GEORGIA MANUFACTURING TECHNOLOGY SURVEY 1994
Summary of Results
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Executive Summary

In the fall of 1994, Georgia Tech researchers conducted a survey of manufacturers with 10 or more employees in the state; 1,180 completed surveys were received. Key findings are summarized below (weighted by industry and size).

Problems and Needs

- Human resources and training, manufacturing process, and environmental and health and safety were the three most commonly mentioned problems by Georgia manufacturers.

- Small manufacturers, with 25 or less employees, were more likely to mention market development and access to financing as problems.

Technologies and Techniques

- The most commonly used "hard" technology was personal computers or terminals for non-manufacturing purposes, used by nine in ten manufacturers. The most commonly used "soft" technology was business or strategic plans, used by seven in 10 manufacturers. ISO 9000 certification was most often mentioned in manufacturers' plans, followed by data collection devices and doing business electronically.

- The average plant reported using eight of the 24 hard and soft technologies in the survey. The top 5 percent of hard and soft technology users reported using twice that amount.

- Manufacturers in the electronics and instruments industries were more avid technology users than those in other industries.

- Plants employing 100 or more employees used twice the number of technologies than those with 25 or less employees. However, the top 5 percent of small firm technology users have similar levels of usage of soft technologies to the top 5 percent of large firm users.

- Although Georgia is known as a "branch plant" state, 84 percent of the plants reported that their investment decisions are made in Georgia.

- 84 percent of manufacturers said they conduct some type of research, development, and engineering activity. More than 60 percent conduct:
- -Manufacturing engineering and process improvement
- -Customized design of existing products
- -New product development or prototyping

Customer and Other Manufacturer Relationships

- Nearly 84 percent of manufacturers often compete on high quality.
  - Seven in 10 said their major customers have established quality performance requirements.
  - Four in 10 said that they often have two or more customers with different quality requirements
  - Three in 10 said major customers often give short-term contracts
  - Only two in 10 said major customers often provide direct assistance to improve quality or solve technical problems. Manufacturers with less than 100 employees were less likely to report receiving assistance from major customers.

- Although 40 percent of the manufacturers said they subcontract or outsource work, only 16 percent of production value, on average, is subcontracted or outsource. Nearly half of this subcontracting work goes to other Georgia firms.
  - 28 percent of Georgia manufacturers ship to defense agencies, prime contractors, subcontractors, or U.S. Department of Energy agencies or contractors.
  - The average manufacturer ships only 5 percent of production value to defense agencies or contractors. However, for 5 percent of the firms shipping to defense agencies, these agencies and contractors account for at least 65 percent of their sales.
  - Manufacturers in metalworking/machinery and electronics/instruments industries were more likely to ship to defense agencies

- Roughly half of Georgia's manufacturers reported participating in some sort of inter-firm collaborative activity.
  - Manufacturers with 100 or more employees were considerably more likely to participate in inter-firm activities than were smaller firms.
  - The most common inter-firm activity was identification of shared industry problems and needs.
  - Manufacturers were most interested in quality assurance/ISO 9000 user groups.

Use of Assistance Sources

- Use of assistance sources is prevalent among Georgia manufacturers.
  - 47 percent used some type of private source (e.g., consultant, vendor, or other private organization) between 1991 and 1993.
  - 27 percent used some type of public or non-profit program between 1991 and 1993. Georgia Tech and Georgia Power Company were the most common sources of assisted used.

  - Roughly 70 percent of all manufacturers using public or non-profit sources also used some type of private source. It is possibly that the public sources act as a resource link to private organizations.
  - Public/non-profit assistance tends to be of shorter duration that private assistance.

Business and Economic Outcomes

- The average (median) manufacturer reported the following operating and economic characteristics for 1993:
  - 17 percentage of employees use computers weekly, 5 percent more than 1991
  - 10 days lead time, unchanged from 1991
  - 3 percent scrap rate, unchanged from 1991
  - 0.5 percent customer reject rate, unchanged from 1991
  - $224 training expenditure per employee, $35 dollars more than 1991.
  - 42 employees in 1993, up 7 percent from 1991
  - average wages of $22,460, an increase of 6 percent from 1991
  - annual sales of $4 million, 20 percent higher than 1991 sales
  - $13 sales per inventory (inventory turns), up 6 percent from 1991
  - virtually no exporting activity, unchanged from 1991
  - productivity (value-added per employee) of $27,078, a 9 percent increase over 1991.
- Manufacturers with higher rates of computer usage and lower scrap rates in 1993 had higher levels of productivity, controlling for plant employment size and industry.

