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Manufacturing Performance Reporting For Continuous Quality Improvement

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Keywords

management control systems, information control systems, continuous quality improvement, employee involvement

Disciplines

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Comments

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Introduction

Recently there has been a great deal of interest among both academic and industry circles in the new manufacturing strategy of continuous quality improvement (CQI). One of the principal aspects of continuous quality improvement is increased control of the production process by line workers. Shifting control to the workers on the shop floor is expected to result in the identification of areas for process and product improvement as workers learn by doing (Aoki 1986). At the Eaton Corporation, for instance, employees working in teams are encouraged to take many small steps to incrementally improve the products they make and the processes used to make them.¹ Because effective learning requires immediate feedback (Einhorn and Hogarth 1978), the central hypothesis in this paper is that the implementation of continuous quality improvement programs requires a shift in the management control system. We test this hypothesis by examining whether the extent of information concerning the current status of manufacturing, such as charts on defect rates or schedule compliance and productivity information, provided to workers on the shop floor is positively related to the implementation of continuous quality improvement programs.

The interrelationships between performance, organizational structure and control systems have been discussed in a number of contexts (Galbraith 1977, Ouchi 1979, Govindarajan and Gupta 1985). Birnberg and Snodgrass (1988) state that the purpose of a management control system is to increase the likelihood of the organization achieving its goals by controlling the flow of information, developing criteria for evaluation and designing appropriate rewards and punishments. Karmarkar, Lederer, and Zimmerman (1990), however, state that little is known about the factors that influence the choice of a manufacturing performance reporting system. The

research question we address is what factors tend to motivate the use of nonfinancial/operational information systems on the shop floor that report performance to workers. Strategies that promote continuous improvement include promoting multiple skills in workers, just-in-time production scheduling, incentives to workers and teamwork. Because these strategies put line personnel in charge of production, their performance will likely improve with the provision of shop floor information. Information provides workers with quick feedback, and encourages learning, which facilitates a quick identification of production problems and solutions by those who are most knowledgeable. Therefore, plants that have implemented these continuous quality improvement strategies will benefit from providing operating information on the shop floor.

Other factors may also influence the provision of information on the shop floor. For instance, implementation of a decentralized strategy may also require the provision of operating information to workers. Moreover, operating information may be of greater use when plants are undergoing product line alterations. We therefore include decentralization of authority and product line changes in our analysis. Using data collected from forty-two U.S. plants we document that the provision of shop floor operating information to workers and supervisors is strongly and positively related to the implementation of continuous quality improvement. To some extent these findings provide insight regarding concerns expressed by Kaplan (1983) and Howell and Soucy (1987) that most traditional U.S. accounting practices do not meet the needs of modern manufacturing.

The paper is organized as follows. In the next section, we describe the factors cited in the literature as influencing the reporting of operational information on the shop floor and relate them to control systems. After describing the sample of firms in the study, the following section

reports on the regression models relating shop floor information to recently adopted manufacturing approaches. The paper concludes with some suggestions for future research.

Factors Affecting the Use of Shop Floor Information

Manufacturing Practices for Continuous Quality Improvement

Major changes in manufacturing strategy are occurring as companies attempt to remain competitive in an increasingly global market. One strategy that manufacturers are implementing is the continuous quality improvement of the manufacturing process by involving the workers on the shop floor in process and product improvements. Widespread use of quality improvement practices is occurring in industry. These practices, sometimes referred to as total quality management (TQM), include top management leadership for quality, statistical process control, employee involvement in problem solving, training, and improved supplier relations (Juran, Gryna and Bingham 1988, Benson, Saraph, and Schroder 1991). Whatever specific practices are chosen, a quality approach requires continuous improvement of the work process by all employees (Deming 1986, Ebrahimpour and Lee 1988, and Garvin 1983, 1986). Four key elements of these quality programs are just-in-time production, the use of multi-skilled workers, quality incentives and teamwork.

