were measured using a survey questionnaire given immediately following task performance. The questions are shown in Appendix 1. The measurement of *group cohesion* was modified from a measure developed by Dailey (1979). *Group task norms* included one question from "Peer Leadership Measure" by Taylor and Bowers (1972). A measure of *peer pressure* included a question from the "Peer Leadership Measure" (Taylor and Bowers 1972). Finally, *prior friendship,* a control measure to help predict cohesiveness that might have developed prior to the experiment, was computed using two questions.

To establish the presence of group norms, as we have defined them, it is important to demonstrate that they are beliefs held in common and that the group enforces them. Goodman et al. (1987) argued that two of the important measures of a group norm are its distribution and enforcement. A belief by one member of the group that the others expect a certain level of output would not be considered a norm if the other members of the group do not share that impression. Likewise, norms do not exist without the threat of sanctions from the group for deviation from that norm. Therefore any measure of group norms should include not only measures of individual impressions of the existence and strength of the norm, but also evidence that those impressions are shared by other group members, and evidence of the enforcement of that norm. We operationalize enforcement of group task norms as peer pressure on subjects who are performing worse than the norm to speed up.

Analyses

Analysis began by testing the internal reliability of the survey items. Correlations were computed and an analysis of the differences between the high and HIF treatments was done. Comparison of means was used to test Hypotheses 1, 2, and 3. Hierarchical analysis of covariance was used for hypotheses relating to cohesiveness and task norms where multiple constructs were involved. These constructs required that our analysis include the covariance of individual measures of norms and cohesion with other members of the same work group. If this covariance effect is significant we argue that it supports the group nature of these constructs.

Results

Analysis of Correlations

Overall means, correlations and internal reliabilities (coefficients alpha) are shown in Table 1. Means for all constructs by treatment are shown in Table 2. Negative correlations with Item and Order # Times reflect a decrease in processing times equivalent to an increase in processing speed. Internal reliabilities are on the diagonal. Correlations predicted by model hypotheses are underlined and in bold type. Measures using

Table 1 **Mean Responses, Correlations of Variables, and Internal Reliabilities**

Variable	Mean	1	2	3	4	5	6
1 Cohesiveness	6.30	0.81					
2 Feedback	7.57	0.08	0.43				
3 Norms	6.81	0.51	**0.37**	0.79			
4 Peer Pressure	5.07	0.23	0.24	0.31	0.77		
5 Prior Friends	5.29	0.38	0.14	0.36	0.24	0.79	
6 Item Times	9.13	0.05	(0.12)	(0.12)	0.17	0.10	
7 Order # Times	10.00	0.04	(0.06)	(0.00)	0.26	0.15	0.52

Note: $n = 98$. Correlations are significant (one tailed) at alpha = 0.01 if over 0.25, at 0.05 if over 0.19, and at 0.10 if over 0.16. Internal reliabilities are on the diagonal.

Table 2 Means and Standard Deviations of Measurements by Treatment

Variable	Measure	Low Inv.	High Inv.	HIF	Large Buffer	Group Pay	Straight Pay
Feedback	Mean	8.09	7.30	7.31	7.31	7.53	7.78
	Std Dev.	1.16	1.49	1.60	1.53	1.51	1.26
Cohesiveness	Mean	6.79	5.76	6.34	6.05	6.61	5.00
	Std Dev.	2.06	1.87	1.99	1.94	1.92	1.88
Task norms	Mean	7.42	6.06	6.94	6.49	7.28	5.00
	Std Dev.	2.02	2.15	2.27	2.24	1.92	2.20
Peer Pressure	Mean	5.24	4.73	5.25	4.98	5.10	5.00
	Std Dev.	2.48	2.30	2.40	2.34	2.43	2.25
Order Times	Mean	9.59	10.22	10.21	10.21	8.85	10.35
	Std Dev.	2.90	3.07	2.66	2.86	2.71	3.29
Item Times	Mean	8.71	9.70	9.00	9.36	9.82	9.76
	Std Dev.	1.69	2.99	1.30	2.33	1.60	2.34

Likert scale questions were reduced to two items each to improve internal consistency levels. All internal consistency levels are acceptable except feedback (alpha = 0.43). As subsequent results will show, this did not reduce statistical power enough to preclude significant findings for the stated hypotheses. Greater reliability for this measure would only increase the significance of those findings.

The correlation among the two measures of processing time, average item times and average Order # Times is high, as would be expected. However, at a correlation of 0.52, separation of these two constructs is warranted.