Georgia Tech Industrial Extension Service

- Between 1991 and 1993, roughly one quarter of the manufacturers were assisted by Georgia Tech Industrial Extension.
- Plants that have been assisted by Georgia Tech's Industrial Extension Service were more likely than plants not assisted by Georgia Tech Industrial Extension Service to:[1]
  - have lower levels of value-added per employee, but greater gains in employment and wages between 1991 and 1993
  - use or plan to use new technologies and techniques
  - conduct manufacturing engineering and process improvement, and new product design or prototyping.
  - ship products to defense agencies
  - have higher increase in percentage of employees using computers weekly between 1991 and 1993

1Analysis controls for plant employment size and industry.

- have improved scrap rate reduction between 1991 and 1993
- have lower customer reject rates.

The survey suggested that firms investing more in technology and quality may accrue faster sales and employment growth, but also be less profitable in the short term, implying that being a "best practice" company is not cost-free. In the future we would hope to identify tangible long-term benefits.

Section 1
Survey Objectives and Methodology

Introduction

Systematic learning about the manufacturing base, its needs and problems, its use of new technologies, and the role of public and private industrial assistance services is extremely important in business and economic development. These analyses contribute to the strategies of manufacturers, industrial groups, industrial technology and service providers, and policymakers.

This document reports on the 1994 Georgia Manufacturing Technology Survey. Undertaken at the Georgia Institute of Technology, the survey represents a major initiative to understand and measure performance, trends, and issues in the state's manufacturing sector (which directly generates one-fifth of the gross state product). The survey, aimed at Georgia manufacturers with 10 or more employees, was directed by Georgia Tech's Economic Development Institute and School of Public Policy, with the sponsorship of the Georgia Manufacturing Extension Alliance.[2] The following sections describe the survey in detail and provide information about its administration and findings.

Objectives

The 1994 Georgia Manufacturing Technology Survey sought to provide a comprehensive baseline assessment of needs, problems, technology use, production and management practices, business linkages, and the use of public and private industrial assistance services in the state's manufacturing sector. An important objective of the study was to provide benchmark data and control groups for subsequent assessments

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[2]The Georgia Manufacturing Extension Alliance (GMEA) is a partnership of organizations in Georgia established to provide a new, integrated model for delivering management and technical assistance to manufacturers in the state. Led by Georgia Tech's Economic Development Institute, the partnership also includes the University of Georgia's Small Business Development Centers, the state Department of Technical and Adult Education's Quick Start, and the Georgia Power Company's Technology Applications Center. GMEA is a member of the National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership and receives funding from the U.S. Technology Reinvestment Program (through NIST) and the State of Georgia.

of the state's industrial extension program--the Georgia Manufacturing Extension Alliance (GMEA). The evaluation of the impact of GMEA will occur over the period 1994-1996. The survey also sought to provide current information which can help manufacturers gauge their relative performance on a series of key indicators and allow GMEA and other providers of industrial services to better meet the needs of Georgia's manufacturers.

Sampling Framework

The sampling unit used in this survey is the establishment. An establishment is defined by the U.S. Census Bureau as "a single physical location where business is conducted or where services or industrial operations are performed." We compiled a list of Georgia establishments from the *Georgia Manufacturing Directory* (1993). This directory is based on a survey conducted by the Georgia Department of Industry, Trade, and Tourism. The *Directory* database had been updated by the regional offices. Georgia Tech researchers also called firms in the *Directory* to verify information for other research projects.

We compared establishment information from the *Directory* with 1991 *County Business Patterns* (U.S. Department of Commerce, Bureau of Census), which is based on tax and regulatory records that firms by law must provide. The updated *Directory* database listed 6,096 establishments with 10 or more employees; *County Business Patterns* reported 4,650. This discrepancy between the two sources may be explained by several factors, including lack of newer establishments in *County Business Patterns*. We compared the distribution of establishments in *County Business Patterns* and the *Directory* by employee size, industry, or county and found that the *Directory* had more firms in virtually every category, which helped address our concern for completeness.

Of course, establishments do not complete questionnaires. The *Directory* provided contact names, but these names (often the president) were not necessarily the appropriate level for completing the questionnaire. Survey cover letters were thus addressed to the general manager of each establishment. Realizing that the appropriate person in large firms would be more difficult to identify, researchers called the 800 largest firms (down to employee size 184) to obtain this information.

