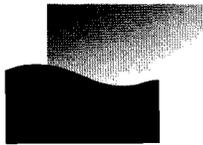


How lean manufacturing changes the way we understand the manufacturing sector

Thomas H. Klier



Manufacturing is currently undergoing a transition from a mass production system to a lean production system which emphasizes quality and speedy response to market conditions using technologically advanced equipment and a flexible organization of the production process. This new manufacturing system has achieved remarkable productivity advances. The success or failure of the Midwest's manufacturing sector in climbing on board this revolution will be central to the region's future prosperity due to the historic role of manufacturing in shaping the region's economy. Successful adaptation to lean manufacturing is likely to require significant changes in both the management of factories and the structure of the economy, such as changes in worker training, job performance, public infrastructure, and perhaps the location of factories and jobs.

These changes are the focus of this article. First, I briefly summarize the main features of lean manufacturing. The next section concentrates on the effects of the introduction of lean manufacturing. I will discuss several aspects of the new manufacturing system: management-labor relationships, worker training, location decisions, and product development. Finally, I discuss policy implications of the change in manufacturing systems. To illustrate, examples from the auto industry will be used throughout the article because it has greatly influenced the way many other businesses organize their factories. However, it is important to note that specific applications of lean manufacturing vary according to industry and firm. Thus, the pic-

ture described in this article is necessarily a general one.

Features of lean manufacturing

Lean manufacturing features teamwork and participatory management. Tasks are performed by teams in which each member can do any of the team's tasks, including maintenance, inspection, and machine setup. Lean manufacturing encourages worker participation and discourages managerial authoritarianism.

In designing the production process, lean manufacturing gives top priority to quality control. This is different from the so called Fordist approach to manufacturing originated by Henry Ford (see Table 1). This approach introduced interchangeable parts and the moving assembly line to the manufacturing process and dominated most of the world's manufacturing from the mid-1950s through 1980. Lean manufacturing regards large inventory stocks as a source of costs and problems rather than a solution. With lower in process inventories, quality problems of a particular assembly operation become apparent faster. Continuous improvement of operations also is central to the lean manufacturing philosophy, with most of these improvements the result of suggestions from the factory floor.

Lean manufacturing systems are designed to turn out small batches of customized products on relatively short notice and at low cost. That makes it necessary to provide flexibility and quick setup capability in a factory, for example,

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TABLE 1**Fordist versus lean manufacturing**

Fordist	Lean manufacturing
Job definition	
Specialization; narrowly defined, repetitive steps	Teamwork; multiple responsibilities
Quality control	
Separate function	Built into production process and each job description
Production process	
Continuous operation of one process	Flexible adjustments possible
Inventory	
Large	Lean
Management	
Hierarchical	Participatory

by reducing the time needed to change dies. As a result, lean manufacturing requires a different process flow design and plant layout than traditional manufacturing, usually occupying much less floor space. However, lean inventories plus the need for flexibility place great strains on the flow of materials. To address these requirements, Toyota pioneered the use of the "kanban" method for moving parts and materials across the factory. Using this method, each container transporting parts downstream in the production process carries a card. As the parts are depleted, the card is sent back to the previous production stage where it signals the need to produce more of these parts. By maintaining a continuous, tightly controlled, but decentralized, flow of parts and materials, lean manufacturing allows flexible adaption of the production line to changes in the demand for the final product.

Finally, lean manufacturing enables a short design cycle by taking an integrated approach to the various steps of manufacturing; market assessment, product design, engineering, component sourcing, and final assembly are integrated into one decisionmaking unit rather than dealt with sequentially.

