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An Investigation of Production Workers' Performance Variations and the Potential Impact of Attitudes

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Abstract

In most manufacturing systems the contribution of human labour remains a vital element that affects overall performance and output. Workers' individual performance is known to be a product of personal attitudes to work. However, in current system design processes worker performance variability is assumed to be largely insignificant and the potential impact of their attitudes is ignored. This paper describes a field study that investigated the extent to which workers' production task cycle times vary and the degree to which such variations are associated with attitude differences. Results show that worker performance varies significantly, much more than is assumed by contemporary manufacturing systems designers and that this appears to be due to production task characteristics. The findings of this research and their implications are discussed.

1. Introduction

In the manufacturing industry, achieving organisational goals and competitive advantage is highly dependant on the efficiency of manufacturing systems. The design of these systems is therefore critical. However, because these systems consist of many human and technological elements it is difficult for designers to accurately predict how all of the elements will function when integrated together. In particular, there is a lack of appreciation during the manufacturing system design processes of how the workers within such systems behave.

Manufacturing systems designers are usually well trained technically but do not possess a comparable understanding of human issues. They tend to treat human performance in a similar way to machine functions by using 'standard time' parameters for evaluations and assume that any performance variations are accounted for by the time study techniques that are employed to derive these times. Human performance variation is not expected to exceed standard time parameters in normal conditions. This is especially the case where production tasks are simplified, short, repetitive, and in addition are constrained by automated processes. Although much research has studied relationships between behaviour and psychosocial variables, well-known effects of worker attitudes on performance are also neglected. Hence, a better understanding of such factors at the system design stage should help to deliver Manufacturing Systems which meet expectations.

This paper describes a study that investigated the extent of variation in workers' performance of production tasks and sought to establish how such variations may be associated with worker attitudes. The structure of this paper is as follows. Section 2 summarises the background to the research problem and explains in greater depth how manufacturing system design has come to consider workers; Section 3 describes the research method employed in this study; Section 4 presents the results gained from an extensive study of a large manufacturing system; Section 5 provides a discussion of the results, the implications for system design, and recommendations for further work in this area.

2. Background

Human work in many modern manufacturing systems has been progressively simplified and regulated, however worker variability and worker attitudes are still of significant impact to system performance. However, these are not sufficiently accounted for in the system design process. The problem is that there is a paucity of work that has thoroughly investigated the extent to which worker performance really does vary within modern manufacturing system designs. This section provides a background to these arguments.

2.1 The simplification and standardisation of human work in manufacturing systems

The development of mass production techniques and large factory systems after the industrial revolution (c.1770) converted manufacturing workers from craftsmen producing entire products to factory operators who only perform isolated production tasks in interactions with machines (Mortimer, 1985; Parker and Wall, 1996). In the early 20th century, the simplification and standardisation of production work was greatly accelerated by industrialists who applied division of labour theory to job design time study techniques (Gilbreth, 1909) and 'Scientific Management' principles (Taylor, 1911). Production tasks were made shorter and more repetitive so that they would require less skill, training and non-productive actions, thereby reducing labour costs and improving efficiency (Sorcher and Meyer, 1968, Kelly, 1982; Parker et al, 2001). The competitive benefits of job simplification, deskilling labour through standardisation of products, and regulation of worker discipline were ultimately demonstrated by the success of Henry Ford's assembly line factory system in 1913. Job simplification dominated the design of shop floor production tasks by the mid-20th century (Parker and Wall, 1996).

In parallel, technological developments and rising human labour costs generated a *"machine school"* of thought which sought to replace workers with more reliable and inexpensive machines wherever possible (Doyle, 2003). For example, mechanical industrial power in the USA rose from 14% to 80% between 1850 and 1950 (Argyle, 1992). It became imperative for organisations to standardise and predict human work performance within these increasingly technical production systems (Nemetz and Fry, 1998). Thus, the variability of human labour that could not be replaced by machinery needed to be minimised and regulated by job simplification and interactions with technology (Mortimer, 1985; McEwan & Sackett, 1998).

2.2 The impact of workers on manufacturing system performance

Manufacturing system designs often include production methods that combine both human labour and mechanistic processes (Buxey, 1982; Womack et al, 1990; Das, 1999; Mital et al., 1999). Most modern technical systems are still reliant on human skills and cognitions (Badham, 1991; McEwan & Sackett, 1998; MacCarthy et al, 2001; Kontogiannis and Kossiavelou, 1999). Productivity, efficiency and safety outcomes have been considered greatly influenced by human interaction (Tepas, 1994; Das, 2001) and even the successful implementation of advanced technology itself has been found to be reliant on the organisation and motivation of workers (Majchrzak, 1997).

Nevertheless, a general neglect of human issues has been cited as a key factor leading to the post-1965 decline in US manufacturing productivity and competitiveness (MIT Commission findings; cited in: Duguay et al, 1997). Consequently, organisations have increasingly adopted worker-centred practices to improve manufacturing strategy, quality, and inventory management (Dean and Snell, 1991) and these have been positively correlated with organisational effectiveness (Clegg et al, 2002). Consideration of worker issues is now seen as a key determinant of productivity and efficiency (Longenecker et al, 1998; MacCarthy et al, 2001; Das, 2001) and *"sustainable competitive advantage"* (Youndt, 1996).

