Japanese Technology Management: Innovations, Transferability, and the Limitations of "Lean" Production

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I. INTRODUCTION

Japanese competitiveness in a number of industries is the result of a combination of factors. Among the most important are a series of innovations and practices in manufacturing and product development that have been referred to as "lean": aimed at high productivity as well as high quality, and thus high price-performance in the value of products delivered to the customer. This paper will outline some of those innovations and practices, particularly as they exist in the Japanese automobile industry. I will then bring up two other issues: how transferable these practices are outside of Japan, and what limitations the Japanese themselves have encountered.

II. PRINCIPLES OF "LEAN" MANAGEMENT

The principles of "lean" manufacturing and production development have been described recently in Womack, Jones, and Roos (1990). More specialized references include Monden (1983), Cusumano (1985 and 1988), and Krafcik (1988) for manufacturing, and Clark and Fujimoto (1991) and Cusumano and Nobeoka (1992) for product development. The key elements, listed in Table 1, made it possible for Toyota and other firms that followed its approach to achieve extremely high levels of quality (absence of defects) and productivity (as much as 2 or 3 times higher than U.S. or European plants in the late 1980s) in manufacturing as well as relatively high levels of flexibility in the sense of being able to produce relatively small lots of different models with little or no penalty in productivity or quality.

Toyota developed this small-lot, "just-in-time" manufacturing approach in response to the needs of the post-World War II Japanese auto market, which was very small in size, with few exports, but growing rapidly in demand for different types of car and truck models. During the late 1970s and 1980s, the 9 major Japanese automakers gradually took advantage of their manufacturing capabilities to shift the primary competitive domain to product development. Led by Honda and Toyota, this shift resulted in rapid development times (estimated at 42 months compared to 65 months or so for the U.S. and European producers by Clark and Fujimoto, a very rapid expansion of product lines by all the Japanese automakers, as well as adoption of full model changes every four years (a practice started in the 1950s). This rapid change and expansion allowed Japanese automakers to introduce new features and technologies into their vehicles more quickly than U.S. or European automakers, which generally had product replacement cycles of 6 to 8 years or more.

With this combination of manufacturing and product development skills, the Japanese automobile industry overall rose to exceed the U.S. industry in total production for the first time in 1980, with over 11 million units, and has continued to dominate the world industry since. Accordingly, this Japanese style of manufacturing and product development, dubbed the "lean" approach by former MIT student and researcher John Krafcik, has come to be studied and emulated around the world. The best U.S.-owned auto manufacturing plants have now achieved relative parity with all but the most efficient Japanese plants (Womack, Jones, Roos 1990). Some U.S. product-development projects are also reported to have been completed as quickly as the average Japanese projects.

But, while U.S. and European automakers continue to study and, at least in

part, emulate Japanese manufacturing and engineering practices, in the 1990s it has become apparent to many Japanese managers, employees, policy makers, and industry observers that the notion of "continuous improvement" -- continually pushing for gains in manufacturing or engineering efficiency -- has resulted in a new set of problems as well as reached some practical limits. This means that Japanese auto makers are now exploring ways to modify or moderate their approaches, even if this means becoming less efficient in manufacturing or engineering. It follows that, if Japanese improvements in manufacturing efficiency or rapid expansion and replacement of product lines have indeed reached a limit, given the improvement programs underway at U.S. and European automakers, who have encountered their own problems with lean approaches but continue to make progress, then the time might not be far in the future when at least the best Western and other Asian firms approach parity with the Japanese in basic manufacturing and engineering prowess. This parity will then make it necessary for all firms to seek competitive advantage not simply by following lean principles -- everyone will know these and be implementing these as best they can -- but by defining other domains of competition, such as in new levels of manufacturing automation, new materials and technologies, innovative product features, or skillful overseas management and expansion into developing markets.

