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Title: The Effects of Just-in-Time/Lean Production Practices on Worker Job Stress


Authors:
Jannis Angelis
Institute for Manufacturing
University of Cambridge
Cambridge CB2 1RX, UK
(E): jja22@cam.ac.uk. (F): +44 1223 765042. (T): +44 1223 338776.

Robert Conti
Bryant College
Smithfield, RI 02917, USA
(E): rconti@bryant.edu. (F): 401 232 6319. (T): 401 232 6462.

Cary Cooper
Lancaster University Management School
Lancaster, LA1 4YX, UK
(E): c.cooper1@lancaster.ac.uk. . (F): +44 1524 594720. (T): +44 1524 594326.

Brian Faragher
School of Management, UMIST
Manchester, UK
(E): brian.faragher@umist.ac.uk. (F): +44 161 200 3505. (T): +44 161 236 3311.

Colin Gill
Institute for Manufacturing
University of Cambridge
Cambridge CB2 1RX, UK
(E): cgg@eng.cam.ac.uk. (F): +44 1223 338177. (T): +44 1223 338776.

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The Effects of Just-in-Time/Lean Production Practices on Worker Job Stress

ABSTRACT

A long-raging debate about the effects of lean production on worker job stress has been waged primarily with case studies and anecdotal evidence. Little statistically valid guidance has emerged to help meet the challenge of operating lean systems that control job stress, and its associated human and operating costs. This is the first large scale, multi-industry empirical study of the relationship of job stress to a range of lean practices, as well as to the degree of lean implementation. The results are based on 1,391 worker responses from 21 manufacturing sites in four UK industry sectors. Eleven work practices are found to be significantly related to job stress and an unexpected non-linear response of stress to lean production implementation is identified.

The results and their implications are discussed, and recommended practices described.

Key words: JIT, lean, job stress
INTRODUCTION

Just-in-Time/Lean Production (JIT/LP) has become the competitive standard in many global markets. It was popularised by the International Motor Vehicle Project (Womack et al 1990:80). That study showed that cars produced in lean plants required one-third fewer hours and had one-third fewer defects than those built using traditional mass production. JIT/LP has demonstrated the potential for achieving high productivity and quality, but evidence suggests that it can also create high job stress. This poses the question as to whether the benefits of JIT/LP are gained at the expense of work-life quality and social welfare.

Literature

There is extensive research on the stressful effects of JIT/LP, but none based on large-scale multi-site, multi-industry studies of specific work practices. Much of the literature has narrowly focused on ethnographic studies of single Japanese auto plants in the US, such as Toyota (Parker and Slaughter, 1988), Mazda (Fulcini and Fulcini, 1990), and Subaru/Isuzu (Graham, 1995). The studies depict unfavourable human effects in fast paced, high intensity, high stress environments. However, generalizing their observations as characteristic of JIT/LP systems, in the absence of larger samples, is open to question. Based on working six months at Subaru-Isuzu, Graham concludes that “The Japanese model (JIT/LP) is not equipped to deliver on its promises to its workers. During a corporation’s quest to maximize profits, workers simply become expendable”. (1995:154). Berggren (1993) similarly equates JIT/LP with mean production, describing the lean environment as: “..unlimited performance demands, the long working hours and requirements to work overtime on short notice, the recurrent health and safety complaints, the rigorous factory regime that constitutes a new and very strict regime of subordination”.

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A multi-site empirical study was conducted by Lewchuk and Robertson (1996), comparing four forms of work organization in the Canadian auto industry: JIT/LP firms, firms changing to JIT/LP, Ford mass production firms and ‘exploitative’ companies. A survey of 1,670 workers at 16 locations showed that workers in JIT/LP plants experienced the greatest job stress, reported heavier and faster work loads and difficulties in getting time off and changing job features. The study is limited to the auto industry and offers little insight into the specific stress effects of the wide range of JIT/LP work practices. Klein (1989:60) does offer several specific suggestions for practices to “mitigate the harsh effects of JIT” – but based on anecdotal observations.

Longitudinal research by Mullarkey et al (1994) reaches a different conclusion. Their study of the job strain and job content effects from implementing JIT/LP and work teams at a UK manufacturer shows “it is possible to introduce JIT/LP and team working without detrimental effects on shop operator’s jobs and psychological well-being”. Jackson and Martin (1996) had similar outcomes in their longitudinal comparison of a JIT/LP line and a traditional line at a UK printed circuit board plant, concluding that JIT can be implemented without “adverse impact in terms of employee strain”.

Mixed conclusions are reached by the Swedish Metal Workers’ Union in a 2003 cross-industry study on the effects of JIT/LP on workers. It identifies both beneficial aspects such as worker participation and team work, and shortcomings such as staff shortages and short cycle time. Anderson-Connolly et al (2002) also reach mixed conclusions in answering the question “is lean mean?”. They report that increased intensity is “unequivocally harmful for both managers and non-managers. Beyond this, however, the conclusions depend upon which dimensions and which employees are being considered”.
Effects of Stress

Stress affects both individuals and organisations. Kvarnström (1997) of the ILO reports that individual stress may impair health and the ability to cope with working and social situations, causing work performance and relationship strains. For organisations, stress causes absenteeism, increased medical costs and higher staff turnover. Cox et al (2000) report that 50-60% of all lost working days are stress related. In Britain, in 2001, this amounted to 17-20 million working days, over 30 times more than caused by industrial action. Stress-related illnesses have overtaken back and neck problems as Britain’s most common workplace ailment, with an annual cost to industry of about £370 million.