2.3 The impact of worker attitudes on production task

Workers' individual differences have been consistently related to a range of work performance criteria (Furnham, 1992; Viswesvaren and Ones, 2000) including the performance of production tasks in manufacturing systems (Doerr et al, 2000; Doerr et al, 2002). Attitudes have particularly been linked to organisational performance and effectiveness by the 'human relations' approach to job design (Quinn and Rohrbaugh, 1983) and are central to both classic and modern job design models (e.g. Hackman and Oldham, 1976; Herzberg et al, 1959; Das, 1999; Parker et al, 2001). Furthermore, worker attitudes have been particularly related to a range of industrial issues, such as technology adoption (e.g. Zammuto & O'Connor, 1992; Slem et al, 1995); safety (e.g. Oliver et al, 2002); quality (e.g. Stone and Eddy, 1996); effects of shift/night work (e.g. Furnham and Hughes, 1999); work group effectiveness (e.g. Bailey, 2000) and to costs and productivity (Norsworthy and Zabala, 1985a, Norsworthy and Zabala, 1985b; Melin et al, 1999; Kleiner et al, 2002). Hence, work-related attitudes are clearly a key influence on performance outcomes and the efficiency of a manufacturing system. Worker attitudes may therefore be a useful indicator of workers' individual differences in respect of their organisational context/work environment (Dormann and Zapf, 2001).

2.4 The consideration of workers in manufacturing system design

Designers tend to consider workers similarly to machine functions, assuming little or no performance variation between or within individual workers (Baines and Kay, 2002; Buzacott, 2002). This simplistic approach is due to three main interrelated reasons. First, the historical 'machine school' focus on technology and the reallocation of human functions has led system designers' expertise in human-related issues to become out of step with their understanding of technical issues (Parasuraman, 1997; Longenecker et al, 1998; Badham and Ehn, 2000). Second, designers do not appreciate the stochastic nature of human/social dynamics within manufacturing systems and how this increases system complexity (Mollaghasemi et al, 1998; Azadeh, 2000; Baines and Ladbrook, 2002; Pacquet and Lin, 2003). Third, system designers assume that human variability in the performance of production is too constrained and regulated by automated/mechanical functions and job simplification to exceed the standardisations derived from time study techniques for line balancing (Carnahan et al, 2000).

The success of manufacturing operations often depends on the extent to which designers consider worker issues (Lehto et al, 1991). However, only basic 'human factors' (e.g. health and safety, ergonomics, line balancing) are typically regarded and even then at a late stage of the design process (Fadier and Ciccotelli, 1999; Stahl et al, 2000; Bonney et al, 2000 Pacquet and Lin, 2003). Therefore, in manufacturing system design inaccuracies may be attributable to the impact of worker variability and individual differences which are *"virtually ignored"* (Doerr et al, 2002). Design stage evaluations may, therefore, be improved by a better understanding of such issues.

3. Research Design

3.1 Aim and Methodology Overview

The aim of this research described here has been to investigate the extent to which workers' production task cycle times vary and the degree to which such variations may be associated with attitude differences. To address this aim our approach has been to first define a theoretical framework as a proposition of possible relationships between production task and attitude variables of the worker. This then provided the basis to design an empirical study and collect actual data to test and develop the relationships speculated in this framework. Here, it was decided to employ a *"hybrid strategy"* research design (Robson, 1993) that would involve a combination of quantitative and qualitative data collection techniques. Finally, to ensure ecological validity and population validity[1], an operational manufacturing system was utilised in a field study.

3.2 Formation of theoretical framework

Many conceptual frameworks linking worker attitudes to performance can be found within the literature, particularly within the field of 'job design'. However, existing models tend to comprise a *"universal list of variables"* that are *"unmanageable"* (Parker et al, 2001) and too *"vague"* (Doerr et al, 2002). It is therefore necessary to develop a theoretical framework specifically for this research which would only include the most relevant context-specific variables. This meant that it was necessary to identify variables to represent task performance and worker attitudes within a modern manufacturing system environment. Each of these are now considered in turn.

3.2.1 Task Performance Variable

To ascertain the degree to which workers' production task cycle times vary it was essential to identify the most suitable measure of that performance. Manufacturing systems design experts, from the host organisation, were consulted and they confirmed

[1] Ecological Validity and Population validity: refers to the extent to which findings can be generalised to the real world context in respect of the situation and group of people, respectively (Coolican, 1999).

that the most suitable indicator would be measurements of the human activity element of assembly line workstation cycle times.

3.2.2 Worker Attitudes Variables

To ascertain which attitudes would be of most likely influence to workers' performance variations the large corpus of literature concerning organisational behaviour and work psychology was reviewed. The literature offered a wide range of work-related attitude constructs but given the specific nature of this research context the set of attitude constructs concerning the quality of working life developed by Warr et al, (1979) and Cook and Wall, (1980) were found to be most relevant. This was because these measurement scales were specifically developed on and for manual workers in the manufacturing industry. They would, therefore, provide valid and reliable measures of attitude constructs relevant to the manufacturing worker population. From the number of attitude scales offered by Warr et al, (1979) and Cook and Wall, (1980) a set were selected for this research based on relevance to the given context; these were:

Work-involvement: a person's attitudes towards work in general.