II. LIMITATIONS OF LEAN IN JAPAN

It is important to point out that, like U.S., European, and other automakers, not all Japanese companies have been able or willing to follow the standards set by Toyota in manufacturing or Honda in product development to the fullest extent. Each of these companies has unique histories and even geographic settings that, as in the case of Toyota, facilitate the famous just-in-time and *kanban* systems. Some of the problems that JIT and kanban create have thus been encountered by other Japanese firms, such as Nissan, when they first tried to introduce these techniques into their own organizations during the 1970s. Similarly, no Japanese automaker has matched the product development performance of Honda (at least for models introduced in Japan). There are several reasons why many Japanese, as well as non-Japanese, firms have been unable or unwilling to follow the lean standards to their fullest extreme. There are also several countermeasures or strategies to deal with these limitations of the lean approaches (Table 2). The Japanese firms are currently exploring these, in autos and in other industries.

Urban Congestion and Geographical Distance

Nissan discovered during the 1970s that the Toyota practice of having suppliers make or deliver components "just-in-time" to assembly lines several times a day, with deliveries controlled by the physical exchange of production or parts delivery tickets (kanban cards), did not work well in congested in urban areas. As more and more Japanese factories in different industries adopted the Toyota practice, traffic worsened to the point where, in the 1990s, the Japanese government has mounted a media campaign to get companies to reduce the frequency of their parts deliveries. Traffic congestion also pollutes the environment, in addition to wasting the time of people stranded in vehicles waiting for traffic to clear and people stranded in manufacturing plants waiting for components to arrive.

Nissan has always had more dispersed plants than Toyota, convincing management that it was indeed more practical, and perhaps more economical, to keep

some more inventory on hand than Toyota did, even though Nissan adopted the practice in the early 1950s, along with Toyota, of reducing unnecessary inventories to save on operating expenses and catch mistakes that might lie hidden or take too much time to identify if workers made parts and stored them for weeks or months. Ultimately, Nissan reduced average inventories from a month to a day or slightly less, but not to the extreme of a couple of hours that Toyota did. Other Japanese automakers in other parts of Japan encountered similar problems, but traffic congestion even in formerly rural areas like Toyoda City and Aichi Prefecture (where most of Toyota's suppliers are located) has forced companies to make JIT a bit less timely.

Similarly, with companies establishing plants in different areas of Japan to escape the congestion and labor shortages in the major urban areas, the once-elegant kanban system, requiring the physical exchange of production or delivery tickets (often in former years by workers carrying kanban cars on their bicycles from station to station or carrying pallets of components with the kanban cards attached), is no longer practical. Suppliers now need to deliver larger loads, sometimes by ship to different islands of Japan or to different parts of North America, Europe, or other parts of Asia. It is not practical to track or control the ordering of components simply by kanban cards or cards attached to pallets, just as it is not practical to make and deliver very small batches of components.

Of course, the Japanese have not reverted completely to the former style of mass-production, where companies made and stored a month or more of companies, and controlled production by inflexible production schedules that "pushed" components into the system regardless of what was happening at individual production stations and tracked the production process through real-time computer systems that invariably ran on inaccurate information. But the days when even Toyota could operate in a highly predictable and geographically small area within Japan are now over. Other companies, especially U.S. firms that made components in one state or country and shipped them thousands of miles, also noticed this limitation of the Toyota practices years ago, even though they benefitted considerably, in productivity and quality, by reducing unnecessary levels of inventory and reducing deliver times from suppliers.

Supplier Management

Another obvious limitation of the lean manufacturing approach is the need for cooperative and reliable suppliers, who account for approximately 75% of manufacturing work in the automobile industry (Cusumano, 1985 and 1988) and approximately half of product development (Clark and Fujimoto, 1991), measured by costs. For the system to work, suppliers must agree to manufacture components in small lots and then deliver frequently to assembly plants -- otherwise they will simply hold inventory, raising their own carrying costs and eliminating their ability to improve quality and productivity through short runs and correction of errors or process improvements made with each new setup. As Japanese companies disperse their plants throughout Japan and other parts of the world, however, they have been able to move with only some of their suppliers. Non-Japanese suppliers have also not complied exactly with Japanese pricing and quality requirements, nor have the Japanese trusted foreign suppliers fully in product development (Cusumano and Takeishi 1991).

