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The Making of Engineers at Ford Romeo and Nissan Yokohama

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An investigation of engineer training in manufacturing involves examining company methods for transferring production knowledge and techniques. Little systematic study has been conducted in this area. Training variation, and its transfer to Mexico in Ford and Nissan plants were studied. Variation appeared to be due more to beliefs about education rather than any inherent demands of the process and machinery. Technology transfer depended on workforce skill, and this influenced the jobs and formation process for engineers at Ford Romeo and Nissan Yokohama.

MACHINERY cannot work without human guidance. As such, people are recognized increasingly in their roles as 'capital' and 'technology' [1] and as part of the company's resource base. Training is one of the ways of improving the role of people in the production process since, even though motivated, employees cannot perform well without understanding their jobs. Although much has been written about training, there has been little systematic analysis of that training since few if any studies have explored even the variation of training within a single production category.

Ford and Nissan are comparably competitive companies. In 1989, Ford was the second largest automobile manufacturer in terms of worldwide production and Nissan was fourth. In Mexico, Ford's and Nissan's engine manufacturing operations (Chihuahua and Aguascalientes) were also comparable in terms of age, size and type of production. They were examined to discover how well original training practices held up in the Mexican context. The two companies' home country operations (in Romeo, Michigan and Yokohama, Japan) could also point to these sources of variation in training. Interviews were conducted with workers, technicians, and engineers as well as managers at all four sites. A potential limitation of interviewing is that cultural differences may complicate the interpretation of responses to questions. This paper summarizes the findings that pertain to the training of manufacturing engineers, who modify and improve the process, and how their training relates to those of other employees at the sites.

One would presuppose that with the execution of similar operations, and similar suppliers internationally, that Nissan's and Ford's training programs for manufacturing engineers would be very similar. The knowledge needed for efficient problem-solving and improved manufacturing would be alike, since both companies are trying to maintain the integrity of design within certain tolerances, and are presented with similar problems of design, maintenance and repair.

But the two companies took very different training approaches that reflected historical, social, and cultural idiosyncracies. Variation in training appeared to be more due to beliefs about education rather than any inherent demands of the process or machinery. The Ford Romeo engine plant and the Nissan Yokohama engine plant best illustrate these contrasts, so training in these sites will be first described: off-the-job training in classrooms and on-site on-the-job training will be followed through job rotation and career paths. The companies' different approaches will then be compared and then examined in the Mexican context.

The two companies' home country operations were not as easy to compare as their subsidiaries: Romeo was in full production for less than two years at the time of interviewing, whereas Yokohama had been in operation for 56 years. Also, where Yokohama was representative of training in Nissan, no single site within Ford could claim it was representative of the company's training practices. Romeo was representative of Ford in the sense that most other Ford operations were also experimenting. Romeo was also a site for testing a 'Team Management' organization, that was declared a possible model for the rest of the Power Train Division and Ford's North American Automotive Division. Nevertheless, comparisons remained valid because the two home country operations were sources of technology for transfer to Mexico.

TRAINING OF MANUFACTURING ENGINEERS AT FORD'S ROMEO MICHIGAN ENGINE PLANT

Ford's plant in Romeo, Michigan makes a V-8 4.6 liter 2-valve dual overhead camshaft engine, and is launching a 4-valve engine. It machines a camshaft, a connecting rod, two types of blocks, two types of crankshafts, and two types of cylinder heads. These are assembled together with parts from suppliers for various full-sized Ford autos at a plant of approximately 960 employees. The Romeo engine plant was chosen for study because of its role in a larger project that consisted of a single home country plant with a Mexican counterpart. At Ford, there was no real 'mother' plant that transferred technology to Mexico; but because each successive launch in the Power Train Division learned from one immediately previous, and Romeo was an appropriate counterpart to Chihuahua, so Chihuahua's organization was being altered to resemble Romeo's.

By many measures, Romeo had been Ford's best launch to date, proceeding in record time (four years), within cost expectations and exceeding other Ford engine plants in quality during launch. Romeo's average TGW (things gone wrong) in the first three months was nearly five times lower than Ford's past few launches, and was competitive with engines of foreign manufacturers.

