INDUSTRY STUDIES ASSOCIATION

INDUSTRY STUDIES ASSOCIATION
WORKING PAPER SERIES

Lean and Reflective Production:
The Dynamic Nature of Production Models

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2006
Industry Studies Association
Working Papers

WP-2006-05
http://isapapers.pitt.edu/

Toyota and its Toyota (a.k.a. ‘lean’) Production system, and Volvo and its ‘reflective production’ system are viewed as occupying opposite ends of the spectrum of production policies and practices (cf. Womack et al. 1990, Adler and Cole 1993, Sandberg 1995). The traditional Toyota Production System (TPS) has worked very well in attaining high levels of customer satisfaction -- a result of strong efforts at quality improvement, operational efficiency, and manufacturing flexibility to meet the demands of a highly competitive and diversified product market (cf. Ohno 1988, Womack et al. 1990, Fujimoto 1999, Pil and Macduffie 1999, Liker 2004). It placed less emphasis on employee satisfaction, the humanization of work, and the attractiveness of manufacturing jobs. Indeed, some suggest TPS attained superior organizational performance at the expense of employee well-being (cf. Fucini and Fucini 1990, Babson 1993). The Volvo reflective production model on the other hand, has aimed to enhance worker satisfaction and involvement (Ellegard et al. 1992, Berggren 1993, Sandberg 1995), some argue at the expense of organizational performance (cf. Adler and Cole 1993).

The tension between organizational performance and employee well-being contradicts the original conceptualization of these production models. In the case of Toyota, Sugimoro et al. noted that a key tenet of TPS is *respect* for humans, which includes ‘1) elimination of waste movements by workers; 2) consideration for workers’ safety; and 3) self display of workers’ capabilities by entrusting them with greater responsibility and authority’ (1977, p557) Gyllenhammar, the Volvo CEO who initiated the original reflective production efforts, argued it was critical that ‘work tasks become more meaningful and at the same time, ensuring that production becomes more efficient.’ (cited in Jonsson et al. 2004, p754). As we will show, significant external pressures have led both

Volvo and Toyota to reassess their production models with respect to organizational and employee outcomes, and search for a better balance between the two.

The last 15 years have seen growing international competition, increasingly demanding customers, shortening product life cycles, and extensive product proliferation (Holweg and Pil 2004). In the early 1990s, firms were also challenged on the labor front: labor shortages, union pressure regarding working conditions, demographic changes, and the shifting employment preferences of the young away from manufacturing. Against this backdrop, this paper compares the evolution in assembly models of Toyota and Volvo during the 1990s and into this century. The study is empirical and exploratory, but we believe the findings will facilitate renewed investigation of the multi-faceted and dynamic characteristics of production models that better satisfy both customers and employees.

We start with a brief overview of Toyota and Volvo's models as 'ideal types' as portrayed in the literature. Drawing on 12 full days of interviews and plant visits at Toyota and 11 days of interviews and plant visits at Volvo that we undertook over the last decade, we show that the production systems as enacted by Toyota and Volvo have undergone dramatic evolution, resulting in convergence in organizational structure, work design, and to a lesser extent, technology.

Toyota Production System – overview:

TPS, with its origins in the post-war history of the Japanese automobile producer consists of several intertwined practices that drive superior performance. These include Just-in-Time delivery of parts, Jidoka (the practice of stopping the line when defects are uncovered), Total Quality Control, and continuous improvement activities (Kaizen). Other elements include inventory reduction via Kanban; leveling of production volume and product mix (heijunka); reduction of 'muda' (non-value-adding activities), 'mura' (uneven pace of production) and ‘muri’ (excessive workload); production plans based on dealers' order volume (genryo seisan), on-the-spot inspection by direct workers (tsukurikomi); fool-proof prevention of defects (poka-yoke); real-time feedback of production troubles (andon); assembly line stop cord; emphasis on cleanliness, order, and discipline on the shop floor (5-S); quality control circles; standardized tools for quality improvement; worker involvement in preventive maintenance; reduction of process steps to save equipment, and so on. Spear and Bowen (1999), distill these practices into what they term the ‘DNA’ of the Toyota production system. Specifically, they highlight how many of Toyota’s practices center on hypothesis testing – the importance of the specification of content, sequence, timing, and outcomes for testing new ways of performing work. The coupling of documentation and its associated control, with testing and experimentation leads to what Adler and Borys (1996) term ‘enabling bureaucracy’ where formalization is an enabler rather than a source of coercion and compliance.

An array of HR practices supports TPS and is integral to its success (Pil and MacDuffie 1999). This includes stable employment of a core workforce; extensive training and development; internal promotion to supervisor; cooperative relationships with labor unions; pay for performance; and team based work. However, until recently, “respect” for employees was as much a by-product of TPS’s pursuit of higher productivity and quality as it was an end in itself.

Toyota’s basic manufacturing capabilities were fairly well articulated in the late 1970s. However, labor and product market demands brought pressure for change.

(1) Employment demands: A combination of structural and cyclical changes in Japan's labor market, made it increasingly difficult to hire and keep automotive production workers in the early 1990s. On the labor supply side, companies were faced with a rapidly

aging workforce. Younger workers increasingly sought jobs in other sectors of the economy, viewing manufacturing as '3-D' (dirty, demanding and dangerous). The expansion of Japan's automobile production peaked in 1990 (at 13.5 million units), placing strain on the demand side for labor. Faced with a severe labor shortage in 1990 and 1991, Toyota's union and management set in motion systematic efforts to enhance the attractiveness of assembly work. While a subsequent recession eliminated the labor shortage, these efforts continued.