A key element that promotes continuous improvement is the use of just-intime (JIT) production approaches. JIT strategies include the use of pull systems, Kanban, reduction of setup times, repetitive master schedules and shorter lead times (Schonberger 1986, Krajewski et al. 1987). In a JIT environment, workers are required to maintain a tight relation between current production and production goals. In addition, there are no longer inventory buffers between workstations. JIT also promotes the involvement of workers and supervisors in continuous

reductions in waste, by eliminating any activity which does not directly add value to the product (Hall 1987). By streamlining the process and producing on demand, workers are given more control over operations (Lee and Ebrahimpour 1984). On the shop floor quality is monitored by making each operator responsible for the detection of nonconforming items. Moreover, these personnel are given the authority to stop production when rework is required. This strategy results in quality being built into the product at all stages of production (Young, Shields, and Wolf 1988). One advantage of this approach is that, because defects are identified closer to the point of incurrence, there is greater likelihood that the cause of the problem will be identified.

Schonberger stresses this benefit of JIT production scheduling (1986, p. 137):

“Lowering quality costs does not deal with the cause of the quality problem, however. Isolating causes is where JIT really shines. In slashing lead times JIT creates a permanent early warning system. As the frontier tracker might say, the trail is still fresh; only a few process changes have occurred. Tracing the cause is not so difficult.”

Closely related to a shift to just-in-time production is the policy of training employees to complete various tasks. As inventory buffers decline with the implementation of JIT there is no room for labor specialization. Instead, an integrated manufacturing process requires workers to be provided with the skills to perform multiple tasks and coordinate activities. The key to continuous improvement is the process innovations created and implemented by employees. Continuous improvement requires continuous training (Schonberger 1986). Moreover, shifting to a tight current production schedule requires quick responses to changing conditions. In Bazeley and Baines’ (1987, p. 292) review of the implementation of JIT at Ingersoll Engineers the importance of a flexible well-trained workforce is underscored:

“People have to adapt from a highly structured, largely predictable environment to one in which aggressively rapid-response to orders and quick decisions are the norm. It is not easy to change to such a radically new method of working, and here education is the key.”

A third element in the strategy for continuous quality improvement is the provision of quality based incentives to employees. A number of studies have concluded that when an individual's rewards are tied to performance along certain criteria, behavior is guided by the desire to optimize performance with respect to those criteria (e.g. Govindarajan and Gupta 1985). With respect to quality Young et al. (1988) find that incentives have both significant independent effects on performance efficiency and interactive effects when combined with a quality program. The incentive plans help break down the traditional lines of authority and focus employees on improvement. O'Brien et al. (1987, p. 312) note in their review of the implementation of employee involvement at an automobile components company:

“It was not feasible to introduce groups of operators with a high degree of autonomy due to the traditional working practices that had been ingrained in the workforce over the years, and which were reinforced through the payment system ... A new system of shop-floor payment was devised, with an emphasis on high basic pay based on skills and knowledge acquired rather than work done, and with a group bonus for quality output.”

The last element in the strategy of continuous quality improvement is to increase employee interaction through the formation of teams for problem solving. Many U.S. plants now encourage workers to tackle problems in production as part of their job. Workers are encouraged to share the knowledge that they have and to participate in quality improvement and the reduction of lead times. Reports by Burghard (1990), Puckett and Pacheco (1990) Rhea (1987) and Rosen (1989) suggest that plants encouraging small group problem solving on the shop floor have substantially improved quality and productivity, and significantly reduced defect rates and cycle times. For instance, Puckett and Pacheco report that teamwork strategies at XEL Communications resulted in a 50% reduction in inventories and a 67% drop in defects. One of the principal benefits from teamwork comes from the interaction among departments. A team

approach helps departments and personnel understand each other's working methods which can result in improvements benefiting all (Sepehri and Walleigh 1987).

Teamwork is also essential to the implementation of the just-in-time and quality improvement policies (Im and Lee 1989). Because just-in-time production requires more interaction among floor personnel as there are no inventory buffers, teamwork is helpful in promoting communication and coordination. Moreover, it promotes cross training which results in an increase in worker skills (Puckett and Pacheco 1990). Quality improvements also accelerate ideas and information exchange between employees. Imai (1986) provides example of how teams of employees interact to solve problems.