It is difficult to assess the contribution of training to Romeo's success because the team management system, the design process, and new relationships with vendors were important as well. Nevertheless, training undoubtedly consumed much of Romeo's effort since there was much that was new to be learned during its start-up in 1987. Romeo rehired much of its blue collar workforce from among the employees of a former tractor plant that had previously been on site, and most of them lacked a background in engine manufacture, which is required through agreements with the United Auto Workers (UAW). Also at Romeo, Ford was not only launching a new engine but a new style of organization called 'Team Management', which involved soliciting worker suggestions in an unprecedented fashion across the whole plant, decentralizing many of the production support functions to the shop floor. Teams were allocated a budget and had input into production decisions, and each was treated as a mini-business. This style of organization at the time was unique in Ford and involved an unprecedented training program, notable for its plant-wide training of hourly employees. The focus of training was to teach the entire workforce about the new Team Management system and to make team members capable of decision making within their team. The training occurred in a context where the emphasis was on cultural change and the hourly workforce, rather than on the training of engineers.

THE JOBS OF ENGINEERS

As at other Ford plants, engineers at Romeo were part of the salaried white collar workforce, while other team members were paid hourly wages negotiated by the company and the UAW. The division between these employees was clearly defined and historically based. Hourly employees could not have supervisory duties, and salaried employees could not touch production machinery. Production employees could achieve top hourly rates within their class and be promoted to machine operators, then to skilled trade status based on examinations. Factory floor managers could rise from the ranks if they acquired a college degree, but 80% of Romeo's line managers did not have experience as production employees. At Romeo, the work of engineers differed from other Ford plants partially because of the new Team Management system; conventionally, engineers reported to the plant's manufacturing engineering department; but under Team Management, engineers reported to the production line manager. This structural change, in contrast to typical practice, put engineers in daily contact with the shop floor. Apart from conventional engineering duties, such as costing, detail engineering for improvements and writing reports on maintenance and quality control, engineers were instructed to do 'whatever it takes to get the job done'. Engineers noticed more clerical work in their jobs than was conventional. Their jobs consequently carried a broader range of responsibilities, from interaction with suppliers to debugging machines. This was because in theory, each team could decide, within contractual and corporate limitations, the responsibilities of its members. The other team members were similarly instructed 'to get the job done' and that overall point was making good engines and 'getting them out the door'. During launch, members of teams functioned also as engineers in the rest of Ford, with input on layout and making engineering changes. Engineering jobs also differed because training was unique to Romeo, and to each plant within Ford, since training programs were the responsibility of the individual plant manager.

In practice, the actual distribution of work within a team depended on the team manager's style as well as workers' problem-solving abilities and motivation, and their jobs varied from team to team.

Engineers were more heavily involved in problem-solving, instruction of operators and skilled trades than in other parts of Ford, in part, because many in the plant lacked experience. For example, in the connecting rod team where operations were relatively smooth, engineers were involved more in analytical work. In the block line, they were solving problems related to machine efficiency. The perception was that engineers' responsibilities would change as the workforce gained experience in production; educated engineers were needed on the line to raise worker skill levels and solve problems. But the rate of skill formation in the workforce was slowed by historical limitations to the amount engineers could teach: they could not touch production machinery and in some cases were watched very carefully and reported if this rule was violated. A further hindrance was the practice of 'bumping' or displacement of hourly workers to different production lines by those with higher seniority. There were also limited financial incentives to improve workforce skill. Negotiated wages at Romeo tended to be higher than average because greater workforce participation was expected. For the most part, wages were based on hourly rates strictly determined according to seniority. But the top pay-scale was often reached within a single year though a skill certification process also linked these hourly rates to this top rate. The incentives for performance were reportedly to remain employed and avoid a plant closing. These incentives worked for most of the workforce, but for an estimated 5% they did not.

OFF-THE-JOB TRAINING

Off-the-job training of manufacturing engineers occurred mainly during new product launches prior to beginning work. Along with other employees, engineers participated in the 172-hour special training program mandatory for all employees involved in plant start-up. Taught by upper plant management and skilled trades, team members were exposed to engine technology, business terminology (such as finance, productivity and quality) and new social skills for Team Management (Team Oriented Problem-Solving, Team Concept). Training from vendors was also provided at unprecedented levels to familiarize plant employees with equipment, almost all of which is custom-designed and unique to a given plant.

