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Practices and Performance of Small and Larger US Manufacturers: Issues and Implications

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Abstract

When it comes to technology use, small manufacturers are very significantly different from larger manufacturers. In this study, small manufacturers are defined as plants employing less than 100 employees and larger plants are defined as those employing more than 99 employees. This paper is based on the responses of 1042 manufacturing plants belonging to industrial classifications SIC 34 to 38 reported in Swamidass (1994).

This paper uses benchmark of technology use as a vehicle for comparing small and larger manufacturers. It starts with the benchmarks of the usage of 15 selected technologies in US manufacturing plants; all 15 technologies investigated are described in Table 1; see Appendix II for the definition of the technologies studied. Notable findings on technology usage are: (1) CAD, TQM and JIT are the most widely used technologies regardless of skill levels, (2) Among extremely skilled users, CNC and CAD are the most widely used technologies, and (3) The extensive use of seven technologies, CAD, CAM, CNC, TQM, JIT, SQC and manufacturing cells is at the heart of competitive manufacturing in US factory floors.

Number of Technologies Used: The average plant used 7 different technologies; only 30 plants (about 3 percent) used none of the fifteen technologies investigated. Eighteen percent of the plants used ten or more technologies.

The average plant is an extremely skilled user of 1.8 technologies, with 63.3 percent reporting extreme skill in the use of at least one technology. About 20 percent of the plants are extremely skilled in the use of four or more technologies.

Most frequently cited benefits: Reduced cycle-time, market share growth, progress towards zero defects, and return on investment (ROI) are the top four direct benefits of technology use reported by the respondents. The most frequently mentioned direct benefit of technology use was reduced cycle

time, cited by 66 percent of respondents. One can infer from the finding that manufacturers are most often investing in manufacturing technologies to reduce the cycle-time from order to shipping.

Benefits of Extremely Skilled Technology Use: JIT took the top honors as the one technology whose extremely skilled use was unfailingly associated with the best performance, regardless of the performance metric used. Complex analyses with the data from the study have shown that the skilled use of hard and soft technologies are associated with increased sales per employee and return on investment (Swamidass, 1996c).

The Technological Advantage of Larger Plants: For every technology used by a small plant, 2.2 large plants us the same technology, and for every technology used with extreme skill by a small plant, 3.4 larger plants do so (Swamidass, 1996b).

Introduction

Manufacturers are eager to know if productivity, quality and profitability are enhanced by investments in manufacturing technologies. What are the most common benefits attributable to manufacturing technology use? Unfortunately, there are very limited information on the subject for searching manufacturers. To acquire such information we must develop industry norms or benchmarks on manufacturing technology use and performance. This paper describes the use of industry-wide benchmarks for comparing and evaluating the use of advanced technologies using data collected in a 1993 survey of manufacturers (Swamidass, 1994). Appendix I explains the data collection and validation procedures used in this study.

One of the common challenges faced by users and researchers of manufacturing technologies is the question of classifying manufacturing technologies. This research has classified manufacturing technologies as hard and soft technologies. The fifteen technologies benchmarked here are identified in Table 1, and each technology is described in the Glossary in Appendix II.

Soft and Hard Technologies

Swamidass (1992, 1994, 1996a) has categorized technology on the factory floor into two kinds: "hard technology" and "soft technology". Hard technologies are hardware (and associated software) based technologies such as FMS, CAD and CAM. Soft technologies, on the other hand, are techniques such as statistical quality control (SQC/SPC), just-in-time production (JIT), and manufacturing resources planning (MRP II).

The Characteristics of the Plants Studied

This is a study of manufacturing plants, *not* entire manufacturing firms with multiple plants. The reason we studied plants as opposed to entire companies is that technology use practices vary significantly among the various plants of a given company. The average characteristics of the plants participating in this study are:

- Employment is 228 workers.
- Plant sales is $47.2 millions.
- Sales per employee is $133K.
- Average pretax return on investment for three years is 12.99 percent
- Plant has 24 product lines
- Inventory turns is 8.04
- The lead-time from order to shipping is 7.19 weeks.
- Rejection and rework rate is 4.00 percent.
- More than 84 percent of the plants participating in the study have export sales.
- Forty-five percent have some sales to the US Department of Defense.
- About 30 percent of the respondents use line or flow production.
- Nearly 45 percent use job shops.
- About 20 percent use manufacturing cells predominantly for production.
- Over 55 percent of the respondents use small batch production.