Until the recent recession, which is probably temporary, Japan has had a

severe and growing shortage of labor (especially blue-collar labor) domestically. The Japanese government has allowed foreign workers from Southeast Asia, the Middle East, and South America in particular to come to Japan and work in Japanese factories, mostly at smaller suppliers. This practice has helped the labor shortage but it has also introduced new problems: the need to train these foreign workers and manage people with little or no literacy in Japanese language. Many companies report quality problems and reductions in worker flexibility as a result of the use of less-skilled foreigners, and this has lowered supplier productivity by forcing managers to reduce work schedules and use more inspection and re-work to make sure that components delivered to Japanese assembly plants are still of high quality.

The Shortage of Blue-Collar Workers

One of the brilliant contributions of Toyota managers such as Ohno Taiichi, inventor of the kanban system and director of manufacturing operations at Toyota during the formative years of its system from the 1950s through the 1970s, was to view automation with skepticism. Automation, unless it was flexible in a physical or programmable sense, introduced rigidity into production processes and was not suitable for labor-intensive assembly operations. As a result, Toyota introduced transfer machinery cautiously and introduced robots in large numbers only in the 1980s, after they had become programmable and reliable. Instead, Toyota relied on relatively well-trained workers and gave them relatively broad responsibilities, including the task of doing much of their own inspection, preventive maintenance, and janitorial work. Line rationalization efforts started by Ohno after World War II also ruthlessly eliminated "waste" from all assembly and production activities, until Toyota became by far the most efficient automaker in the world, in terms of labor productivity (Cusumano 1985 and 1988; Lieberman, Lau, and Williams, 1990).

The incremental introduction of automated manufacturing systems meant that Toyota and other Japanese automakers who followed its lead at least in part had to rely heavily on large numbers of cooperative and skilled human workers. They have to work very hard within a rigorous and physically demanding, though relatively flexible, mass-production system.

But another part of the reality today is that there are more jobs available for every Japanese high school graduate than there are people, and this intense competition for blue-collar workers exists not only in small suppliers but also in the assembly facilities of major companies. In addition, young Japanese workers will leave blue-collar jobs and, increasingly, even white-collar jobs, if they feel over-worked or unhappy for other reasons. Toyota, for example, has encountered serious difficulties staffing its factories near Toyoda City because of the severe shortage of blue-collar workers (women are still not permitted to work in most Japanese auto assembly factories) and turnover rates of approximately 30% annually. This is not, actually, a new problem for Toyota. But the labor shortage and turnover is likely only to worsen rather than to improve. As a result, a change in strategy and tactics has become necessary that will likely reduce the productivity advantage Toyota has enjoyed in its home base.

Product Variety

The veritable explosion in product variety from Japanese producers particularly for their domestic market has enabled the most successful companies to expand their market shares and regularly convince customers to buy new versions of automobiles, video recorders, stereos, laptop computers and wordprocessors,

microwave ovens, and dozens, if not hundreds, of other consumer products. The JIT/kanban system was designed to facilitate small-lot production when combined with fast equipment set-up or changeover times, synchronized parts production and rapid delivery, and versatile workers who can quickly move to solve problems or shift to parts lines and assembly lines for rapidly selling products.

But too much product variety and options offered to the customer results in parts makers and assembly plants having to accommodate very small and very rare orders frequently. This requires more frequent equipment set-ups and kanban exchanges, as well as many deliveries of very small lots of components, just when workers, suppliers, and traffic systems have reached a sort of limit. As a result, Japanese firms have concluded that, in the short term, they need better scheduling and control systems to handle so much variety, and they need to reduce variety. It is now impractical to let the exchange of kanban "pull" new orders of components into the system and relay all production information; there are better methods available (such as use of bar code readers and other electronic forms of moving information) for plants with very high levels of variety -- which covers most Japanese automakers and many other producers in many industries.

Another problem is the environment. Japanese companies have been introducing replacements of existing models every 4 years, in addition to continually expanding their product lines, such as into higher luxury segments. Japanese government regulations and mandatory fees or maintenance charges for automobile inspection also encourage consumers to replace their vehicles every 4 or 5 years. One outcome is consistently high domestic demand for Japanese cars and trucks. But another outcome is an environmental problem -- the need to dispose of all these replaced vehicles. Some are exported as used cars to other parts of the world, but Japanese companies now realize they need to think about how to recycle automobile materials more effectively.