Research need and questions

Both the competitive power of JIT/LP and its potentially negative effect on workers should be addressed by managers, trade unions and government agencies. These groups need factual information about the stress consequences of JIT/LP, to make reasoned choices on work-life issues. Anderson-Connolly et al (2002) support this position: “If it is accepted as inevitable that some workplace changes will occur, then the researcher can play a more positive role by determining which particular changes are the most beneficial and which are the most harmful and use his or her position to steer social policy in the appropriate direction”. This is the objective of the study. It addresses a limitation of job stress studies that have “focused on individual coping and adaptation to stress rather than on work environments and how they can produce or alleviate stress” (Jaffe, 1996:19). The study addresses two questions:

- What is the relationship between worker stress and the level of JIT/LP implementation at lean production sites?
- What are the relationships between specific JIT/LP design and operating practices and the
levels of worker stress?

**METHODOLOGY**

Variables and Survey Strategy

The study is at two levels – sites and workers, using linked management and worker surveys. The level of JIT/LP implementation was assessed by managers and the work practices and associated stress levels were reported by workers. The response variable is worker job stress, as measured by the ASSET Survey. The independent variable for the first research question is the degree of JIT/LP implementation at each site. The use of each of ten key JIT/LP techniques was measured on a five-point scale in the management survey. The scale structure is based on that of Powell (1995). The Cronbach alpha of .816 is central within the generally accepted threshold range of .70 to .90. The ten values were averaged to measure implementation depth. Implementation breadth was estimated by the percentage of assembly utilising lean production – also on a five-point scale. The two measures were averaged for total implementation. A plant tour at each site, prior to the management interview, helped to assess the validity of the management survey responses.

Sample size and selection

For the Likert scales used, approximately 50 responses yield an estimated precision of plus or minus 10% of the mean, with a confidence level of 95%. The Survey Research Handbook states that “The maximum practical sample is about 1000 respondents under ordinary conditions..” (Alreck and Settle, 1995:62-63). A target of 1000 responses was chosen, setting the minimum number of sites at twenty. Based on similar studies, a 50% response rate was estimated, requiring distribution of an average of 100 surveys per site to yield an average of 50 responses. A higher average was distributed for a safety margin. A minimum site size of 60 assemblers was set. At
each site surveys were distributed to 100% of the assemblers up to a maximum of 300. A random selection of 300 was made from larger assembly pools. The sample space is the population of UK manufacturers implementing JIT/LP to some degree, and having at least 60 assemblers. Cook and Campbell’s (1979) method for heterogeneity sampling was used to recruit sites differing widely in their lean practices. The 21 sites cover a wide range of products, workforce sizes and practices - in four Standard Industry Codes (SICs): 35 (machinery), 36 (appliances), 37 (transportation equipment) and 38 (instruments). Employment of the SICs guided the sample distribution, but the study measures stress effects of work practices – not industries. The sites are all ‘brownfield’ with a mix of union and non-union workplaces. See Table 1.

<table>
<thead>
<tr>
<th>SIC</th>
<th>No. sites</th>
<th>Percentage</th>
<th>Percentage production employees*</th>
</tr>
</thead>
<tbody>
<tr>
<td>35xx</td>
<td>5</td>
<td>23.8%</td>
<td>33.8%</td>
</tr>
<tr>
<td>36xx</td>
<td>5</td>
<td>23.8%</td>
<td>25.7%</td>
</tr>
<tr>
<td>37xx</td>
<td>8</td>
<td>38.1%</td>
<td>29.2%</td>
</tr>
<tr>
<td>38xx</td>
<td>3</td>
<td>14.3%</td>
<td>11.0%</td>
</tr>
</tbody>
</table>

Table 1. Sample summary.

Only assembly workers were sampled. Assemblers outnumber machine operators in lean factories and they do not have the opportunity to relax during machine cycles. Also, assemblers and machine operators are subjected to different stressors, making a common survey impractical. It should be noted, however, that lean production can be applied to fabrication and machining operations. Each selected assembler received instructions and was given the worker survey in a stamped envelope for anonymous posting to the authors. Reminders were distributed one week later. The response rate was 1,391 out of 2,555 questionnaires distributed (54.4%), with an
average response rate per site of 66.4%.