Questionnaire Design

The questionnaire was designed to probe manufacturers' problems, needs, use of hard and soft technologies, production and management practices, business linkages, and the use of public and private industrial assistance services. Numerous items in the questionnaire had been used in other instruments. This reliance on previously used questions meant that (1) their validity and reliability had been tested, and (2) comparative data would be available. Question sources included:

- U.S. Department of Commerce, Bureau of the Census, *Manufacturing Technology*

1988; and the 1989 and 1993 Survey of Technology Use in West Virginia:[3] use of information/quality/management/ and production methods, research and development, and inter-firm collaboration items (Questions 2, 3, 4, 5, 9, 15, 18, 21)

- Industrial Technology Institution, Ann Arbor, Michigan:[4] plant layout, CAD/CAE/CAM, EDI, operating characteristics, and value-added questions (Questions 4e, 4f, 6, 9c, 9d, 10, 11, 12, 13, 14, 29, 30, 31, 32).
- National Institute of Standards and Technology Quarterly Reporting and Client Progress Tracking: most significant problems, operating characteristics, and value-added questions.[5] (Questions 1, 10, 11, 12, 13, 14, 22, 23, 24, 29, 30, 31, 32)

Once a draft questionnaire and cover letter had been designed, we conducted a declared pretest with the help of the Columbus Regional Office. Four manufacturers provided indepth comments about the draft questionnaire's cover letter, cover page, instructions, layout/appearance, logical flow, and individual item wording. Along with extensive program management and staff review, these comments were incorporated into a final version, presented in Appendix 1.

Administration

The survey was conducted from July 1 to September 30, 1994. In July 1994, a packet containing a questionnaire, letter from the GMEA director, and self-addressed,

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[3]Bureau of the Census, *Manufacturing Technology 1988, Current Industrial Reports,* Washington, DC: U.S. Department of Commerce, 1989; Philip Shapira and Melissa Geiger, *Modernization in the Mountains: Use of New Technology in West Virginia Manufacturing*, Regional Research Institute, West Virginia University, Morgantown, WV, 1990; Terance Rephann and Philip Shapira, *Manufacturing Technology Use in West Virginia*, Report of Survey, Regional Research Institute, West Virginia University, October 1993.

[4]Permission to use these items was sought and received from Dan Luria at the Industrial Technology Institute, Ann Arbor. This (and subsequent) assistance is gratefully acknowledged by the authors.

[5]Comparability with these items will also help GMEA in tracking and reporting its performance to NIST and other sponsors.

postage-paid envelope was mailed to 6,096 manufacturing establishments. A second follow-up mailing went to all non-respondents. A third follow-up mailing was sent to 1,500 randomly selected non-respondents. Each regional office was assigned 20 manufacturers to call and solicit responses. The Georgia Chamber of Commerce sent out letters to its members asking them to encourage their manufacturers to participate. Researchers made 1,000 telephone calls to encourage responses in particular employee sizes, industry groups, and regions, thereby improving the representativeness of the survey sample.

The response to the survey was as follows:

Companies in initial database		6,096
Returned undelivered, out of business		500
Not a manufacturer	78	
Outside of target population (less than 10 employees)		117
Declared refusals		39
Non-respondents		4,182
Completed survey forms		1,180
Response rate		28.0%

The response rate was calculated by dividing the number of completed survey forms by the total number of operational manufacturing establishments, in the target population (manufacturers with 10 or more employees).

To evaluate the representativeness of the survey responses, Table 1.1 compares them to *County Business Patterns* data. Smaller establishments with less than 20 employees and those in apparel, lumber and wood products, and printing and publishing industries are most noticeably underrepresented in the sample. Because of the importance of scale and product characteristics in determining firm behavior such as technology use, we have stratified the sample by industry and establishment size and applied an expansion weight.[6]

[6]See Terance Rephann and Philip Shapira, *Survey of Technology Use in West Virginia Manufacturing*, Morgantown, WV: West Virginia University Regional Research Institute, December 1, 1993, p. 8. Non-respondent surveys were not conducted. However, a few non-respondents told us that they did not understand, use, or feel that the technologies mentioned in the survey were applicable to their business. It is possible that the survey respondents are more advanced in technology use than the non-respondents.

Table 1.1
Number of Establishments by Industry and Employment Size
County Business Patterns (1991) vs. Survey Respondents