The benefits from these workforce policies for continuous quality improvement are fully realized only when they are jointly implemented. It is well-known that quality practices must be well in place before JIT can be effective (Crawford, Blackstone, and Cox 1988). Otherwise, production will not be completed in the allotted time. While many perceive the primary benefit of just-in-time production to be the reduction of inventory carrying costs, more pronounced benefits can result from the product and process improvements that result from streamlined production. By reducing inventories, JIT exposes the entire manufacturing process to the workers. In this environment, workers are able to identify non-value adding activities, as well as the critical links in the production process. Because quality programs call for the building in of quality at every step of the process, workers are given the authority to halt production and implement solutions. Taken together, the increased authority over quality and the more conducive environment for learning, enhances continuous quality improvement. In fact, Young et al. (1988) provide empirical results which indicate that the benefits of just-in-time production are realized only when a quality program has been implemented. In summary, it is the interaction

of these approaches that promote and facilitate continuous quality improvement by providing shop floor workers with the incentives, authority and ability to control production.

Information for Continuous Quality Improvement

Because control systems are mechanisms that organizations utilize to insure that an entity moves towards its objectives, a switch in operating strategy may necessitate a revision in control systems. Ouchi (1979) provides a framework for examining control systems given different operating environments. In his analysis an organizational control system depends on the programmability of the task and the availability of outcome-based measures of performance. Task programmability is the degree to which the rules of behavior can be prespecified by management. Tasks that can be easily programmed can be effectively controlled by providing instructions on desired processing behavior to line personnel. Therefore, effective control mechanisms need only monitor behavior. If task programmability is low, however, control is best exercised by monitoring outcomes or through social control.

Traditional mass production manufacturing represents tasks that are highly programmable. As in Ouchi's tin-can plant example, effective behavior in this environment is obtained by providing process controls which dictate and monitor employee behavior, an approach consistent with a top down or hierarchical approach to management and control. The strategy of continuous quality improvement, on the other hand, relies on line personnel working together to identify problems and implement solutions. Hutchins describes (1988, p. 149) the new strategy for employee involvement as follows:

“The idea was that teams of workers from the same department, sharing common work interests and with common work experience, could, if they so desired, be trained in problem-solving, and should be given time on a regular basis to identify opportunities for

improvement, make recommendations and, where possible, themselves implement the improvements.”

Eisenhardt (1985) finds that selection of employees, training and cooperation are policies indicative of social controls. To some extent these policies are consistent with the CQI approaches to teamwork and emphasis on employee training. For instance, Puckett and Pacheco state that XEL’s teamwork include an organizational adherence to a value system built on trust, respect, dignity, honesty and caring.

CQI will also benefit from the coordination, goal setting and learning that information systems facilitate. The reduction in inventory buffers requires more coordination among activities (March and Simon 1958). Providing information to employees alleviates the coordination problems that occur when slack is not built into the process (Galbraith 1977). Therefore, information becomes necessary for coordinating activities in a continuous improvement environment that maintains a tight relation between production goals and current production (Daniel and Reitsperger 1991a). Plants may also benefit from information systems that promote organizational objectives. Prior research has shown that performance can be enhanced by providing concrete goals and feedback information to individuals (Locke et al. 1981). Providing information to employees makes goals explicit and helps directs worker behavior as the decision maker is more informed about the structure of the task. Therefore, providing information on the shop floor is useful in directing employee behavior (Daniel and Reitsperger 1991b).

In addition to helping in coordination and goal congruence, information on the shop floor facilitates learning (Banker, Potter, and Schroeder 1991). Much psychological research has documented that immediate feedback is essential for learning to take place (Einhorn and Hogarth

1978). Because continuous quality improvement shifts the decision making to line personnel who are encouraged to learn by doing, information is useful in detecting areas for process improvement. The information helps identify and solve problems which interfere with providing quality (meeting the customer's requirements at the next process step). The rapid feedback to employees of such information as defect rates, schedule compliance, and quality is critical to improving quality at the source. The value of such timely feedback information is also consistent with organizational behavior and psychology research that has shown that it is essential for learning and promotes task oriented behavior (Ashford and Cummings 1984, Ilgen, Fischer, and Taylor 1979). Foster and Homgren (1987, p. 25) sum up many of the views expressed above in their review of JIT plants:

“The general trend in cost control activities at both the shop level and the plant level that we have observed in JIT plants is: a declining role for financial measures, and an increasing role for personal observation and nonfinancial measures. One reason for this trend is that production workers play a pivotal role in cost control activities. Workers directly observe nonfinancial variables on the shop floor, where they are intuitive and easy to comprehend.”