WORK PRACTICE HYPOTHESES

Theoretical Basis

The Karasek-Theorell model was used to link lean production practices to expected worker stress. (Karasek and Theorell, 1990:57). It associates high stress with high physical demands, high psychological demands, low control and low social support. Initial hypotheses were developed by Conti and Gill (1998). The hypotheses and questionnaires were reviewed by a panel of researchers and practitioners. Based on their suggestions, a number of hypotheses and survey items were added on job demand, support and control. The tested hypotheses are:

H1  Job stress is positively related to work pace and intensity.
H2  Job stress is positively related to the frequency of resource removal to force process improvement.
H3  Job stress is positively related to the inability to work the desired number of hours per week.
H4  Job stress is positively related to decreasing cycle time.
H5  Job stress is negatively related to the use of buffer inventories between work stations.
H6  Job stress is positively related to the frequency of having to do the work of absent fellow workers.
H7  Job stress is positively related to the perception of being blamed for defects.
H8  Job stress is positively related to the display of individual output.
H9  Job stress is positively related to the degree of ergonomic difficulty experienced in performing tasks.
H10 Job stress is negatively related to the opportunity for team working.
H11 Job stress is negatively related to support from peers and supervisors in meeting time and
quality standards.

H12 Job stress is positively related to the frequency of quality problems of parts not fitting.
H13 Job stress is positively related to the frequency of work flow interruptions.
H14 Job stress is positively related to the lack of training support.
H15 Job stress is positively related to the lack of tool/equipment support.
H16 Job stress is negatively related to the level of control of work pace.
H17 Job stress is negatively related to autonomy to make improvement changes.
H18 Job stress is negatively related to the ability to comment on proposed work changes.
H19 Job stress is negatively related to the degree of participation in continuous improvement activities.
H20 Job stress is negatively related to the frequency of job rotation.

The implementation hypothesis reflects the tendency for JIT/LP to increase work intensity and worker monitoring. This increases demands, reduces control and increases stress. Higher implementation leads to increased intensity and monitoring, and higher stress. Therefore:

H21 Job stress is positively related to the level of JIT/LP implementation.

Work Pace and Work Intensity – A Clarification

The importance of work pace and intensity in job stress necessitates a clarification. Graham (1995:142) refers to a “forty-to-fifty-second-a-minute work pace”. This actually describes work intensity - the portion of total working time spent performing production tasks. Work pace is the speed at which tasks are done, measured on a scale with 100% defined as ‘normal’. Pace and intensity are determined separately when setting time standards. Pace is set first, typically at 100%. Time study analysts ‘rate’ the actual pace of a studied worker and adjust the time to a
100% pace. Computerised standard systems use 100% pace times. Intensity is set by adding a fatigue allowance, usually between 15% and 25%. Assume it takes 48 seconds to perform a task at 100% pace. With a 25% allowance, 12 seconds are added to the 48, and the time allowed – the ‘standard time’ – will be 60 seconds, based on a work pace of 100% and an intensity of 48 seconds per minute, or 80%. Workers can vary the mix of pace and intensity to exercise some control over the work cycle.

Validation Check of Survey Stress Measurements

The ASSET survey stress values were compared to the normative ASSET values which are based on a sample of UK white-collar workers. Both sets of values have comparable variability. However, the JIT/LP survey mean values are significantly lower, with 13.94 for physical stress and 22.92 for mental stress compared with 14.16 and 23.95 respectively for the ASSET norms. This agrees with the UK Department of Trade and Industry “Work-Life Balance Survey” of 2002. Stress levels of manufacturing workers were found to be significantly lower than those of white-collar workers.

IMPLEMENTATION HYPOTHESIS TESTING RESULTS

Analysis of the relationship between job stress and JIT/LP implementation revealed a high degree of non-linearity and the best fit was achieved with the convex quadratic curve shown in Figure 1 (F=6.65, df=1388, p<.001). Hypothesis 21 is rejected on the grounds that the relationship is more complex than hypothesised. It exhibits an initial zone of increasing stress at low implementation. Stress then levels off in a middle zone until it reaches an inflection point. Further implementation is associated with decreasing stress.
Figure 1. Stress and JIT/LP implementation

The ASSET survey also measures job dissatisfaction, worker commitment to the firm and perceived commitment of the firm to the worker. The relationships of these measures to JIT/LP implementation are plotted to assess the validity of the stress response. The plot of dissatisfaction versus implementation exhibits the same shape as the stress curve, with the null hypothesis of a linear relationship rejected (p<.001). This is consistent with the significant positive correlation between dissatisfaction and stress (r=0.511, p<.001). Plots of worker commitment to the firm and perceived commitment of the firm to the worker versus JIT/LP implementation exhibit mirror images (concave curves) to those of stress and dissatisfaction, and are also non-linear (p<.001). This is as expected, since the correlation with stress is negative and significant for both worker commitment (r=-0.208, p<.05) and for perceived firm commitment (r=-0.407, p<.05). The dissatisfaction and commitment response curves appear to support the hypothesis of a non-linear (possibly quadratic) relationship of stress to JIT/LP implementation. The implications of this relationship are analysed in the Discussion section.
WORK PRACTICE HYPOTHESIS TESTING RESULTS

Statistical Procedure

The work practice survey items employ five-point Likert scales. Analysis of Variance (ANOVA) was used to check the means and 95% confidence intervals for the stress responses to each of the five levels of work practices. The confidence interval estimates were adjusted for both finite population sampling and for the response rate at each participating site. The total of physical and mental stress was the dependent variable. The point-by-point analysis provided important insights into some of the work practice-stress relationships. Noticeably, some of the relationships were non-linear; in order to achieve more acceptably linear relationships for multivariate analysis, sequential levels where the means did not differ significantly were combined and the variable redefined for subsequent analysis. To make some allowance for multiple testing, the significance level for each of these analyses was set at a level of .001 or less. Multiple regression of the redefined variables was used to test the hypotheses. For this analysis, the test criteria were significance levels of .05 or less and regression coefficients having the hypothesised sign.