Intrinsic Job Motivation: motivation to perform well in present job for personal task success rather than for extrinsic rewards such as pay and conditions.

Perceived Intrinsic Job Characteristics: the extent to which certain work motivation factors are perceived to be present in a job.

Job Satisfaction: satisfaction in relation to a range of work environment features from two dimensions of the job a) intrinsic factors and b) extrinsic factors.

Interpersonal Trust at Work: good intentions toward/confidence in other people at work within the sectors of a) work group peers and b) management.

Organisational Commitment: feelings of attachment to the organisation, its goals/values, and one's personal role in relation to this.

3.3 Design and execution of the empirical study

To measure both worker performance and attitudes variables, two parallel data collection studies were devised and conducted at a UK automotive component factory assembly line, separated for ethical and methodological reasons. First, to avoid making individual workers accountable for productivity levels it was necessary to circumvent any direct personal identification and association with performance data. Second, in order to avoid spurious data being produced by workers' behaving atypically by their awareness of the performance measurement it was necessary to record performance discreetly.

Ten workstations were selected from the assembly line as they were evaluated to demand the greatest levels of worker effort, as opposed to more machine-led work at other workstations. Each selected workstation was located within a separate section of the line that was operated by a different work team. As workers rotated through tasks within these sections systematically, upon the hour, the production task performance times of different individuals could be identified by the hour. Therefore, recording of human task completion times enabled statistical comparisons between different tasks/teams and individual workers.

Participants' knowledge of their involvement in a study can induce atypical behaviour or 'reactivity' (Bryman, 1988). It can also augment behaviour of the criterion measure as people tend to behave as they think they are supposed to in studies through 'demand characteristics' (Orne, 1969, Orne, 1971). It is, therefore, often more advantageous to employ objective measures in performance data collection studies (Brewerton and Millward, 2001). It was decided that objective quantitative data concerning workers' production task performance times should be derived to provide a 'true' measure of work rate variability that was not affected by direct observation or acquiescent participation. The most suitable measurement method was therefore to electronically record complete workstation cycle times on a real production line.

Production task performance times at each of the selected workstations were measured by electronic sensors which recorded the time each product arrived and left a workstation. This method provided accurate recording of the duration each product had spent at each of the workstations and, therefore, theoretically represented the time that workers had taken to perform their given tasks on the product. After installation, and a short pilot test study, the time data was recorded over a total period of 12 weeks. Care was taken not to alert workers to the recordings at all installation, testing and data collection stages and not to engage in any direct observations so as not to impose experimenter effects that might jeopardise the accuracy of the readings. The data was ultimately collated into an extensive database system for processing and analysis.

The participant sample consisted of volunteers from two shift crews from the assembly line workforce (n=139). The attitude survey was presented as an independent study to participants so that disclosure of the parallel work performance study did not affect responses.

In contrast to the remote data collection method designed for the measurement of worker performance, outlined above, it was inevitable that workers would need to be surveyed directly to measure the selected attitude constructs. However, rather than simply distribute a questionnaire the attitude scales were administered via interview as this would improve both the quantity and quality of responses. Additionally, by conducting one-to-one interviews it would be possible to record any extra qualitative information offered by participants. The interview questionnaire was therefore designed to not only include the items that would measure the selected attitude scales listed above but also include questions that would elicit basic demographic details and encourage dialogue to provide richer qualitative data to support/explain responses.

4. Results

4.1 Production Task Performance Study

The continuous 12 week recording of workstation activities produced large datasets of over 200,000 data points per workstation. The datasets comprised a large number of extreme data, outlying at minimum and maximum ends of the time spectrum, which clearly signified cycle times that could not be representative of 'normal' production task performance. The remote method of recording prevented discrimination of times that might have been affected by atypical system conditions and disturbances so it was necessary to remove as much spurious data as possible through a series of smoothing procedures.

Many affected data points could be removed immediately as major disturbances to productions and to the workforce constitution as these were identifiable through records provided by the host organisation. However, numerous extreme random data points still remained in the datasets that was clearly not representative of normal human work performance. Figure 1 shows data collected from a single workstation over one day, where each data point signifies a completed task cycle. The clustered data points reflect where task cycles has been completed in similar times and, conversely, the outlying data points reflect where the cycle has not been completed normally, perhaps due to system disturbances. Given that workers rotated on the hour, the different structure of data point clusters per hour in this graph clearly shows that people do have unique working patterns that are typical for them. The problem at this stage was to identify the data points that were not representative of their typical task performance.