For classwork unrelated to the launch, training was an individual responsibility: individuals recorded and tracked their own training history through a 'Skills Management Process', begun in 1991, that was reviewed jointly by employees and their managers. A curriculum for different types of engineers was available based on courses offered internally and externally; but follow-through was up to individual initiative. Romeo's parent division, Power Train Operations, itself offered an estimated 1500 courses for access by Ford engineers and other salaried employees. These courses were generally produced on videotape by external sources, and covered topics as diverse as computer and operating systems, business politics, and stress management. In the field of electronics, there were courses on all major computer systems and languages, even those that had been obsolete for years. Courses were also available from the Human Resources Development Center, and other parts of Ford, as well as from local community colleges, universities and consultants.

Romeo's system of classroom training was guided by a skills matrix established by headquarters for each plant position. This matrix specified required competencies in the area of quality control, and personal and organizational development. Romeo modified this matrix to reflect the greater content of production in their engineering jobs. Coursework was at individual employees' discretion, in conjunction with their supervisors and the Romeo training department, which controlled the training budget. This organization presented problems as well as opportunities. According to one account by a skilled tradesperson, manual controls were used rather than the available electronic control system for thirteen years because 'they had no idea of how it worked or how to repair it'. This was subsequently remedied in a single three and a half day class. If motivated, individuals could successfully use the training system to meet their needs; however, if no employees took an individual initiative to receive training in a given area, related problems would continue to remain unaddressed. Team members commented that at Romeo, training requests were more quickly fulfilled and addressed than at other traditionally organized plants.

Provision of classroom training at the plant level was closely associated with new product launch and depended greatly on the launching schedule, which was highly variable at Ford. The division had recently engaged in a series of major launches, one after another, in the US, Europe and Mexico after a period of almost a decade without major launch activity. Fluctuations of personnel and training within the division were reportedly associated with fluctuations in 'launch production', and a special group of launch training specialists was required within the corporation to provide continuity from launch to launch.

ON-THE-JOB TRAINING AT FORD ROMEO

For the purposes of the study, on-the-job training was considered to comprise of previous experience, job rotation and, with time, career path. Engineers at Romeo came from a variety of backgrounds: some had previous experience with Ford while others gained their experience at Ford's suppliers and other engine manufacturing operations. Most, however, were hired upon graduation and were unfamiliar with the Ford system. Engineers considered most of their technical training to have occurred in school, and found most of their learning at Ford occurring in the area of the company's internal information and communication systems (such as accounting); and in learning to work in an environment with union regulations.

For technical aspects of their work, on-the-job training during launch occurred initially through a 'Dimensional Control Process', a technique used to improve design machinery to control aspects of the process, based on its interface with the dimensional requirements of the product. Engineers learned about the particular machinery in their area initially from vendors, but later learned on their own and with help from operators with more experience in the area. This was a complicated process since the information that engineers had to learn on-the-job was embodied in the machinery, which differed at each engine plant. These differences existed because each plant bought its own equipment by benchmarking the best processes available at the time of purchase. Engineers with a base of experience also had much to learn unassisted, since the plants were somewhat in competition with each other. This restricted available information prior to reassignment.

For the most part, engineers were expected to arrive on-the-job prepared as 'experienced hired hands'. Apart from the mandatory classroom training prior to the job, there was no formal induction program for engineers to the shop-floor, nor were there mentorship programs. Each team introduced engineers to their jobs in their own way. In a conventional Manufacturing Engineering department, engineers had access to a Career Development handbook that outlined expectations of backgrounds for people considered for executive roles. But at Romeo, because engineers' experience of the shop-floor was unconventional, their career paths were less well defined.

The engineering section of the Power Train division offered special training programs; some rotated college recruits internally, and others assigned recruits to departments for specialized training. These programs, however, were the responsibility of the plant manager, both outside of the division and within its plants.

Launch period training was intended to build a base of expertise that could diffuse throughout the workforce. But this program did not account for the working conditions at Ford, characterized by high internal turnover. Engineers rotated within Romeo, partly because of the plant's policy for job rotation (for those being groomed for higher positions), and also because of promotions and 'raiding' from other Ford plants to obtain experienced personnel for their own launch programs. On an individual level as well, people were motivated to rotate on the implicit belief that they needed to demonstrate performance in different environments such as machining and assembly, to qualify for management and other advanced positions. As many as 50% of the salaried workforce changed jobs a year after launch.