(2) Product market demands: The 'bubble economy' era in the late 1980s was the final stage of 40 years of continuous growth in Japan's domestic automobile production. In the early 1990s the bubble burst and Japanese automotive production plummeted 25% from 1990 to 1995 with Toyota's sales dropping from 5.4 million units to 4.8 million units. Faced with lower demand, Toyota turned to enhanced responsiveness and flexibility to make itself robust to the fluctuating demand patterns, shortened product life cycles, and increased variety levels that are typical in matured auto markets (Pil and Holweg 2004). At a fundamental level, Toyota recognized that emphasis on level production in the factories, needed to be tempered with the real demand / pull of customers.

(3) Changes in strategic priority: The Japanese automakers enjoyed abundant cash flow in the late 1980s thanks to the bubble era. The companies also believed capital investments could be made at negligible cost by issuing convertible bonds when stock prices were soaring. Many auto manufacturers viewed massive capital investments as a solution to labor concerns. With the stock market collapse in the early 1990s, problems of cash flow shortages surfaced, and companies were forced to evaluate capital spending much more conservatively. Toyota faced these challenges from a position of strength that

permitted it to take the time and effort to re-evaluate its priorities and meet the environmental shifts independently, without recourse to a foreign partner.

Reflective production system -- overview

Volvo's first efforts at work redesign date back to the Kalmar assembly factory which opened in 1974. Vehicles in that plant were assembled in a cross between assembly lines and docking stations, with work cycles of 15-40 minutes per worker (Sandberg T. 1995). The vehicles were constructed by about 20 teams, with each team responsible for four to five stations. Some sub-assemblies were also constructed off the main line in more of a craft format by teams of workers.

In the mid-1980s, Volvo decided to build a new factory, and sought ideas on how to further enhance the attractiveness of assembly work. It wanted to design a plant that could effectively use workers representing all ages and both genders, including at least ¼ over age 45. In the resulting Uddevalla factory, teams of 8 to 12 built up complete vehicles in cycle times of two hours.

Both Kalmar and Uddevalla represent reflective production in its purest form (Ellegard et al. 1992, Berggren 1993, Sandberg 1995). However, key elements were also found in high volume Volvo plants at Torslanda (Sweden) and Gent (Belgium). Volvo's reflective production model is characterized by parallel work flow (and in the case of Uddevalla, no line at all), the professionalization of workers, low levels of multi-functional automation, naturally grouped assembly work, ergonomically sound production tasks, and flexible production levels. These are supported by long cycle times, special parts-delivery and order systems, self-managed team based activities, and extensive on-the-job training. Like at Toyota, labor and product market demands brought pressures for change.

(1) Employment demands: One of the driving factors for reflective production was a labor shortage coupled with extremely high levels of unplanned absenteeism. Reflective production provided conditions more amenable to individuals with diverse backgrounds and talents, and opportunities for worker development and self-actualization. It was hoped this would make production work more attractive. However, in the early 1990s, new legislation in Sweden resulted in a dramatic reduction in sick days. Unemployment rates rose from 2% in 1988-1990 to a record 18.2% in 1993. The labor market imperatives leading to reflective production were no longer present.

(2) Product market demands: In the late 1980s, there was tremendous demand for Volvo products. Volvo's production increased from just over 350 000 vehicles per year in 1983 to 423 000 in 1987. However, by 1991, when Uddevalla opened, worldwide competition in the near-luxury segment had escalated, and Volvo's production fell to 273 500 vehicles. This resulted in a board decision on November 1992 to shutter Uddevalla and Kalmar, leaving Volvo's higher volume assembly-line based plants to carry on. By 1994, total Volvo production had fallen to 257 000 vehicles per year, forcing the company to shift its attention to meeting customer demands. Volvo decided that focusing on enhancing unit revenue was critical as volumes were too low to permit the minimization of unit cost. The outcome was a major emphasis on understanding and meeting shifts in customer needs, and ultimately, moving to customer-ordered production.

(3) Changes in strategic priority: In the early 1990s, Volvo and Renault announced plans to merge their operations. While the merger did not go through, initial information exchange between the two highlighted for Volvo fundamental differences in production philosophy and it is believed by some that these drove Volvo management to re-evaluate work design (Sandberg 1995). One unequivocal outcome was greater emphasis on

productivity and quality – an emphasis further re-enforced in Volvo's merger with Ford (Van Hootegem et al. 2004).

The synopses of work practices at Uddevalla often read like a post-mortem (Sandberg 1995, Adler and Cole 1994), but there has also been extensive debate on Uddevalla's suitability as a model for future assembly designs (Ellegard et al. 1992, Berggren 1993, Adler and Cole 1993, Shimokawa et al. 1997). A clear way to assess the reflective production model more generally is to look at Volvo's practices today and how they have evolved over time[*].

New production concepts

The production models of Toyota and Volvo have evolved significantly since the early 1990s. The changes are most easily assessed in the assembly area where the components are installed on the painted metal body shell. For Toyota, the evolution in thinking was first visible in its new Miyata Plant of Toyota Motor Kyushu Inc. established in late 1992 (henceforth Kyushu Plant for simplicity). The new assembly concept has diffused to subsequent plants including the Motomachi RAV4 assembly line (renovated in 1994), the Toyota Motor Manufacturing #2 line in Kentucky, US (TMM II, new in 1994) and from there to the full set of plants.