The above discussion suggests that the extent of benefits derived from continuous quality improvement is dependent on the provision of shop floor information to workers and supervisors for coordinating and improving the production process. Consequently, it is hypothesized that plants that have instituted this approach are more likely to collect and report certain types of operational information on the shop floor than plants that have not implemented this policy.

Information for Decentralization and Innovation

Other factors may also promote the use of shop floor information. The plant's extent of hierarchial authority may impact the need for control and hence the demand for shop floor

information. Plants with strong hierarchial control are likely to require information for managers for purposes of monitoring and control. Flatter organizations, on the other hand, where workers have more authority over production line decisions require more coordination (Galbraith 1977). Therefore we expect that operating information may be more available in decentralized plants than in highly centralized plants.

In addition, many plants are undergoing considerable changes in their products due to competition and rapid innovation in their product markets. Because many of their products are in the early stages of their life cycle, the gains to learning may be greater for these plants than plants that have been producing the same products for a number of years. Therefore, it is expected that plants with high product turnover will be providing more operating information on the shop floor than stable plants with low product turnover.

Continuous improvement practices may also be related to decentralization and new innovation. Continuous improvement also entails greater employee authority over production. Therefore, we expect plants implementing CQI to have a labor force that is more decentralized. Moreover, because more improvement is likely to be possible in the early stages of the product's life cycle, we expect product line turnover to be positively related to a strategy of continuous quality improvement.

Sample Construction and Empirical Estimation

We build on the study of manufacturing performance reporting conducted at the worker level by Banker, Potter, and Schroeder (1991). The data for the study were obtained by randomly selecting sixty plants from three industries: electronics, machinery and auto component

suppliers. Each plant manager received a letter and phone call requesting his or her participation. From these sixty plants, 42 agreed to participate in the study. This high rate of response was probably due to the personal nature of the contact and that the plant would receive feedback from the study. The mean number of plant employees was 638 and the average plant area was 316 thousand square feet.

We personally visited twelve of these plants and interviewed managers involved in accounting, production, inventory management and engineering. A questionnaire was also pilot-tested during the plant visits. The plant visits allowed us to observe the use of information on the shop floor. In many of the plants, there were charts and graphs showing the latest results in areas such a schedule compliance, quality control, productivity, and maintenance. These charts were posted near the work places and included graphs and tables which were updated regularly.

Answers to the following five questions were solicited to determine the extent of usage of information on the shop floor. Each of these questions used a Likert scale ranging from “5 = strongly agree” to “1 = strongly disagree”.

- 1) Quality = Information on quality performance is readily to employees.
- 2) Productivity = Information on productivity is readily available to employees.
- 3) Defects = Charts showing defects are posted on the shop floor.
- 4) Schedule Compliance = Charts showing schedule compliance are posted on the shop floor.
- 5) Machine Breakdown = Charts plotting the frequency of machine breakdowns are posted on the shop floor.

Information concerning quality and productivity were solicited in the surveys based on the arguments in Kaplan (1983) and the related literature on manufacturing reviewed above. Questions concerning charts were asked to investigate specific operating data used for feedback purposes. For each of the five measures the responses of three supervisors and ten workers at each plant were averaged to obtain an overall plant response.

Insert Table 1

Summary data on the information variables are presented in Table 1. The mean plant responses for the availability of quality and productivity information are 3.63. The mean response for machine breakdown information is 2.37, more than a full point lower. The differences in the means suggest that plants are likely providing access to more information on quality and productivity than just charts on the shop floor involving defects, schedule compliance, and especially machine breakdowns. One reason why information on machine breakdowns may be less prevalent is that plants may keep their maintenance information in the maintenance department and not on the shop floor. Also, maintenance information may not be as essential to workers and supervisors in problem solving as the other four types. The correlations among these five variables range from 0.437 to 0.784. This suggests that many of the information variables may be driven by the same economic circumstances.