Lean manufacturing comes to North America

Expanding the geographic boundaries of lean manufacturing has become one of the

hallmarks of Japanese auto companies as their so called transplants have been remarkably successful in North America and Europe. In 1982, Honda of America began to assemble automobiles in Marysville, Ohio. By 1991, seven Japanese transplants produced almost 1.4 million cars in the United States. Honda can now produce cars in North America as efficiently as those made in Japan; and Nissan's Sunderland plant in England is referred to as one of the most efficient car plants in Europe.¹

While changes in the production system were pioneered and successfully transplanted by Japanese producers, American auto manufacturers have been adopting the new manufacturing techniques in order to compete effectively internationally.² The Big Three have made strong gains in manufacturing productivity during the last few years. By one account, Ford has improved its assembly productivity by 36 percent since 1980.³ Specifically, some Ford plants have all but erased the labor cost advantage enjoyed by the most efficient Japanese auto producers; among these is Chicago's Taurus plant. Chrysler, in turn, has improved its assembly productivity by 33 percent since 1980. GM has increased the productivity of its assembly operations by 11 percent since 1980; most notably in the launch of its Saturn line in 1991. Recent gains in market share experienced by the Big Three may well be related to improvements in manufacturing efficiency.⁴

Management-labor relationships

One of the characteristics of lean manufacturing is its emphasis on constant improvement in operations. Most of the improvements are actually suggested by the factory workers. However, for an employee suggestion system to be effective, it must be embedded in cooperative management-labor relations since workers would not have an incentive to increase productivity if the end result was only that some of them lost their jobs. That requires a switch from the decades old practice of dividing work into simple, repetitive tasks carried out by workers who were not greatly respected by their bosses nor trusted to perform without being prodded and closely supervised (see Box 1). In a lean manufacturing environment, management treats workers primarily as assets, not as costs. The potential benefits of cooperative management-labor relationships are well known. For example, Luk Inc., a small

The case of NUMMI

New United Motor Manufacturing (NUMMI), the GM-Toyota joint venture in Fremont, California, serves as an excellent case study for the adaptation of lean manufacturing techniques to the United States. GM opened this assembly plant in 1963. It became known for its abysmal productivity and quality records, as well as a very confrontational relationship with the UAW local, and was subsequently closed in 1982. In 1984, the plant reopened as a joint venture between Toyota and General Motors. At its opening, 85 percent of NUMMI's hourly workers came from GM's previous work force. Within two years, its productivity was higher than that at any other GM factory and more than twice as high as it had been under GM management. In fact, it was almost as high as Toyota's Japanese factories. The same was true of quality.

According to a recent study, the main factor in turning NUMMI around was a new management approach.¹ Under the old, Fordist style of manufacturing, Taylorist time and motion studies were implemented by means of a hierarchical, authoritarian style of management.² More than 80 industrial engineers would measure in minute detail the activities of workers and then standardize and accelerate their tasks. Supervisors would impose these standards on workers who were never consulted. Under lean manufacturing at NUMMI, Taylor's scientific management techniques are combined with participatory labor-management relations. The work force was divided into 350 teams, consisting of five to

seven people and a team leader. Team members were taught Taylor's techniques for describing and analyzing physical tasks. Team members now design all the team's jobs, time each other with stopwatches, and explore ways to improve their performance. The results are compared across teams of different shifts. In addition, team members are trained to do each other's jobs and regularly rotate tasks. The surprising turnaround at NUMMI is ascribed to the fact that Toyota could persuade workers that they are the key element to the factory's success. NUMMI management won workers' trust and commitment by instituting a no lay off policy, as well as implementing extensive training and maintaining constant consultation with the workers.³

¹Adler (1993).

²In his 1911 book, Frederick Taylor argued that the productivity of physical labor could be increased by measuring in great detail the activities of workers, and then standardizing and accelerating their tasks.