In the case of Volvo, innovations and modifications in thinking since the closure of the original Uddevalla plant are more diffuse. We will be focusing primarily on Volvo's

[*] Uddevalla reopened in January 1995 under a joint venture between Volvo and Tom Walkenshaw Racing. By spring of 1997 the plant was back in operation with 660 employees. In week 47 when we first visited after the re-opening, it produced 125 cars per week. The layout was similar to what it had been at closure, but teams no longer built up the whole vehicle. These were built up in two main phases, with a third stage for processes that were automated. Volvo eventually dropped TWR as a partner, and eliminated dock vehicle build in favor of an assembly line in 2002. Currently the plant is owned by a joint venture between Pininfarina and Volvo.

two remaining automobile factories: Volvo Torslanda (Sweden), and Volvo Gent (Belgium). We will also draw on insights from several visits we undertook to Volvo Uddevalla, both while it was engaged in stationary build, and after it introduced an assembly line. Volvo had another facility in the Netherlands until the late 1990s, but that facility also produced Mitsubishi products, and was sold.

We will examine in detail the evolution in production system characteristics that historically represented key areas of divergence between Toyota and Volvo and their respective emphasis on customer satisfaction and employee satisfaction: Assembly line design and related assembly philosophy, team activities and team member roles and skills, related HR practices and policies, ergonomics, and automation.

Line work and functionally autonomous processes

A primary hallmark of Volvo's reflective production system was the elimination of single flow assembly line work in favor of parallel work in docking stations where cycle times are long, and work content and process follows a holistic approach to vehicle assembly. Parts were grouped in relation to their function and position on the vehicle, and work was designed to give workers complete control over the production of a sub-system or functionally coherent portion of the vehicle. This was expected to enhance worker involvement, skill development, and understanding of and commitment to the work tasks. At Toyota in contrast, the emphasis in the 1970s and 1980s was on a Ford-style moving assembly line, divided into three main areas: trim, chassis, and final assembly. There were no buffer stocks in the line – a taut system helped enhance productivity, reduce inventory carrying costs, and forced problems to surface. Work tasks were broken down into elemental components and distributed across workers to minimize non-value added time in the 1-2 minute cycle times that were the norm. As a result, many workers were assigned mutually unrelated and inherently meaningless sets of tasks in efforts to optimize line balance and minimize non-value added activities.

While Toyota plants still use an assembly line, line design and use have changed dramatically. Starting with the Toyota Kyushu plant, and at all subsequent renovations at other plants, Toyota has subdivided the assembly line into segments (typically 10 or 12). Each segment contains 20 workstations, corresponding to a group of about 20 workers reporting to one supervisor. Sets of functionally related assembly tasks are assigned to each segment (e.g. piping). This creates group-level task identity. Group cohesiveness is furthered by a dedicated group meeting area for each subsection, training center, and Andon boards showing the group's performance. Functionally grouping work enhances group identity, but also simplifies the trace-back of quality defects to their root cause and the rapid feedback loops further enhance identity. Segments have independent line speed control and are linked by a buffer zone where up to five vehicles in process can be stored temporarily. This makes line segments semi-independent, and allows them to experiment with line balancing and work allocation without directly impacting the remainder of the organization. This brings back the original Toyota emphasis on 'respect for humans' '…where workers are allowed to display in full their capabilities through active participation in running and improving their own workshops…' (Sugimori et al. 1977, p554). At the individual level, line segmentation makes workers more comfortable in stopping the line – a practice that had become increasingly uncommon, yet was conceptualized as a key driver of worker independence in the original Toyota model.

A second fundamental change in work design is 'parts-complete' (buhin-kanketsu) assembly, where the assembly of a given component needs to be undertaken by a single worker. This is a major departure from the focus on value-added activity in the 1980s and early 1990s, and was a key factor in increased worker satisfaction. However, the extent of parts-complete assembly is still constrained by very short cycle times.

While there are efforts to create worker identity and provide some degree of group autonomy, Toyota continues the emphasis on variability reduction, standard operating procedures, and documentation of practice (Adler and Borys 1996, Fujimoto 1999). Borrowing from models established decades ago by the American *Training Within Industry* initiative, workers are taught how to participate in developing standard operating procedures (Dinero 2005).

At Volvo in Torslanda, a similarly long assembly line was subdivided to create 12 segments. Each segment has two teams and one supervisor. The idea behind the segments, like at Toyota, was to create group cohesion within the supervisory group. Like at Toyota, there are several cars between line segments. While workers have a button they can push when they encounter a problem, there is less of a norm of stopping the line if a problem occurs. At Toyota, the line stops in a particular segment if the problem is not resolved in the normal cycle time of one-two minutes. At Torslanda, there was an emphasis to keep the line moving: unless a problem is not solved in five minutes, the line does not stop. In Gent, production workers cannot stop the line at all. While the involvement of team leaders and the ability to stop the line is present at Torslanda, there are no group-level Andon boards and less group autonomy and control. As we will see in the next section, however, the extensive development efforts and incentives geared at teams as well as individuals compensate for the lower emphasis on group autonomy. Furthermore, while tools like Andon boards at Toyota are an effective means to publicly broadcast production information and problems to groups, one of their key features is to delineate responsibility.

In the case of Volvo, many of the team-related responsibilities provide a direct means for the teams to understand their role in problem resolution, and to take on a structured role and responsibility to prevent the recurrence of problems.

