3C. Human Resource Policies in an Environment of High Labor Turnover and Rapid Technological Change

Vincent M. Valvano

3C.1 Introduction

Two of the semiconductor wafer fabs in our sample are located in the same local technology district in a country outside of the U.S. This district is characterized by rapid growth of new and existing technology firms and a local unemployment rate that hovers near 2%. Both of these fabs are also closely matched in terms of their process technologies, product mix, and business strategy. Where they differ significantly is in their manufacturing performance, as measured by a number of yield and productivity measures calculated by the Competitive Semiconductor Manufacturing Program.[1] Accordingly, it's possible to inquire about the sources of performance variation between these two fabs, while being relatively confident that most of this variation will not arise from different external influences or technology. In effect, our comparison of the two fabs can control for the influence of labor market and product market conditions, which are difficult for fabs to change and yet greatly influence fab performance. This case study suggests that the two fabs have implemented human resource policies which are quite similar and are designed in response to the constraints imposed by the labor and product markets these fabs operate in. Where the fabs differed (at least at the time of our visits) was in their ability to use automation and information technology inside the wafer fab to mitigate workforce-related problems that their HR policies were relatively ineffective in confronting.

We proceed by first summarizing each fab's technology and the product and labor markets within which they operate. Then we compare the core human resource policies in place at each fab. We conclude by examining whether there are significant differences in HR policies that might account for the variation in performance or if other factors might explain the variation.

3C.2 Overview of Fab Technologies, Markets and Performance

The two fabs opened within one year of each other and have been developing and introducing new process technologies more or less continuously since then. (Note that the two companies that own these fabs have been in existence for a longer period of time and each operates several wafer fabs.) The rapid introduction of new technology is in part a function of the large amount of contract business both fabs do with other semiconductor companies—manufacturing chips using the designs supplied by their customers. They have a similar strategic focus on strong manufacturing technology and efficiency in lieu of being at the leading edge of new product and process innovation (but they are not far behind). The process and product mix of each fab is relatively complex. At the time of our visits, both had six major process flows running which allowed for a wide range of product lines based on both memory and logic chips.

Both fabs operate in the same local labor market, which is characterized by full employment and strong demand for labor by a rapidly growing technology sector. Consequently, the fabs have experienced high labor turnover, primarily of their operator workforce. Turnover rates of 40% for operators were the norm at these fabs, but turnover among engineers was only 5-10%. Because operators at both fabs are almost entirely female, some of the operator turnover was attributable to women leaving the workforce upon getting married or starting a family. But a survey of former employees by one of the fabs indicated that much of the turnover was also driven by the ease of getting a job elsewhere, often outside the industry. If new employees didn't like working the night shift, which most new hires are initially assigned to, or working in a clean room environment, they had no compelling economic reason to try to adapt to those conditions. The level of engineer turnover is unremarkable by technology company standards and may reflect the positive reputations of both fabs with respect to their technology and management. Of course, the fabs' stated policy of positioning their pay levels at or near the top of the range of pay levels offered by their competitors may have also contributed to the loyalty of the engineering workforce.

Because their product and process mixes are similar, comparisons of the technical performance of these two fabs is insightful. (Henceforth, we will identify them as Fab A and Fab B.) The direct labor productivity of both fabs was closely matched and ranked above average in the overall sample of 29 wafer fabs for which performance data has been collected by the CSM study. Both fabs also ranked highly overall on stepper throughput, although Fab A had better scores than Fab B. The defect density scores of each fab were only average, and again Fab A ranked higher than Fab B. Major performance differences existed for line yield and cycle time. Fab A ranked very high with regard to both metrics whereas Fab B ranked in the bottom third on both metrics. In sum, it seems fair to conclude that Fab A's manufacturing performance was significantly better than that of Fab B.

3C.3 Comparison of Human Resource Policies

We can compare the human resource policies of Fab A and Fab B along the following dimensions: pay policy, performance evaluation, career paths and training. In addition we assess the overall skill levels of the two workforces.

Pay Policy and Performance Evaluation

A direct comparison of pay levels and earnings profiles is not possible because of lack of data from Fab B. Fab B claimed to set its pay levels so that they would be 5% above its nearest well-paying competitor, although it was not clear if this policy applied to all occupations. Base pay levels are only part of the compensation policy at each fab. They both make extensive use of performance-based bonuses. Fab B distributes a fixed percentage of its net profits to employees by way of a profit-sharing plan. In the year the fab was surveyed, this amounted to 4 months of salary. Fab B also distributes a quarterly bonus, equivalent to two months of salary if department goals are met. Similarly, Fab A has a profit sharing plan and a quarterly incentive plan, which can be as high as one month's base salary. When surveyed, Fab A had just completed a "good" year, in which total pay with bonuses had amounted to 19.5 months of base salary. Both fabs also had employee stock ownership plans and suggestion pay. These policies applied to all employees at each fab.