10.	JIT	...	Just-in-time manufacturing
11.	Manufacturing cells		See glossary in Appendix III
12.	MRP	...	Material requirements planning
13.	MRP II		Manufacturing resource planning
14.	SQC	...	Statistical quality control
15.	TQM	...	Total quality management.

An Overview of the Respondents

The descriptions of the industries participating in this study and the number of participants from each Standard Industrial classification (SIC) are given below:

	Participants	Percent
SIC 34: Fabricated metal, except machinery & transport equip.	442	42.5%
SIC 35: Industrial, commercial machinery, computer equipment	293	28.1%
SIC 36: Electrical, other electrical equipment	164	15.7%
SIC 37: Transportation equipment	92	8.8%
SIC 38: Measurement instruments, photo goods, watches	51	4.9%
Total Usable response	1042	100.0%
Other manufacturing or unknown (excluded from all subsequent analyses)	79	---
Gross response	1121	---

Respondents

The questionnaires were completed by one of the members of the top management in the manufacturing facilities participating in this study.

Annual Sales

The average annual sales for a plant is $47.2 million. The combined total sales for all the plants in this study is in excess of $49 billion. Seventy-one percent of the respondents have annual sales of less than $20 million, and 91.5 percent have annual sales of less than $100 million dollars. Small plants average $5.35 million in sales and large plants average $87.2 million in sales (100 or more employees).

Export Sales

Only 15.5 percent of the plants in the study do not export. About half (44 percent) export less than 10 percent, while one-fifth (20.2 percent) export more than 20 percent of their sales. Among small plants, 22 percent had no export sales whereas, among the larger plants, only 6.5 percent reported no export sales.

Defense-Related Sales

More than one-half of the manufacturers do not make defense-related products, while another third send less than ten percent of their output to the Defense Department.

ISO 9000 Certification

Only four percent of manufacturers in the industries covered by this study are already certified in the ISO 9000 series. However, a healthy 23 percent (about one-fourth) are in the process of certification. Only 13 percent are not interested in ISO 9000 certification. Among smaller plants, one percent are certified, whereas 7.8 percent of larger plants are certified. While 15.6 percent of the small plants are in the process of certification, 33.2 percent of larger plants are in the process of doing so.

Table 2
A Comparison of Averages for Small & Larger Plants

		Small Plants Employment <100	Larger Plants Employment ≥ 100
Sample size	(n)	551	463
1.	Sales ($ million)	$5.35	$87.2
2.	Employment	46	443
3.	Sales/employee ($000)	114	144
4.	Rejections %	3.48%	4.54%
5.	Inventory turns	8.3	7.8
6.	Cost-of-goods sold	58.9% of sales	62.50% of sales
7.	Product lines	23.7	23.51
8.	Models	71.5	143.00
9.	Average lead time (weeks)	6.25	7.97
10.	Direct labor costs	21.5% of sales	14.67% of sales

Dominant Manufacturing Processes

Job shops are the most common in the survey sample. This is explained by the fact that 54 percent of manufacturers employ fewer than 100 employees. One-fifth (20.7 percent) of all plants predominantly use manufacturing cells. While 13.8 percent of small manufacturers use cells predominantly, 28.2 percent of larger manufacturers do so; that is, larger plants use cells twice as often as smaller plants. Manufacturing cells provide and an important avenue for capturing cost efficiencies as well as flexibility.

Small versus Larger Plants

There is an across-the-board difference in technology usage between small (less than 100 employees) and larger plants (100 more employees). It is notable, however, that small manufacturers use all the technologies investigated in this study. Table 2 compares small and larger plants on a number of basic characteristics. In the following sections small and larger plants are compared in their use of technologies, which is very revealing. The difference in technology use between small and larger plants has significant implications for training.

Manufacturing Technology Use

Figure 1 assesses the penetration of manufacturing technologies in all plants surveyed, but does not distinguish between extremely skilled users and others. According to Figure 1, CAD (84 percent) TQM (72 percent), JIT (71 percent) and CNC (71 percent) have the most widespread use in US manufacturing. AGVs are not used widely because they are either not relevant to most operations, or they are not cost efficient in most situations.