Similarly, the base of expertise in production workers was also difficult to build. According to UAW contract rules, those production workers with more experience could have priority in work shifts. Often a single displacement would trigger others. Consequently, the locus of production knowledge varied from team to team: in some teams engineers were spending most of their time training new team members, and in others, production workers remarked that *they* were training the transient team managers and engineers. Engineers for the most part learned on-the-job.

In terms of classroom training, however, the hourly workforce at Romeo was among the best-trained in Ford, having attended the mandatory training program, along with programs of enrichment in mathematics. Romeo's program for the hourly workforce was more than double the level typically offered at other Ford plants where operators received training only in safety at the plant level.

Romeo's system of on-the-job training was the responsibility of individuals and their supervisors, and highly dependent on circumstance. Engineers at Romeo learned their areas of responsibility by being told to 'do it'. International experience was not common: an estimated 5% of engineers had worked abroad, mostly in Mexico and Canada.

TRAINING OF MANUFACTURING ENGINEERS AT NISSAN

Nissan's engine plant in Yokohama was part of a larger production complex comprised of a casting plant, forging plant and sintering operation, as well as axle and transmission facilities that had been in operation since 1935. The engine department alone employed 875 production workers who were supported by complex-wide staff. Additionally, there were 550 part-time workers, but this number fluctuated depending on the needs of production. Plant Maintenance (852 people) and Plant Engineering personnel (194 engineers) complete the list of employees. The engine department made three basic types of engines: a V6, S6 (straight or inline 5), and the V8 for the Fairlady Z, Pathfinder, Infiniti, Maxima and March/Micra models. They designed, prototyped and tested other models with launches occurring regularly every four years. From the Yokohama plant, production lines and technology were directly transferred from Japan to Aguascalientes Mexico on a scheduled basis. In contrast to training during launches at Ford, training of engineers at Nissan was part of an on-going program that was co-ordinated with the company's hiring schedule.

THE JOBS OF ENGINEERS

At Nissan, Plant Engineering was the functional equivalent of Manufacturing Engineering departments in a typical Ford plant; and employees would be comparable to Romeo's engineering team members. Of the 194 engineers in Plant Engineering, approximately 40 process engineers serviced the Yokohama engine plant, together with another twelve engineers from the inspection area, and equal numbers from gauge control in the Production Control Department, which includes machine maintenance, production scheduling and machine and tool purchasing. Engineers were college educated union members, reporting to support functions, with no supervisory authority. The shop-floor essentially ran itself: production workers were promoted from the bottommost rung to positions of supervision, and later to the non-union status of *katyo* (over 40-year-olds), responsible for entire machining and assembly areas. Engineers were in a separate but parallel career ladder, and were also union members until promotion to *katyo* at about age 40.

This production workforce was trained to perform many tasks associated with industrial engineering in the US, such as determining standard operations and analyzing performance. They were paid in part by their job rank (determined by skill), and in part with bonuses that were tied to corporate performance, such that incentives to improve skill levels were also strong.

Because the shop-floor ran itself, the work of engineers at Yokohama appeared to involve higher engineering content, the precise nature of which depended on experience. Young engineers (with less than five years' experience) were responsible for meeting improvement targets, which at the time of writing were 10% improvement in efficiency per year. Activities, such as experiments and drafting, consumed most of their day (two-thirds). For the remainder, they were found walking on the production floor helping to solve the more serious problems, often in consultation with maintenance workers and suppliers.

Senior engineers also spent some time on the line, but a greater part of their activity was directed to the overall improvement of quality and production efficiency over the longer term. They formulated annual business objectives and oversaw projects requiring 1–3 years, such as new production introduction. They were in contact with design engineers and the inspection department, production control as well as the managers of production areas to determine the feasibility of their ideas on the shop-floor. On a daily basis, representatives of these departments, mostly junior engineers, met to discuss the previous day's problems, and how to solve them; decisions for production improvement were made jointly, and involved mostly senior engineers. Further contact with shop-floor workers was through courses on machinery operation, quality and materials that senior engineers taught to their blue collar counterparts.

Manufacturing engineers were in contact with design engineers as far back as conceptualization. Design engineers first discuss their ideas with manufacturing engineers, then make drawings based on their input. Plant employees consider the feasibility of the performance standards proposed, and would respond with an estimation of performance in terms of work capacity and projected quality. Based on these interactions, the design department made a prototype and planned production trials which manufacturing engineers help implement.