The correlation of task norms with group cohesiveness (0.51) is higher than would have been expected given this set of hypotheses. While we predicted that both these constructs would be positively correlated with the low-inventory treatment and, therefore, some positive correlation was expected, the result is higher than warranted by this explanation alone. One possibility is that group cohesiveness predicts or directly influences the development of task norms. We note this possibility now, and discuss it more fully later.

Analysis of Mean Differences

Means and standard deviations for all constructs with all four treatments are shown in Table 2. The effects of the feedback given in the HIF treatment are negligible. We tested for discrimination of the two treatments, High and HIF, on all dependent variables using Hotelling's T^2 test. Although the relationships of all constructs, except peer pressure, are in the predicted directions the overall effect is not significant ($F(6,58) = 0.36$). Differences in variable means were also tested individually using t tests assuming unequal variance which failed to show significant differences (at alpha = 0.1) for any variable. For this reason it was decided to combine high and HIF into one treatment, which we refer to as the large buffer (LB) treatment.

Tests of Hypotheses 1, 2, and 3 using mean differences are shown in Table 3. Hypothesis 1 was supported; mean feedback under the low treatment (8.09) was significantly higher than mean feedback under LB (7.31). Hypothesis 2 was supported by item times and weakly supported by Order # Times (at an alpha of 0.1) as mean times of the slowest in each group were faster under low (Item = 9.5, Order # = 11.4) than LB (Item = 11.0, Order # = 12.9). Hypothesis 3 was not supported by either item times or Order # Times. Mean times of the fastest workers were not significantly slower for the Low (Item = 8.0, Order # = 7.7) than the LB (Item = 7.9, Order # = 7.7) treatments.

Multivariate Analysis

Hierarchical analysis of covariance was used to test interrelationships among the multiple hypotheses relating to group cohesiveness and task norms. Team membership was coded from 1 to 33 and entered as categorical covariates into the models before main effects.

Table 3 Results of Mean Difference Tests

Hypothesis	Brief Description	Test Used	Test Stat.	Sig Level
1	Low increases Feedback	*t*-test	2.40	$p = 0.01$
2	Slower workers work faster in Low			
	Item Times, slowest workers	*t*-test	1.80	$p = 0.04$
	Order # Times, slowest workers	*t*-test	1.45	$p = 0.08$
3	Faster workers work slower in Low			
	Item Times, fastest workers	*t*-test	0.20	$p = 0.41$
	Order # Times, fastest workers	*t*-test	0.00	$p = 0.49$

Note: All *t*-tests were one tailed, assuming unequal variance.

Cohesiveness. There are two hypotheses predicting greater cohesiveness, Hypothesis 4 with the low Treatment and Hypothesis 8 with Group Pay. The data support both of these hypotheses. A single model was run with the measure of cohesiveness as the dependent variable. Independent variables included the team covariate, dummy variables for the low treatment and the group pay treatment, and a control variable for prior friendship. The overall model was significant ($F = 7.89$, $p = 0.00$). All of the variables were significant at an alpha of 0.01. A full factorial model was run separately and none of the interaction terms were significant.

Task Norms. Three hypotheses predicted stronger task norms. They are Hypothesis 5 concerning feedback, Hypothesis 6 dealing with the low treatment, and Hypothesis 7 relating to group pay. The data support Hypotheses 5 and 7. A model was run with norms as the dependent variable. The independent variables included team membership as a covariate, dummy variables for the low treatment, and the group pay treatment, and a variable for feedback. Due to the high correlation with task norms noted before, Cohesiveness was also added as an independent variable. The overall model was significant ($F = 4.89$, $p = 0.00$). Group pay (Hypothesis 7), feedback (Hypothesis 5), and group cohesiveness were significant at alpha = 0.00. When all elements of this model are included the low treatment (Hypothesis 6) showed no significant direct impact on the strength of group norms at an alpha of 0.10. This supports the idea, first proposed in the covariance analysis section, that low-inventory does not directly increase task norms, but rather works through group cohesiveness and feedback. A full factorial model was run separately and none of the interaction terms were significant.

As mentioned before, Goodman et al. (1987) argued that options must be shared among group members before they can be classified as group norms. Our measure of norms is shared among group members as demonstrated by the significance of the covariance with team membership ($F = 10.28$, $p = 0.00$).

Goodman et al. (1987) also argued that norms will be accompanied by evidence of their enforcement. We operationalize this as slower workers will show a positive relationship between task norms and peer pressure. This hypothesis was supported by a correlation of .43. Using a sample size of 33 (the slowest worker on each team) this is significant at an alpha of .01.