The typical working time on the vehicle for production workers on Torslanda's main line is two minutes. However, there has been a long-standing practice to make assembly tasks of individual workers coherent (to have workers install a whole component, or do a complete and coherent activity on the vehicle). However, unlike at Toyota, at Volvo Torslanda, some workers follow the vehicle across multiple work stations to complete their tasks. Thus, the main line of Torslanda has parallel work embedded in it (multiple workers need to perform the same task if it exceeds the standard cycle time). In the original reflective production model, individuals' work tasks were so extensive that problems were idiosyncratic in both character and origin. Such problems are inherently difficult to resolve. A more scripted approach to parts complete assembly enables the company to retain some of the motivational aspects of the original reflective production model, but resulting quality issues are more systematic in nature, and root causes are more easily traced.

One of the outcomes of the changes at both Toyota and Volvo is that the pressures around both customer responsiveness and employee engagement in process improvement, have led the firms to converge on a production framework that is fundamentally novel. While they started from a different position, the two firms have converged on a model that entails segmented line production, coupled with multiple related task assignment (see Table 1).

Insert Table 1 about here

Team work and small group activities

One of the hallmarks of reflective production is its reliance on teamwork, along with extensive individual skill development. At Volvo's Uddevalla plant, teams originally consisted of 8 to 12 workers who collectively did the assembly of whole vehicles. There were various team roles that were developed. These included team representative, quality, responsibility for tools, and so forth. Team members rotated through these roles as they developed additional skills. The team structure at Torslanda is very similar to that used at Uddevalla in the early 1990s. Each team has between 10 and 15 members. Team members take on key specialist functions: Maintenance, line balancing, product quality, development and training, personnel, team leader... In conjunction with their supervisors, workers request to become a specialist in a particular area (team leaders are elected). After a few weeks of training, workers help their team in the area that they specialized in. Some workers learn more than one specialty, but only perform one within the team. Not all choose to become specialists. In particular, older workers are reluctant to take on additional tasks, and many hold no specialty.

At the end of the 1990s, Volvo Gent's annual employee survey suggested production workers sought a broader role within the assembly plant. The factory decided to push the team concept a step further. Specialties vary from team to team and depend on the team's tasks and roles. All workers have at least one specialty. Unlike in Torslanda where the goal is to have a person with each specialty per team, at Gent, the goal is to develop a pair of individuals in each team per specialty to ensure continuity in the presence of turnover or absenteeism. However, Gent adopted Torslanda's competency management system to track skills in its workforce. Training is customized based on discussions between team leaders and team members. Indirect tasks, such as safety, which were once the purview of specialized units are integrated into the team structures. In the past, particularly at Uddevalla, there was quite a bit of rotation within teams as members took turns at different specialist functions. This was viewed as suboptimal from an efficiency standpoint. While team size in Gent and Sweden are similar, the teams in Gent are broken down into sub-groups that have about five members who perform systematic rotation. Each team is overstaffed by one or two people. In addition to unscheduled absenteeism, these provide relief so that each team member gets at least two hours every other week to work on their specialty.

At Toyota, teams originally consisted of five members and a team leader who was appointed by management. Toyota cut the team leader function in its Japanese factories, shifting to a group structure corresponding to the line sub-segments described above. These groups collectively take on tasks that would be undertaken by a 'specialist' team member at Volvo. For example, at Toyota line-balancing efforts are undertaken as a group. However, changes in the standard operating procedures need to be approved from higher up. While process engineering at Volvo develops standard operating procedures, workers have more leeway to alter how they perform their tasks, and one of the team members specifically works on line balancing. When changes are proposed from higher up, workers have to approve the changes. The direct involvement of the on-line teams in balancing loads is useful in helping the plants manage greater variety and shifts to building to customer order[†].

[††] Some suggest that stationary build permits plants to handle greater variety than a traditional assembly line (Jonsson et al. 2004). This may be technically true, but variety places tremendous demands on worker skill development that may be hard to meet in stationary build. For example, when Uddevalla was building two different products in the late 1990s, we found that 20% of stations were only able to handle one product because of insufficient worker skill. Given the six months required for worker skill development, coupled with shorter product life cycles, this is a significant issue.

There is some debate in the academic literature whether short-cycle times allow workers to develop deep skills (Fucini and Fucini 1990, Rinehart et al. 1997). However, others argue that skill development is critical. As Liker noted, ‘The Toyota way preaches that the worker is the most valuable resource – not just a pair of hands taking orders, but an analyst and problem solver’ (p145). De Treville and Antonakis note that while on-line skills may be easy to learn, the problem solving and continuous improvement efforts require expansion of workforce skill and knowledge (2006). New at Toyota is a system to evaluate and formally certify individual skill levels. The new skills system, implemented in the early 1990s, consists of four levels -- each requiring progressively greater skill and seniority. The goal of systematically tracking and codifying skill was to broaden worker skills and create systematic training programs. The work life plans that result give the workers a series of goals to meet, and a reward to more senior workers that may not be promoted to group leader. In many ways, this is similar to Volvo’s system of specialties that provides workers with a means to grow and broaden their skills and provide them with something akin to a career. It also provides the company with the means to track and evaluate where skills reside.

