# The Search for Flexibility: Skills and Workplace Innovation in the German Pump Industry

**CEO Publication**
**G 98-3 (331)**

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March, 1998

To appear in the *British Journal of Industrial Relations*

The authors thank the German Marshall Fund and the U.S. Department of Labor which provided the funding for this research and the many pump companies that gave them time and access to data. They also thank Mari Sako, an anonymous reviewer, Pepper Culpepper, Arndt Sorge, David Soskice and Jay Tate for comments that helped improve this article.

Abstract

The German skill-creation system has been a vital part of the success of its "diversified quality production" model. Some argue that this success is now threatened by the spread of lean production and that the existing skill-creation system may hinder, rather than help German manufacturers to restructure. We explore this argument in a detailed study of a nationally-representative sample of German pumpmakers. We find that the existence of a highly skilled workforce may deter the adoption of multifunctional work teams, but that countervailing strengths of the German skill-creation system can potentially help firms develop a new, distinctive German production model.

## Introduction

Throughout the 1980s the highly skilled German manufacturing sector and the apprenticeship system on which its success was built were seen as a model worth emulating by U.S. and UK policymakers (Hamilton, 1990; Daly, Hitchens and Wagner, 1985). In the last five years, however, fortunes have been reversed, with the German economy falling into crisis while the U.S. and UK are now seen as models of flexibility (OECD, 1994). The German economy has recovered somewhat from the depths of the recession, but the high ongoing levels of unemployment and decisions by leading German corporations (e.g., Mercedes, BMW, Siemens) to concentrate new investment outside Germany raise questions about whether it will reemerge as a success story or face more severe structural problems (Carlin and Soskice, 1997).

Germany's traditional success in capital goods manufacturing was built on a system of "diversified quality production" (DQP), where highly skilled craft workers and engineers were able to design and build technically superior machines that could command a price premium in global markets (Streeck, 1989). The success of the DQP strategy, however, now appears to be threatened by the emergence of a new paradigm — lean production (Womack et al., 1990). First perfected by Toyota and then emulated by other Japanese and American companies, lean production enabled these manufacturers to turn out cars of comparable quality far more quickly and less expensively than their German rivals. Herrigel (1996) contends that not only is lean production proving superior to DQP in increasing segments of manufacturing industry, but also that the very sets of institutions, skills and organizational culture that made DQP thrive in Germany may undermine the capacity of German firms to adapt to the new lean production paradigm.

This study examines how German manufacturers have responded to this competitive challenge. We chose to focus on an industry — pump manufacturing — which shares many of the characteristics typical of Germany's most successful postwar manufacturing sectors and differs substantially from automobile assembly plants, on which much prior research about new work practices has been based (e.g., Shimokawa, Jürgens and Fujimoto, 1997; Mason and O'Mahony, 1997). Among the questions which the study addresses are:

- What changes in market conditions have compelled firms to restructure?
- What strategies have German pumpmakers adopted to become more flexible and increase competitiveness?
- Have these efforts been helped or hindered by the existing skills-creation system and other elements of DQP?

## The Evolution of New Production Strategies

There is a growing political economy and management literature on how new production strategies evolve and diffuse across countries (e.g., Piore and Sabel, 1984; Kogut, 1991). Typically one company or a small set of firms develops a new organization of production that represents a significant competitive advantage over its rivals. As this firm gains market share, other organizations and researchers will seek to study the organization and understand the factors underlying its success. The attempts at emulation of these new organizational concepts are likely to occur first in those companies most closely connected to innovating firms: direct competitors in the home country, foreign competitors, and suppliers or customers. As the new ideas gain wider currency, then firms in other industries with similar production requirements are likely to experiment with them.

In the process of diffusion the original production model will be modified to fit the particular context of each adopter, with variation likely based on at least three factors: 1) regional/national institutions, 2) product/technical requirements, and 3) individual company characteristics (e.g., Broedner, 1990). As a consequence of the different levels of variation, the production regimes described in the literature — whether mass production, DQP, or lean production — were never accurate representations of the majority of firms in a country. Rather, they are best seen as ideal types of organization based on the experience of some leading companies that can serve as models for other firms to adapt to their own circumstances (e.g., Lawler, 1996; Meyer et al., 1993).