³At the start of NUMMI, it was agreed to not lay people off, except in the most dire straits and then only after managers' pay was cut along with other expenses. This agreement became part of the UAW contract with NUMMI. It was put to test in the late 1980s when production at NUMMI fell sharply. Capacity utilization fell to about 60 percent and about 10 percent of the work force were idle. The idle workers were rotated into four week training programs, at full pay, until production picked up around eight months later. See Uchitelle (1993).

company that makes clutch plates for manual shift cars in Wooster, Ohio, introduced such a new work ethic. Its 340 employees are now encouraged to constantly search for ways to improve output and quality. As a result, Luk improved productivity at its plant to the extent that it could overtake the market leader which had shifted its production to Brazil, in an attempt to economize on labor costs. Luk's constant improvements to its efficiency rendered the foreign operation of its competitor unsuccessful.⁵

In another example, Eaton Corp. instituted teams on the factory floor and encouraged workers to improve incrementally the products they make and the processes used to make them. A system of bonuses serves as an incentive to solicit suggestions. The company's productivity rose by 3 percent a year over the last decade; that compares to an average increase of 1.9 percent

for all U.S. manufacturers. Some of that increase in productivity was the result of conventional belt tightening efforts; Eaton closed four plants in 1991 and laid off 807 workers. However, due to improved management-labor relationships and productivity gains at its Lincoln, Illinois, plant, Eaton relocated 70 jobs from Mexico.⁶

Worker training

Under lean manufacturing, a worker also maintains the equipment, cleans up the work area upon completion of other duties, and performs quality control functions. If the worker spots a flaw in the production process, the group leader is alerted. The manufacturing error is then corrected instantly, either while the car is still moving on the assembly line or after the line has been stopped by the group leader. Of course, shutting down the assembly line to

correct defects requires highly skilled line workers who must be able to recognize and correct defects in order to restart the assembly line quickly. Whirlpool Corp. decided to teach its workers how to improve quality and productivity at a tooling and plating shop in Benton Harbor, Michigan. In addition to implementing a system of financial incentives to reward productivity gains, Whirlpool focused on improving the skills of its employees. It set up a new training center at its plant that offers interactive computer lessons on everything from general math skills to learning how to handle gauges and other tools. Workers from the Benton Harbor shop went to see the assembly plant for washing machines to learn how the parts they produce are put into the final product. With this understanding, they were able to make adjustments that helped the line flow more smoothly. As a result, the Benton Harbor plant's productivity has surged more than 19 percent since 1988.⁷

Higher demands on workers' education and skills raise the barriers of landing a manufacturing job. For example, in order to apply at a Carrier Corp. compressor plant in Arkadelphia, Arkansas, one must be a high school graduate or have a general education diploma. Applicants take a standardized state test; only those scoring in the top third advance. The applicants who advance past the interviews take a

six week course prior to receiving a job offer. Five nights a week for three hours, they learn blueprint reading, math such as fractions and metric calculations, statistical process control methods, some computer skills, and how to solve problems in dealing with fellow workers. Successful completion of the training sessions virtually guarantees a job at the plant.⁸

Location decisions

Recent evidence indicates that automobile manufacturing is reviving in the Midwest (see Table 2). Rubenstein (1992) refers to two structural trends. First, increasing fragmentation of the market for passenger cars since 1960 reduced the need for branch plants; that is, plants producing identical models at centers of demand for regional distribution. Of the four West Coast passenger car assembly plants in operation 10 years ago, only NUMMI's Fremont, California, plant still operates. A fair amount of geographical restructuring of the automobile industry has also occurred within the Midwest over that time period. GM alone closed seven and opened four plants in the Midwest during the last 10 years.⁹ Surprisingly, the age of an existing assembly plant does not seem to increase its likelihood of being shut down. Ford Motor Company, for example, has not opened a single new assembly plant for passenger cars in the U.S. in the last decade, yet

TABLE 2

U.S. car production by state
(percent of U.S. total)

Model year	IL	IN	MI	OH	WI	Midwest ¹	Midwest without transplants ²
1991	9.5	0.9	31.9	16.7	1.8	60.8	46.5
1990	9.2	0.2	32.0	13.5	3.4	58.3	46.4
1989	7.6	—	32.6	11.9	4.7	56.8	48.8
1988	5.9	—	35.8	12.5	5.8	60.0	52.5
1987	7.8	—	34.0	12.5	3.6	57.9	53.4
1986	6.7	—	32.5	11.5	3.8	54.5	52.1
1985	6.4	—	29.0	9.8	4.6	49.8	47.8
1984	6.6	—	28.2	10.7	6.1	51.6	50.2
1983	6.8	—	33.3	8.8	5.2	54.1	53.5
1982	5.7	—	36.0	5.9	2.0	49.6	49.6
1981	6.1	—	30.4	4.3	4.8	45.6	45.6

¹Midwest is defined as Illinois, Indiana, Michigan, Ohio, and Wisconsin.