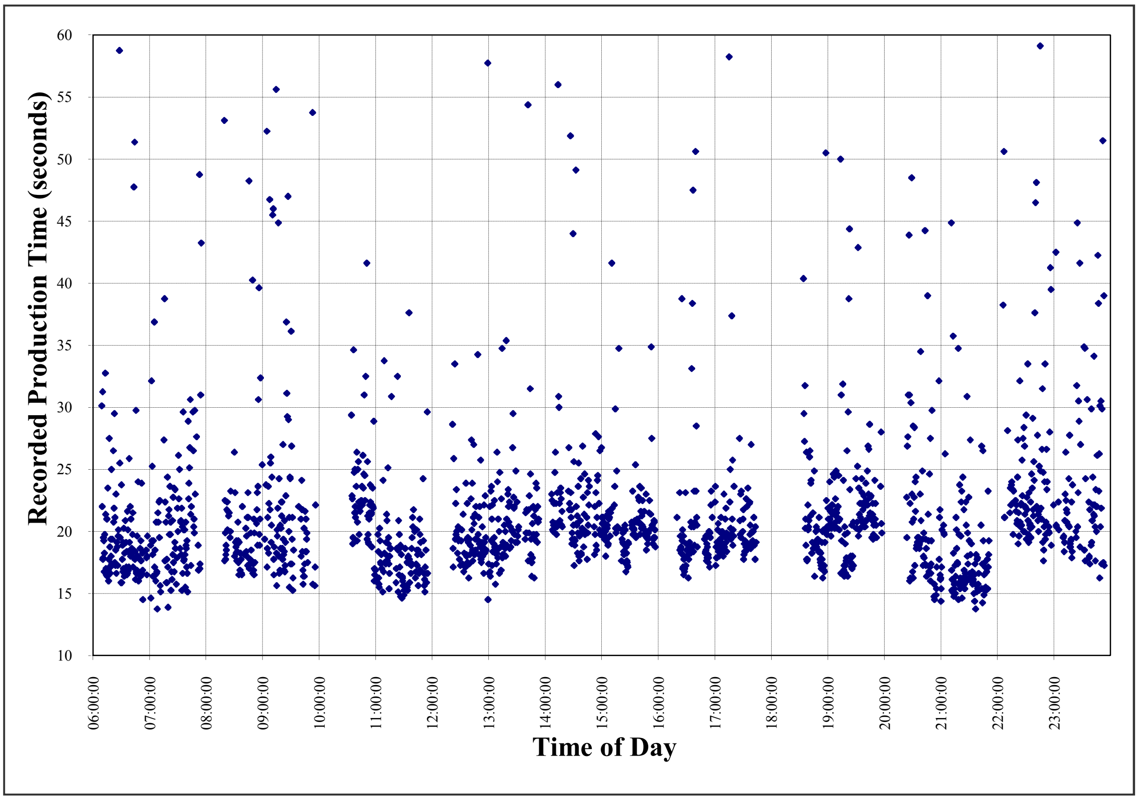

Figure 1. Production Task Performance Times Recorded Over One Day: Evidence of Normal Vs Non-normal Work Activity

With no method by which non-normal task performance data could be consummately identified and removed, the datasets were truncated to be more representative of human performance using the statistical box and whisker plot method of identifying extreme and outlier data points. Although this method still did not guarantee exact identification of normal human performance it was a pragmatic and objective method to use in the absence of exact identification.

The reduced smoothed workstations datasets together comprised a total number of 214,222 data points. These were analysed through a series of different procedures to investigate Temporal Factors Effects, Real Time Ranges, and Differences Between Crews, Teams, and Individuals

4.1.1 Temporal Factors Effects

To examine the potential effects of temporal factors the datasets were analysed using 'compare means' methods, i.e. Analysis of Variance (ANOVA) and t-test procedures. These techniques were used to test for any significant differences between time-related conditions, namely: shift, week, day of the week, hour of day, hour in shift. In this series of analyses, no significant results were found for any of the time-related conditions, signifying that temporal factors have little or no effect on workers' production task performance overall. The results are, therefore, not reported herein.

4.1.2 Real Time Ranges

The 'real' times recorded for each workstation were compared with the 'standard times' used in the design of this assembly line. Standard times are based on the principle that 100% represents normal (average) worker performance, and that normal worker performance variability ranges between 120% & 80% of this average time.

Figures 2 and 3 show the real times for the first and last workstations monitored (as these are proximally least likely to be subject to effects from the same system conditions); reference lines illustrate the standard times and ranges. It can be seen that the production tasks are generally being performed faster than the expected rate, a feature that was common across nine of the workstations. Moreover, in six out of the ten workstations monitored the work rate tendency is faster than the 120% level. This indicates that most of the monitored production tasks were performed faster than the minimum expected time by system designers using standardised times.