Lean production is itself an amalgam of earlier production innovations. Toyota gradually combined the insights of scientific management and total quality management with its own innovations to create a distinctive production system. The lean production concept, popularized by the MIT automotive study (Womack et al., 1990), has had such a large impact in manufacturing because it appears to offer a means to satisfy two seemingly irreconcilable objectives, combining the economies of scale of mass production and customization to individual client needs typically associated with DQP (Streeck, 1996). The process of *mass customization* is achieved by harnessing the capabilities of flexible machine tools and a fundamental redesign of the production process. Key features of the lean model include: breaking the assembly line down into component cells, team work, building close partnerships with suppliers who deliver on a just-in-time basis, and creating a system of continuous improvement through heavy emphasis on standardization and sharing of best practices. While many parts of lean production are compatible with German "new production concepts" (e.g., Kern and Schumann, 1984), we focus our discussion on a central element of lean production that is seen as potentially problematic given Germany's institutional structure: the organization of production around multifunctional work teams (Womack et al., 1990; Herrigel, 1996; Levine, 1995). Like other elements of lean production, multifunctional work teams are not new, but rather are a specific means of attaining the earlier underlying concept of *functional flexibility,* where broadly skilled employees are able to shift easily among different tasks (Pollert, 1988; Wood, 1989).

Lean production concepts are just emerging in the pump industry, but they have already begun to change the sector's competitive dynamics. Given the differing technical requirements between the pump and automobile industries, some features of lean production, such as the division of production jobs into sets of operations that can be performed in a minute or less (Jürgens, 1997), would neither be feasible nor desirable for most pumpmakers, which have more varied and changing production requirements. Rather, we would expect to observe a distinctive German response to lean production given the capacities (e.g., the broad skill set of apprentices and *meisters*) and the constraints (the high labor costs and restricted work hours) facing German pumpmakers that could enable them to offer comparable flexibility at competitive prices. Thus our study focuses on improving our understanding of the extent to which multifunctional teams are being used in Germany, how these teams operate, where they are not being used, and what alternative work organization firms are using to remain competitive.

**Research Methodology and Sample**

The findings presented here are based on a larger research project which analyzed how German and U.S. pump manufacturers are responding to the challenges of increased global competition and technological change (see Finegold and Wagner, 1997). This paper concentrates primarily on the German data, using the U.S. case to provide illustrative contrasts in order to explore intra-national variation and allows us to devote greater attention to the impact of the existing skill-creation system and other institutional factors on German pumpmakers' restructuring efforts.

The pump industry employed 46,500 people in 1995 and accounted for approximately 25% of output and exports in one of Germany's key manufacturing sectors — general industrial machinery (VDMA, 1996; United Nations, 1995). We chose the pump industry because it is representative of the general German metalworking sector, with predominantly small and medium-sized private companies (the *Mittelstand)* employing a high percentage of skilled workers to both machine and assemble specialized products for worldwide markets. It thus bears strong similarities with many second-tier automotive suppliers and jobs shops, but differs substantially from the heavily-studied large automobile assembly plants. The industry divides into three main types of production: standardized pumps that are typically built-to-forecast, assemble-to-order pumps where modules from a catalog are assembled to meet an individual customer order, and engineered pumps or systems which are designed to meet precise customer specifications.

The primary means of gathering data was half-day visits to plants producing many different types of pumps (e.g., centrifugal, rotary, vacuum) by the pair of U.S. and German researchers. The visits consisted of interviews with the general manager, and in many cases other members of the senior management team (e.g., manufacturing manager, human resource manager), and observation of the shopfloor to get further details on the production process, machinery layout and utilization. We then sent a short survey to all participating plants to gather additional data and document changes between 1993 and 1996 in different elements of the new production organization. Follow-up phone calls were used to obtain any missing information.

The sample of plants was identified through trade directories, and includes a mix of facilities that were part of larger multinationals (both foreign and German owned) and independent operations. The visits were made in two rounds in 1995 and early 1996 to establishments scattered across West Germany and Berlin. We limited the sample to West Germany because the East German mechanical engineering sector is still in transition to a market economy (Hitchens et al. 1993). In all, the sample included 18 German pump manufacturers that appear to be broadly representative of the industry as a whole (see Table 1).

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**Pressures for Restructuring**

The German pump industry, like the rest of German manufacturing, suffered a significant decline in the deep recession of the early 1990s. Total employment fell by 10% between 1989 and 1995 and capacity utilization dropped from 91% to 79% (VDMA 1996). Despite the decline, Germany retained its position as the world's leading exporter of pumps, with 21% of the world liquid pump market and a similar proportion for vacuum pumps in 1994 (see Table 3). It lost market share, however, to the U.S. (16% of world sales) and Japan (15%) and some smaller, new entrants. Exports, at 3.4 billion DM in 1995, were more than double imports (1.55 billion DM), generating a healthy trade surplus, with just over half of German exports going to the European Union.