But perhaps the most pressing concern for managers is the cost of new model development and model replacement now that money is expensive in Japan. Bank interest rates have reached international levels, and banks can no longer make large cheap loans because their portfolios of stocks and real estate (needed as a basis for loan limits as a percentage of bank assets), and the portfolios of their customers (normally used as collateral), have declined in value. And companies can no longer raise capital on the stock market because of the reluctance of Japanese investors to buy securities in a market that has dropped 50% in value over the past several years. The only source of truly "free" money -- used in the past for product development as well as capital investment -- is operating profits. In the current recession, however, operating profits have also declined dramatically for Japanese firms.

Thus, for the intermediate term, Japanese managers have realized that they need to reduce their overall investments in new product development (which also requires major investments in manufacturing preparations) as well as cut the amount of variety they have in components and final products. Companies in the automobile industry, for example, are planning reductions of parts and product varieties on the order of 30% to 50% or higher in the coming years. This will ease problems in assembly plants and at suppliers, as well as save money in engineering and manufacturing-preparation costs. The risk, of course, is that sales will no longer grow as fast as they did when Japanese companies continued to introduce streams of new models and replace old models quickly. Sales may even decline, although profits may rise as a

percentage of sales.

III. CONCLUSIONS

In autos and other industries, leading Japanese companies have maddeningly pursued continuous improvement in inventory reduction and "just-in-time" manufacturing, and the continuous expansion of market share through productivity and quality gains as well as through non-stop investment in new products and upgrading of old products. One result has been great wealth as the Japanese economy has expanded. But another result is that Japan has become a nation in a sort of "gridlock": Traffic jams are everywhere as all companies and stores now want just-in-time deliveries. Companies have trouble finding good workers. Banks have trouble making loans. Managers have difficulty finding money for new investment.

In a sense, Japanese companies are now being forced to become more like everybody else in the world: more short-term profit oriented! How short-term profit-oriented the Japanese become remains to be seen, however. Managers are accustomed to treating themselves and employees as permanent assets (due to lifetime employment and relatively little labor mobility), and company practices generally evaluate investments for their long-term strategic value. Nonetheless, Japanese companies are facing a host of difficulties that will make them more like us and less competitive in manufacturing productivity and quality, and in new product development. This unfortunate situation for the Japanese presents opportunities for the rest of the world's companies -- in the United States and Europe, as well as in Asia.

Table 1: Principles of "Lean" Management

Production (Toyota Model)

JIT "small-lot" production
Minimal in-process inventories
Geographic concentration of assembly and parts production
Manual demand-pull with kanban cards
Production leveling
Rapid set-up
Machinery and line rationalization
Work standardization
Fool-proof automation devices
Multi-skill workers
High levels of subcontracting
Selective use of automation
Continuous incremental improvement mechanisms

Product Development (Honda Model)

Rapid model replacement and expansion
Overlapping development phases
Compressed development phases
High levels of supplier engineering
"Heavy-weight" project managers
Design team and manager continuity
Strict engineering schedule and work discipline
Creative Freedom for New Model Development
Extensive communication mechanisms
Design leveraging (multi-project management)
Multi-skill engineers and design teams
Skillful CAD/CAE/CAM usage
Incremental and occasionally radical improvements

Table 2: Limitations of Lean: Japan in the 1990s

PROBLEMS

Production

JIT/Kanban and Urban Congestion or Distance
JIT/Kanban and Supplier Cooperation
JIT/Kanban and Product Variety
Shortage of Blue Collar Workers

Product Development

Cost of frequent model replacement
Cost of frequent model line expansion
Environmental & recycling problems

SOLUTIONS

Production

Less Frequent Deliveries
More Electronic Data Transfers
More Computerized Control Systems
More Attention to Supplier Needs
More Product and Parts Standardization
More Manufacturable Designs
More Automation
More Dispersed Japanese Production
More Overseas Production

Product Development

Less Frequent Model Replacement
Fewer Model Lines
Less Frequent Auto Purchases
More Parts and Materials Recycling

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