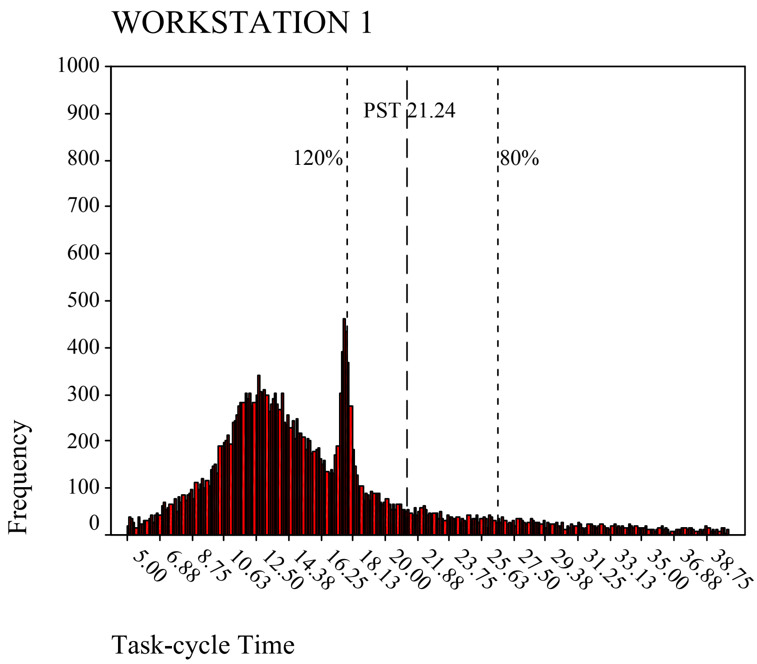

Figure 2. Real Production Task Performance Times in Relation to Production Standard Times (PST) Derived from Work Study; workstation 1

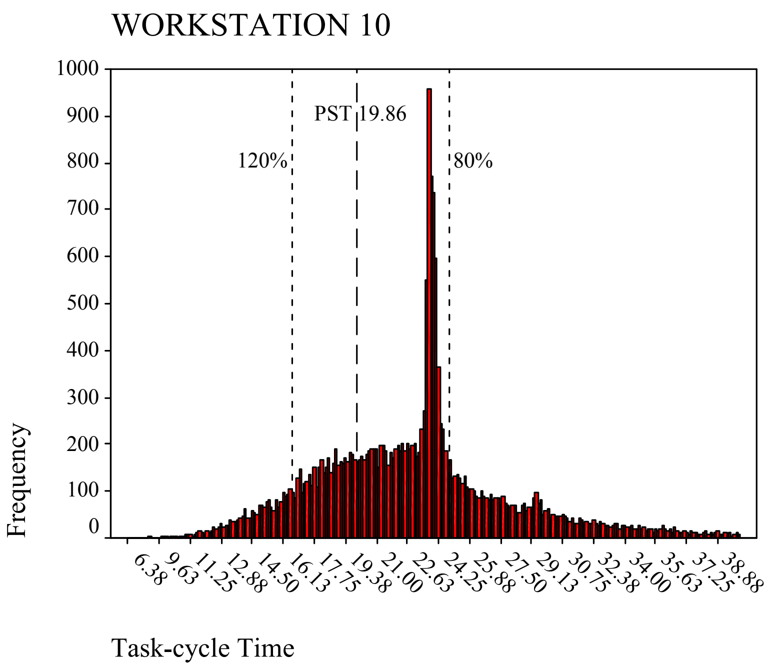

Figure 3. Real Production Task Performance Times in Relation to Production Standard Times (PST) Derived from Work Study; workstation 10

4.1.3 Differences Between Crews, Teams and Individuals

The individual production task completion times for each worker were grouped based on the rotation pattern. In order to allow for possible effects of different task demands/ characteristics the data was standardised. A one way between-groups ANOVA was then performed on the standardised dataset to assess the magnitude of differences between the means of the grouped scores which represented individual workers' performance times. The results showed a significant difference between scores [F(129,214062)=907.34, p<.0001] and this was supported by a 'large' calculated eta squared effect size (η=.35)^2.

The significant differences that were found were determined to be the result of task characteristics more than human differences. Figure 4 shows a histogram of the standardised grouped score means for each individual worker and according to divisions per workstation. Clearly, there is a convergence of similar performance times according to the workstation indicating that the significant disparities are attributable to the nature of the production task.

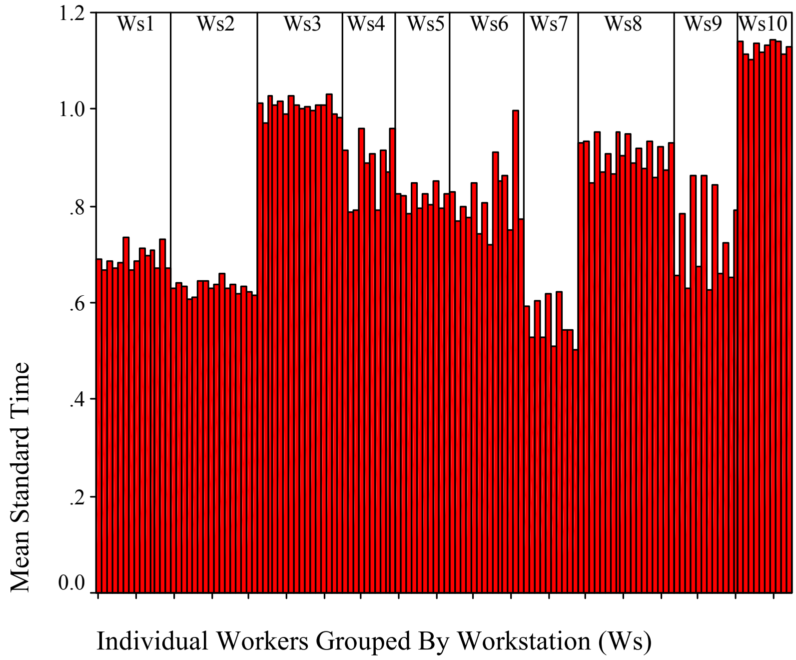

Figure 4. Individual Workers' Mean Standardised Production Task Performance Times: Evidence of Workstation / Task Characteristics Effects