	County Business Patterns		Georgia Survey	
Industry	# estab.	% estab.	# estab.	% estab.
Food and kindred products and tobacco	289	6.2%	84	7.1%
Textile mill products	436	9.4%	113	9.6%
Apparel and textile products	457	9.8%	66	5.6%
Lumber and wood products	512	11.0%	79	6.7%
Furniture and fixtures	140	3.0%	36	3.1%
Paper and allied products	186	4.0%	57	4.8%
Printing and publishing	523	11.2%	72	6.1%
Chemicals and allied products	273	5.9%	107	9.1%
Rubber and misc. plastic products	242	5.2%	77	6.5%
Stone, clay, and glass products	296	6.4%	62	5.3%
Primary metal industries	77	1.7%	31	2.6%
Fabricated metal industries	337	7.2%	107	9.1%
Industrial machinery and equipment	422	9.1%	138	11.7%
Electronic and other electrical equipment	147	3.2%	53	4.5%
Transportation equipment	113	2.4%	46	3.9%
Instruments and related products	76	1.6%	26	2.2%
Miscellaneous manufacturing industries (including leather and petroleum)	124	2.7%	26	2.2%
	4650	100.0%	1180	100.0%
Number of employees				
10-19	954	20.5%	150	12.7%
20-99	2519	54.2%	581	49.2%
100+	1177	25.3%	449	38.1%
	4650	100.0%	1180	100.0%

Refusal to participate in the study is not the only type of non-response. Some respondents preferred not to answer one or more of the items on the questionnaire. Inter-item response rates are presented on each table. In many cases, the response rates neared or exceeded 90 percent, but for a few questions, response rates were below or near 50 percent. What these item response rates mean is unclear. For example, the 40 percent response rate for training dollar expenditures might mean that the manager could not remember this figure, whereas the 54 percent rate for payroll may reflect a preference not to disclose this information.

Table 1.2
Inter-item Response (% answering question)

Question	%	Question	%
24 training $	40%	5d problem solving teams	90%
23 payroll	54%	21a shared problems	91%
31 parts/materials	61%	9g CIM	91%
32 inventory	67%	1 Plant problems	92%
13 scrap	70%	4c data collection	92%
29 sales	76%	4f business electronically	92%
11 % employees use computer	78%	5a documented quality	92%
10 # keyboards, manuf. & design	79%	5f JIT from suppliers	92%
18c 2 cust, different qual. req.'s	79%	9d CAD/CAM	92%
18a major cust, short term contract	80%	9h automated inspection	92%
18b major cust, quality requirement	80%	5e JIT to customers	93%
18d cust. assists with quality/improv	80%	9a NC/CNC	93%
14 reject %	81%	9b programmable controllers	93%
17 75% sales	83%	9e lasers	93%
30 exports	83%	9f robotics	93%
5c ISO 9000	84%	22 # employees	94%
12 lead time	86%	15d R&D to commercialize tech.	94%
21e ISO 9000 groups	86%	5g maintenance	94%
21f cooperative marketing	87%	9i automated material handling	94%
28a8 ass, marketing	87%	16c unique product	95%
20 defense	88%	4b computers, shop floor	95%
26c Tech, regional	88%	9c CAD/CAE	95%
26d Small Bus. dev ctr	88%	25 union	96%
26e technical inst	88%	15b customized design	96%
26f Georgia power	88%	4e software (MRP)	96%
26g NASA, etc	88%	15a process improvement	97%
28a4 ass, mgt	88%	15c product development	97%
28a5 ass, financing	88%	16a low price	97%
28a6 ass, energy	88%	27 assistance, private	98%
28a7 ass, new product	88%	16d short delivery time	98%
4d LAN	88%	4a computers, non-manufacturing	98%
5b SPC/SQC	88%	3 Plant description	99%
21b cooperative design	89%	6 layout	99%
21c cooperative manuf.	89%	7 business plan	99%
21d cooperative training	89%	8 energy management	99%
26b Tech	89%	19 outsource	99%
28a1 ass, environment	89%	16b quality	99%

28a2 ass, production	89%	26a assistance, public	99%
28a3 ass, training	89%	33a only plant	99%
28b days assisted	89%		

Another step in the analysis involved verification of the accuracy of responses to certain questions. The project team ran checks on answers to the performance measure questions. For items that fell outside generally accepted ranges (e.g., scrap rates of more than 50 percent, payroll per employee, or average wages of more than $100,000), the team telephoned the respondents to verify and, in many cases correct, the information on the survey.

Georgia Tech Extension Assistance

Because Georgia Tech has operated an industrial extension service for some 30 years before GMEA, researchers sought to take the ongoing nature of the program into account in measuring firm-level change. We asked respondents to report information recalled from two years earlier (1991), acknowledging the difficulty involved in a firm's ability to recall whether it received assistance in the past two years. The person with whom the public or private organization was working may have left the firm. The assistance provided may have been unknown to the (generally high-level) person completing the questionnaire.

Comparing questionnaire responses about use of Georgia Tech services with internal program files provides data on the degree of discrepancy in recollecting assistance. We compared our survey database with program files for each of Georgia Tech's then 13 regional offices. Regional office staff were asked whether any of the manufacturers in their region who responded to our survey were customers during that time period.