²Transplants refer to U.S. facilities of foreign auto assemblers, including joint ventures.

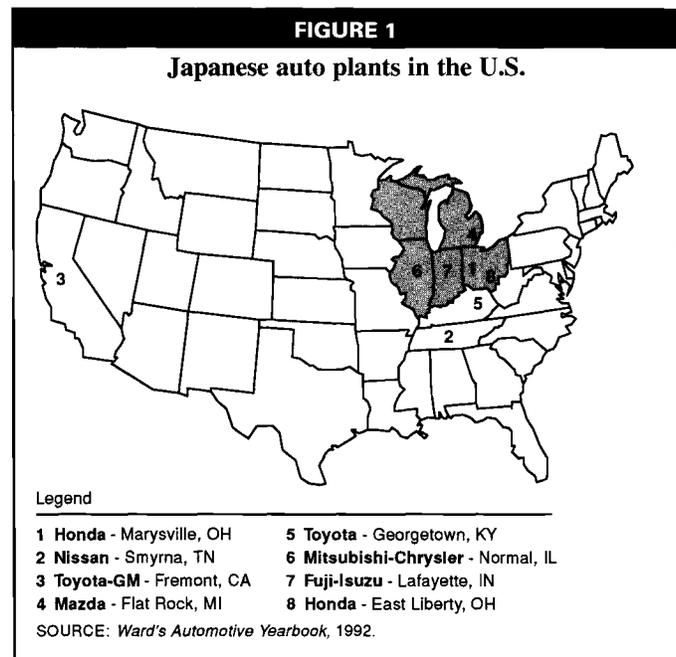
SOURCE: *Ward's Automotive Yearbook*, 1982-1992.

it currently ranks as the most productive of the Big Three.¹⁰ The results of a study by Rees, et al. (1986) on the spread of automated technology in the American machinery industry support the same conclusion and suggest an explanation. It reports that older plants are more likely users of new production technologies than newer plants; evidence for a continuous retooling process taking place in the more established industrial areas of the country.¹¹

Second, nearly all of the Japanese transplants have located in the Midwest, in proximity to the indigenous automobile industry's supplier industry (see Figure 1). In fact, that development is responsible to a large extent for the revival of automobile manufacturing in the Midwest. In model year 1992, transplants produced 23.5 percent of all the automobiles in the Midwest, up from 3.4 percent in model year 1983.

However, the sites chosen by the Japanese were not traditionally associated with motor vehicle assembly. Note in Table 2 the southward shift of automobile assembly; losses in Wisconsin's share of automobile assembly were compensated by gains in Illinois and Ohio. The location of transplant assembly plants on mostly rural greenfield sites is generally seen as the result of the perception that flexible work assignments may be difficult to implement in urban locales where the influence of strong labor unions may resist such changes.¹² Japanese plants desire low cost locations, which avoid strong union centers yet have access to an adequate labor pool (Rubenstein, 1992). Accordingly, a complex pattern of industrial growth and decline emerged in the Midwest.¹³