4.2 Worker Attributes Study

Initial tests of the attitude scales' reliability found that all were satisfactory and higher than was expected, given the short number of items per scale (Cronbach $\alpha > .5$)[3] (Pallant, 2000). The implication of this reliability is not only that the scales were appropriate for this sample but also that this sample could be relied upon for providing sincere responses. The attitude survey responses were then analysed to investigate:

Comparison to Normative Data (how responses from this sample compare to the 'benchmark' data for this type of workforce supplied by the attitude scales' developers)

Intercorrelations (within-sample relationships between attitudes and demographics)

Qualitative Data (results of the additional questions asked during the interview surveys)

These different analyses are now described in turn.

4.2.1 Comparison to Normative Data

All sample scores show some variation from the UK norm and standard deviations (SD) data (Table 1). However, it is noteworthy that ALL of the sample SD data are smaller than normative SD, signifying a particularly homogeneous and cohesive workforce.

	UK norm	UK SD	Sample mean	Sample SD
Work Involvement (WI)	32.83	5.94	31.68	5.451
Organisational Commitment (OC)	45.37	9.56	47.98	8.027
Intrinsic Job Motivation (IJM)	36.25	5.51	35.46	4.959
Interpersonal Trust in Team Members (ITtm)	34.51	6.60	38.86	3.746
Interpersonal Trust in Management (ITm)	28.53	8.24	30.23	7.584
Interpersonal Trust at Work total (IT)	63.04	10.23	69.08	8.755
Perceived Intrinsic Job Characteristics (PIJC)	32.74	8.39	30.21	6.825
Extrinsic Job Satisfaction (JSe)	37.99	8.36	42.49	5.751
Intrinsic Job Satisfaction (JSi)	32.61	8.25	32.85	6.006
Job Satisfaction total (JS)	70.53	15.42	75.33	10.358

Table 1. Comparison of Sample and Normative Attitude Data: Evidence of a Cohesive and Homogeneous Workforce

4.2.2 Intercorrelations

A correlation matrix was generated to investigate the magnitude of differences in worker attitudes and biographic data; this presented various intercorrelations. These demonstrated that Age and Length of Employment (LE) showed similar associations: small positive relationships with Intrinsic Job Motivation (IJM) but moderate negative relationships with Interpersonal Trust in Management (ITm) / Interpersonal Trust at Work (IT) and Extrinsic Job Satisfaction (JSe). Small negative associations were also found between LE and Organisational Commitment (OC). LE results were mirrored by

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[2]A reliable scale should ideally achieve a Cronbach alpha coefficient of more than .7 but this is often much lower when scales consist of a small number of items (e.g. <10; Pallant, 2000).

those for Employment Status (ES) indicating an understandable link between the two biodata. Gender was found moderately related to OC with females reporting greater commitment levels, although due to a huge disparity between samples in these two groups this result is not robust.

The developers of these scales found intercorrelations between the attitude constructs and some relationships with age (Warr et al, 1979; Cook and Wall, 1980). To examine the possible relationship between age and attitudes scores for each worker were analysed using standard multiple regression. The results presented a poor fit of just 21% of the variance in age accounting for the measured attitudes (r^2_{adj}=.214). However, the overall relationship was significant [F(8,102)=4.74, p<001]. Only two attitudes were found to make a significant contribution to the regression equation: ITm (beta=.449, p<.001) and IJM (beta=-.235, p<.03).

Overall, worker attitudes were particularly homogeneous with higher scores of IJM, JSe and Interpersonal Trust in team members (ITtm) than would be expected based on the normative data. Significant differences between crews in OC, IJM, ITm, IT at Work, and Intrinsic Job Satisfaction (JSi) were judged to be related to age and length of service. Attitudes did not differ significantly between the teams and were not significantly different between individuals apart from in respect of ITm and IJM.

4.2.3 Qualitative Data

The questions added to the survey to elicit richer contextual information to explain *why* certain attitudes may be held involved asking respondents to state which work-related factors a) gave them the most *satisfaction*, b) gave them the most *dissatisfaction* and c) they would most like to change (given opportunity and resources). Using simple content analysis the issues cited in responses were grouped into broad themes. Responses (Figure 5) show worker satisfaction is reported to be related to two main factors, namely, pay (37.8%) and fellow workers/teams (21.6%), these are followed by the nature of the job itself (15.3%) and job security (11.7%).

Worker dissatisfaction (Figure 6) was mainly attributed to factors concerning the shift pattern and work hours at the plant (39.6%). Interestingly, the nature of the job itself was the second most frequently cited factor causing dissatisfaction as it was cited for satisfaction, and in a similar percentage of responses (16.2%).