Regression results

The summary of the stepwise regression results for the hypothesised practices is shown in Figure 2. The model F is 30.771 (df=20.370), p<.001, and the adjusted R square is .300. There is no evidence of collinearity, with all VIF values within 1.500. Examination of the normal distribution plot of model residuals indicates an excellent fit to a linear model.
### Coefficients

<table>
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<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
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<th>Tolerance</th>
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<th>Collinearity Statistics</th>
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<td>1</td>
<td>(Constant)</td>
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<td></td>
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<td>Parts fit</td>
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<td>.887</td>
<td>.794</td>
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<td>Flow interruptions</td>
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<td>.764</td>
<td>.778</td>
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<td>Absentee worker</td>
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<td>.783</td>
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<td>Ergonomics</td>
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<td>5.697</td>
<td>.000</td>
<td>.758</td>
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<td>Job rotation</td>
<td>-.121</td>
<td>-.233</td>
<td>.816</td>
<td>.864</td>
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<td>Removal frequency</td>
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<td>.810</td>
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<td>Team work</td>
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<td>.906</td>
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<td>Cycle time</td>
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<td>3.094</td>
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<td>.779</td>
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<td>Pace/Intensity</td>
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<td>.851</td>
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<td>Lack of tools</td>
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<td>2.584</td>
<td>.010</td>
<td>.803</td>
<td>1.246</td>
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<td>Buffer use</td>
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<td>.821</td>
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<td>.182</td>
<td>.892</td>
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<td>.224</td>
<td>.929</td>
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<td>-.748</td>
<td>.455</td>
<td>.910</td>
<td>1.098</td>
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<td>Indiv. output display</td>
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<td>.385</td>
<td>.700</td>
<td>.948</td>
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<td>Blame</td>
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<td>.776</td>
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<td>Improvement projects</td>
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<td>.009</td>
<td>.887</td>
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<td>Desired hours</td>
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<td>6.692</td>
<td>.000</td>
<td>.848</td>
<td>1.179</td>
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</table>

a. Dependent Variable: Physical and Mental Stress

Figure 2. Work practice and job stress regression results.

Eleven of the twenty tested hypotheses are supported with statistical significance of p=.05 or less and regression coefficients of the hypothesised sign. The hypothesis test results are analysed in the Discussion section.

**DISCUSSION OF WORK PRACTICES**

Discussions of the twenty work practice hypotheses are based on the regression and results. Hypothesis numbers are shown in brackets.

**Rejected Work Practice Hypotheses**

**Autonomy for Process Changes [H17]**

The relationship between process change autonomy and stress is not statistically significant, and
Hypothesis 17 is rejected (p=.182). It appears that workers view participation in process improvement programs as more important than autonomy to make process changes.

Job Rotation [H20]
The relationship between the frequency of job rotation and stress is not statistically significant and Hypothesis 20 is rejected (p=.816). Job rotation can have mixed effects for workers. It can relieve repetitive task monotony, but also interrupts the repetitive rhythm that some workers value. It should be noted that job rotation can help to prevent repetitive motion injuries.

Lack of Training [H14]
The relationship between the lack of adequate training and job stress is not statistically significant and Hypothesis 14 is rejected (p=.224). Training can affect the ability to meet time and quality standards. However it appears that variations in performance attributed to training are not viewed as particularly stressful by the workers. This may be due to the widespread use of de-skilled repetitive tasks that require little training.

Display of Individual Output [H8]
The relationship between displaying of individual output and job stress is not statistically significant and Hypothesis 8 is rejected (p=.700).

Work Pace Control & Buffers [H5, H16]
The control of work pace and use of buffers are related, since buffers between work stations make it possible for workers to control pace by ‘working ahead’ to build up the output buffer, and relaxing while the buffer is depleted. Hypotheses 5 and 16, for buffer use and pace control, are
rejected with significance levels of .901 and .281 respectively. While the survey sites employ a wide range of work practices, there is an exception in the use of buffers. Of the 21 sites, only one operates with one-piece, synchronised, buffer-less flow – and with no control of work pace. This may account for the lack of significant relationships between the practices and stress.

Worker ‘Voice’: Commenting on Work Changes [H18]
The opportunity to be consulted and comment on proposed work place changes provides workers with a ‘voice’, but Hypothesis 18, for a negative relationship between this type of voice and stress, is rejected. The standardised coefficient has the hypothesised sign but the significance is only .455. Perhaps the low frequency of consultation opportunities, as compared to the frequencies of the other practices, reduces the importance of ‘voice’ to the workers.