FMS use at 26.2 percent is notable because these are very expensive systems, which build flexibility in small-volume production through automation. Additionally, CIM use at 39.7 percent should be considered a major progress because CIM is expensive and time-consuming to implement.

Figures 2 and 3 show how technology use differs with size. While 75.5 percent of small plants use CAD, 94.8 percent of the larger plants do so. JIT use is more common among larger plants by nearly a 20 percent margin. The proportion of larger plants using manufacturing cells is twice that of small plants. In the case of some technologies in the figures, the proportion of larger plants using the technologies is many times the proportion for small plants; thus, larger plants more frequently employ advanced technologies than their smaller counterparts. Some of the accepted explanations are affordability, know-how and the risk-taking capability of larger plants.

Skilled Users of Technologies

In Figures 4, 5 and 6 technology use by skill levels is displayed. Figure 1 and 4 show that, while the use of JIT and TQM is widespread, fewer users are extremely skilled in the use of these technologies when compared to the use of CAD and CNC.

Figures 5 and 6 show how small and larger plants differ in the extremely skilled use of technologies. While only 25.5 percent of small plants are extremely skilled in the use of CAD, the corresponding percentage for larger plants is 43.8 percent. The two Figures 5 and 6 reveal that the training needs for small and larger plants can be very different.

Superior Technology Base of Larger Plants

In a recent study Swamidass (1996b) found that larger plants have a distinct technological advantage over small plants. The advantage could be summarized as:

1. On average, small plants use 5.4 technologies where as larger plants use 9 technologies.
2. On average, small plants use 1.2 technologies with extreme skill but larger plants use 2.6 technologies with extreme skill.
3. For every small plant using a specific technology, 2.21 larger plants do so.
4. For every small plant using a specific technology with extreme skill, 3.4 larger plants do so.

Given the above differences, large plants have a superior technology base than smaller plants.

The Benefits of Investment in Technologies

Manufacturing technologies, when wisely selected and used, enable manufacturing firms to compete better through reduced cost, increased quality, reduced manufacturing lead-time, reduced time-to-market and increased product variety. In spite of the many benefits of manufacturing technology use, however, the adoption of manufacturing technologies is often slow due to reasons including poor and confusing equipment justification methods, poor understanding of the benefits of modern technologies, and/or lack of capital. This study strives to correct the lack of information about the benefits attributable to manufacturing technology.

Figure 7 reports the claims of respondents concerning benefits attained from the use of advanced manufacturing technologies. Two out of three respondents report that reduced cycle-time was a direct benefit of their investment in advanced manufacturing technologies--far and away the most oft-cited benefit. The overwhelming frequency with which this benefit is mentioned (66 percent), was unexpected. Based on Figure 7, one could conclude that the reduction of cycle-time is one of the most significant reason for investing in new technologies. Prior to this study there was no definite link between technology usage and cycle-time reduction. In

Figure 7, other top rated benefits of advanced technology use are: market share growth, zero defects, ROI, focused production, and wider product lines.

The average plant reported 3.7 benefits from the list in Figure 7 as a direct result of technology use. More than 85 percent of the respondents reported one or more benefits. About a fourth of the respondents reported six or more benefits. Extremely skilled users of JIT reported a superior inventory turn at 10 (average=8.04), the second lowest manufacturing lead-time at 7.2 weeks, the lowest rejection and rework rate at 2.9 percent (average = 4.00 percent), superior sales-per-employee at $178K (average = $133K) and the best ROI at 17.6 percent (average 12.99 percent). With these rewards associated with JIT, it is no surprise that we found that JIT is used by nearly 90 percent of those who consider it relevant to their operations.

Benefits Increase as Skill Level Increases

Often a single technology is associated with more than one benefit. Using a multiple regression model, we investigated if the number of benefits increased with increased skill in technology use. Skill level in technology use was coded as: extremely skilled use = 3; moderately skilled use = 2; some skill in technology use = 1; do not use the technology = 0.

Based on our multiple regression model (Model R^2 = .28; significance = .0001) and its partial R-squares, we find that, as the skill level in the use of manufacturing cells and JIT increases, the number of benefits to the manufacturer increases. To a lesser degree, the same is true for the use of FMS and MRP I. We infer from this that, in general, the number of benefits from soft technologies such as manufacturing cells, JIT and MRP I increases with their skilled use while the number of benefits from hard technologies, with the exception of FMS, do not seem to increase much with their skilled use. The explanation for this finding may lie in the cross-functional impact of JIT, manufacturing cells and MRP. That is, their implementation cuts across many functions; some more than others. Therefore, multiple benefits are bound to accrue with the skilled use of these technologies.