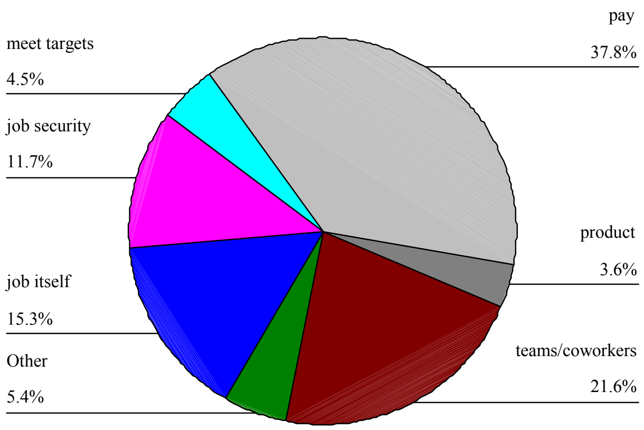

Figure 5. Factors Associated With Satisfaction at Work

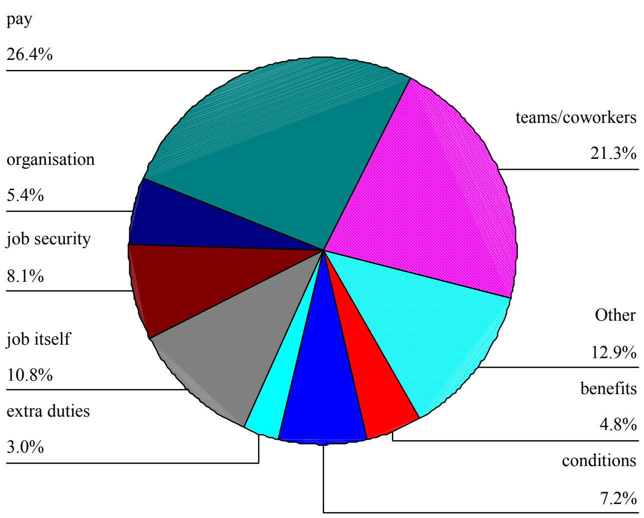

Figure 6. Factors Associated With Dissatisfaction at Work

The most common factor that workers cited they would change (Figure 7) concerned issues regarding their work conditions (27.9%), followed by 'downtime' issues (19.8%), which concerned keeping the line functioning and avoiding disturbances and breakdowns.

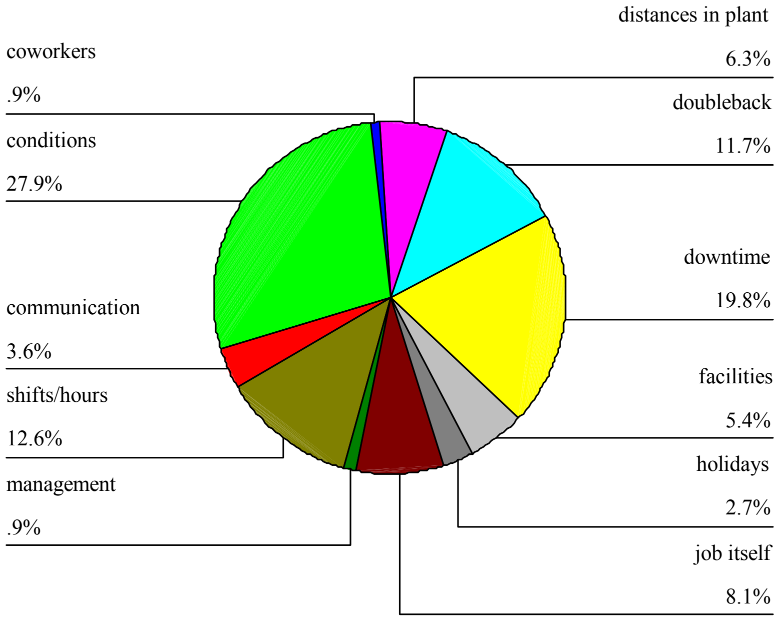

Figure 7. Factors Workers Would Change If They Could

The additional qualitative information gathered during the attitude survey was successful in providing a greater insight into contextual issues that may explain the production task performance cycle time variability results. Workers reported considerable interest in improving the smooth running of the assembly line and their production task cycles for two primary reasons. First, the monotony of the job was considered to be made easier by fast production task cycles; many workers stated that they exert autonomy by pacing faster and slower when the line was running consistently to relieve the repetitiveness of their work. Interruptions to the line meant the workers could only clean up their work area or spend time idle for which they would be "criticised" by foremen. The workers expressed annoyance about machine breakdowns and poor provision of maintenance, repairs, and parts and stated an interest in having greater control and particularly being more responsible for maintenance in their own area. Respondents reported that they were too often held accountable for productivity shortfalls for reasons which were beyond their control and which they felt were highly preventable. There were also many related comments complaining about a lack of control over the delivery of parts for which they would prefer to have better access to. Secondly, many workers expressed a desire to achieve production targets. Again, the reasons were twofold. Some workers stated a more personal interest in respect of their job security, i.e. that they were in competition with other plants within their organisation so their jobs were safer if their production levels were higher. Alternatively, other workers were more concerned about the extra pressures that they said were applied by foremen and line managers when production levels were low.

4.3 Overall Summary of Results

Table 2 illustrates the main results of the analyses concerning performance and attitudes. It shows that production task performance was found to differ significantly at all levels of analysis whereas differences in worker attitudes are only significant in certain cases (significant associations are represented by the ticked cells; brackets denote weak/unstable results).