There is a convergence towards the Toyota conceptualization that worker involvement in standardizing work generates enabling bureaucracy (Adler and Borys 1996). Workers have ownership and involvement in the process of standardization and are given the tools for such involvement. As observed by de Treville and Antonakis (2006), ‘responsible autonomy is less related to whether the worker can operate without constraints and more related to the degree to which the worker plays an active role in setting the rules by which he or she is bound and whether these rules are congruent with the worker’s reasoning’ (p110). The formal skill development and tracking, emphasized at Volvo, and now also at Toyota, ensure that capacity-building for deep engagement with the process of variability reduction, and documentation of best practice is routinized. Group-level autonomy and feedback further strengthens and leverages this collective expertise distributed in the group.

Supporting HRM policies

Both Toyota and Volvo have substantively altered some of their supporting HR policies and practices associated with their production models to meet the changes in their labor markets and product markets. We will look at two in detail: working time and compensation systems.

It was extremely difficult in the late 1980s for Volvo to find new workers. The high skill demands on employees made work more interesting but also made it is harder to utilize temporary labor in the production process. The difficulties arising from not being able to use temporary workers were amplified as Volvo shifted to building vehicles to order (it now builds almost all its product within Europe to order). Numerical flexibility became a necessity and Volvo introduced flextime arrangements at the Gent and Uddevalla factories. At the Uddevalla factory, for example, which built a convertible (sales of which are highly season dependent), management could fluctuate working hours by up to 10% (185 hours) per year, with a maximum of two hours per day. At the end of each year, the balance was checked and any excess hours worked had to be paid in cash. Overtime deficits had to be settled in four years. While the hours banks provide significant flexibility, it was not enough for Volvo Gent which had to rely upon temporary workers to manage new product introductions in 2004 (Van Hootegem et al. 2004).

Toyota too started with a desire to secure a stable workforce, and switched to a continuous two-shift system. The system, in which day shift and night shift are conducted back to back so that the second shift ends at midnight, was introduced in Toyota's assembly plants in 1995[‡]. Moving to the continuous two shift enabled female workers to work the shifts on a rotation basis (midnight work by female workers is banned by law), and made assembly work more friendly to aged workers. While this provided Toyota with greater flexibility in meeting the employment shortages on the hiring side, it radically reduced flexibility to expand production through overtime because the shifts run back to back. Toyota believes it may have given up too much flexibility and has shifted to an extensive use of temporary workers. In some factories a third of the production workforce in the assembly area has temporary status. This makes job rotation harder. Furthermore, because temporary workers often have lower skill, Toyota has had to re-introduce quality gates in some of its assembly processes.

In an effort to improve product quality, Volvo in Sweden introduced a bonus system of 15 Swedish crowns (~2 US$) per hour based on individual, team, and plant performance. All individuals are responsible for their quality, and place a personal stamp on a manifest indicating what operations they performed. If quality problems are found, they lose the individual portion of the bonus pay. The Gent plant has resisted the shift to pay for performance on the basis that workers should be doing all they can to ensure top quality and productivity. The threat of being an overseas location of the parent company leads workers to believe their continued employment depends in part on exceeding Swedish performance.

Toyota too has altered its compensation system – away from bonuses. In the 1980s, productivity levels were extremely important and individuals and groups were evaluated

[‡] The Toyota Kyushu Miyata plant adopted this shift pattern from its inception.

based on their performance relative to engineering targets (called the coefficient of production remuneration or CPR). However, this engendered a lot of employee dissatisfaction. One of the first changes for Toyota was to develop goals based on actual data gathered three months after product launch, rather than projections (Shimizu 1995). Data is now pooled across multiple plants, permitting more systematic comparisons and learning. The importance of productivity in the payment system has been reduced to a third of its original level, and was replaced by a system that ties a bonus into cost, quality, and safety metrics.

Ergonomics and work environment

The overall ambiance at Uddevalla in terms of lighting and noise levels is dramatically lower than at any other assembly plant we have visited, and its stunning seaside location is hard to beat. However, there have been dramatic efforts to improve the general work environment at Volvo Torslanda as well – particularly on the noise and lighting front. At Toyota, general work environment traditionally has not been an important consideration. However, in efforts to enhance the appeal of manufacturing jobs to potential employees who like the work environment associated with the service sector, Toyota felt a need to invest significant resources to enhance the ambiance of its factories. Toyota's Kyushu factory is a beautiful facility striving for ‘harmony between people, society, and nature’. The buildings, located on a plateau overlooking the harbor, are painted light grey and white tones on the outside, and are surrounded by a large ditch to contain vibration and any potentially harmful run-off. Inside the facility there is tremendous effort to contain and reduce noise and vibration, and to enhance the lighting.

These include, for example, the isolation of the foundations of stamping equipment from the rest of the factory floor, low-noise power tools, and low-noise roller-friction conveyors.

As important as the overall work environment are the ergonomic conditions of the assembly work itself. Volvo has always had strong concern for ergonomic implications of work. One of the drivers of the original efforts at reflective production was enhanced ergonomics. It was believed that if workers had a more varied set of tasks to perform, the likelihood of repetitive strain injuries would be dramatically reduced. At plants like Torslanda, which retain a main line, workers rotate jobs approximately every two hours to reduce repetitive strain injuries. Furthermore, there is extensive use of lifter and other 'automation assist' (MacDuffie and Pil 1997) equipment to reduce exertion and the likelihood of injury.

More fundamentally, Volvo was quite early to redesign its overall products and production process to improve the overall ergonomic character of assembly worker tasks. Thus, it was one of the first companies to completely separate out power train from vehicle assembly. Engines, transmissions, struts, fuel and brake lines, fuel tank, exhaust systems, and so forth are all built up on one platform, and then are lifted up into the vehicle. This eliminates the overhead work that is usually required for these installation activities. Toyota did not adopt this practice until the opening of the Toyota Kyushu factory in 1992.

