



## Small-Lot Production: Key to Japanese Innovations in Auto Manufacturing

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### The Need to Produce Efficiently at Low Volumes

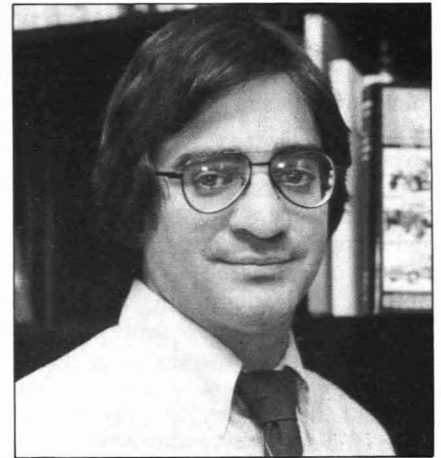
An examination of Toyota and Nissan in the years after World War II reveals that an overriding concern driving Japanese managers to become more efficient than their U.S. counterparts was the need to produce a growing variety of models at extremely low volumes, relative to the U.S. (or Europe), and at low cost, due to a rapidly rising number of competitors. Some Japanese managers have referred to this as the need to master «small-lot production.» This was in contradiction to the mass-production techniques pioneered by U.S. auto producers, which attempted to lower costs by minimizing product diversity and maximizing economies of scale.

Japanese auto production in 1950 consisted of 31,597 cars and trucks — little more than one day's output for the U.S. auto industry. Four local companies shared the market — Nissan, Toyota, Isuzu, and Hino — and half-a-dozen more would enter the field by the early 1960s — Mitsubishi, Honda, Mazda, Daihatsu, Suzuki, and Prince (which merged with Nissan in 1966). Japanese auto makers could use American-style mass-production equipment and techniques for trucks made during World War II, since they produced these models in relatively large runs (compared to passenger cars), and with few changes. For example, it was possible to machine or stamp thousands of identical components, as U.S. manufacturers did for much higher volumes, and store the excess for future months. It was expensive to pay for equipment in this way, but possible with high prices under the protected market that existed in Japan from 1936 to 1945 and then from 1953 until the mid-1970s. Nissan's history illustrates this strategy. In the mid-1930s, Nissan entered into an

agreement with Graham-Paige (which sold out to Dodge before World War II) and bought specialized and expensive American machine tools and stamping presses to produce the U.S. company's standard-size truck. A dozen high-salaried American engineers came to Japan for two years and set up operations. Nissan then sold nearly all its output, at rather high profit margins, to the Japanese army until 1945, and continued to make the same truck and engine, with only minor changes, until the late 1950s.

After World War II, when the military market disappeared, Nissan, Toyota, and other Japanese auto makers had to make the transition from trucks and buses (about 95 % of production in 1950) to passenger cars. Car production at the leading Japanese auto makers rose from merely 5 % of output in 1950 to about 65 % in 1970. Passenger vehicles also came to require far more equipment and options, as well as a variety of styles and more frequent model changes, especially as the Japanese companies improved their vehicles incrementally. Nissan and Toyota, for example, each went from producing only two basic models each ca. 1950 — one standard-size truck and one small truck, which they also fitted with a car body to create a passenger vehicle — to several models each by the end of the 1950s.

Believing that low volumes per model would perpetuate high costs and make it difficult for Japan to compete in international markets, Japan's Ministry of International Trade and Industry (MITI) adopted two major policies. The most successful was to help domestic auto producers cover their high costs by limiting imports to about 1 % of the Japanese market following the postwar U.S. Occupation. Prices for Japanese-made vehicles still dropped between the



early 1950s and the early 1970s, as the number of local firms competing for domestic customers tripled by the early 1960s, but the domestic market grew faster than supply, enabling each company to make a significant profit.

Another policy, which was largely a failure, was an attempt to «rationalize» the auto industry by encouraging mergers and specialization. Directly after World War II, MITI tried to convince firms to abandon passenger car production. Then, during the 1960s, MITI wanted to reduce the number of producers competing in the industry, to raise scale economies for any one manufacturer. But company executives at nearly a dozen firms saw great potential in the auto industry and repeatedly refused to bow to the wishes of government planners.

An additional incentive to increase productivity and reduce costs was the desire of Japanese auto makers, beginning with their first attempts in the late 1950s, to expand car sales beyond the limits of the small domestic market. But car prices in Japan (and, presumably, production costs) still did not match international levels for comparable small cars until the late 1960s. Due to high prices as well as to problems in some design features and components (for example, the first Japanese cars shipped to the U.S. in the late 1950s and early 1960s were underpowered and burned oil, rusted easily, had leaky radiators, and did not come with automatic transmissions), exports increased in importance slowly. They were still only about 20 % of total production as late as 1970, and did not exceed 50 % of output until 1977.