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Like many German equipment producers, pumpmakers' heavy reliance on exports helped shield it from the worst effects of the domestic crisis. The pump industry also enjoyed some additional structural advantages. Differences in technical pump standards and the accompanying test requirements (the German DIN is dominant in Europe, while the U.S. API standards are most common in Asia and North America) placed some limitation on imports into Germany. And finally, pump spare parts — like razor blades — are a form of annuity business, with companies often selling the initial product at or below cost in order to get the lucrative business in replacement parts over the life of the good. Thus, firms with a large installed base have a steady revenue stream even when current orders decline, although competition in the spares market is also increasing.

Despite these factors, German pump manufacturers have been compelled to undertake major restructuring in order to remain competitive. Like many segments of German manufacturing, pumpmakers have traditionally prospered by targeting market segments where buyers were willing to pay a price premium in return for high quality, very reliable, customized products. In the 1990s, the increasing intensity of global competition and the pressure on their customers to cut costs has substantially eroded this price premium. High product quality continues to be a key driver of German firm's success; it was cited by 39% of all German managers we interviewed as their primary source of competitive advantage, more than twice the percentage for any other competitive factor (e.g., cost, delivery time). Customers, however, now increasingly assume quality as a minimum criteria for firms to be considered for an order and focus competition on price. "Where in the past we could expect to win an order if we cost 20% more than our competitors because of our reputation for quality, now we are lucky if we can get a 3-5% price premium," said one general manager. The growing influence of large engineering contractors, key customers for many pump companies, has contributed to this price pressure; in the past, German manufacturers could justify a higher initial price based on an engineering advantage — e.g., a pump with greater energy efficiency or reduced maintenance requirements — that produces lower lifecycle costs. It is now more difficult to obtain this price premium because it would cut into the already thin margins of their customer, who is often not the ultimate end user of the product, and thus pays more attention to cost than performance benefits.

The emergence of new, lower cost competitors has further intensified pressure to reduce costs if firms are to maintain any profit margin. In some standardized market segments, low-cost producers in Asia and, more recently, eastern Europe, are manufacturing complete pumps that compete directly with German products; however, for the majority of German pumpmakers which are in more specialized markets, the impetus for change is focused on rethinking the production or sourcing of components.

Labor intensive operations such as basic machining and casting are increasingly difficult to perform competitively in Germany given its high labor costs, so many pumpmakers have turned to suppliers in eastern Germany, eastern Europe or Asia to perform these functions.

Another source of pressure for restructuring has been the significant increase in German labor costs. German manufacturers have been accustomed to operating with shorter working hours and higher labor costs than their rivals in the U.S., Asia and southern Europe. With the reduction in the length of the work week to 35 hours in 1995, however, German firms suffered a significant further reduction in competitiveness that is forcing managers to rethink their use of labor and future investment strategies. In response to intensifying competition and cost pressures, German pumpmakers are restructuring to obtain greater flexibility.

### *Skills and the Use of Multifunctional Teams*

The German vocational education and training system (VET) has long been cited as one of the cornerstones on which Germany's manufacturing success has been built (Streeck, 1989). The apprenticeship system ensures that close to two-thirds of all young people entering the workforce have a high status craft qualification, while the colleges and universities produce managers with unusually high levels of technical competence relative to most other countries (NEDO, 1987). Herrigel (1996) argues, however, that this education and training system and the types of skills it produces were well-suited to diversified craft production, but are hindering German firms' ability to adapt to the new competitive conditions. Specifically, he contends that the high degree of specialization among skilled workers and the narrow functional orientation of German managers from different disciplines — e.g., manufacturing engineering, product engineering, marketing, purchasing — make it difficult to establish the multifunctional teams on the shopfloor and integrated product teams or concurrent engineering in the product development process that are hallmarks of lean production. The obstacles, he argues, are not only structural, part of the organization of the firm and VET system, but are also part of individual identities as skilled workers and managers have come to define themselves based on their relatively narrow functional capabilities.

Our study of German pumpmakers' efforts to restructure their operations provided some empirical support for Herrigel's central argument that craft workers will resist the adoption of lean production techniques. It also, however, revealed other strengths of the German VET system, that Herrigel does not emphasize, which can support new, more flexible forms of production. We first highlight some of the obstacles German employers face in creating team-based organizations and then explore some of the positive aspects of the skill-creation system that support new alternative forms of flexible organization.