Work Flow Interruptions [H13]
Hypothesis 13 is rejected. There is not a significant relationship between the frequency of work flow interruptions and job stress (p=.764). There are mixed worker responses to interruptions. They can be viewed as favourable, since they reduce intensity through unscheduled breaks, but can also be considered unfavourable, since they disturb the rhythm that some workers value.

Parts Fit Difficulties [H12]
The relationship between parts fit difficulties and stress is not significant (p=.887), and Hypothesis 12 is rejected.

Supported Work Practice Hypotheses
The analysis of the supported hypotheses is grouped into sets of related practices, and is based on
the regression results.

**Work Pace/Intensity [H1, H2, H6]**

The relationship of work pace/intensity to stress exhibits the third largest standardised coefficient (beta=0.143, p<.001) and Hypothesis 1 is supported. Pace and intensity are measured by a WERS98 survey item – the extent to which workers feel that they do not have enough time to “get their work done”. (1999:171). The bivariate correlation between pace/intensity levels perceived by workers and the shop tour observed levels at their sites, is significant (r=0.189, p<.001), indicating realistic worker perceptions. The large proportion of stress variation explained by pace/intensity is expected, since much of the lean production literature characterises it as a high intensity, fast paced system. It is also consistent with the model of Bheer and Bhagat, which proposes that a stressor’s effect is proportional to its importance and duration. (1985). The pace/intensity duration is continuous throughout each cycle. Therefore, if the magnitude is above normal, job demands can be very stressful.

The use of faster than normal pace/intensity may appeal to managers, since output increases for a given input of labour and capital. This short term gain, however, ignores the negative long term costs of the increased absenteeism and labour turnover associated with increased stress. Klein recognises this, advocating that lean systems “Emphasise flow, not pace”. (1989). Controlling lean production job stress appears to require ‘normal’ levels of pace and intensity – achieved through policies for setting time standards, labour manning levels and process improvement (‘kaizen’) programs. Formal time standards should use pace levels of 100% or lower and intensity levels of 83% or less (fatigue allowance of 20% or higher). It should be noted that this restriction is included in many US collective bargaining agreements. Adler, however, feels that
“formal work standards developed by industrial engineers and imposed on workers are alienating”. (1993). He favours “..procedures designed by the workers themselves..”. Participation of workers in setting standards is desirable since it tends to eliminate disputes over ‘tight’ standards, reduce the cost of time study departments and result in reasonable pace and intensity levels. While time standards determine design levels of pace and intensity, actual levels can be increased by ‘speed-ups’ - if production is increased without adding workers. This decreases each work station cycle time, forcing workers to perform tasks at a higher pace and intensity. If increased demand requires more output, it should be met by overtime production in the short run and increased manning in the longer term – not by stressful speed-ups.

There is a more subtle form of speed-up – the removal of resources (eg. line workers, kanban containers of parts) from a smoothly running line while maintaining the same output. The remaining line workers must speed up to maintain output and sub-assemblers must work faster to refill the more rapidly circulating containers. This is portrayed as ‘improvement by stress’ – an appropriate assessment as evidenced by the support for resource removal Hypothesis 2 (beta=.065, p=.009). The objective of resource removal is to identify flow ‘bottlenecks’ and improvement opportunities. However, this stressful tactic overlooks the ability of process analysis, with worker participation, to identify flow barriers and lead to improvements that allow subsequent reductions without speed-ups. Post-improvement resource reduction was favoured by Shigeo Shingo, co-architect of the Toyota Production System. For example, he recommended using inventory buffers, or ‘cushions’, to maintain flow in the face of process variations – with buffers reduced only after “the causes of the variations are identified” and corrected. (1981:51). Speed-ups are also imposed by assigning workers to the tasks of absent colleagues, in addition to their own work. Hypothesis 6 for this practice is supported (beta=.080, p=.002). A pool of cross-
trained standby, or ‘floater’, workers could fill in for absentees. When not needed, they could work at high-value activities such as ‘kaizen’ improvement projects and pilot production.

Ergonomic Difficulty [H9]
The work required for production tasks is the product of the force required and the distance through which the force acts. The effort required, a measure of physical job demand, is proportional to the rate at which the work is done (work per unit of time). The time is set by the pace/intensity level, while force and distance are determined by process ergonomics. Therefore, effort is increased by a combination of greater ergonomic difficulties and shorter time allowances (faster pace/intensity) – increasing physical job demands and stress. Hypothesis 9 is supported, with the relationship of ergonomic difficulty to stress having the second highest standardised coefficient (beta=.147, p<.001). Like pace and intensity, ergonomics affect every work cycle. Since lean production is predominantly a short cycle, highly repetitive system, the ergonomic impact is repeated many times per hour, with potentially stressful results. Ergonomic difficulties must be addressed at the design stage by integrating ergonomics into product and process design. (Helandar and Namagachi, 1992). All products should be subjected to periodic ergonomic audits, with worker participation. The researchers witnessed a number of ergonomically difficult tasks in otherwise exemplary lean operations. These may have been overlooked during slow-paced pilot production runs. An ergonomically acceptable pilot task can become intolerable when repeated several times an hour in full-scale production.