Our model shows that, of all the technologies considered, the skilled use of manufacturing cells is associated with the most sizable increase in the number of benefits. Therefore, for manufacturers looking for multiple benefits from investments in technology, the first and the foremost choice ought to be manufacturing cells. Further, we found that the use of cells is closely associated with the use of JIT and TQM because cells facilitate the implementation of these technologies; this is an added benefit of using cells.

Benefits of Extremely Skilled Technology Use

We investigated plant performance on five indices of performance when technologies are used with extreme skill.

***Inventory Turns*: ** Extremely skilled users of AGV, SQC, JIT and automated inspection outperform others on inventory turns. Since all these technologies are generally implemented in repetitive manufacturing environments, the high inventory turns associated with these systems is consistent with expectations.

***Lead time from Order to Shipment*: T**he most commonly mentioned benefit associated with advanced technology use was lead-time reduction. MRP II is associated with the shortest average lead time at 6.5 weeks. Hard technologies such as AGV, automated inspection and robots are associated with longest average lead-times. The average lead-time for all plants is 7.19 weeks.

Rejection and Rework Rates: Extremely skilled use of FMS and JIT offers the lowest rejection and rework rates. On the opposite end of the spectrum, CIM, CAD, and SQC are associated with higher rejection and rework rates. The apparent paradox could be explained by several possible reasons. High average rework and rejection rates for SQC users could be due to the very nature of the manufacturing environment. That is, rejection rates could be even higher if not for SQC. Also, SQC is often implemented by laggards among manufactures after quality levels have deteriorated to a serious level. Still another possible explanation is that SQC identifies the defects that desire to be rejected or reworked before shipping to customers. But, non-SQC environments may be hiding defects that are not detected before shipping to customers. Additional investigation is needed to understand this more fully. The average rejection and rework rate for all plants is 4.0 percent; small plants average 3.47 percent and larger plants average 4.54 percent.

Sales per Employee: Hard technologies such as AGV, CIM, robots, and FMS are associated with higher sales per employee, which usually improves with automation. The average sales per employee for all plants is $133,000 (smaller plants average $114K and larger plants average $144K, which is expected). Extremely skilled use of robots, JIT and FMS are associated with superior sales per employee. In a recent study, Swamidass (1996c) found that **the skilled use** of hard and soft technologies significantly explained the variations in sales per employee; although, this effect had been suspected by researchers, this is the first time an empirical study confirmed the relationship.

Return on Investment: Extremely skilled use of JIT, MRP II and AGV is associated with superior return on investment. JIT's appearance at the top of the list should not surprise anyone. It is significant that, while the average ROI for all plants is 12.99 percent (11.5 percent for small plants and 14.7 percent for large plants), extremely skilled users of all technologies report much better than average ROI in every case except automated inspection (12.7%). JIT use leads all other technologies on ROI (17.6 percent). JIT's emergence as an effective and efficient technology is notable. Extremely skilled use of JIT is associated with the best performance or close to the best performance in each of the five performance measures. Either JIT use is found in the best performing firms, or the best performing firms use JIT. Either way, for the practitioner, the conclusion is easy to see, USE JIT!

Implication for Future Investigations

In a recent study (Swamidass, 1996c) using the data from this study, it was found that the skilled use of hard and soft technologies had a significant effect on sales per employee, and return on investment. The findings indicate that the skilled use of technologies is more likely to yield results than the mere use of a technology. The role of training and other efforts to increase the skilled use of technology is the focus of another study by the author.