The result of this effort is a comparison group of assisted firms reconstructed from recalled information and historic program files. This comparison group allows us to test the analysis we propose to use in evaluating the GMEA program. It also provides extensive analytical information to GMEA program managers about changes in previous clients of Georgia Tech's Industrial Extension Service.

Combining responses to the manufacturers survey and regional office staff responses resulted in 25 percent of firms being classified as "Georgia Tech extension assisted." Nearly 10 percent of Georgia Tech assisted firms (according to internal program files) did not report being assisted by Georgia Tech's regional offices on the survey form. Larger firms are more likely to fail to report being Georgia Tech regional office customers when internal files indicate otherwise. Less than 8 percent of firms with under 100 employees failed to report being Georgia Tech regional office customers compared to more than 17 percent of firms with 100 or more employees.

Throughout this analysis, we will define a firm as "Georgia Tech extension assisted" or "Georgia Tech assisted" if it was either indicated in internal files or reported on the survey form. Because of a lack of consistent records for the previous two years, there is no information on the exact dates of the assistance (in some cases the assistance may have been given before or after this time period), the type of assistance provided, the number of on-site visits, how many hours of staff time was involved, and other service delivery characteristics. This service delivery information is currently being collected and will be available when the survey is repeated in 1996.

Organization

This report is divided into five sections. Section 2 focuses on use of manufacturing technologies and techniques. Section 3 examines customer relationship issues. Section 5 summarizes survey responses about use of information and assistance sources, including Georgia Tech. Section 6 concludes by exploring intermediate business and regional economic impacts.

Throughout this report, information will be broken down by industry group and number of employees in 1993. Industry groupings and their two-digit standard industrial classifications (SIC) are described in Box 1.

Industry Group Definitions

Industry Group	Two-Digit SIC	Description
Food products	20	Food and kindred products
	21	Tobacco manufacturers
Textiles, apparel	22	Textile mill products
	23	Apparel and textile products
Resource industries	24	Lumber and wood products
	25	Furniture and fixtures
	26	Paper and allied products
	28	Chemicals and allied products
	32	Stone, clay, glass, and concrete products
Metals, machinery	33	Primary metal industries
	34	Fabricated metal industries
	35	Industrial machinery and equipment
	37	Transportation equipment
Electronics, instruments	36	Electronics and other electrical equipment
	38	Instruments and other related products
Plastics, printing, misc.	27	Printing, publishing, and allied products
	29	Petroleum refining and related industries
	30	Rubber and miscellaneous plastic products
	31	Leather and leather products
	39	Miscellaneous manufacturing industries

Box 1

The Appendix contains a breakdown of survey responses for every question on the survey form. Percentages of general managers answering each question and item response rates are shown. For questions which ask for quantitative information, percentile breakdowns, means, and standard error of the means are presented.

Section 2
Problems, Technology Use, and Research and Development

Problems and Needs

The survey began by asking, "In which of the following areas do you have the most significant problems in your plant?" Alternatives were designed to parallel current program service categories.

Human resources, manufacturing process difficulties, and environmental and health and safety issues[7] were the three most frequently mentioned problems facing Georgia manufacturers. Plant layout, quality assurance, and business systems for planning, scheduling, and inventory control also ranked high among manufacturers' problems. Small manufacturers in the state--those with 10 to 25 employees--had additional concerns about market development and financing. (See Figure 1.) The larger the manufacturer, the more likely was the respondent to report problems in environmental, manufacturing process, energy, business systems, quality assurance, product development, material-related issues, and hard technology (CAD/CAE/CAM, automation/robotics, EDI/LAN/communications) areas. The average respondent reported 2-3 problems. Only 7 percent checked none of the problems.

The emphasis given to specific problems differed by industry. Environmental and health and safety concerns were greatest in food processing and resource-intensive sectors such as chemicals, pulp and paper, and stone, glass, and cement. Human resource and training difficulties figured very high in apparel and textiles. Concerns about manufacturing process, quality, business systems, and product development were prominent among electrical, electronics, and instrument manufacturers.