Volvo's approach has been to fundamentally alter or redesign whole vehicle sub-systems and processes to eradicate ergonomically awkward work, and it involves production workers at the design stage to help it this effort (Munck-Ulfsfalt et al. 2003). However, it was not until the fall of 1998 that it started to systematically analyze individual jobs and associated tasks with the goal of redesigning or re-distributing tasks to enhance ergonomics. Using a system called Ergosam it is classifying all tasks into one of three categories: ergonomically unsound, ergonomically problematic, and no ergonomic problems. These categories are based on a detailed analysis of movements and loads undertaken in the task. This detailed analysis of workstations matches Toyota's approach.

At Toyota, the issue of ergonomics has never had the level of attention that it has received at Volvo. Indeed, Toyota was cited by OSHA for ergonomic problems at its NUMMI factory when it introduced a new car model in 1993 (see Adler et al. 1997). In the early 1990s Toyota created a measure known as TVAL ('Toyota Verification of Assembly Line'), to analyze the work load of each assembly job quantitatively (see Niimi and Matsudaira 1997 for details). Based on experiments, Toyota evaluates work posture and load, along with task duration at each workstation. TVAL enables process planners to identify physically demanding jobs in an objective manner, prioritize the work stations to be improved, and concentrate efforts for improvements where they will have the greatest effect. Changes include low-cost automation assist, height adjustable conveyors, power assist devices, and distribution of high-strain tasks. Job rotation also became more common, with a 2-hour rotating pattern becoming the norm at Toyota Kyushu in 1995. While Toyota improves the ergonomic character of specific tasks, it does not approach Volvo's long-standing efforts to fundamentally alter production processes and product designs to systemically reduce ergonomic loads.

Automation

In automobile assembly the trend in the 1980s was to go for complete automation of assembly processes where automation made sense for either quality or labor content reasons. However, automating assembly processes is expensive and space intensive, often artificially segmenting and breaking the flow of the assembly lines. A further outcome of large-scale assembly automation is monotonous and meaningless ‘residual work’ (Jurgens et al. 1986), and there is little role for direct workers in either the operation or maintenance of equipment, or in process improvement (Kawamura et al. 1993). Toyota used innovative alternatives to full automation in an effort to broaden and enhance the work tasks of line workers. In contrast, Volvo focused its efforts on better optimizing the interface between traditional equipment and the line worker.

Starting with its Kyushu factory, Toyota abandoned full automation efforts in assembly, focusing instead on ‘in-line mechanical’ automation. This automation consists of equipment and component jig-pallets synchronized with the auto bodies moving on the conventional continuous conveyers. This permits automation zones and manual assembly zones to coexist on the same assembly line. With in-line automation, mechanical methods of alignment between auto bodies, jigs, equipment and component are used to the extent possible instead of sophisticated methods like vision sensing technologies. Because mechanical methods are less expensive, simpler, and easier to monitor and fix, production workers can take over responsibility from maintenance staff. The equipment is also designed to complement rather than substitute for, production workers’ assembly tasks. For example, in the case of under-body bolting equipment, a worker sets parts and positions bolts, which are then tightened to the proper torque by in-line equipment.

At Volvo, automated sections are isolated from the main production line and run at higher speeds to compensate for breakdowns. While there have been no major changes in the type and location of equipment on the line, there have been significant efforts to integrate maintenance tasks into production worker activities. At Torslanda, this takes the form of a team-member specialty. At the Volvo Gent factory, the changes in the relationship between line workers and automation is even more systematic with some maintenance work incorporated into all production worker tasks. This has lead to a sharp reduction in the number of maintenance workers in the plant. Even more significant are changes on the supervisory side where supervisory and technical roles are being combined into one. These new supervisor/technicians in the body shop at Volvo Gent play a supervisory role for a smaller group of people and are responsible for the technical aspects of the area that group works in. Thus, effort to expand and amplify the role of workers is not limited to production workers, but is extending to the management level.

Insert table 2 about here

Discussion

Toyota and Volvo have been used as exemplars for two extremes in production choices. However, their operations no longer reflect those extremes. Indeed, as shown in Table 2, the two companies have converged in their practices and policies on multiple fronts. Important differences do remain. Volvo continues to have some very long cycle operations, and has more experience than Toyota with the concepts of natural learning and whole work. Toyota has more experience in fine-tuning individual tasks and in using group activities for that and other purposes. It has followed Volvo in certifying worker skill, but Volvo continues to be the company that places more emphasis on the professionalization of the individual. Volvo further provides structured relief time so individual workers can systematically go off-line to engage in their off-line specialties. Interestingly, the low unemployment and very high demand for cars that inspired Volvo to implement the reflective production model are the same conditions that inspired Toyota in the early 1990s to adopt elements of that model. Changes in those conditions for Volvo –

dramatic reductions in demand, and high levels of unemployment, were drivers pushing Volvo to move rapidly in the direction of Toyota's traditional production system[§].