VARIABLE	LEVEL OF ANALYSIS		
	Crew	Team	Individual
Production Task Performance	(✓)	✓	✓
Work Involvement			
Organisational commitment	✓		
Intrinsic Job Motivation: total	✓		✓
Interpersonal Trust: team members		(✓)	
Interpersonal trust: management	✓		✓
Interpersonal Trust at Work: total	✓		
Perceived Intrinsic Job Characteristics			
Extrinsic Job Satisfaction			
Intrinsic Job Satisfaction	✓		
Job Satisfaction: total			

Table 2 Summary of Statistically Significant Differences Results According to Crew, Team and Individual Levels of Analysis

The statistical significance of attitude differences is generally quite small over the entire series of analyses denoting that although some results could be used to support the existence of relationships between production task performance variations and attitudes, there is little evidence of such relationships *overall*. Additionally, the significant results of attitudinal differences found at the crew and individual level of analysis appeared to be related to biographic data whereas performance differences appeared to be more related to workstations.

5. Discussion and concluding remarks

This study set out to investigate the degree to which worker performance in modern manufacturing systems varies beyond what is currently accounted for by system designers, and how such variations may be related to attitudes. The study measured worker performance and worker attitudes in a real working production system. As this research generated two separate bodies of data, for attitudes and production task performance cycle times, the resulting datasets were not statistically relatable. Consequently, the findings of this study can only be logical interpretations of co-variations between worker performance and attributes. Nonetheless, as we have found worker attitudes to be quite homogeneous but performance times significantly different it is reasonable to assume that attitudes are not a major influence on production task performance variations.

Taking the evidence as a whole, it seems more likely that the significant differences found in workers' production task performance are attributable to task characteristics rather than worker attitudes. Firstly, although the pronounced bimodality in the histograms featured in Figures 1 and 2 cannot be consummately explained at this stage due to the remote data collection method, it is likely that the secondary modal peaks are due to the effects of task-related features that cause regular time delays or accelerations - such as stock handling or maintenance procedures. It is feasible that the subsidiary peaks represent a human characteristic such as two common work-pace patterns but this is unlikely given that Figure 3 shows how differences in worker performance are distinctly related to a particular workstation on the assembly line. Moreover, as between-task variation was to some extent already accounted for by the truncation of the datasets to isolate human performance, and by the use of standardised values in much of the analyses, this lends further support to evidence of task-related differences.

The qualitative information derived in this study indicates that the statistically significant performance variations found are likely to be a product of interrelationships *between* task and human characteristics. Workers reported being able to pace their own work, in normal conditions if they wished, regardless of the constraints of mechanical processes. However, engaging in this activity must also be dependent on the individual worker's personal inclinations to do so. Altogether this means there is evidence to suggest that performance variations are likely to be due to interactions between task characteristics and worker attributes rather than one or the other exclusively. Figure 8 shows how these interactions are likely to take effect, based on the evidence.

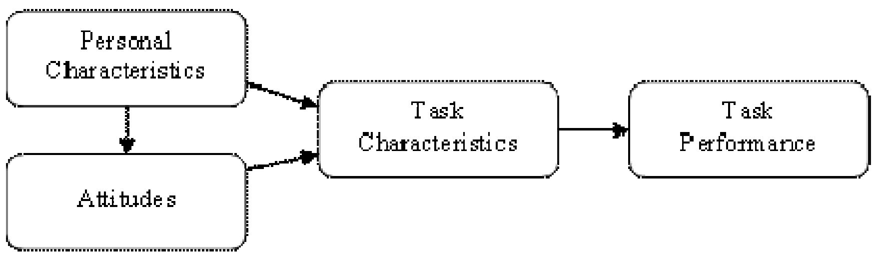

Figure 8. How Interactions Between Workers Personal Characteristics and Attitudes Are Likely to Affect Production Task Performance

The attitudes of this sample were distinctly harmonised. The attitude scales used in this study were developed on participants from different organisations but the sample in this survey, were all from the same organisation and workforce. Thus, these results indicate a homogeneity of worker attitudes that is likely to be attributable to the effects of enculturation within the manufacturing plant.

In order to more conclusively explain results it would be profitable if further study could a) directly relate workers' personal data to their performance; b) make direct observations which could provide more conclusive explanations for phenomena, such as the bimodality in task performance times; c) conduct studies across workforces and organisations and d) consider measuring additional/alternative attitudes and individual differences. In order to do this it may be necessary to compromise wholly objective measurement and make workers aware of the monitoring process. However, as accurate design evaluations are so important to system performance and organisational competitiveness, and evidence from this study shows that current evaluations seem to be inaccurately representing worker performance, further work in this area is warranted.

A major implication of this research is that it has provided evidence that human performance can be significantly variable - despite the constraints and regulations imposed by job simplification and mechanical functions in modern manufacturing systems. Related to this, the mode of production task cycle times greatly exceeds the standardised performance parameters that are customarily used by system designers for design evaluations and line balancing. Together, these findings support that the accuracy of design evaluations is indeed likely to be affected by a deficient representation of human variability. The evidence certainly raises questions about the efficacy of current time study techniques, line balancing, and assumptions of job simplification/regulation.

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