Discussion

This research is the first to test the effects of low-inventory policies on the group dynamics of workers. It contributes to the understanding of group dynamics, as well as the interrelationships of work interdependence, feedback, group cohesion, group norms and work speed. Many of the hypotheses have been tested individually before, but they have not previously been integrated nor tested as a comprehensive theory. We used a contrast between high- and low-inventory that is particularly important as modern manufacturing becomes leaner. It also serves to demonstrate clearly the importance of behavioral considerations in manufacturing design decisions.

The model is supported by the data. The results support several of our specific research hypotheses. Low-inventory manufacturing provides task feedback that can motivate performance. Interdependent work, as found in low-inventory, encourages the development of group cohesiveness. The combination of cohesiveness and interdependence with high quality feedback stimulates the development of task norms. These norms encourage co-workers to exert peer pressure, most strongly on the slowest member of each work team, to work harder. The data fail to support hypotheses that faster workers would slow down.

We believe the effect of this model partially explains productivity increases with low inventory. Stronger norms do not, by themselves, mean increased work speed. However, due to the goals suggested by the feedback, as well as social loafing and role theory, we suggest that slower workers will speed up even if faster workers slow down. The first reduces the bottleneck constraint on output while the second merely reduces the apparent idle time of the fastest workers, at least up to the point where they begin to interfere with the slower workers. Therefore idle time will be less, and throughput will be higher, than previously modeled.

A complete measure of productivity should include not only processing speed but also production quality. If workers sacrifice quality for speed then any observed increases in speed may mask underlying quality problems. The theories tested here make no direct predictions regarding quality because the feedback available in low inventory does not include quality information. Nonetheless it is important to establish that quality did not suffer before we claim a relationship between work speed and productivity. We measured quality as the percent of orders correctly entered into the computer. There was no significant difference between the two treatments (LB 87%, low 89%, t-stat 1.13, $p = 0.26$, two-tailed t-test assuming unequal variance). We also tested the quality levels of the slowest members of each team since these workers showed the greatest difference in processing times. There was no significant difference (LB 81%, low 87%, t-stat 1.69, $p = 0.10$, two-tailed t-test assuming unequal variance).

We found no significant difference between the high inventory and the high inventory-feedback treatments. The difference between the two treatments was the provision of feedback that reproduced the evaluative data available in low-inventory without providing other aspects of the low-inventory treatment. This result is consistent with the idea that the evaluative data available with low-inventory is not as important to the dynamics of the group as the social signals and personal consequences.

It previously has been established that group pay can increase productivity in interdependent work situations. Our data support the premise that the mechanism for this relationship operates through the effects of group pay on the strength of cohesiveness and norms. The overall effect was expressed well by one subject who, during a discussion after the experiment, stated that while he quickly forgot he was being paid a little bit more for each piece he completed, he never forgot that his teammates were. This could explain the difficulty in establishing direct links between group outcomes and group effectiveness since the relationship is indirect and may be dependent on the reinforcing nature of other aspects of the work environment. We conclude that the effectiveness of group incentives in interdependent work situations is due, at least in part, to the strengthening of task norms and cohesiveness.

The results suggest that the development of task norms depends on group cohesiveness. Our interpretation of the previous literature is that, while cohesiveness is required for the enforcement of norms, it is not a prerequisite for their development. Our data suggest that task-based group cohesiveness appears to be necessary before task norms will be recognized. Because we did not predict this effect we do not offer it as a conclusion, but recommend the relationship of cohesiveness to the development of task norms as an area for further study.

Building on Hackman's (1992) theory of task-based cohesiveness we have established the beginnings of a theory on the development and effectiveness of task norms. Hackman (1992) argued that group effectiveness can be enhanced by cohesiveness when cohesiveness is task-based and emphasizes the value of feedback and knowledge of the work. We support the importance of these job characteristics and argue that these conditions are available in JIT. Furthermore we propose that the link between task cohesiveness and effectiveness works through task-based norms and peer pressure. The establishment of these norms is encouraged by task interdependence, that helps to form task cohesiveness and make cooperation, through the development of norms, an effective strategy for increasing group effectiveness. Task feedback helps in the development of norms by encouraging task discussion and by allowing malfeasance to be noticed and punished. Interdependent outcomes increase the motivation for development and enforcement of task norms. Once formed, norms influence outcomes in part through the exertion of peer pressure on group members who fail to meet the standard.