While we have highlighted some of the external elements driving the change, there are other pressures we have not discussed. For example, the shift away from dock-build at Volvo is mirrored by a broader shift away from stationary build in the Swedish economy more generally (Jonsson et al. 2004). In Japan, many companies launched innovative factories to deal with the labor challenges (for example, Honda Suzuka, Mazda Hofu, and Nissan Kyushu). However, these all placed a great reliance on high automation levels, rather than the more integrative approach of balancing traditional performance metrics with greater worker engagement and involvement. While we have placed great emphasis on environmental pressures, it should be noted that firm specific factors also played very important roles. For example, Ford ownership of Volvo played a role in the greater push for manufacturing efficiency (Van Hootegem et al. 2004). Likewise, at Toyota, the union played a critically important role in early 1990 in directing management's attention to worker well-being.

The reflective production as it was originally envisioned for Kalmar and Uddevalla has evolved significantly, and will continue to do so. Similarly, the Toyota production system of today is not that envisioned by Taiichi Ohno and Eiji Toyoda. Their once diametrically opposed customer driven and employee driven systems are converging at the level of work practices, operations, and technology, if not theories and principles. As various authors have pointed out, it would be tautological to claim that the capabilities of

[§] It is not clear whether Toyota consciously imitated key aspects of Volvo's reflective production model. According to some executives we have spoken with, that has not been the case. Volvo, on the other hand, has been learning from TPS, even if sometimes indirectly through participation in industry benchmarking activities, and via its joint venture car manufacturing operation with Mitsubishi in the Netherlands. This experience dispelled many of its prejudices about the negative aspects of lean production.

organizations are best identified via their performance (Priem and Butler 2001). Rather, the capabilities are reflected in the dynamic evolution in practice that firms undertake when faced with increasing pressures from both the product and labor markets. That is not to say that performance does not matter. Toyota, as early as the 1970s was more efficient than US plants by a factor of 2 to 1, and almost 3 to 1 in relation to a Swedish factory (Sugimori et al. 1977). While Toyota's practices have evolved dramatically, from a performance standpoint, Toyota continues to gain market share, and exhibits on-going robust financial performance (Fujimoto 1999, Spear and Bowen 1999, Shah and Ward 2003). Volvo too is currently a shining light in Ford's portfolio. However, in the case of Volvo, there is on-going debate as to whether the shift away from dock-based production was a poor choice from a performance standpoint. Indeed, there are academic arguments suggesting that parallel flow required less material handling, and resulted in superior quality (Jonsson et al. 2004). Our data collection efforts at Uddevalla suggest a different story. At 15 hours of direct labor to assemble a vehicle after years of experience with the model, the dock model as it was used in the second half of the 1990s was not efficient. Furthermore, more than 10% of the total factory employee base was involved in picking parts to support the team-based build (in addition to direct labor). By the factory's own metrics, productivity improved by over 20% after the initial introduction of an assembly line, coupled with the team-structures, skill distribution, etc., found at Gent and Torslanda. Quality levels initially were similar, but the standard deviation on quality issues was much lower, suggesting greater opportunity for improvement. We conducted employee surveys, both before and after the change-over, and found that while workers reported a reduction in freedom regarding pace (expected given the line pacing), there was no significant reduction in job satisfaction. This is in line with the observation by de Treville and

Antonakis that “the positive impact of a high feedback-responsibility-low choice configuration on intrinsic motivation might be greater than a low feedback-responsibility – high-choice configuration” (2006, p116).

The evolution in practice at Volvo has had beneficial outcomes. There are nevertheless parts of that model as originally conceived that could add further value. For example, Medbo describes how material kitting can enhance value-added activities and can help workers better understand their work (2003). Toyota has recently started kitting smaller components and sending the kits down the line with the vehicle as it is being assembled. This has reduced non-value added time, and has helped Toyota cope with increasing variety.

Companies, as well as academics, that rely on Toyota and Volvo as template organizations for two different production systems will need to recast their thinking to encompass the dynamic characteristics of these two ‘model’ companies, and the evolving nature of environmental pressures. The strength of production models lies not in understanding how tightly interwoven systems of practices interact in synergistic ways. Rather, it rests on the ability to leverage that understanding in a directed manner to identify novel changes in practice to meet evolving environmental demands. In the case of Toyota, the novel approaches come together at Toyota Kyushu. However, many of the elements emerged individually at other factories. For example, the Toyota Motomachi plant experimented with parts-complete assembly in the 1980s. Toyota’s Kentucky facility had short line segments from the start. Similarly, while Volvo Uddevalla is often considered the prototype for Volvo’s parallel and reflective production model, many valuable insights were garnered at Gent and Torslanda. The result was new models of skill development and team work that ultimately made their way into Uddevalla in its final existence as a Volvo-owned facility.

As Teece et al., note, a key challenge for studying successful organizations is that their dynamic capabilities facilitate a continuous evolution and reconfiguration in resources and capabilities as they react to shifting environmental demands (1997). It has been argued that these dynamic capabilities can lead to equifinality in outcomes (cf. Eisenhardt and Martin 2000). We show that in the case of Volvo and Toyota, equifinality was the result of convergence in systems rather than the outcome of divergent practices – Systems that integrate key benefits from both the reflective and TPS models. This includes developing and leveraging the adaptability, motivation, and unique abilities of workers at the individual and group level, while building organizational capacity for responsiveness, variability reduction, and innovation.

Competitive pressures, including the need for flexibility and responsiveness, continue to evolve. Furthermore, Toyota and Volvo are facing a number of new issues such as changing relations with suppliers, evolving product architectures, new customer value propositions, the role of non-core labor, etc. We have highlighted the critical importance of considering the dynamic character of production models in academic research. However, only time will tell whether the convergence in systems between Toyota and Volvo persists, or represents a common way-station as each continues to evolve.