OFF-THE-JOB AND ON-THE-JOB TRAINING AT NISSAN

Promotion of engineers required training and this was arranged by the personnel department which could adjust the curriculum to reflect the company's business goals. In 1992, for example, to improve the balance sheet, classes in cost reduction were added.

For internal training of professionals, each department planned the content of training given by the plants on site, but ensured that context was shared across site and throughout the company. For example, the machining section co-operated with machining areas company-wide to form curricula. Recent concerns to update and equalize skill levels company-wide had motivated the personnel and engineering department to jointly develop a formal program for all of Nissan's engineers. For the first five years, the goal was to develop professional engineers, and afterwards to cultivate their managerial ability and keep them abreast of the latest technologies. Classes were interspersed with on-the-job training as presented below.

THE FIVE-YEAR SEQUENCE

Engineers attended a two-week program before their jobs began and learned about the different functions of the company (from design and manufacture to sales), and then about engineering at Nissan in an intensive six-month program with experience in their particular department. In the case of engine production, a course may have covered topics such as 'How to machine', 'Standard operations' and 'Inspections', and was designed to ground their later experiences in design, production planning or other related departments. Courses could last from several hours to several days.

Within the first five years a total of nineteen classes related to processes in production were offered; their specific topics ranged from engine manufacture to courses about personal computers, CAE/CAD systems, patents, technical English, and technical presentations. Subsequent years repeated topics and introduced product planning and equipment control, and aspects of production control (cost, quality, statistics and equipment). Further tools to assess production (engineering economics, industrial engineering, reliability engineering, and layout methods) were covered in the third year, and new product introduction, methods for testing, system-wide problems (regulation, rust protection, environmental control, lubrication), and electronics technologies (sensor technology, circuits, mechatronics) would be taught in later years. Nissan's curriculum also revealed a sequential change in content from factual to evaluative, then to innovative and to a system-wide perspective.

By the end of this five-year program, engineers would supposedly understand manufacturing technology from the bottom-up, within and across each of the component processes, and become comfortable with problem-solving based on data analysis, having developed 'the mental attitude of technical people. (Problem-solving is done in a systematic and prescribed way; for every problem in production, engineers try to attribute causation to several categories of variation: man, machine, or material.)

The number of courses internally available for engineers (70) was smaller than Ford's but, because of the program's thorough implementation and repetition, the knowledge was broadly shared by all engineers. Training was also individually motivated as self-study (*zikokohai*) through correspondence and night schools was common.

On-the-job, a year and a half after joining the company, new engineers were assigned a *senpai* or mentor, who was responsible for a single person. The word *senpai* in a broad sense is anyone who is older and has more seniority in a company, school or in any other social context. Conventionally, it is assumed in Japan that older and more experienced people are to help those who are younger and with less experience. Helping is often considered a formal duty and responsibility. With experience, new engineers themselves become *senpai* and were correspondingly given specialized training for this role, taught pedagogy (how to teach), problem-solving and implementation of projects. Only after they had learned, and taught what they had learned, were they considered professionals, since teaching cemented their newly-acquired knowledge. Evaluations were based somewhat on how well engineers taught; and the higher one rose in the hierarchy, the greater were the training responsibilities entailed in their jobs. Training, in effect, served a double duty because students and future teachers were being trained in one step.

Along with the coursework given, assignments to different positions gradually formed a career path. Often engineers began their careers in machining and then rotated into engine assembly. Inspection and gauge control engineers often had experience in both areas, because of their even greater problem-solving complexity. Career paths involved a series of jobs with increasing problem-solving complexity. Rotations within a department were scheduled every three to five years.

The actual experience of Nissan's manufacturing engineers was contrary to the conventional beliefs about broad, cross-functional experience in Japanese companies. Engineers' experience typically narrowed considerably after the first two years of training and would usually be within a single department. Over time, engineers could experience all the areas *within* a department, a career path pattern that has been described by Koike [2] as 'breadth within a specialization'. This system of job rotation and experience contrasts with Hitachi, whose design engineers that are successful in developing new products are transferred from headquarters R&D into design departments in factories to supervise and assist in implementing their plans. The nature of electronics production, involving quick cycle times, lends itself more easily to this type of rotation than in engine production.