In a lean manufacturing environment, the location of suppliers seems to be influenced by the need for a tightly controlled flow of parts and materials, including a timely supply of materials from outside suppliers.¹⁴ It is therefore no surprise to find relationships between car assemblers and suppliers to be characterized by high levels of communication and mutual commitment. These close relationships may help to explain the fact that lean manufacturing assemblers have chosen to buy directly from only a



small number of "first tier" suppliers. Mair, et al. (1988) analyze the effect of lean manufacturing on the locational pattern of supplier operations for Japanese transplants in North America. They find existing geographical patterns of transplant locations to be a direct result of the desire of Japanese automobile producers to transfer lean manufacturing techniques to North America. Rubenstein (1988) and Rubenstein and Reid (1987) analyze the changing supplier distribution of American motor vehicle parts suppliers. Their sample consists of about 1,000 suppliers from Ohio. They cannot establish a clear cut effect of lean manufacturing on location, yet they do find a change from the long term locational pattern of auto supplier companies which prevailed until the 1970s. With the introduction of a tiered supplier structure, increased cooperation, and longer term contracts between car assemblers and suppliers, first tier suppliers are found to locate new plants near their customers' assembly plants. However, there are also countervailing pressures. The pressure to reduce production costs leads to geographical dispersion, especially for lower tier suppliers; that often means setting up shop in a nonunionized rural area, or even a low wage foreign country.

Product development

Under lean manufacturing, the development process is not the sum of the individual work of a large number of narrowly focused specialists.

Instead, the development of an automobile is guided by a team which includes members from marketing, design, research, logistics, production planning, engineering, and sales. The team stays together for the life of the model and its leader has a range of real decisionmaking powers within the organization of the company. Chrysler's recent introduction of its LH-cars illustrates the benefits of this approach.¹⁵ The LH-car was developed in 39 months with a technical staff of 740, as compared with the development of the K-car, which was introduced in the early 1980s and took 54 months and a technical staff of 2,000.¹⁶ Development of the K-car followed the sequential process of Fordist manufacturing.

The lean development process also relies on contributions from parts suppliers. Chrysler received almost 4,000 suggestions from its suppliers in the development of the LH-car, saving \$156 million.¹⁷ Instead of being played against each other in competitive bidding, supplier companies now enter into long term contracts with producers. As part of the new sourcing relations, the supplier may need to develop a component, or subsystem, with the assembler merely giving final approval of the part. Therefore, rather than produce parts according to predetermined specifications, outside suppliers must increasingly conduct product research and development both on their own and in consultation with assemblers. Turning over complete component systems to suppliers enabled Chrysler to drastically reduce the number of vendors with which it does business. It now deals with 230 parts and materials suppliers in producing its new LH-platform using the lean manufacturing system.¹⁸ That compares to 456 suppliers for the 1992 version of the Chrysler New Yorker, a car introduced in 1988 and built according to the Fordist system.¹⁹

Implications for economic development policy

This article has highlighted some dramatic changes to the auto industry brought about by the introduction of lean manufacturing techniques. If other Midwest manufacturing industries are to compete globally, they must follow the lead of the Midwest auto makers and parts suppliers and adopt the more efficient lean manufacturing standards. What are the implications of these changes for the direction of regional economic development policy? The main goal has to be to ease the transition and sustain the changeover to lean production in autos and

broadening it to other manufacturing sectors. However, since there will be a multitude of adjustments, which vary from industry to industry, and even plant to plant, there is no single or simple policy measure that can address all of the necessary adjustments. Rather, in many instances policymakers will have to rely on a well-chosen array of customized policy measures.²⁰

First, the creation and upgrading of labor skills is a major requirement for lean manufacturing operations. Successful implementation of lean manufacturing in factories rests on the ability to enhance skills and responsibilities of assembly line workers within a team oriented management approach. This will require job training programs that teach how to improve quality and cooperative management in order to successfully harness ideas for improving the production process. Policy measures include apprenticeship programs, vocational training schemes, and part-time enrollment in local universities. Training on the job can be used to improve the skills of the workforce during low capacity utilization periods. For example, when NUMMI experienced weak demand for its products during the late 1980s it put idle workers on job training programs. The state government of California subsidized some of the cost, justifying the outlay with the argument that unemployment would have been more expensive.²¹