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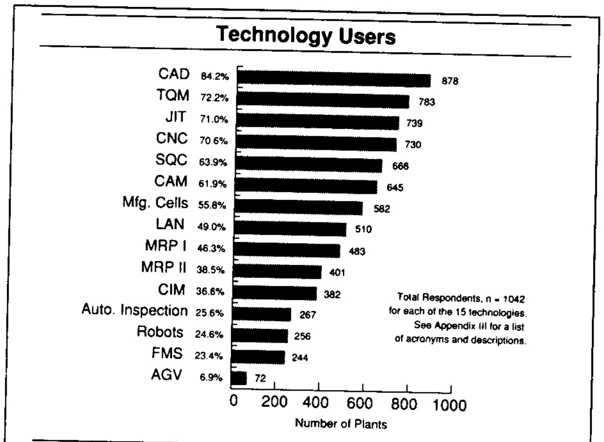

Figure 1

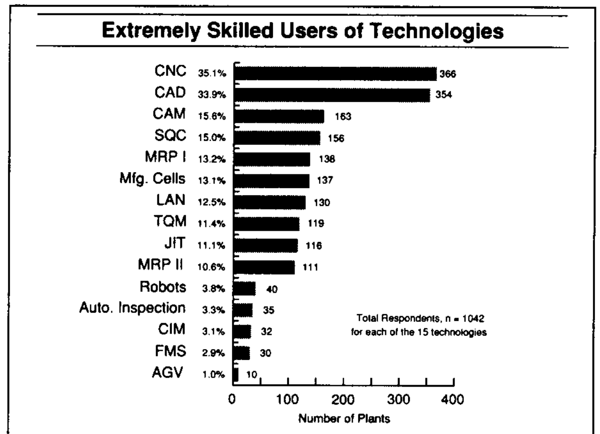

Figure 4

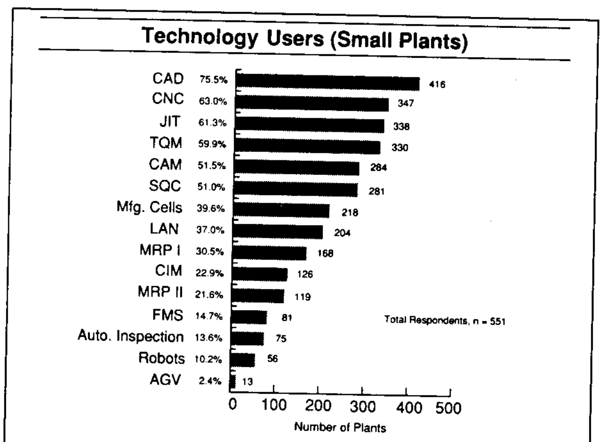

Figure 2

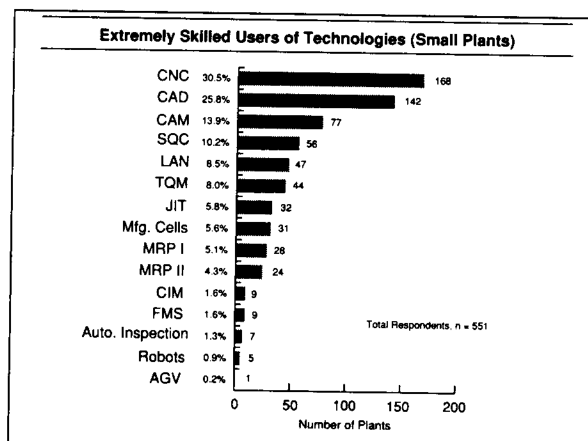

Figure 5

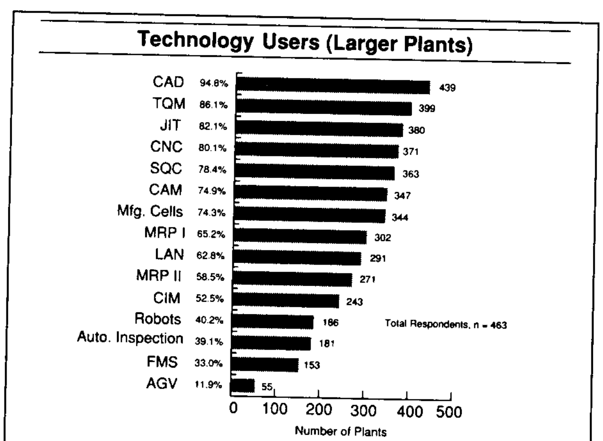

Figure 3

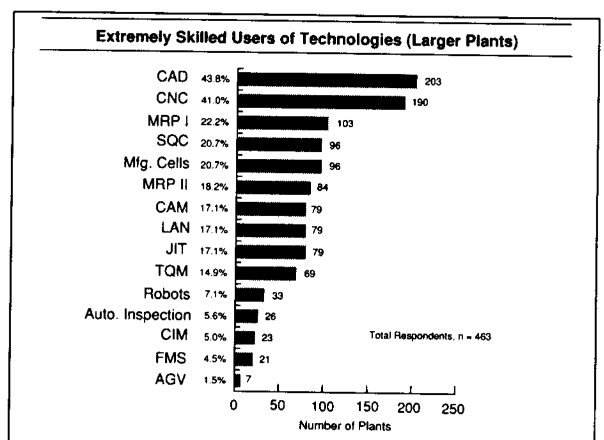

Figure 6

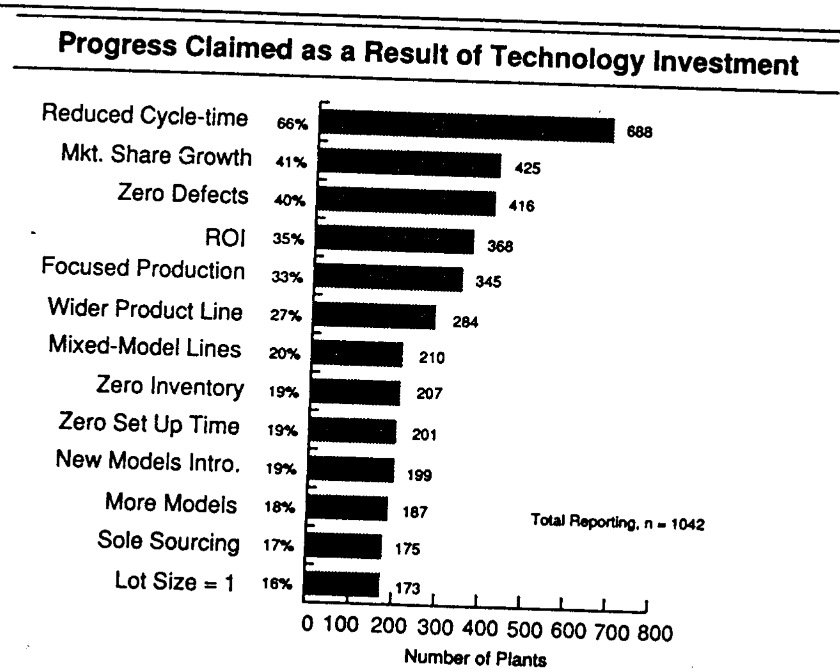
Progress Claimed as a Result of Technology Investment
Reduced Cycle-time 66% 688
Mkt. Share Growth 41% 425
Zero Defects 40% 416
ROI 35% 368
Focused Production 33% 345
Wider Product Line 27% 284
Mixed-Model Lines 20% 210
Zero Inventory 19% 207
Zero Set Up Time 19% 201
New Models Intro. 19% 199
More Models 18% 187
Sole Sourcing 17% 175
Lot Size = 1 16% 173
Total Reporting, n = 1042
0 100 200 300 400 500 600 700 800
Number of Plants

Figure 7

Appendix I : Sample and Validation

This is a study of individual manufacturing plants, not a study of manufacturing firms. A questionnaire was sent to 4,453 member firms of the National Association of Manufacturers (NAM) in the SIC industrial classifications 3400 through 3899 (followed by reminders) in the later part of 1993.

To examine the validity of the study, we developed a split sample. After mailing the questionnaire and one reminder, we received 556 usable responses; this formed the first "half" of the split sample. We sent the entire questionnaire once again to those firms that did not respond to the first mailing. The second "half" of the sample yielded 565 usable responses; 25 responses were unusable and 3 responses came after 2-15-94, the cut-off date; the resulting response rate being 25.8 percent. Our estimate shows that the response from larger plants (more than 99 employees) was about 42%.

Table A1 compares the distribution of plants by size in the split samples. The two samples are very similar on the basis of this comparison; no particular bias is evident.

Industry: In Table A3 below, we compare the distribution of plants by SIC classification with the BOC study serving as the reference.

Size: The industries covered by this study are identical to those covered by a Bureau of Census (BOC) study published in 1993[1]. The BOC study estimated the total number of plants in the US with 20 or more employees in 1991 in each industrial classification; the BOC estimate predates this study by at least two years.