Independent variables in our model include two scales designed to measure the continuous quality improvement (CQI) and decentralization (DECENT) strategies. Similar to the dependent variables, the measurement of the questions comprising these scales were answered on the range from “5 = strongly agree” to “1 = strongly disagree.” The questions were asked in a random order. The specific questions used to construct the scales are provided in Table 2. The CQI scale is comprised of questions related to the four elements discussed above: just-in-time production, multi-skilled laborers, quality incentives and teamwork. Implementation of CQI requires workers with multiple skills. Questions one and two are designed to provide information on this element. Just-in-time implementation involves a shift toward greater production control by workers with compliance to a daily production schedule and authority over the production

line. Questions three and four are intended to capture the link between current production and production goals. Questions five and six address the authority of labor to stop production. Young et al. (1988) state that a key aspect of a quality program is that production stops when a problem is discovered.

Insert Table 2

Responses to these first six questions were provided by process engineers, supervisors, workers and production and inventory managers. Questions seven and eight are included to capture the role of incentives in driving continuous quality improvement. These questions were answered by workers and their supervisors. The teamwork questions, numbers nine through eleven, measure the extent to which workers organize into small teams to solve problems encountered on the shop floor. These questions were answered by workers, supervisors, and support staff. We identify a single factor, which we name CQI, from a principal component analysis of the 11 questions. CQI explains over fifty percent of the variation in the eleven questions. The factor loadings indicate that each question loads on the factor.²

The decentralization scale, DECENT, measures the extent to which workers and supervisors can make decisions without consulting their supervisors. This scale was developed and validated by Aiken and Hage (1966) to measure decentralization of authority. Internal consistency for this scale was adequate with Cronbach's alpha of over 80%. Principal component analysis verified that the scale loaded on a single factor.

As mentioned above, the demand for performance reporting systems may also be driven by the rate of innovation or change occurring at the plant. Specifically, plants with new products may derive more benefits from information as their rate of learning is likely to be greater. We

construct a variable that represents the percentage of production that comes from products that have been introduced in the last five years, NEWPROD.

An age variable, LOGAGE, is also constructed for the analysis. This variable was constructed as the logarithm of one plus the length of time in years that the plant had been engaged in a just-in-time program for quality improvement. This metric is introduced to control for the time lag in the implementation of an information systems. The length of time since implementation is potentially important because information system changes often lag behind production system changes (Karmarkar, Lederer and Zimmerman 1990).

Descriptive information on the predictors is provided in Table 3, Panel A provides some summary statistics. The CQI scale has a mean of zero by design. It is interesting to note that the percent of new products ranges from zero to 100%, suggesting product line turnover varies considerably by plant. Also of interest is that 50% of the plants indicate they have had a just-in-time program for three years or less and that at least 25% have no program in place. The pairwise correlations in Panel B indicate that many of the variables are related, as expected. Both NEWPROD and DECENT are strongly associated with CQI. This suggests that plants implementing CQI are more decentralized and are undergoing more changes in their product lines than plants that have not implemented CQI. Interestingly, DECENT is not related to NEWPROD. LOGAGE is also related to all of the other predictors.

Insert Table 3

The following system of regression equations is specified to model the relation of shop floor information in plants to the independent variables of interest:

$$Y_{jp} = \alpha_j + \sum_{i=1}^6 \beta_{ij} X_{ip} + e_{jp}$$

where:

- Y = shop floor information variable j; j = 1 . . . 5
 X = CQI, DECENT, NEWPROD, LOGAGE and industry variables,
 p = plant p; p = 1 . . . 42.

Regression errors across the five dependent variables for any plant are likely to be correlated. In general, estimation using seemingly-unrelated-regression (SUR) techniques is necessary to provide efficient parameter estimates. In our model, however, the independent variables are the same for each dependent variable. Therefore, ordinary least squares (OLS) estimates are identical to those estimated using SUR (Theil 1971, page 310).