Both fabs have in place fairly elaborate systems of performance evaluation which have a small impact on pay. At Fab A, all employees receive an annual performance evaluation in which performance is rated along 9 different dimensions, including motivation, development of subordinates, teamwork, communication, judgement and decision making, planning and organization, improvement and innovation, and overall performance. These appraisals are shared with the employee and include setting goals for the coming year. A maximum bonus of 10% of base salary is awarded to the highest performers (usually the top 10% of employees), while the bottom 5% of employees receive no bonus and the rest receive something in between. Fab B also conducts annual performance evaluations of its employees, although the appraisals are not shared with technicians or engineers. The evaluations include performance relative to specific departmental targets or time-based goals for completion of specific projects. Bonuses vary depending on the level of success in meeting these targets.

Both fabs intensively monitor the performance of their operators. At Fab B, operators receive a monthly review that compares their targets for various performance measures, including wafer scrap, moves, and absenteeism, to actual results. Fab A conducts a similar monthly review of its operators. One suspects that this level of monitoring is related to the high turnover of the operator workforce, which results in a relatively high proportion of inexperienced operators working in the fab at any one time.

In general, the pay and performance monitoring policies of these two fabs appear to be very similar. Both have performance-based pay, bonuses and profit sharing and evaluate employee performance against both group objectives and individual measures of performance.

Career Ladders

The fabs in this case study have well-defined career ladders for their employees. At both fabs, experienced operators can be promoted to lead operator and then to technician. At Fab B, promotion to lead operator requires a high school diploma and 5 years of tenure. Almost all of the technicians at this fab have been promoted internally rather than hired from outside. In contrast, production supervisors tend to have college degrees and are usually hired from outside.

The advancement opportunities afforded to operators at Fab B are unusual in the semiconductor industry. But as discussed below, the technician job category in this fab appears to be relatively low-skilled. Hence, the actual skills acquired by operators along this career ladder may not be as great as one would normally presume.

Rapid growth has also contributed to plentiful career opportunities for engineers and managers at these fabs. It has been possible for engineers to advance quickly in terms of responsibility and income. At Fab A, there are technical and managerial career ladders for engineers. Engineers must choose one of the ladders within their first 5 years at the fab. Of course, like technology firms everywhere, these fabs find that it is sometimes difficult to retain highly skilled technical employees. Fab B indicated that after a particularly large profit-sharing bonus was distributed or when the stock market was booming, engineers often left to work for startups.

Training and Workforce Skill Levels

Relative to other fabs in the CSM study, the operators and technicians in these two fabs are not intensively trained and do not exhibit high skill levels. Most operators are trained on-the-job by the lead operator. At Fab A, equipment and process engineers do some training of operators and technicians, but technicians do not train operators. Neither fab offers much SPC training to its operators, although Fab A has increased its training as it has implemented computer-aided manufacturing (CAM) technology in the fab. In both fabs, operator training seems to be oriented towards equipment certification. Operators must pass a test showing they are qualified to run a particular piece of equipment. In Fab A, yearly certification is required. The emphasis is on acquiring the know-how to run many different machines. At Fab B, two experienced operators we interviewed said they were each certified on 17 machines in their area, and that the average operator was certified on 10 machines. In fact, operators were rotated to different machines every 3 months to encourage this process. This emphasis on breadth rather than depth is likely to be a response to high turnover.

Curiously, the technicians at these fabs were not highly trained either. Their jobs were generally limited to routine equipment maintenance or assisting engineers in more advanced maintenance. They did little independent trouble-shooting. At Fab B, technicians did not receive vendor training. At Fab A, they did not write up maintenance specifications for particular pieces of equipment and seemed to adhere to operating instructions for performing machine maintenance. Advanced trouble-shooting, repair, and modification were the province of engineers and vendor staff. In an index of equipment maintenance skills, both fabs were at the bottom for both operators and technicians.[2] The equipment engineers at Fab A ranked very high on this index, while those at Fab B were in the middle of the ranking.

Most of the knowledge base and activity in the area of process control were the domain of process engineers. Operators and technicians at both fabs ranked relatively low in our index of Statistical Process Control Skills. There was virtually no operator participation in SPC teams or improvement teams in Fab A. Operators occasionally gathered data for the improvement teams in Fab B but otherwise they did not participate. However about 40% of the operators in Fab B did participate in quality circles. One project focused on yield problems in the etch area and traced misprocessing to a particular machine. Consequently, rotations at this machine were lengthened from 3 to 6 months. Another solution was to institute a routine of double checking operator actions after two misprocessing mistakes have been made. This suggests that Fab B has experienced a significant amount of operator error, contributing to its poor line yield performance.

Problem-solving activity by operators in these fabs is largely nonexistent. At Fab A, when an out-of-control event occurs in processing, the operator changes machine status to prevent further processing and calls the appropriate engineer.