Feeling of Blame for Defects [H7]
The strength of the blame relationship with stress is noteworthy considering the low frequency of finding defects in lean production – in contrast to the continuous and high frequency effects of
pace/intensity and ergonomics. The strength of the support for Hypothesis 7 puts blame on the level of pace/intensity and ergonomics as a major stressor, with the fourth highest standardised coefficient \((\beta=.142, p<.001)\). Rapid and consistent feedback of performance is a hallmark of lean production. Ordinarily this is considered desirable for minimising uncertainty and role ambiguity. Many of the sampled workers, however, appear to take this feedback personally and interpret it as blame, even though the sites tend to use enlightened practices. The feeling of blame appears to persist. It may be reinforced by past line stoppages creating anxiety about future defects. This anxiety can be reduced by the use of ‘poka-yoke’ fool-proof process design. Poka-yoke reduces assembly errors by removing task discretion and eliminating error opportunities. Shingo cites its use on installing retainer clips on Toyota door liners. (1981:30). Two million clips were installed each month, so even very low rates of missing clips resulted in regular line stoppages. The clip installers were exhorted to be very diligent – and they were - at the expense of high anxiety over the concentration required. A poka-yoke project fitted the assembly fixtures with electrical limit switches that were actuated by each of the clips. If a liner was lifted out of the fixture with a missing clip, the un-actuated switch triggered an alarm. The defect rate went to zero and worker anxiety subsided.

Poka-yoke techniques are ideal for workers to learn and apply. Workers can use their experience, knowledge and creativity to improve products. This off-line job enrichment may counteract the effects of on-line performance of de-skilled tasks. A Japanese executive described this approach to one of the authors as “our workers using their minds to make their work tasks more mindless”. Some researchers propose that the linked-flow interdependency of lean production leads to feelings of blame. Huber and Brown state that “Because feedback is more immediate and shared by group members, employees may feel more accountable for their work. This may increase
stress levels for employees”. (1981). Delbridge and Turnbull (1992) suggest that the interdependent flow of JIT/LP and the ability to trace defects to individuals encourages a “blame culture”. If some degree of blame is systemic, then controlling the episodic feedback of errors assumes increased importance. Schonberger describes concerns about defect blame at a Boeing aircraft plant. A consultant suggested banning the terms ‘error’ and ‘defect’ and substituting ‘mishap’, as being less emotional and less likely to induce a blame reaction. (1996:186). Managers should be aware of both the direct and indirect consequences of perceptions of blame. Feedback about defects is usually given by supervisors. Therefore, they should be trained in ‘no fault’ feedback techniques.

Working Desired Number of Hours [H3]
The relationship between the inability to work the desired number of hours and stress is strongly supported, with the highest standardised coefficient (beta=.163, p<.001). The WERS98 study reported that 62% of assemblers work overtime primarily for money. (1999:157). Therefore, the differing financial needs among workers leads to differing attitudes toward the total hours worked. However, there appears to be a consensus that the inability to work the desired number of hours is stressful. It appears desirable to make overtime voluntary. Such a policy presents a challenge in lean production since all work stations on a flow path must be manned by qualified workers. This requires a high degree of cross-training to make it feasible to man all work stations with qualified volunteers; and a favourable union-management climate to avoid disputes leading to overtime bans. The worker survey contains an item to measure the effects of overtime worked. However, the item was unusable because annualised hour schemes at some sites created uncertainty over what constitutes overtime.
Lack of Tools [H15]

Hypothesis 15, for the relationship between lack of proper tools and stress, is supported (beta=.065, p=.010). Assembly departments of lean production plants are usually much less capital intensive than fabrication and machining departments. Relatively simple hand tools and fixtures tend to be used in assembly. Therefore, there appears to be little justification for a shortage of proper, well-maintained tools to meet time and quality standards.

Worker Participation in Process Improvement [H19]

Hypothesis 19, for a negative relationship between process improvement participation and stress is supported (beta=-.062, p=.009). Worker participation in improvement, or ‘kaizen’ programs, can ameliorate the stressful effects of de-skilled repetitive tasks. The ANOVA analysis showed no significant differences in the stress responses between levels two through five. The relationship converges to two states: participation and non-participation in improvement programs. It appears that the opportunity to participate in an ongoing improvement program may be more important than the frequency of program activities.