At Toyota, the desire of managers to produce efficiently at low volumes inspired modifications of equipment and techniques, using engineering practices and concepts found in U.S. textbooks and



non-automotive factories such as the U.S. military aircraft industry. Specific changes in production management helped Japanese managers overturn traditional American assumptions about minimum efficient scales, the value of large manufacturing lots and buffer inventories or absolute economies of scale, the importance of worker and machine specialization, the role of labor and suppliers in the manufacturing process, as well as the practical limits to worker productivity. In retrospect, however, market requirements in Japan appear to have provided the initial motivation for Toyota and then other Japanese auto makers strove to become more efficient at producing a variety of models at low volumes.

### Departing from American Mass Production

In the lean years following World War II, Japanese managers were not sure how to accommodate changing market needs and potential export requirements of low-cost, high-quality vehicles. U.S. engineers had designed much of their equipment and influenced much of their thinking. Not surprisingly, many Japanese managers, especially at Nissan, first believed that the best way to compete in automobile manufacturing was to copy as closely as possible the best techniques perfected at Ford, GM, and other mass producers.

The U.S. model for mass production involved a set of techniques and concepts that assumed the following practices were most efficient: high levels of worker and equipment specialization; extensive automation; long production runs on huge machines requiring long set-up times; large manufacturing scales with buffer stocks to keep the expensive machines and specialized workers constantly active, making as many parts or assemblies as possible in a set period of time; and the «push» concept of production control. The push concept involved manufacturing and delivering components according to a master schedule, which was also designed to keep machines running and components coming in despite problems that might develop at a few stations or suppliers. To inspect all the components made in huge lots required too many inspectors, so companies adopted statistical sampling techniques to test a few parts and determine if an entire lot met an «acceptable quality level,» even though this meant some defectives would pass through the system at every stage. U.S. auto makers also tried to bring in house as

much of components production and assembly as possible, to insure acceptable levels of price, quality, and supply. In contrast, led by Toyota's Taiichi Ohno (born 1912), Japanese managers realized that the best way to manufacture in volumes far smaller than were common in the U.S. or even Europe was to increase the «flexibility» and utilization of the key elements in their manufacturing systems — equipment, workers, and suppliers. They also sought to lower, as much as possible, investment needed for in-house personnel, factory or warehousing space, and variable costs such as in-process or finished-goods inventories. While individual Japanese auto makers made these changes with varying degrees of success and in different years, all pursued three basic policies:

#### Just in Time Manufacturing:

Beginning in the late 1940s at Toyota and in the mid-1950s at Nissan, managers introduced the «just-in-time» (JIT) concept for in-house production or assembly, and deliveries of components. This required several departures from U.S. practices: faster setup times for machine tools and stamping presses (techniques first written about in the U.S. and incorporated in American equipment such as Danley stamping presses), so each piece of equipment could be used for different models or components without long waiting times; tighter synchronization between subassembly production, parts deliveries, and final assembly, to increase equipment utilization and reduce in-process inventories; mixed scheduling of different components or models on single machines or assembly lines, to avoid specialized but underutilized equipment and workers; and broader job specifications, so managers could get by with less workers through shifting people to different jobs as needed at any given moment.

These modifications appear to have resulted in higher productivity as workers ended up operating several different machines simultaneously, and doing much of their own machine maintenance, janitorial work, and inspection, especially in times of slow demand. The discipline imposed by the just-in-time pace, reduced «buffer stocks» of extra components, and the small-lot production philosophy, also tended to improve quality. Workers paid more attention to what they were doing and could no longer rely on extra parts or rework piles if they made mistakes. More rapid throughput on the line, since workers made only a few parts at a time for the stations immediately ahead of them, rather than

making large lots to store in inventory for weeks or months, also led to rapid «feedback» between stations regarding process problems or defects. Small lots thus seem to have improved learning rates and reduced defectives, both of which resulted in higher yields — another boost to productivity.

#### Temporary Reduction of Process Complexity:

A second policy was to gain some benefits from the concept of scale economies, even at low volumes compared to the U.S., by reducing unnecessary complexity in product designs and manufacturing processes. Nissan and Toyota accomplished this by standardizing components across different car and truck lines, eliminating wasteful «annual model changes,» and limiting the number of options available to customers. Until recent years, Japanese auto makers tended to offer models in only two combinations — standard and deluxe. Exported models still come with pre-packaged options. The increasing flexibility of assembly lines and small-lot production, on the other hand, made it possible to introduce gradually a greater variety of models, options, and variations for different export markets — with little or no decrease in productivity. Nissan and Toyota actually doubled the number of models they were offering between the mid-1960s and 1980s, and dramatically improved product sophistication and overall quality, while maintaining the same high rates of productivity! This observation — that, with the type of production techniques pioneered in Japan, there need not be any «tradeoffs» among high productivity, high quality, and even process flexibility — has recently been confirmed in an M.I.T. survey of major auto assembly plants in Japan, the U.S., and Europe.