Second, within individual states, efforts have been made to support the adaptation of lean manufacturing technologies. For example, in 1989 Pennsylvania instituted a "Manufacturing Innovation Networks" program that supports the growth of lean manufacturing networks by means of eight industrial resource centers. These regional centers introduce smaller and medium sized manufacturers to leading manufacturing process technology. The centers are overseen by independent boards and the programs are customized to local identity and economic conditions. Since 1988, industrial resource centers have worked with about 10 percent of Pennsylvania's manufacturers (Greenberg, 1992). Other programs, like Michigan's Technology Centers or Ohio's Edison Technology Centers are more broadly targeted and serve as an intermediary organization for technology development in specific industries. The main objective of these programs is to share both information and knowledge on the application of lean manufacturing techniques. A national economic strategy in support of commercial

research and development and manufacturing excellence has been proposed by the National Center for Manufacturing Sciences. It launched an initiative called the Manufacturing Application and Education Center Network. It represents a collaboration among state governments, academic institutions, economic development organizations, and industry. Funding for the centers is equally split among the federal and state governments and private industry. Of the planned 150 centers, three are currently in operation. Each center will be tailored to address regional industrial needs and will provide manufacturers with access to new technologies and equipment, better business practices and new materials and products.²²

Third, international competition and direct foreign investment in the U.S. have been im-

portant elements supporting the introduction of lean manufacturing techniques into North America. The success of the Japanese transplants has shown the ability to transfer manufacturing technology internationally. Fostering openness to trade and investment are therefore crucial for the Midwest's and nation's success in an environment where advances in manufacturing technology are being made around the world.

Last, but not least, lean inventories render frequent timely deliveries of parts and materials crucially important for the successful application of lean manufacturing. That places great emphasis on a well designed and maintained system of public transportation infrastructure.

FOOTNOTES

¹The Economist Newspaper (1992), survey p. 6.

²In developing the lean manufacturing system, Japanese companies, most notably Toyota, were influenced by their own analysis of the Fordist system as well as the quality enhancing ideas of American consultant W. Edwards Deming.

³White (1992).

⁴After reaching 30 percent in 1991 and 1992, the Japanese share of U.S. car sales fell to 27 percent in the first two months of 1993, while the Big Three's market share rose three percentage points to 68 percent (Miller and Mitchell 1993).

⁵Uchitelle (1993). No information is available on changes in the overall employment level at Luk; however, employees who are not adjusting to the new job requirements end up with a smaller degree of job security.

⁶O'Boyle (1992).

⁷Wartzmann (1992).

⁸Norton (1993).

⁹In December 1991, GM announced that as part of its corporate restructuring it would close 21 factories, including 6 final assembly plants. Since then it has only identified 2 of the 6: the minivan plant in Tarrytown, New Jersey, and its Willow Run plant near Ypsilanti, Michigan. See Treece (1992).

¹⁰White (1992).

¹¹Rees, et al. (1986), p. 215. The authors explain this

finding with the fact that most of the new technologies are discrete units that can be introduced into an existing plant in an incremental fashion.

¹²See Linge (1991) and Testa (1993).

¹³Rubenstein (1991), p. 129.

¹⁴According to newspaper reports, Saturn Corp. will charge suppliers who disrupt the production process by sending inferior or mislabeled parts \$500 per minute for the delays they cause. The policy went into effect November 1, 1992. See Frame (1992).

¹⁵Ford was the first of the Big Three to successfully implement the team approach in developing the Taurus, launched in 1985. As part of the recent major corporate reorganization taking place at GM, all new development projects are being carried out by teams as of January 1993. Models created by these teams are not scheduled to appear on the market until at least 1996, however (Levin 1993).

¹⁶Stertz (1992).

¹⁷Stertz (1992).

¹⁸Platform refers to the structural underbody of a car. For example the Dodge Intrepid, Chrysler Concorde, and Eagle Vision are separate models, yet are all LH-platform vehicles.

¹⁹Ward's (1992), p. 53.

²⁰See Ettlinger (1992) and Scott (1992).

²¹Uchitelle (1993).

²²National Center (1992).

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