The model of the effects of group dynamics on work speed presented here is also closely related to Guzzo and Shea (1992), who proposed that group effectiveness is a consequence of outcome interdependence, task interdependence and potency. Task interdependence is provided by low-inventory work situations while outcome interdependence is provided by group incentive pay and potency is enhanced by task feedback. We contribute to this theory by showing how these factors interact through cohesiveness, norms and peer pressure. We also note that, in our example, group effectiveness is not as much an increase in output from high to low, but rather attaining the same output with fewer resources. This is accomplished by increasing the speed of the slowest workers even if other workers may slow down. We would be interested in further research to test the power of these relationships in other work settings.

Conclusions

The group dynamics of low-inventory lines have their greatest effect on the slowest worker in each group. The slowest workers feel peer pressure and receive feedback signals to work faster and, in fact, do work faster in low- than in high-inventory situations. This is consistent with the complaint that JIT's success is due to increased pressure. However it suggests that the source of the pressure may be as much from peers as from management. This result is important to managers because it is the slowest process on any line that forms the bottleneck and determines the output of that line. By speeding up the pace of the slowest workers, low-inventory decreases the imbalance of the line and improves throughput.

It is clear from this analysis that changing from high-inventory work systems to low-inventory work systems can have a profound effect on the way people perform their jobs. Yet these effects are typically not included in OR models when comparing different line designs or when modeling changes in buffer size. This omission could lead to decisions to carry inventory above optimal levels to reduce anticipated idle time.

Not all serial lines will display the dynamics shown here. There are many other factors operating on the group dynamics of workers in a factory that, by design, were controlled in this study. Further research showing the conditions under which this phenomenon is likely to be significant would be of interest. What other considerations exist that could completely overshadow the effects noted here? Under what conditions do stronger task norms fail to lead to increased productivity? For instance, increased worker cohesiveness in plants with a history of labor-management strife could result in lower, not higher, output. Some processing times are machine-paced and not as readily influenced by worker motivation. The next logical step would be to confirm this analysis with factory workers. The fact that cohesiveness, norms, and peer pressure developed significant differences during two hours of production speaks to the strength of the underlying motivations at work in this study. Nonetheless it remains to be demonstrated that these effects are lasting and significant in a factory setting.

This research contributes to the understanding of the development of productivity norms. We believe that feedback encourages the development of norms by focusing interpersonal contacts on the task and by giving information for norm enforcement. Task interdependence encourages the development of productivity norms by making group behaviors important to task accomplishment. Outcome interdependence encourages task norms by giving members a stake in the accomplishments and justifying intervention in the behavior of co-workers.

This research is also important to understanding group dynamics in the workplace and to the management of low-inventory systems. We have explored the interrelationships of feedback, cohesiveness, norms, peer pressure and interdependent outcomes on how work design affects group output. This expands the current state of knowledge about how groups perform. We have also demonstrated some of the behavioral effects of low-inventory systems and argued that the effects on variance are at least as important as the effects on overall average processing speed.[1]

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Appendix 1. Questionnaire Items

*indicates question was dropped due to internal inconsistency

A. *Cohesiveness*: 5-point Likert scale from "Strongly Disagree" to "Strongly Agree."

1. I believe members of my work group feel a strong sense of personal attraction to the group.
2. I have a strong sense of belonging to my team.
3. *Satisfaction with team membership is low among members of my group.
4. *The benefits of being a member of my work group far exceed the costs.

B. *Feedback*: 5-point Likert scale from "Strongly Disagree" to "Strongly Agree."

1. Most of the time I had enough information to determine how well I was doing.
2. Most of the time I was given enough information to do the job well.
3. *Most of the information I was given during the job was useless (reverse scaled).

C. *Peer Pressure*: The first question is asked twice, once about each of the subjects two co-workers.

1. Did that worker ever hint or tell you that you should be working harder? Possible responses were 1. I don't know; 2. This co-worker was satisfied with my effort; 3. Didn't hint or tell me but they thought I should; 4. Hinted but didn't tell me; 5. Yes, Told me.
2. *My co-workers would have reacted strongly if they thought I was not working hard enough. Measured on a 5-point Likert scale from "Strongly Disagree" to "Strongly Agree."

D. *Group Norms*: The first question is asked twice, once about each of the subjects two co-workers

1. Did that worker care about how hard you were working? Measured on a 5-point Likert scale from "Didn't care at all" to "Cared a lot."
2. *To what extent did people in your work group maintain high standards of performance? Measured on a 5-point Likert scale from "None" to "A Lot"

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