**Vertical «De-Integration»:** The third policy involved decreasing levels of inhouse vertical integration between components production and final assembly, while building up networks of lower-wage subsidiaries (and other subcontractors). Toyota began establishing a network of suppliers in the late 1930s and founded all its major subsidiaries during the 1940s, while Nissan took longer to set up a supplier network. Still, by the end of the 1970s for Nissan, and as early as the 1940s for Toyota, Japan's leading auto firms demonstrated levels of «group integration» (with groups defined by the percentage of total costs they accounted for in-house plus payments to subsidiaries in which Nissan

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or Toyota held a minimum 20 % equity share) that were far higher than the most integrated U.S. auto producer, General Motors. This made it possible to achieve many of the benefits of vertical integration without the higher personnel or other costs that formal integration would have required.

For example, in 1983, for each small car Nissan and Toyota produced, their subsidiaries accounted for about 50 % of manufacturing and other operating costs. These subsidiaries, furthermore, paid wages equal to merely 80 % of those received by Toyota and Nissan workers. But, while wages were lower at subsidiaries, productivity gains were not. By working with these companies to improve their production systems as well as the quality of their components or assembly services, value-added productivity tripled between 1960 and 1983. This was a rate of increase slightly faster than the improvements registered at Nissan and Toyota in this same period.

### What have we learned?

The history of Japan's auto industry is a story both of American lapses and Japanese innovations. These innovations involved a spectrum of changes in conventional production management, broadly conceived. Toyota was the most radical, while most other Japanese auto makers, typified by Nissan, incorporated less extensive modifications of U.S. practices and equipment. There are many lessons from this story, and not all are pleasant for American (and some Japanese) managers to hear. Be that as it may, two concluding thoughts seem relevant for managers of any country and in any setting.

**Manufacturing Innovation and Competitive Advantage:** An obvious point is that manufacturing is not a trivial activity, and that innovation in this function can lead to competitive advantage. A company might compete equally or more effectively through high quality or innovative designs, or customer service and advertising, rather than low-cost production. But customers must see a substantial advantage in products or services. This means that a company competing in the broader marketplace, rather than specialized segments such as luxury goods, cannot afford to fall too far behind productivity leaders. If competitors offer even comparable products at lower prices, catching up in manufacturing efficiency and reestablishing an edge in product designs may prove to be inordinately difficult. If

competitors offer superior products at lower prices, then less efficient companies will certainly encounter trouble in the marketplace, and may require manipulation of the market — government-guaranteed loans, or import quotas — to survive.

**This is what happened in the automobile industry:** Relying on a series of process innovations pioneered at Toyota in response to the small but highly competitive Japanese market, Japanese companies caught their U.S. and European competitors first in physical productivity. Then they continued improving their manufacturing processes, as well as product designs. The result by 1980 was that U.S. and many European companies lagged so far behind in productivity that they were no longer competitive, either in cost or quality. U.S. firms may also have cut back on design programs that could have led to more popular smaller cars, and chosen to procure less costly components, with the results that the offerings and overall reliability of U.S. vehicles suffered. But the major story is that Japanese firms consistently introduced highly reliable and increasingly stylish products at low prices — leaving only a few premium European producers with a defensible market niche, and even this the Japanese have been attacking successfully.

**Improvement as an Incremental, Continual, Integrated Effort:** There is a tradition in manufacturing dating from Adam Smith, but seen best perhaps in Frederick Taylor and his principles of «scientific management,» that called for managers to analyze a process, divide it into small pieces, freeze the process, and then dictate to workers and suppliers their roles in the process. Management might introduce automated equipment or even radically new procedures. But, meanwhile, there is not much room on the manufacturing floor for creativity, innovation, or incremental improvement. Nor is there any recognition that workers and suppliers might participate more fully, such as by doing some of their own inspection and maintenance, operating more machines, or delivering supplies in fewer quantities but more frequently.

Toyota and Ohno Taiichi were as concerned with productivity as Taylor was, and to a large degree built upon his foundations in process analysis. But, from Toyota and other Japanese companies came another obsession: continual rather than a one-time improvement, achieved through successive

process refinements and a greater integration of workers and suppliers into the production system.

Equally important to understanding what happened in Japan is what went on in the U.S. By the early 1960s, American managers came to view automobile manufacturing as a stable or «mature» technology, assuming certain limits to productivity, minimum efficient scales of production, unit costs, quality, and the ability of workers and suppliers to cooperate (or be coerced), as well as to contribute to improving a total production system. The original «American paradigm» characterized by large production runs, push-type of scheduling, high levels of automation and worker specialization, with large numbers of inspectors using statistical sampling, dominated the thinking, and the goals, of U.S. (as well as many European) managers.

There was nothing particularly wrong with this approach to manufacturing. It proved to be remarkably effective for high-volume production of a limited number of models. But market conditions and financial constraints in Japan after World War II presented an opportunity for Toyota and other Japanese auto producers to challenge convention and become equally or more efficient at far lower volumes. This drive led to incremental but, over time, major improvements in a variety of areas, before Japanese firms benefitted from huge production scales in the 1970s: higher worker output and utilization rates for machinery, faster inventory turnover, and even higher quality, since «just-in-time» systems did not tolerate defectives or equipment breakdowns, and Japanese workers producing in smaller lots found they paid greater attention to what they were doing — as opposed to American workers making thousands of components of one type, with large piles of buffer stocks to draw on if they made mistakes.

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