Rotations also occurred across departmental boundaries, particularly between areas that communicated with each other frequently. This type of rotation not only built expertise, but also improved interdepartmental relations. Only employees with the most promising careers (10%) were rotated between departments (*bu*) and were often explicitly told that their talent to accomplish projects across departments was an important consideration in their promotion. A surprisingly large number of international assignments were included in rotation: an estimated fifth of the engineering workforce had this experience.

Nissan's training through career paths would not be possible without its system of long-term, but not lifetime, employment that insured returns to training. People frequently received assignments that they did not like, but remained with the company in the hopes that their next assignment would be more desirable and that over the long-term, employment would be rewarding. The personnel department, through influencing job assignments, ensured that talent was evenly distributed company-wide.

Continuing technical education for Nissan's engineers was available through the newly established Nissan Technical Center (NTC) that offered thirty-three courses. Completion of all of the NTC courses facilitated an understanding of the entire range of electronics technology including physical hardware, programming, robotics applications, CAE system design, and factory-wide automation systems. Finally, there was exposure to applications in manufacturing and in automobile components (vehicle microprocessors, engines and instrumentation panels).

Apart from technical training, engineers were groomed for other duties as they progressed in their careers. They were instructed internally in some topics, such as finance, and patent law. Engineers cultivated communication skills through seminars on debating, and through making presentations about the products, parts and processes they would like to see developed. Presentations were seen to stimulate ideas on how to improve production (free consultation) as well as inspire engineers and their fellow employees. These multiple uses of training created greater benefits than the sum of the individual sessions. With further promotion, training from external providers and communication opportunities with other companies were included in the training process. After six to nine years of experience, engineers were trained for management positions in an organized, substantial fashion. A background in manufacturing management and participation in launch was apparently essential for Nissan's past presidents. This is true of other Japanese companies as well. Some members of the board of directors preferred to be called 'engineers' rather than board members.

Nissan's training for engineers was highly organized, blurring the traditional lines between off-the-job and on-the-job training through organizing on-the-job experiences with mentorships. Experiences were sequentially arranged based on problem-solving complexity. In this system, training was the responsibility of the corporation, rather than individuals, and part of corporate policy. A well-formulated training policy could spread uniformly good training company-wide.

LEARNING FROM OTHER NATIONAL INSTITUTIONS: GETTING HELP IN TRAINING

A hidden but significant influence on the training programs at Ford and Nissan was that of external institutions. In the case of Ford, these took the form of consultants who helped set up the new Team Management system, and programs in collaboration with universities. In fact, most of the engineers in the Power Train Division had become familiar with electronics technology through a joint Ford–Wayne State University Master's program designed by the Ford Car Products Development. Universities comprised a larger portion of external training providers, augmented by the frequent independent study of engineers completing coursework required to maintain professional society credentials, keep up with relevant computer technology, or to pursue business-related degrees.

Nissan received assistance in curriculum content and training program formation from large, private, non-profit-making organizations created solely to gather best-practice information and diffuse it among Japanese companies. Notable among them was the Japan Union of Scientists and Engineers (JUSE) whose influence on curriculum for engineers was primarily through the Deming prize. Plants competing for this prestigious national award underwent a rigorous review process and to improve their chances of winning, companies often sent their blue and white collar workers to JUSE courses, and requested on-site JUSE instruction. To a large extent, the widespread uniform implementation of quality control and shop floor training in Japan could be attributed to this organization. Instruction was intensive with ratios of one instructor to every two students. Also upgrading the electronics technology skills of Japanese engineers was the Advanced Technics Development Center established by the Japanese Government's Ministry of Labor. Instructional equipment included computer link-ups to satellites, miniature assembly lines that could be programmed for flexible manufacture of electronic goods, and assembly lines for completely automated factories supplied by robots.

COMPARISONS

Ford Romeo and Nissan Yokohama's engineers were organized differently and had different jobs. Romeo's engineers were involved to a greater extent in operational problem-solving and reported to production teams; Nissan engineers did more work on production improvements and reported to the engineering department. In part, this was the outcome of corporate policy regarding the organization of Romeo's engineers, but job differences were partially due to workforce motivation and skill. The skill-related job content differences were demonstrated even within the Ford connecting rod and block lines. In contrast to training during launches at Ford, training of engineers at Nissan was part of an on-going program that was co-ordinated with the company's hiring schedule.