Georgia Tech-assisted firms were more likely to report quality assurance, environmental, business systems, product development, and manufacturing process problems.[8]

Technologies and Techniques

Modern technology and best-practice production, management, and quality

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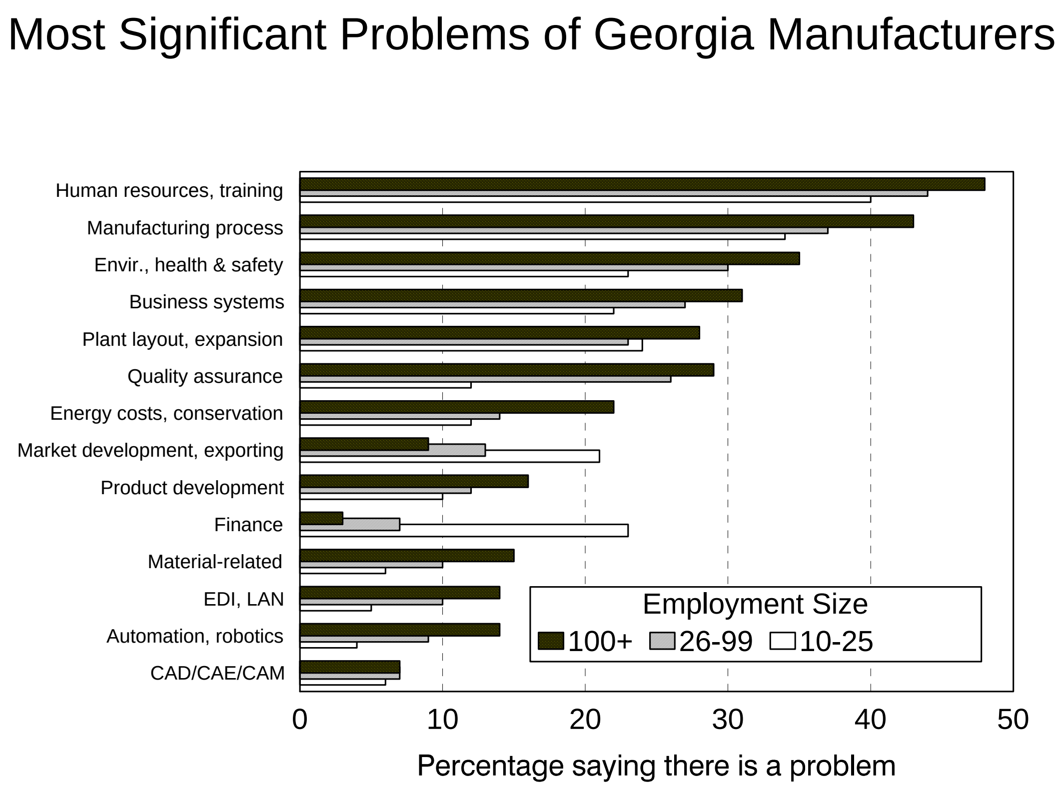
[7]The survey's timing may, in part, explain the high rating of environmental, health, and safety issues. New regulations for wastewater treatment/discharged were issued in Georgia in the summer of 1994.

[8]See Section 1, discussion of Georgia Tech-assisted firms for a description of how these firms were defined and identified.

methods are essential ingredients needed by Georgia manufacturers to succeed in today's competitive markets. The survey asked a series of questions about use of information, quality, management, and production technologies and methods used. These questions can be grouped into "hard technology" and "soft technology" questions. (See Box 2.)

Figure 1



Georgia Manufacturing Technology Survey 1994 - weighted response of 1,180 manufacturers

Box 2
Georgia Benchmark Technology Survey: Hard and Soft Technologies

HARD TECHNOLOGIES

Personal computers or terminals on the manufacturing shop floor
Data collection devices (e.g., bar code readers)
Local area networks (LANs)
Doing business electronically (sending or receiving invoices, electronic mail, or payments via electronic funds transfer)
Numerical control/computer numerical control (NC/CNC) machines
Other programmable controllers
Computer-aided design (CAD) or computer-aided engineering (CAE) software
CAD data to generate machine instructions (CAD/CAM)
Laser technologies
Robotics
Computer-integrated manufacturing (CIM)
Automated in-process inspection
Automated material handling systems
Personal computers or terminals-nonmanufacturing

SOFT TECHNOLOGIES

Software to use in scheduling, inventory control, or purchasing (e.g., MRP)
Documented quality policy
Statistical process or quality control (SPC/SQC)
ISO 9000 certified
Employee problem-solving/improvement teams
Just-in-time deliveries *to* customers
Just-in-time deliveries *from* suppliers
Preventive/predictive machine maintenance program
Business or strategic plan
Energy management plan

Figure 2 presents the percentage of manufacturers currently using and planning to use these hard and soft technologies. More than 90 percent of manufacturers use personal computers, although less than 40 percent use them on the shop floor. More than 35 percent use programmable controllers other than numerical control/computer numerical control (NC/CNC) machines, computer-aided design or computer-aided engineering (CAD/CAE) software, or do business electronically. Of these, doing business electronically was most often mentioned as a planned capability, by nearly 30 percent of the firms. NC/CNC and other numerical controllers had among the lowest percentage of planned users. Twenty percent of the firms said that CAD/CAE was not applicable to their operation.