Acknowledgments:

This research was supported by the MIT International Motor Vehicle Program and the Alfred P. Sloan Foundation (grant #B2001-49).

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Table 1: Task assignment and line structure: Volvo – Toyota convergence

	Single Task Assignment	**Multiple Unrelated Task Assignment**	**Multiple Related Task Assignment**
Continuous line	Big 3 (1970s)	Toyota 1980s Most Japanese today Some Big 3 plants today	Volvo Torslanda early 1990s (along with Booth build for sub assemblies)
Segmented Buffered Lines		Most European today Some Big 3 plants today	***Toyota Today*** ***Volvo Today***
Booth Build	Pre-Ford (assembly gang)		Craft System Volvo Uddevalla late 1990s (pre- line) Mercedes Ratstatt mid 1990s

Table 2: Evolution in key parameters of lean and reflective production

	Toyota Original	**Toyota Revised**	**Volvo Original**	**Volvo Revised**	**Convergence?**
Assembly line	Long assembly lines broken into three main areas	Assembly line broken into multiple segments -- correspond to supervisor group. Functionally related work brought together in each segment	Elimination of line in some instances, and great emphasis on docking stations	Emphasis on line work. Supervisor groups correspond to line segments. Removal of docking stations in most areas	Yes
buffers	No in-process buffers	In-line buffers used to create group autonomy	Buffers develop naturally between stations	In-line buffers exist but rarely used to enhance autonomy	Yes - although usage differs
cycle time	Short (1-2 minute) cycle times	Short cycle time	Long cycle times – up to two hours	Short cycle times except where in-line work spans stations	Yes
task coherence	Work tasks based on balancing and minimizing non-value-added	Parts-complete assembly *within* cycle time for individual; move to holistic and coherent work at group level	Tasks based on notion of 'holistic' work	Parts complete assembly, at individual level, even if requires more than one station	Yes - although Volvo goes further in notion of whole work for individual
andon	Extensive use of Andon, and indicators of plant and line performance	Andon, team areas, and info sharing continue but are now focused on line-segment	No Andon, few standardized work processes	No Andon, worker driven efforts to standardize processes and feedback direct to group	Yes - efforts to link results directly to originating team
line stop	Workers can stop line if problems occur	Workers can stop line but new use -- buffer helps absorb impact of / facilitate group driven innovation	Workers inherently control line speed	Workers rarely stop line, but group develops and tests process improvements	Yes - convergence on group-based innovation
Team work	Team as a whole develops expertise in areas like quality and line balancing	Team expertise continues, but efforts to increase and document individual worker skills	Team members rotate through specialist roles such as team leader, personnel, maintenance	Team members each develop own specialties. Two team members per specialty. Relief person so team members can exercise specialties	Some - but Volvo more emphasis on individual worker development and *off-line* roles
size	Teams have five or six members	Converted to groups of 15-20 members	Teams have between 10 and 15 members	Team size unchanged but Volvo Gent has sub-groups of five workers	Yes
leader	Team leaders are appointed	Team leader role eliminated	Team leaders elected	Team leader elected, but in Gent appointed	No - different team leader roles persist
skill	Egalitarian spirit within team	Skill ranks created, to give workers opportunity for documenting skills for advancement	Emphasis on professionalization	Strong emphasis on recording of skills spread through company	Yes

	Toyota Old	Toyota New	Volvo Old	Volvo New	Convergence?
Supporting HRM – *flexibility*	Flexibility through overtime and non-core workers	Flexibility reduced because of back-to-back shifts. Greater use of women. Dramatic increase in temp. workers	Flexibility through employment fluctuation and overtime, recent use of temporary workers	Flexibility through flex-time and temporary layoffs to meet demands of building vehicles to customer order	Some - great emphasis on numerical employment flexibility, but attained differently
bonuses	Bonuses important fraction of salary – depend on performance in relation to theoretic performance criteria	Bonuses tied to productivity are 1/3 of original level – greater emphasis on cost, quality, and safety. Productivity assessed in relation to actual performance across multiple plants	Few bonuses. Salary increases tied to skill levels	Bonuses tied to individual, team, and plant performance. Great emphasis on tracking individual performance. Volvo Gent not using bonus system	Some - less emphasis at Toyota, but more so at one of the Volvo plants
Ergonomics	Not a key concern	Great emphasis on measuring ergonomic characteristics of individual work stations	Great efforts to design vehicle and overall assembly process for superior ergonomic characteristics	Continued efforts to improve ergonomic characteristics of design. Efforts to evaluate individual work stations introduced	Some - efforts to evaluate systematically individual work stations new at both, but Volvo more emphasis on product/process design
Automation	Large-scale, ‘complete’ automation initiatives; stop/go nature of automation breaks up continuous flow of line	In-line mechanical automation – synchronized to work with conventional continuous conveyor. Greater use of ‘Automation assist’ Line worker tasks integrated with automated tasks	Large-scale, ‘complete’ automation initiatives. In docking stations, simple, multi-functional equipment	Large-scale, ‘complete’ automation initiatives. Greater use of ‘automation assist’	No - divergence on types of automation used although greater use of automation assist at both
Maintenance	Independent maintenance department	Simpler designs permit greater assembly worker involvement in maintenance	Independent maintenance department	Maintenance work integrated into line-worker tasks. Maintenance de-centralized. In some areas supervisory and technical jobs combined into one	Yes - convergence on maintenance front, but Volvo has gone further in the direction of integration of maintenance and direct activities