Table A2 compares the distribution of plants in this study with the distribution of plants in the BOC study on the basis of size (employment). The NAM study is slightly biased towards larger plants. Yet, the two samples are similar in that , by far, the plants with 0-99 employees are the largest sub-group in both samples, and plants with 550+ employees form the smallest sub-group in both samples. The slight bias towards larger plants in the NAM sample is because the BOC sample covered all plants with 20 or more employees. Fewer firms with 20 to 50 employees tend to be members of NAM. Yet, the sample is reasonably comparable to the BOC estimate.

Industry. Table A3 compares the distribution of manufacturing establishments in the US is roughly comparable to the distribution of the respondents to this study with a slight bias towards SIC 34 (metal fabrication industry) in the NAM sample.

[1] U.S. Bureau of Census, *Manufacturing Technology: Factors Affecting Adoption 1991*, AMT/91-2, Current Industrial Reports, Government Printing Office, 1993.

Table A1
Distribution of Respondents by Size in the Split Samples
(Including outliers and miscellaneous manufacturing)

Employment	Sample 1 Respondents	%	Sample 2 Respondents	%	Total Respondents	%
Less than 49	159	29.18%	178	32.60%	337	30.89%
50-99	121	22.20%	122	22.34%	243	22.27%
100-499	196	35.96%	192	35.16%	388	35.56%
500+	69	12.66%	54	9.89%	123	11.27%
Total Providing Employment Data	545	100.0%	546	99.99%	1091	99.99%
Total Responding	556		565		1121	

Table A2
Comparison of the Distribution of Plants by Employment Size

Employment	BOC estimate 1991	NAM sample 1993
0-99	71%	53.2%
100-499	24.1%	35.6%
500+	4.9%	11.3%

Table A3
Distribution by Industry

	BOC estimate for the US (firms with 20+ employees) (percentage)	1993 NAM respondents (percentage)
SIC 34	31.6%	42.5%
SIC 35	33.2	28.1
SIC 36	16.6	15.7
SIC 37	9.5	8.8
SIC 38	9.1	4.9
	100.1%	100%

Appendix II: Glossary[2]

1. Automated Guided Vehicles (AGV)

AGVs are unmanned carriers or platforms that are controlled by a central computer that dispatches, tracks, and governs their movements on guided loops. AGV systems utilize infrared, optical, inertial, embedded wire, or ultrasonic methods for guidance. AGVs are primarily useful for materials handling, where they deliver inventory from holding to production areas, or between work stations as a replacement for conventional forklifts and rigid transfer lines. Some AGVs are used in assembly systems, while others provide production platforms that support products such as automobiles and engines while work is performed.

2. Automated Inspection (AI)

Automated inspection is defined as the automation of one or more steps involved in the inspection procedure. AI takes advantage of highly advanced sensor technologies to perform inspection functions once performed by humans (or not performed at all). AI can reduce manufacturing lead times and product cost associated with manual inspection. Further, AI allows for 100 percent inspection to be integrated into the manufacturing process.

3. Computer-Aided Design (CAD)

CAD is a computer software and hardware combination used in conjunction with computer graphics to allow engineers and designers to create, draft, manipulate, and change designs on a computer without the use of conventional drafting. CAD systems allow for tremendous speed, precision and flexibility over traditional drafting systems.

4. Computer-Aided Manufacturing (CAM)

CAM incorporates the use of computers to control and monitor several manufacturing elements such as robots, CNC machines, storage and retrieval systems, and automated guided vehicles. CAM implementation is often classified into several levels. At the lowest level, it includes programmable machines controlled by a centralized computer. At the highest level, large-scale systems integration includes control and supervisory systems.

5. Computer-Integrated Manufacturing (CIM)

CIM involves the total integration of all computer systems in a manufacturing facility; the integration may extend beyond one factory into multiple manufacturing facilities in one or more countries and into the facilities of vendors and customers. CIM integrates all computer systems that handle everything from order to shipment of final product. The integration may involve accounting, finance, management, engineering, design, production, manufacturing, and equipment. The idea is to form one large system that connects all activities so that common information is shared on a real-time basis. While CAM's scope is generally limited to the factory floor, CIM's scope can extend far beyond the factory floor.