Insert Table 4

The results of the five regression relating shop floor information to manufacturing strategies are presented in Table 4. All of the variables were standardized with a mean of zero and a variance of one before the parameters were estimated. Electronic and machinery dummy variables, ELECIND and MACHIND, are included as explanatory variables to control for potential industry effects. Overall the regressions are significant. At least 50% of the variation in the provision of quality and productivity information can be explained by the predictors. Moreover, at least 40% of the variation in chart information is also explained by these variables. The most striking result across the five regressions is that the CQI variable consistently seems to provide the explanatory power. It is always significant at the 1% level or better. With the exception of the LOGAGE variable, the other variables add little to the regression. However,

industry representation is related to information on productivity ($p = 0.0608$) and DECENT is negatively related to information on quality.

Overall, the results indicate that plants which have jointly instituted the continuous improvement strategies of just-in-time production, employee training, incentives for quality and teamwork are more likely to be providing information to workers and supervisors on the shop floor. In fact, the strategy of continuous quality improvement seems to be the only predictor that can consistently explain variation in shop floor information systems. We found that decentralization is not positively related to the presence of shop floor information. This may in part be due to the fact that decentralization is highly related to CQI. We also found that after controlling for the workforce strategies, shop floor information is not generally related to the turnover of the plant's product lines. Again, this may be due to the fact that plants with higher product line turnover tend to have implemented the strategies for continuous quality improvement.⁴

Conclusion

Many plants have recently incorporated strategies that promote continuous quality improvement for manufacturing excellence. The common objective of these strategies is in promoting manufacturing innovations and improvements by the workers on the shop floor. Because this strategy relies on worker involvement to implement product and process improvements, we hypothesized that to maximize the benefits from these strategies plants are likely to provide operating measures of manufacturing performance to workers on the shop floor. Using a sample of 42 plants, we document that the existence of the continuous quality

improvement strategy is positively related to the provision of nonfinancial information to line personnel.

We also found that decentralization did not help to predict the likelihood of information on the shop floor. Nor did industry representation or the rate of product line turnover generally make a difference in these predictions. The findings suggest that the way the plant is managed, by use of progressive practices such as just-in-time production, training, incentives and teamwork, is more important than these other factors in explaining use of operating information by workers and supervisors. This finding raises a number of questions. One important question is whether the provision of information to workers on the shop floor results in productivity gains over and above those attributable to continuous improvement. If so, what type of information is most useful in explaining these gains? Also of interest are worker perceptions of the value of shop floor information. Of course, more work can be done on how the use of new production strategies affects the information system in use. We have found strong empirical support for some of the effects that have been previously suggested in the literature by Kaplan and others. Continued research is needed to more fully address the link between corporate practices and information systems.

Notes

- ¹ Wall Street Journal 6/5/92, “A Manufacturer Grows Efficient by Soliciting Ideas From Employees.”
- ² There was only one other factor with an eigenvalue of at least one. All of the analysis presented in this paper was also conducted including this additional factor. No substantive differences are noted.
- ³ Variables standardized with zero mean and unit variance.
- ⁴ An examination of Belsley et al.’s multicollinearity diagnostics suggested no multicollinearity problems.

Table 1. Descriptive Information for the Nonfinancial Information Variables ($n = 42$)

Variable	mean	st.dv.	Min	Quartiles			Max
				25%	50%	75%	
				<i>Information availability</i>			
Quality	3.63	0.572	2.16	3.30	3.70	4.02	4.60
Productivity	3.63	0.527	2.50	3.29	3.65	4.07	4.75
				<i>Charts on shop floor</i>			
Defects	3.30	0.763	1.75	2.61	3.50	3.84	4.46
Schedule compliance	3.36	0.552	2.00	3.00	3.39	3.76	4.46
Machine breakdowns	2.37	0.543	1.72	2.00	2.21	2.61	3.86