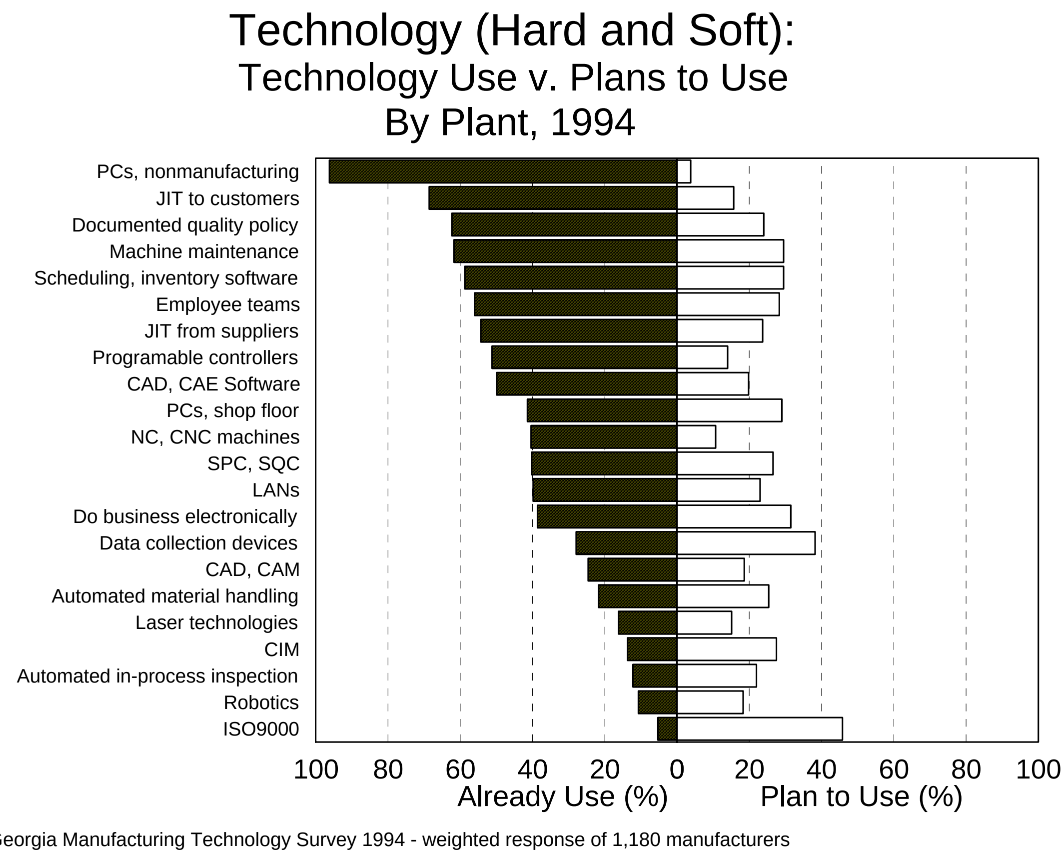
A second tier of hard technologies, used by more than 20 percent of the manufacturers, included local area networks (LANs), NC/CNC machines, and data collection devices. Data collection devices figured into the plans of an additional 32 percent of the firms.

The least commonly used hard technologies were robotics, computer-integrated manufacturing (CIM), laser technologies, and automated in-process inspection. Roughly 10 percent of the firms used any one of these production technologies. Automated material handling figured into the plans of another 20 percent of the firms responding. Nearly one in three manufacturers felt that laser technologies were not applicable to their business.

Manufacturers in the electronics and instruments industries were most apt to use hard technologies. (See Table 2.1.) The food industry ranked relatively high in their use of programmable controllers, doing business electronically and using automated in-process inspection. CAD/CAM/CAE and NC/CNC and other programmable controllers were prominent among firms in metals and machinery industries. A larger percentage of textile and apparel firms (42 percent) use data collection devices than do those in other industries. Firms with 100 or more employees were significantly more likely to use hard technologies than were smaller firms.

Many more general managers reported adoption of soft technologies. More than 70 percent have a business or strategic plan. At least half the firms surveyed reported using scheduling, ordering, or inventory software; having a documented quality policy; and using employee teams, just-in-time deliveries, and preventive-predictive machine maintenance. Twenty-three percent adopted energy management plans. Less than 5 percent reported being ISO certified, although ISO certification figured in the plans of 37 percent of the firms--the highest rate of planned usage of any technology. Firms in electronics and instruments industries had high usage of documented quality policies and statistical process/quality control (SPC/SQC). Documented quality policies were also common in food industries. SPC/SQC had a strong showing among food and textile/apparel firms. (See Table 2.2.)[9]

Figure 2



[9]Some manufacturers may have overstated their use of various technologies and techniques. They may not have understood the question or may have wanted to appear more advanced than they actually are.