We found some evidence, both within and across plants in Germany, that the more skilled the workers, the less likely the organization was to adopt a team-based structure. In order to test this relationship, we divided the sample plants into two groups: higher skilled (more than two-thirds of the production workforce had completed an apprenticeship) and lower skilled (under two-thirds skilled); we then rank-ordered all of the plants in terms of the percentage of shopfloor workers in teams and used the nonparametric Mann-Whitney test to analyze whether the two groups had different levels of team implementation (see Table 4). The result was significant (two-tailed test =.04), a surprisingly strong result given our small sample size. Another way of expressing this relationship is that all of the plants with a low percentage of skilled workers (though some were still highly skilled in comparison to their U.S. counterparts) had implemented at least some work teams, while more than half of the highly skilled plants had no teams in place.

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Given the still early nature of the restructuring efforts, there was, not surprisingly, a high degree of variation across plants in the extent of work redesign; more than two-thirds of the sample had introduced some team work and/or cellular production, but only six of the plants had a substantial portion (more than 30% of the workforce) in teams. In general, plants producing a more customized, and hence highly varied output, were less likely to move to a team-based organization (see Table 5). This finding corresponds closely to the response to lean production in the German auto industry, where plants producing more standardized cars have been far more likely to adopt multifunctional teams than more specialized producers such as Mercedes (Jürgens, 1997; Springer, 1997).

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The results from our U.S. sample suggest that it is the strong occupational orientation of German workers' training and the identity this creates, rather than the level of skills, which appears to be the main barrier to the formation of multifunctional work teams. In the U.S., just the opposite pattern was apparent, with the more highly skilled plants making the most significant moves toward team-based organizations. In the U.S., most of the highly skilled workers did not come through a formal apprenticeship, but rather acquired their competencies through a mix of vocational courses and ongoing, on-the-job training. Without a strong craft identity, these workers generally embraced the move toward more self-managed teams and the accompanying opportunities for greater rewards. In contrast, it was the relative lack of skills in some of the more standardized American plants that appeared to be a significant deterrent to the implementation of teams.

An illustration of the impact that skilled worker identity can have on the move toward lean production came from a contrast within a specialized German pumpmaker. It started in 1992 with the introduction of a team in the receiving and shipping department, the lowest skilled part of the plant. The team was able to boost productivity by 30%. The next year when management attempted to replicate this success in the machine shop, however, they encountered unexpected obstacles. The plan was to move from the traditional plant layout, where machines were grouped by type of function (e.g., turning, grinding, cutting, etc.) to create component cells. Two years later these cells were still not operating as planned. The main stumbling block has been resistance from the plant's skilled machinists. The technical director explained the source of their opposition as rooted in the way individuals' define "skills":

> "They view it as a reduction in skill because they focus solely on the technical skills and not the other responsibilities that would come with the move toward cellular production. For them it means producing one range of parts on a few CNC machines, whereas in the past they could produce any part on any machine in the plant. What they fail to take into account is the other skills that the team requires — production scheduling, ordering, managing supplier relations, programming and the communication required to make a team work effectively across several shifts. This is the change in mindset we're trying to bring about."

In contrast, the plant which had been most successful in the introduction of self-managed teams had one of the least skilled workforce's in the sample prior to restructuring; only 10% of factory workers were skilled machinists, with another 10% of the workers qualified through an apprenticeship in an unrelated field, a skill profile far more similar to U.S. plants than the typical German metalworking firm. What further distinguished the plant from most German pumpmakers was that a majority of the machine operators were women, supporting earlier research suggesting that women are more likely to embrace team-based, cooperative structures than men (e.g., Hofstede, 1980). As part of the total restructuring of the work organization, machines were moved into product cells with teams of 8-15 members operating each cell. The teams covered 2-3 shifts with only one skilled worker in each group. The rest of the workers were given a "mini-apprenticeship", an intensive program of further training that included six weeks of technical training and 25 hours of training on how to operate in teams. By following this short course with ongoing, informal training and job rotation within the team each individual was able, within 15 months, to operate all of the machines within the cell. In addition, the self-managed teams took complete responsibility for setting their own hours so that they could meet biweekly production targets that were established through a simple, demand-pull *kanban* system. To improve product quality, teams analyzed the main sources of defects and began working closely with suppliers to increase the consistency of materials they were receiving. The teams also prepared proposals for the purchase of new capital equipment, which entail calculations of payback rates and strategic justification based on careful tracking of quality problems or production bottlenecks caused by existing machinery. A sign of the workers' commitment to the new system was that they volunteered for additional technical training in unpaid time. Although they are just over halfway toward the full introduction of a cellular production system, the restructuring has already produced dramatic results. On-time deliveries improved from 82% to 98%, inventory fell by 25%, with the main reduction coming in finished goods and work-in process, and the cost of quality was halved.