Ford and Nissan took very different approaches to training their engineering workforce, that appeared to reflect different beliefs and orientations in training. If one assumes that training is an individual responsibility and a discrete process prior to job assignment, then individual decisions would ideally determine curricula. At Ford, training responsibilities were decentralized from headquarters to the plant manager level and, subsequently, to individual engineers and their supervisors, guided by the skills management process. Also, some responsibility for training was placed on external providers which, at Ford, were mostly universities. Romeo was unusual in the additional plant level training provided during launch, but most training was conducted prior to the job and within the proscribed timeframe of launch, and this method placed most of the responsibility for training on the individual. At Nissan, training was considered a corporate responsibility: classes that were taught externally at Ford were administered internally at Nissan. Structured along career paths and integrated with classes, training was continuous and interspersed throughout an engineer's career.

The two companies' approaches also differed on-the-job. At Ford, on-the-job training was up to the individual. The high volume of turnover made internal expertise difficult to build since on-the-job training was generally due to circumstances and learning by doing. At Nissan, on-the-job training was systematic: rotation was based on problem-solving complexity, and mentors who were experts who had just finished going through the same process.

With each engineer responsible for his/her own curriculum at Ford, there was much diversity in training backgrounds, encouraged by the diverse sources of training in-house and from consultants. Diverse sources of training appeared to enhance the tendency towards specialization (e.g. launch training specialists). Nissan's training policy, by contrast, appeared to form engineers whose background was narrower but more broadly shared: Nissan offered approximately 70 courses internally, compared to Ford's 1000 (with Ford's mostly on videotape). In part, the narrower and more uniform nature of Japanese offerings were explained by the assistance Nissan and other companies received from institutions such as the JUSE and the government.

With very different approaches to training, a question arises of what would happen when the attempt was made to transfer these approaches to Mexico.

TRANSFERABILITY OF TRAINING TO MEXICO: WORKERS' SKILL AND THE WORK OF ENGINEERS

One would expect that Ford and Nissan would try to replicate their methods of training abroad as closely as possible to preserve technological and product integrity. They *did* try, but some aspects of their systems were transferable and others were not.

In part, conditions unique to Mexico, such as the union structure, language, and high economic growth rate anticipating a US free trade agreement, affected transferability but offered similar opportunities and challenges to each company. Both companies faced a high employee turnover rate, with Ford Chihuahua (14%) less than Nissan Aguascalientes (70%).

Both companies' original training practices survived somewhat intact. Ford Chihuahua, like Romeo, was an entrepreneurial effort showing the same pattern of intensive pre-job training associated with new product launch, and lower amounts of organized on-the-job training. Nissan's training in Aguascalientes produced lines directly corresponding with those in Yokohama, and also showed the same pattern as in Japan: there was less intensive pre-job training, and comparatively more organized on-the-job training with increased guidance at all levels. Subsidiaries generally shared the effects of being in Mexico, with less access to resources, and less extensive course offerings than at headquarters.

What was not anticipated was the curious pattern of work and training distribution: engineers' work changed depending on the organization and skill level of the workforce which, in turn, depended somewhat on skills imparted through local education, and the incentives and limitations stipulated by union rules. Depending on this and corporate policy, engineers participated to varying degrees within the actual production line structure.

At Ford Romeo the workforce, largely from the tractor plant, was inexperienced. Engineers were put on production lines because of the complexity of problems encountered. A similar state of affairs existed at Ford Chihuahua but local union regulations allowed production workers to rise to the level of supervisor, and made it attractive to do so. Approximately half of the supervisors were engineers and half were from the production line and *técnico* (somewhat equal to the skilled trades in the US). But those higher up, overseeing production lines had engineering backgrounds.

At Nissan Aguascalientes, engineers were found higher up than at Ford plants, supervising entire areas, for example, all the machining lines rather than a single line, but still described their work as involving more problem-solving on the production floor and less related to new product introduction, compared to their Japanese counterparts. This does not mean that high school graduates were not found among salaried ranks in equivalent positions at Ford, but that the situation was much less common there. Incentives were not deliberately structured to encourage this type of internal career ladder at Ford to the same extent they were at Nissan.

Nissan Yokohama looked very different from the other three sites. There, engineers were definitely not part of the production line hierarchy. Positions through the level of supervising entire production areas, were occupied by high school graduates who had slowly risen through the ranks. Engineers were found only in the support functions such as Plant Engineering.