6. Computer Numerical Control (CNC) Machines

CNC machines are locally programmable machines with dedicated micro- or mini- computers. CNC provides great flexibility by allowing the machine to be controlled and programmed on the floor by the machine operator. Further, CNC allows machines to be integrated with other complementary technologies such as computer-aided design (CAD), computer-integrated manufacturing (CIM), and computer-aided manufacturing (CAM). CNC also serves as the building block for Flexible Manufacturing Systems (FMS).

7. Flexible Manufacturing Systems (FMS)

A flexible manufacturing system is a group of re-programmable machines linked by an automated material-handling system and a central computer. The intent of such a system is to produce a variety of parts that have similar processing requirements with low set-up costs. The typical FMS system is designed around and dedicated to manufacture a family of parts. The FMS is typically designed to run for long periods, with little or no operator attention, and fills the need for machining in a batch environment. FMS, unlike the old dedicated production lines, can react quickly to product and design changes.

8. Just In Time (JIT) Manufacturing

The concept of just-in-time manufacturing is a philosophy that requires materials and goods to arrive "just in time" to be used in production or by the customer. The philosophy of JIT has imbedded in it a "continuous habit of improving" and the "elimination of wasteful practices". Eliminating wasteful practices refers not only to looking for ways to cut cost, but also to continually eliminating everything that does not directly contribute to the company's objectives or adds value to the product. One of the most recognizable aspects of JIT is the low levels of inventory with which it is associated. In the JIT system, inventory is seen as a necessary evil.

9. Local Area Networks (LAN)

Local area networks are the backbone of communication systems that connect various devices in a factory to a central control center. The LAN, through the control center, allows for the various devices connected to the network to communicate with each other for exchange of information and control. The type of devices that can be attached to the network include computers, programmable controllers, CNC machines, robots, data collection devices, bar code readers, vision systems, automated inspection systems, and so on.

10. Manufacturing Cells (MC)

A Manufacturing cell is composed of a small group of workers and machines in a production flow layout, frequently a U-shaped configuration, to produce a group of similar items called "part families" in dedicated production areas. Proponents of cellular manufacturing have claimed several benefits for this type of production system, including less inventory, less material handling, improved productivity and quality, improved worker job satisfaction, smoother flow, and improved scheduling and control. Cells can be used for machining, fabrication and assembly, as well as combinations of the three. Cells permit a degree of automation, improved flow, reduction of direct labor, and provide the vehicle for implementing manufacturing innovations such as FMS and CIM. Flow patterns in cells vary considerably. Some resemble flow shops, while others are more like job shops. Because manufacturing cells are so adaptable, almost any manufacturer could gainfully use cellular manufacturing.

11. Materials Requirements Planning (MRP or MRP I)

MRP I is primarily a scheduling technique, a method for establishing and maintaining valid due dates or priorities for orders using bills of material, inventory and order data, and master production schedule information as inputs. MRP I has been around since mid 1960s.

12. Manufacturing Resource Planning (MRP II)

Manufacturing resource planning is a direct outgrowth and extension of closed-loop materials requirements planning (MRP) through the integration of business plan, purchase commitment reports, sales objectives, manufacturing capabilities and cash flow constraints. MRP II reports may include dollar value of shipments, product cost, overhead allocations, inventories, backlogs, cash flow projection, profits, etc.

13. Robots

The Robotics Institute of America defines the industrial robot as: "A programmable, multi-functional manipulator designed to move material, parts, tools or specialized devices through various programmed motions for the performance of a variety of tasks."

The basic purpose of the industrial robot is to replace human labor under certain conditions. The programmable nature of robots provides the flexibility to make a variety of products. The industrial robot was developed to generate higher output at a lower cost in situations that require, high repetition, high precision, large capacity work loads, and hazardous environment. (e.g., paint booths, chemical processing and welding).

14. Statistical Quality/Process Control (SQC/SPC)

SQC/SPC apply the laws of probability and statistical techniques for monitoring and controlling the quality of a process and its output. SQC/SPC can be used to reduce variability in the process and output quality. It contributes to the implementation of JIT & TQM.

15. Total Quality Management (TQM)

TQM is built on the principle of continuous quality improvement in manufacturing, as well as the entire organization. It works well with frequent feedback of performance measures to various system elements empowered to make changes in their operation such that the system moves closer and closer to its stated goals.

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[2]Under the guidance of the author, complied by Michael Hickman, graduate research assistant at the Thomas Walter Center, Auburn University.