Table 2. Scale Measures * for Manufacturing Strategies

-
- I. *COI Scale Questions (loading coefficients in parentheses)*
- 1) Direct labor undergoes training to perform multiple tasks in the production process. (0.321)
 - 2) Plant employees are rewarded for learning new skills. (0.340)
 - 3) Our schedule is designed to allow time for catching up, due to production stoppages for quality problems. (0.240)
 - 4) We usually meet the production schedule each day. (0.240)
 - 5) Production is stopped immediately for quality problems. (0.245)
 - 6) Direct labor is authorized to stop production for quality problems. (0.238)
 - 7) Workers are rewarded for quality improvement. (0.364)
 - 8) If I improve quality, management will reward me. (0.359)
 - 9) During problem solving sessions, we make an effort to get all team members' opinions and ideas before making a decision. (0.321)
 - 10) Our plant forms teams to solve problems. (0.307)
 - 11) In the past three years, many problems have been solved through small group sessions. (0.297)
- Eigenvalue = 5.75. Explains 52.27% of variation.
-

II. *DECENT Scale Questions*

- 1) I can do almost anything I want without consulting my boss.
 - 2) Even small matters have to be referred to someone higher up for a final answer (Reverse scale).
 - 3) This plant is a good place for a person who likes to make his own decisions.
 - 4) Any decision I make has to have my boss's approval (Reverse scale).
 - 5) There can be little action taken here until a supervisor approves a decision (Reverse scale).
-

* Each response is measured on a scale from "strongly agree = 5" to "strongly disagree = 1."

Table 3. Descriptive Information on Predictor Variables ($n = 42$)*Panel A. Summary statistics*

Variables	mean	st.dv.	Min	Quartiles			Max
				25%	50%	75%	
CQI	0.00	2.398	-4.03	-1.85	-0.34	1.63	5.41
DECENT	3.17	0.387	2.43	2.94	3.13	3.36	4.11
NEWPROD	0.58	0.409	0.00	0.05	0.70	1.00	1.00
AGE	2.83	2.713	0	0	3	5	9

Panel B. Pearson correlation matrix

	CQI	DECENT	NEWPROD	LOGAGE
CQI	1.000			
DECENT	0.464*	1.000		
NEWPROD	0.333*	-0.041	1.000	
LOGAGE	0.266*	0.452*	0.290*	1.000

* Significant at 5 percent level for one-tailed test.

Table 4. Regression Estimates Relating Standardized Nonfinancial Information to Standardized Predictor Variables³ ($n = 42$)

$$Y_{jp} = \alpha_j + \beta_{1j} \text{CQI}_p + \beta_{2j} \text{DECENT}_p + \beta_{3j} \text{NEWPROD}_p + \beta_{4j} \text{LOGAGE}_p + \beta_{5j} \text{ELECIND}_p + \beta_{6j} \text{MACHIND}_p + \varepsilon_{jp}$$

	Information availability		Charts on shop floor		
	Quality	Productivity	Defects	Schedule compliance	Machine breakdown
Intercept	NA	NA	NA	NA	NA
CQI	0.808** (5.70)	0.838** (6.03)	0.522** (3.43)	0.746** (4.46)	0.516** (3.10)
DECENT	-0.257* (1.77)	-0.161 (1.12)	-0.213 (1.36)	-0.208 (1.21)	-0.140 (0.82)
NEWPROD	-0.019 (0.14)	-0.017 (0.13)	0.067 (0.64)	-0.055 (0.35)	0.136 (0.87)
LOGAGE	0.232* (1.76)	0.120 (0.92)	0.442** (3.11)	0.119 (0.76)	0.269* (1.74)
ELECIND	-0.149 (1.08)	-0.333* (2.43)	-0.260* (1.95)	-0.188 (1.15)	-0.016 (0.10)
MACHIND	-0.117 (0.84)	-0.126 (0.91)	-0.242* (1.62)	-0.098 (0.60)	-0.046 (0.28)
R ²	0.5582	0.5951	0.5246	0.4271	0.4329
p (model)	0.0001	0.0001	0.0001	0.0022	0.0019
p (industry)	0.5316	0.0608	0.1645	0.1585	0.9598

[Absolute t-value in parentheses].

* Significant at 5 percent level for one-tailed test.

** Significant at 1 percent level for one-tailed test.

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