Production workers in Japan were found performing many of the functions of engineers in the other three plants: designing and testing prototypes, making and implementing standard operations, overseeing the launch of new equipment and products and establishing relations internally, and with suppliers, as well as managing lines. They were responsible for solving all but the most severe problems, and their work involved training, and writing training and machine manuals. Many had risen from the very bottom to become managers of all the plant's machining areas. (High school graduates in Japan are so well trained technically, that they have had the equivalent of one years' college math by the time they have graduated—even university graduates with law majors can and do act as engineers in Nissan's system.)

Blue collar talent (utilized at the level of line manager) was cultivated on-site at the Yokohama skill center where employees themselves built simple simulators to illustrate principles of hydraulics, and shop floor workers were seen writing programs to control robots. Company-wide programs also developed skills: within the plant, programs included licensing systems for each skill, special 'internships' in the industrial engineering department, and instruction from engineers. Within the company but outside of the plant, graduates of the Nissan Technical Center (NTC) two-year program were capable of building and converting production machinery from manual to electronic controls. At both Yokohama and NTC programs were intensive: the student/teacher ratio was between 2 and 8 to 1, but in programming classes, student to teacher ratios was even smaller, typically 3 to 1.

With workforce skill encouraged and cultivated to such a high level in Japan, engineers were spending more time in design and improvement and less in problem-solving of machine breakdowns. This aspect of Nissan's production system was difficult to transfer abroad because of local educational practices, union rules, higher turnover, and cultural aspects that resulted in a lower level of workforce skill. Even Nissan managers in the US encountered similar problems in replicating work content of their counterparts in Japan because they must spend more time 'fire fighting'. In Nissan's Mexican subsidiary, the disparity in workforce skill even caused the work of different departments to change: plant engineering, production control and inspection departments were actively involved in problem-solving, where in Japan, their activities were more closely linked with their specialty. Workforce skill and motivation were determining the jobs of managers and the work of engineers as well as the distribution of work between and within departments.

If the skill of shop-floor workers determines the work of engineers, then the degree to which this skill accumulates at all levels is critical. To some extent, skill development depends on a country's educational system as well as company training, since the success of this training is somewhat dependent on previous education. Higher skill levels allow a given plant to perform more sophisticated work and make better decisions with the same number of employees, since there is more time for engineering and analysis.

Koike [3] has written about methods of problem-solving in an integrated fashion depending on workforce skill, and ways in which both workers and engineers can participate in the process. Alternatively, in his separated system, workers perform simple, repetitive operations, while engineers perform more complicated problem-solving. To his notion, one may add the idea that problem-solving can be moved up, or upscaled. The types of problems treated by the entire workforce can be, as a whole, more sophisticated depending on blue collar skill and motivation.

IMPLICATIONS FOR ENGINEERING EDUCATION

Ford's program appeared to transfer easily to Mexico, both in terms of job content and associated training. Nissan's program appeared less easily copied. The high level of workforce skill in Japan was difficult to replicate in Mexico and appeared to cause large differences in training as well as job content of engineers. A higher level of workforce skill and motivation resulted in engineers performing more analytical tasks, while lower skill levels created more problem-solving tasks. Nissan's career structure, incentive systems, and internal training programs developed blue collar skills, affecting the tasks required of engineers.

Training variation depended in part on workforce motivation and skill. Additionally, training variation also appeared to be due more to education philosophy than inherent technology demands. The very different approaches of Ford and Nissan's programs for engineers reflected different answers to some of the classical education dilemmas of how knowledge is best conveyed, and how to balance aspects of training between corporate policy and individual discretion. Trade-offs in choice versus policy, diversity versus conformity, and experimentation versus standardization in training practices, were evident. Variation between Ford and Nissan also show different concepts of what is considered as training. Training in the US was often considered a period of investment to improve the quality of labor's output; as a process prior to production (and consequently most appropriate during launch). The two company's approaches to investment also affected the training of engineers: fluctuations in launch scheduling and associated fluctuations in personnel and competition among plants fostered more of a 'learn by doing' training style, and a group of launch training specialists. With policies for personnel rotation, co-operation among plants and scheduled launches, more knowledge could be effectively shared beween the plants internally, and a more systematized training program appeared possible. At Nissan, not only was there a broader scope of activities labeled training (mentorship, career paths), but training itself was multifunctional, multiplying the returns of investment. In such a context, the conventional belief in a trade-off between investment (training) and return (work) becomes less valid.

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