In both fabs, team activity and problem-solving is still largely the province of engineers. Ownership of SPC resides with engineering departments and particular teams. Fab B has started to involve its technicians in more quality control activities but, compared to other fabs in our sample, the level of such activity is still low. In the case of Fab B, it may not be surprising that engineers dominate equipment maintenance and process control issues. For a fab of its size, as measured by wafer output, it had nearly twice as many engineers on staff compared to similar fabs in the CSM sample. More generally, given the product markets that both fabs compete in, which dictate the continual introduction of new process technologies and new processing equipment, it's not surprising that the organization of work at each fab is engineering skill-intensive. In such an environment, the development of operator and technicians skills, which is necessarily a long-term project, is not likely to be accorded high priority.

3C.4 What Matters for Performance?

The core human resource policies at these two fabs are remarkably congruent. This suggests that internal and external factors that these fabs have in common—the product markets in which these fabs compete, their technology strategy, and local labor market conditions—have had a major influence on the choice of HR policy. The need to continually bring new processes into the fab and ramp up volume as quickly as possible contribute to an engineering-dominant culture. Both fabs are quite good at new process introduction, but they appear less successful at dealing with yield problems associated with volume processing, such as equipment-induced problems and operator errors and misprocessing. Yet both fabs have very good direct labor productivity. Apparently they do not shy from pushing as many wafers through their fabs as possible, stretching their operator workforces to the limit. Given such a strategy, combined with the high turnover, it seems unlikely that the skill levels and problem-solving abilities of their operators will expand any time soon.

Even so, there are important differences in performance between these two fabs that need to be explained. As noted above, Fab A has much higher line yield and lower cycle time than Fab B. It appears that some part of this difference can be explained by Fab A's more advanced use of computer-aided manufacturing technology and automation in its fab. This technology tends to mistake-proof certain relatively routine steps in wafer processing, to compensate for a low-skilled and taxed operator workforce. It also speeds processing times and speeds the processing of information, enhancing the problem-solving capabilities of whoever in the workforce is responsible for resolving problems.

The difference between Fab A and Fab B in this regard was fairly stark at the time we visited the fabs. Fab A had largely automated the loading and unloading of wafer lots at equipment stations. Moreover, each lot was equipped with a smart card that contained information regarding the next processing operation. This greatly reduced operator setup time and misprocessing errors. The lot could not be loaded into a machine if the smart card did not corroborate that the processing step was correct. Although this system stopped short of automatic recipe download and automated SPC—both required operator key-in of data—this level of automation was being planned for future implementation.

Fab B had no comparable level of CAM in the fab. One or two machines had auto-recipe download, but all lots were manually loaded onto machines. Records of lot processing were made on paper and later collected and summarized by an engineer at the end of the shift. SPC measurements were manually keyed into computers by the operators. In effect, Fab B was exposed to a higher degree of potential misprocessing error and needed more time to determine the causes of that error, given the level of manual data processing in the fab.

Fab A has more effectively used technology to compensate for the constraints imposed both by the external labor market and its product market strategy. Given the environment in which it operates, this strategic choice to invest in technology rather than in the skill-upgrading of its operators and technicians appears to have yielded clear benefits in the short-term.

3C.5 Conclusion

Over the next several years, these two fabs, and semiconductor fabs in general, will continue to invest in information technology systems and automation. Given the enormous competitive pressure to bring up the volume and yield of a new process as quickly as possible once it is transferred to the fab, real-time collection and analysis of process control data has become critical to success. Accordingly, the extent to which skill-upgrading of operators and technicians compliments such investment is a key human resource policy issue confronting fab management. The initial experience of Fab A suggests that automation of wafer lot processing substitutes for a skilled operator workforce. But additional information technology will be focused on data collection and analysis. If a fab is abundant in engineering resources, IT could be implemented in a fashion which increased the ability of engineers to access real-time data and continue to do all major trouble-shooting and problem-solving. Operators and technicians would participate in minimal levels of data collection. Whether such an approach would be cost effective is far from clear. Alternately, if engineering resources are relatively scarce, a more effective approach may be to increase the data-analysis and problem-solving skills of operators and technicians in tandem with increased investment of information technology inside the fab. We suspect that both approaches will be tested in the coming years.

[1] See Robert C. Leachman, ed., The Competitive Semiconductor Manufacturing Survey: Third Report on Results of the Main Phase, Report CSM-31, Engineering Systems Research Center, University of California at Berkeley, July 1996.

[2] For details on the indices of equipment maintenance and SPC skills see Melissa M. Appleyard, "Skills and Work Tasks," in The Competitive Semiconductor Manufacturing Human Resources Project: Second Interim Report, Clair Brown, ed., Institute of Industrial Relations, University of California at Berkeley, May 1996.