A couple of more customized plants employing predominantly skilled workers had also undertaken major restructuring, but their new organization differed in important ways from lean production. Rather than multifunctional work teams where each member could perform the same relatively narrow array of technical tasks, they reorganized using the earlier plants-within-a-plant concept (Wildemann, 1987). These mini-business units, which often included engineers and support personnel along with skilled craftsmen, were charged with taking a product line from raw material to the customer. As with lean production, the flow of the work process was improved and frontline workers were given greater responsibility for production scheduling and quality. Workers in each group, however, retained their specialized technical expertise necessary to cope with the complex and changing array of tasks associated with more customized production (see Kuhlmann and Schumann, 1997, for further discussion of the distinction between groups and teams). Further training increased, but since the workers were already skilled, the training focused on higher-level competencies, such as team dynamics and project management. The results of the restructuring were impressive: one plant had been able to cut its throughput time in half and reduce costs due to the reorganization and numerous suggestions by workers for process improvements. Another had boosted productivity by 40% in three years while substantially reducing batch sizes and inventory.

The plants, both standardized and customized, that had most successfully redesigned the shopfloor accompanied the reorganization with a set of other changes in human resource and management practices designed to support a more flexible form of "skill-based manufacturing" (Broedner, 1990). These changes included: much greater sharing of financial and market information with frontline workers, with each cell having access to a computer that enabled them to check the progress of any order in the plant and a detailed set of statistics relating the cell's performance to overall plant targets. Management and back office space had been redesigned so that purchasing, sales and design engineers worked as teams and were much closer to the relevant manufacturing cells, facilitating communication and joint problem-solving. The pay and measurement structures had been revised to reward teams performance.

In summary, workers' openness to work redesign appears to be governed, at least in part, by what they may gain or lose as a result of the restructuring. For German skilled workers, the shift to multifunctional teams may potentially threaten their identity by reducing the comprehensive technical responsibilities that have been their assurance of job security, high status and high wages, while increasing the demand for more general 'social' skills needed for communication, cooperation, and intensifying customer and supplier relations. For semi-skilled workers, however, the shift toward multifunctional work teams and cellular manufacturing appears to be a clear benefit, offering both greater technical skills and a whole set of new challenges, with accompanying boosts in rewards and potential job mobility. The challenge for companies with a lower skilled workforce is whether they can develop the capabilities needed to make such teams operate effectively.

## The Benefits of Skills for a German Model of Team-Based Production

While the strong role that technical skills plays in the identity of German skilled workers appears to be a significant barrier for some companies in the adoption of multifunctional teams, there are countervailing strengths of the German VET system that could, with continued reforms of the apprenticeship system, facilitate moves toward a structure based on groups of empowered, highly skilled production workers responsible for running their own interrelated mini business units, or plants within plants (Kern, 1997). The central features of the existing system that we identified as supporting the transition to this new organization are: the strong general and applied skills which apprenticeships provide, the firm-based delivery of most training, *meisters*' combination of comprehensive technical, economic/business and pedagogical skills that can support the transition to team-based organizations, and the already relatively broad span of control in most German plants.

**Apprenticeship.** Frontline workers require a substantial set of capabilities to make a team-based organization effective (Cohen and Bailey, 1996). Unlike the U.S., where there is a small cadre of skilled craft workers and most production workers are typically given relatively limited training for a narrow set of tasks (Finegold and Mason, 1996), German apprenticeships provide the vast majority of production workers with many of the technical and general skills necessary for the new form of work organization. Herrigel stresses the traditional, relatively narrow technical specialization of German metalworking apprentices, downplaying the significance of the major reforms which took place in the apprenticeship curriculum in the 1980s and the large general education component that has always been a part of the dual system. The reforms, which were completed in 1987, broadened technical skills and eroded demarcations by reducing the number of separate occupations within metalworking from 44 to 6. All courses share common first-year training modules and then divide the second year into six broad groups, from which students can choose one of 17 sub-specialties in the final year (Casey, 1990).