Frequency of Stress Exposure [H4]

High stress potential is encountered at the end of each task cycle when work is transferred to the next station. Two negative outcomes are possible. It can take longer than allowed to perform the tasks, causing blocking and starving of work stations along the line; and if the transferred component is defective, discovery at the next station may stop the line, causing stressful feelings of blame. Shorter cycle times result in more frequent transfers, and Hypothesis 4, of a positive relationship between decreasing cycle times and stress, is supported (beta=.079, p=.002). This agrees with the conclusions of Melamed et al (1995), who show the stressful nature of short
cycle, high repetition production. The cycle time for a total flow path is determined by the required output. If 60 units per hour must be assembled, the overall cycle time must be 60 seconds. The configuration of the product flow paths, however, can increase individual workstation cycle times. For example, if two parallel lines are operated at an output of 30 per hour each, total output remains at 60 per hour but the individual station cycle times will double to 120 seconds. Parallel lines are most practical when the capital investment per flow path is modest. For paths with small numbers of stations, an effective way to significantly increase cycle times is to have workers ‘walk the line’, proceeding from station to station, performing all tasks: sub-assembly, final assembly, testing, and packing. This also eliminates line balance delays and affords a high degree of pace/intensity control.

Task Support [H11]
The availability of help from peers and supervisors in meeting time and quality standards appears to reduce job stress. Hypothesis 11, for a negative relationship between support and stress, is supported (beta=-.068, p=.005). While task support appears desirable, it may be a mixed benefit in the long run. It amounts to a speed-up for the helpers and if it becomes a regular occurrence - with the same cast of dependent and supporting characters - resistance to the practice may develop and its effect may become unfavourable. Peer task support is best used for emergencies. It should not be used as a substitute for adequate manning and the redesign of tasks that regularly require support.

Team Working [H10]
The relationship between team working and stress is statistically significant and the coefficient is negative, supporting Hypothesis 10 (beta=-.089, p<.001). It appears that for the sampled workers
the advantages of peer support outweigh the burden of periodically filling-in for absent colleagues.

The Role of Job Control

The stress responses to job demand and job support practices are much stronger than job control responses. Seven of the nine job demand hypotheses and three of the six support hypotheses are supported, but only one of the five linked to job control. This apparent lower utility of job control can favour both product and work-life quality. Conti and Warner (1997) show that non-discretionary assembly tasks are a necessary condition for producing high reliability complex products. Herzberg et al (1959) differentiate between motivational and hygienic job factors, with the latter only able to de-motivate workers. It is unlikely that motivation can be achieved by providing high control and discretion for the short cycle tasks that are typical in lean production. However, non-discretionary designs can prevent demotivating and stressful task uncertainties like parts not fitting – as well as improving product reliability. Jaguar’s change to ‘no-adjust’ assembly during the 1990s helped the brand to move from last place to the upper region of the reliability league table. The use of Standard Operating Procedures for performing production tasks can reinforce non-discretionary job designs and promote organisational learning - by preserving improvements when workers are transferred. The sampled workers seem to favour task predictability over job control; making the demand and support factors more effective predictors of lean job stress than job control.

Work Practice Analysis Summary

The hypotheses test findings shed light on the relationships between lean production practices and job stress. They show a substantial managerial effect in the determination of job stress –
through choices of policies and practices. The regression model indicates the scope of the potential management influence, with work practices explaining 30% of the variations in stress. The ethnographic literature provides a valuable litany of mismanaged lean practices. These negatively affect both stress and performance since several stress reduction techniques can also contribute to improvements in productivity and quality – practices such as continuous improvement programs, use of poka-yoke designs, eliminating ergonomic difficulties and providing proper tools.

Discussion of JIT/LP implementation [H21]

Hypothesis 21 assumes that intensity and monitoring of work, and hence stress, increase over the full range of lean implementation. The hypothesis is rejected, with the stress response exhibiting the three stages shown in Figure 1. It should be noted that the relationship was derived from a cross-sectional study, and the independent variable is not time. It is the various implementation levels at the 21 sites, with given levels reached at different elapsed times at different sites. The three implementation stages in Figure 1 appear to correspond roughly to the three phases of reaction to major change described by Fineman: an initial period of distress, followed by periods of acceptance and recovery. (2003:124). Any major change can cause a sense of loss and uncertainty. A change to lean production exposes workers to new technologies, working relationships, expectations about productivity and quality and shop floor responsibilities. The resulting uncertainty can create distress – and the higher stress, increased dissatisfaction and lower commitment exhibited by sampled workers. Fineman’s second and third phases may seem to apply to the corresponding JIT/LP implementation stages. However, they are not linked to any particular practices, and normally the full three phase change cycle is experienced in a matter of months – not the years required for JIT/LP. Koenigsaecker cites his experience with multi-year
lean conversions. He characterises the first two years as “dissension and anti-change”, the third year as one of change stabilisation and “building the long-term foundation” and years four and beyond as the period when change becomes the norm, “pride in …lean accomplishments” develops and results begin to compound. (2000). The mean elapsed implementation time at the survey sites is about four years. It appears that the lean practices are the major determinants of the stress pattern in the later implementation stages.

Conclusions about the effects of implementation on stress must be based on both the shape of the response curve and the net change in stress. The distribution of implementation levels at the 21 sites are as follows: 2.0 to 2.5 = 2 sites; 2.6 to 3.5 = 7 sites; 3.6 to 4.5 = 11 sites and 4.6 to 5.0 = 1 site. Sampling only JIT/LP sites eliminates a zero point. The total of 18 sites in the mid-range of 2.6 to 4.5 appears large enough to define the convex response curve at an acceptable goodness-of-fit – and provide the justification for rejecting Hypothesis 21. However, the magnitude and sign of the net change in stress over the full range of implementation is inconclusive, since the end points of the curve are defined by only three sites.