In addition, apprenticeships have always contained substantial general content that prepares workers for wide responsibilities — e.g., knowledge of the whole enterprise, communication and writing skills, problem-solving and basic math skills. These skills are key ingredients for the new approach to quality, production scheduling, planning, controlling and assessing work, cooperation with customers and suppliers, and personal responsibility (Geer and Hirschbrunn, 1994). Because of their skills German workers achieved a high degree of autonomy in teams (see Table 6). They were given full responsibility for quality control and scheduling, responsibility for maintenance (88%) and proposals for new machinery purchases (70%); it was less common, however, for teams to work with suppliers (40%). Where German teams were introduced with an already high percentage of skilled workers there was less need for and time devoted to cross-training existing employees and rotating them through different production tasks. Because of their broad initial training, skilled workers already had mastered the different machine operations and routine maintenance tasks needed to operate the manufacturing cell when team-work was introduced.

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Evidence of the good potential fit between apprenticeship training and the demands of the new production organization was that firms with a semi-skilled workforce that had moved furthest toward the adoption of lean practices and team-based work environment had increased the number of apprentices to build the necessary skills. The relevance of skilled workers was clearly recognized in a firm with a semi-skilled production environment that had attempted to introduce multifunctional work teams. Although the workers were very receptive to the changes and received a large increase in training, the plant encountered major quality problems and disappointing results with the work redesign; managers found that many of the semi-skilled workers did not have the general and technical skill base needed to tackle the broadened tasks in a team and to take over the widened responsibility for self-managed teams (see Hartmann et al., 1994, for similar findings in the textile industry).

Our study found relatively consistent, ongoing employer support for the apprenticeship system in plants with skilled workers. Although roughly one-half of the firms had cut back on the number of apprentice places as a result of reduced internal company demand for new hires and the higher costs associated with reforms of the apprenticeship (Wagner, 1997) they stressed the advantage of training their own skilled workers in a firm-specific context. Apprentices accounted on average for 6% of production employment (see Table 4) and 15 of 18 firms offered apprenticeship places.

**Work-Based Training.** One of the virtues of the apprenticeship system is that most of the content is delivered in the workplace under the supervision of experienced trainers. Formal standards and curriculum may be slow to adapt — e.g., only limited content on CNC/CAD — but the training delivered in firms that have restructured reflects their new work organization and fosters more active, team-based learning. In virtually all of our sample plants we found that it is common for apprentices, particularly in the latter phases of their course when they are highly productive, to be integrated into production; this is not the isolated exception to official regulations that Herrigel suggests. Some plants had set up complex projects for teams of apprentices to do where the value of the output exceeded the costs of the trainees.

**The Role of *Meisters*.** Making the transition to team work is far easier if supervisors are qualified to coach the new teams and help them gradually assume more responsibilities until they can become truly self-managed. The comprehensive *meister* training helps equip German supervisors to support this transition. To obtain the *meister* qualification, individuals must have completed an apprenticeship and then, after demonstrating their competence in the workplace for at least three years, have gone back to school, on their own time and using their own funds, for an additional year to obtain further training in technical and general business areas as well as problem solving and pedagogical skills. In contrast, Anglo-Saxon supervisors rarely had this combination of skills, typically either promoting the best skilled workers or hiring new 2- or 4-year college graduates who had better people management skills, but lacked the necessary practical expertise to effectively coach machinists (Mason, 1996; Finegold and Mason, 1997).

With the adoption of a lean production organization and empowered teams, the traditional role of the supervisor — to maintain control over production — declines in importance. Those German companies which were making the transition to team work have reduced their traditional supervisory positions by 25-50%. While existing supervisors may naturally resist this reorganization of the workplace, German managers stressed that this has not diminished their need for individuals with *meister* qualifications. They continue to encourage skilled workers to pursue the *meister* qualification as leaner operations demand better qualified people to do more complex technical and organizational planning activities: design and monitoring of quality control systems (e.g., obtaining and re-qualifying for ISO 9001), leading continuous improvement efforts, acting as a representative of manufacturing on integrated product teams (IPTs), serving as programmers or working as an expert within the team, or coaching a larger number of teams. To better equip *Meisters* for the new work environment, the standards and curriculum for their courses have been reformed; further emphasis has been placed on communication, cooperation, planning, technical and coaching skills (Scholz, 1996).

**Broad Existing Span of Control in Production.** Long before the interest in empowering frontline workers, most German plants already had a relatively flat organizational structure (Lane, 1989; Maurice et al. 1980; Prais and Wagner, 1988). A typical establishment has just one or two layers between the top management team that includes a plant manager and skilled workers on the shopfloor, with some plants having a formal, separate designation for supervisors or lead men: *Meisters*. The number of supervisors per worker in Germany was lower than in the U.S. for all types of production; in custom production plants, in particular, the skilled workers have had a high degree of autonomy (see Table 7).

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The establishment of teams typically entailed elimination of the traditional supervisory position and the creation of a new role of cell or team leader. Managers indicated that team members were given a greater span of control over their immediate work and consulted more on the decisions affecting the group, with an accompanying reduction in the number of traditional supervisors. Between 1993 and 1996, it was the standardized manufacturers which had successfully transformed themselves into team-based organizations that were able to make the biggest reduction in supervisors, cutting the ratio of supervisors to shopfloor employees by one third. Customized manufacturers, which entered the 1990s with relatively few supervisors because of the high degree of autonomy given to skilled workers (Streeck, 1996), found they had to retain, and in some cases increase, the relative number of supervisors in order to oversee the production process, which had become more decentralized with the introduction of mini-business units.

## Conclusions

Lean production evolved in the Japanese auto industry as a superior alternative to a mass production system staffed by semi-skilled workers (Womack et al., 1990). This study of the pump industry, which has a much wider variety of production methods and skill requirements than automobile assembly plants, examined how German manufacturers are attempting to adapt their existing organizations to the competitive threats and opportunities posed by innovative production concepts. It revealed that the existing institutions, skills mix and product markets can have a strong influence on the type of strategy that firms adopt. The pumpmakers have begun to pursue greater functional flexibility by restructuring the production process and introducing flatter organizational structures. Plants that initially had a less skilled workforce have moved the furthest with the introduction of mulitfunctional work teams. In order for these teams to succeed, however, they have had to significantly increase the training of the workforce. These multifunctional teams are well-suited to standardized production where the variation in tasks and consequent level of multi-skilling is relatively limited. In contrast, the complexity and variety inherent in customized or small-batch production found in much of the pump industry continues to necessitate a level and type of skill, combining broad and specialized expertise, that makes it difficult to implement this kind of work team. Implementation appears further hindered by the personal identity of German skilled workers, who may see the blurring of individual roles and narrower set of technical skill requirements as threatening their status within organizations. A few customized plants, however, have adopted an alternative plant-within-a-plant concept that achieves many of the benefits of lean production while preserving individual worker skills and autonomy.

While some aspects of German firms' product strategies and training systems may mitigate against Japanese-style lean production, our study revealed a set of counter-balancing strengths that appear to facilitate the transition to new, flatter, more flexible organizational forms. First, the reformed, modern metalworking apprenticeship provides individuals with strong theoretical and applied training that is highly valuable when a broader set of work tasks and traditional supervisory responsibilities are shared among members of self-managing teams. To obtain the full benefits from these skilled workers, however, managers need to stress the importance of broadened responsibilities that individuals are being given and create reward systems that value these new, non-technical skills to overcome the personal identity problem. Placing greater emphasis on interpersonal skills in the training of apprentices might help them to value the broadened non-technical responsibilities as skilled workers.

Likewise, while the adoption of flatter hierarchies reduces the need for traditional supervisors, the large supply of individuals with the *Meister* qualification in Germany can help firms' restructuring efforts. During the transition to a more team-based structure, *Meisters* have the right set of broad skills — both pedagogical and technical — needed to act as effective team leaders/coaches or to advise teams on how to attain the required skills and to move to higher self-responsibility. And as this transition continues, they are playing new roles in flatter organizations, such as fostering continuous improvement, overseeing process standards and production planning, and contributing to new product development.

If German companies are to complete the process of adopting new production concepts to their own organizational context — and most of our sample was still in the early phases of this transition — then a number of issues regarding the skill system will need to be resolved. One issue which the German dual system faces is the relatively slow pace of change in the formal skill standards and accompanying curriculum for apprenticeship. The large firm-based training component is able to adapt flexibly to the new needs of the work environment, but this can create a growing gap between the workplace and what individuals are learning in the days off at school. The school-based education, both the formal curriculum and the way it is delivered, will have to be adapted to the technological and organizational requirements of lean enterprises. This could entail standards that include a greater focus on areas that are already part of the curriculum (e.g., continuous improvement techniques, broader business understanding, communication skills), somewhat reduced time devoted to hands-on technical areas that are becoming less important with the spread of CNC, and a shift from lectures to more group instruction and action-learning that would help reinforce the skills needed to operate in a learning organization. Efforts have been underway for the last two years to update the curriculum more quickly, and the process for changing courses is itself being streamlined to facilitate more frequent updates in the future (Schmidt, 1996).