A strategy for coping with the staged nature of implementation stress is offered by a lean manufacturing executive: “..make a decision (to implement lean) and stick with it. We decided we were going lean…, and there was no turning back. We stopped ‘dabbling’ in lean and went after it and got some tremendous results. It was no longer a question of ‘if’ but ‘when?’. It’s easy to say we’ll try it “here” for “this long”” or “we’ll see what happens”. These are phrases of someone sitting on the fence. Expect resistance but keep an unwavering focus on the project”. (Sharing, 2002). This combination of commitment and continuity appears to be essential.
CONCLUSIONS

The discussions contain several recommended stress-reduction practices. A pattern emerges, showing that worker well-being in lean production is not deterministic. It depends on the management choices of production practices. Adler answers the question of whether lean production can be compatible with reasonable health standards with a “Maybe” – making his response conditional on “good implementation”. (1998). Practices recommended in this study qualify as part of a ‘good’ implementation program.

Most survey site managers reported that lean production has led to improved performance. The level of implementation at the sites is positively correlated with managerial estimates of the improvements in quality ($r=0.749, p<.001$), productivity ($r=0.429, p=.046$) and delivery times ($r=0.577, p=.005$). The question of whether lean performance improvements are associated with stressful work practices was examined. Analysis of the correlations between performance improvements at the sites and mean stress levels show that none are significant: quality ($r=0.113, p=.625$), productivity ($r=0.143, p=.536$) and delivery ($r=0.022, p=.925$). Stressful practices do not appear to be necessary for gaining the performance benefits of a lean system. This was the experience at the Toyota plant built in Kyushu, Japan in 1993. The plant employed the newly formulated Toyota philosophy that “just-in-time (lean production) should not be applied to the people” (Shimuzu, 1995). The plant incorporated ‘humane’ practices, many of them similar to those recommended in this study. The 2001 JD Power Initial Quality Study rated Kyushu the best auto plant in the world. Kyushu is still much less worker-centred than Volvo’s innovative Uddevalla plant. However, comparing Uddevalla with lean production at Toyota’s NUMMI plant, Adler concludes that “.Uddevalla’s accomplishments are of great potential value; but…NUMMI’s “democratic Taylorist” model of work organisation is likely to provide a more
robust model for the foreseeable future of labour-intensive volume production”. (1994). This position is supported by the shut-down of Uddevalla; and the challenge appears to be the development of more worker-friendly versions of lean production.

Serious consideration of job stress implies a broad view of lean production. The narrow ‘less of everything’ definition is sub-optimal – especially if ‘less’ does not include worker job stress; a major form of ‘waste’. A more appropriate definition may be “the repetitive, small-lot production of high quality, cost effective products – using an optimum level of resources and reasonable health standards”; in short, enlightened lean production.

Limitations and future research

The study should be considered preliminary, since it is the first large scale, multi-industry attempt to assess the relationship between lean production and worker stress. The study examined a wide range of work practices. It was impractical to also pursue in-depth, detailed investigations of issues such as the details of continuous improvement programmes or the specifics of blame.

The sample of manufacturers is not random, and the sites are likely biased toward enlightened human resource practices and concern for their workers. No lean production ‘sweat shops’ are likely to agree to have their workers surveyed about stress – and none are included in the study. The ethnographic studies demonstrate the potential of lean production to create a hostile, high stress environment. In contrast, the stress-reduction practices identified in this study appear to have the potential for achieving effective lean performance at reasonable stress levels.

The 1,391 worker returns represent a very large sample. The sample size of 21 survey sites,
however, is moderate. This was partially addressed by the procedure for selecting sites, which generated a wide range of lean practices. The measurement of stress-related variables is almost always self-reported, especially in large-scale assessments like this study. The research design attempts to minimise the limitations of self-reporting by following the recommendations of Beehr in avoiding “the use of the word “stress” in questionnaire items, and the use of job dissatisfaction as a strain measure” (1995:131). The sample sites are all in the UK, providing control over cultural differences in stress responses. It may, however, limit the validity of applying the results to manufacturing sites in other countries. The relationship between stress and lean production implementation is based on a cross-sectional study with the degree of implementation as the independent variable. Longitudinal studies will be needed to employ elapsed time as the independent variable.

It would be valuable to follow-up this study with research to extend its results and address its shortcomings. The response of stress to JIT/LP implementation should be examined by longitudinal studies of a sample of firms embarking on JIT/LP, in a variety of industries. This would add to the understanding of the implementation cycle stress pattern and to the net change in stress over the complete cycle. Replicating the study in other countries would examine the effects of cultural differences on stress responses in a similar sample of lean production sites. This could help to identify work practices most susceptible to cultural influences. The stressful feeling of blame for defects is an important job stress issue that should be pursued further - to better understand the underlying causes and develop avoidance and coping practices for managers and workers.
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