If Germany is to retain its strong manufacturing base, and the apprenticeship system that supports it, German firms need to develop their own set of production concepts that builds on the country's existing strengths. This entails creating an organizational and reward structure that enables them to fully utilize the potential of their highly skilled workers and newly-deployed *Meisters* by pushing greater responsibility to teams of frontline workers and aggressively restructuring the rest of the enterprise to match the functional flexibility on the shopfloor (Womack and Jones, 1996).

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**Table 1**

**Size Distribution of Sample Pump Plants and German Metalworking Industry**

| Employment size group | Number of Pump Manufacturers in the Sample | Percentage of Employment in the Sample | Percent of Employment in German Engineering Industry* |
|---|---|---|---|
| under 199 | 6 | 12 | 34 |
| 200-399 | 7 | 28 | 18 |
| 400 and over | 5 | 60 | 48 |
| total | 18 | 100 | 100 |

* Note: the metalworking industry numbers include many small job shops that are much smaller than the typical pump plant

Source: Statistisches Bundesamt, Fachserie 4, Reihe 4.1.2, engineering (Maschinenbau, Sypro.no. 32), 1993.

**Table 2**

**Output and Performance of the German Pump Industry**

| | Nominal Output per Employee in DM | Real Output per Employee in DM | Capacity Utilization (percent) | Export Orders as Percentage of All Orders |
|---|---|---|---|---|
| 1990 | 164.000 | 164.000 | 91 | 41 |
| 1993 | 172.000 | 149.000 | 78 | 40 |
| 1994* | 188.000 | 165.000 | 79 | 46** |

* united Germany

** an increase of about three percentage points has been added by the East German manufacturers

Source: VDMA 1996, Statistisches Handbuch für den Maschinenbau, liquid pumps.

**Table 3**

**Shares of World Pump Trade**

| | Liquid Pumps | | Vacuum Pumps and Compressors | |
|---|---|---|---|---|
| | 1989 | 1994 | 1989 | 1994 |
| Germany | 24.7 | 21.4 | 25.1 | 19.0 |
| U.S. | 15.9 | 16.3 | 20.4 | 17.9 |
| Japan | 12.6 | 15.1 | 11.3 | 11.2 |

Source: VDMA 1996.

## Table 4

## Significant Inverse Relationship Between Skills and Teams

| Skill Level | Mean Rank | Mean % Workers in Teams |
|---|---|---|
| Low Skill (N=5) | 13.5 | 55% |
| High Skill (N=13) | 8.0 | 17% |

Mann-Whitney Test of Two Tailed Significance = .04

Low skill plants = 40% of frontline workers are skilled on average

High skill plants = 88% of frontline workers are skilled on average

**Table 5**

**Product/Skill Mix and Adoption of Multifunctional Teams in 1996**

| Product Type | Average % of Shopfloor Workers Who are Skilled | Average % of Shopfloor Employees in Teams | Apprentices as % of Shopfloor Employees |
|---|---|---|---|
| Standardized | 40 | 41 | 4 |
| Assemble-to-Order | 78 | 29 | 5 |
| Customized | 91 | 19 | 10 |
| Total Sample | 70 | 30 | 6 |

**Table 6**

**Responsibilities of Teams**
**(Percentage of Plants with Some Teams Reporting)**

| Team Responsibilities | Germany |
|---|---|
| Scheduling | 100 |
| Quality Control | 100 |
| Supplier Relations | 40 |
| Maintenance | 88 |
| Proposals for New Machinery | 70 |

## Table 7

## Number of Supervisors per 100 Shopfloor Workers

| | U.S. | | Germany | |
|---|---|---|---|---|
| Product Type | 1993 | 1996 | 1993 | 1996 |
| Standardized | 5.6 | 4.6 | 4.1 | 2.7 |
| Build to Order | 7.2 | 4.6 | 4.3 | 3.9 |
| Custom | 6.8 | 8.1 | 3.3 | 3.8 |
| Total | 6.5 | 5.8 | 3.9 | 3.5 |