Table 2.1
Hard Technology Use by Industry
(percent currently using technology)

Hard Technology	All Respondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
Personal computers/terminals-nonmanuf.	90.6%	89.7%	87.6%	88.1%	89.9%	100.0%	96.4%
Other programmable controllers	39.4%	47.5%	34.9%	37.1%	46.8%	54.4%	33.1%
CAD/CAE software	39.4%	31.7%	32.4%	33.2%	55.1%	71.3%	33.6%
Personal computers/terminals-shop floor	36.6%	33.9%	38.8%	29.0%	37.5%	73.5%	36.9%
Doing business electronically	35.2%	49.3%	36.8%	38.7%	31.3%	41.8%	26.0%
Local area networks (LANs)	31.7%	33.8%	36.4%	26.1%	34.4%	52.1%	27.5%
NC/CNC machines	28.6%	25.0%	21.2%	19.9%	46.7%	36.3%	29.0%
Data collection devices	23.1%	18.5%	41.9%	16.7%	13.3%	36.5%	22.8%
CAD/CAM	17.0%	10.6%	14.9%	10.7%	30.0%	42.7%	12.4%
Automated material handling systems	17.0%	25.3%	16.6%	24.4%	9.0%	23.3%	9.7%
Laser technologies	11.3%	6.7%	6.0%	8.1%	11.2%	18.8%	21.2%
Computer-integrated manuf. (CIM)	10.2%	14.7%	11.1%	7.8%	7.6%	26.3%	10.1%
Automated in-process inspection	8.9%	22.1%	5.8%	6.9%	5.0%	25.4%	10.6%
Robotics	7.7%	7.8%	9.8%	1.9%	9.4%	21.8%	9.1%

Table 2.2
Soft Technology Use by Industry
(percent currently using technology)

Soft Technology	All Respondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
Business or strategic plan	71.3%	80.9%	72.3%	72.3%	65.1%	82.8%	83.9%
Just-in-time deliveries to customers	61.7%	60.6%	56.0%	60.7%	63.6%	59.3%	68.0%
Documented quality policy	59.5%	76.2%	57.3%	57.6%	60.5%	84.0%	51.1%
Prevent./predict. machine maint. prog.	59.2%	60.6%	56.2%	61.3%	51.4%	58.4%	66.7%
Software for sched., inventory, purch.	56.1%	51.2%	57.9%	52.2%	57.3%	82.2%	54.0%
Employee problem solving/imprv. teams	52.8%	57.4%	46.1%	52.3%	50.0%	64.4%	58.5%
Just-in-time deliveries from suppliers	48.5%	49.2%	43.5%	47.5%	51.3%	49.7%	51.8%
SPC/SQC	36.2%	50.7%	47.6%	32.3%	31.5%	54.4%	25.7%
Energy management plan	23.5%	48.8%	29.2%	22.1%	14.7%	30.7%	24.0%
ISO 9000 certified	4.2%	4.8%	3.7%	4.7%	4.0%	10.3%	2.6%

To further assess use of hard and soft technologies, researchers developed an index by adding up each plant's technology use scores. Scores were obtained by assigning a "1" to technology use, a "0" to the responses "plan to use" or "do not plan to use," and excluding "not applicable" responses. The survey found wide variations in how the state's industrial companies use these technologies and techniques.

Georgia has a group of leading manufacturers whose adoption of technology significantly exceeds that of more typical firms. The top 5 percent of technology users in the state generally employ more than twice as many hard and soft technologies than does the median company in the same industry group. (See Figures 3 and 4.)[10] The typical small firm with 25 or fewer employees lags behind firms with more than 100 employees in usage of hard and soft technologies; however, the top 5 percent of small-firm technology users have similar levels of usage of soft technologies and techniques as the top 5 percent of larger firms. Raising as many companies as possible closer to current best-practice levels of hard and soft technology use could significantly strengthen Georgia's industrial competitiveness.

Georgia Tech-assisted firms were significantly more likely than those not assisted by Georgia Tech to adopt hard and soft technologies. This high level of adoption is significant even after controlling for industry and employment size, as illustrated in Table 2.3. Figure 5 shows that Georgia Tech-assisted firms also had higher rates of plans for using these technologies. When this analysis is repeated in two years, the more accurate information about the nature of the assistance Georgia Tech provided will yield a clearer picture of the relationship between Georgia Tech assistance and technology adoption.

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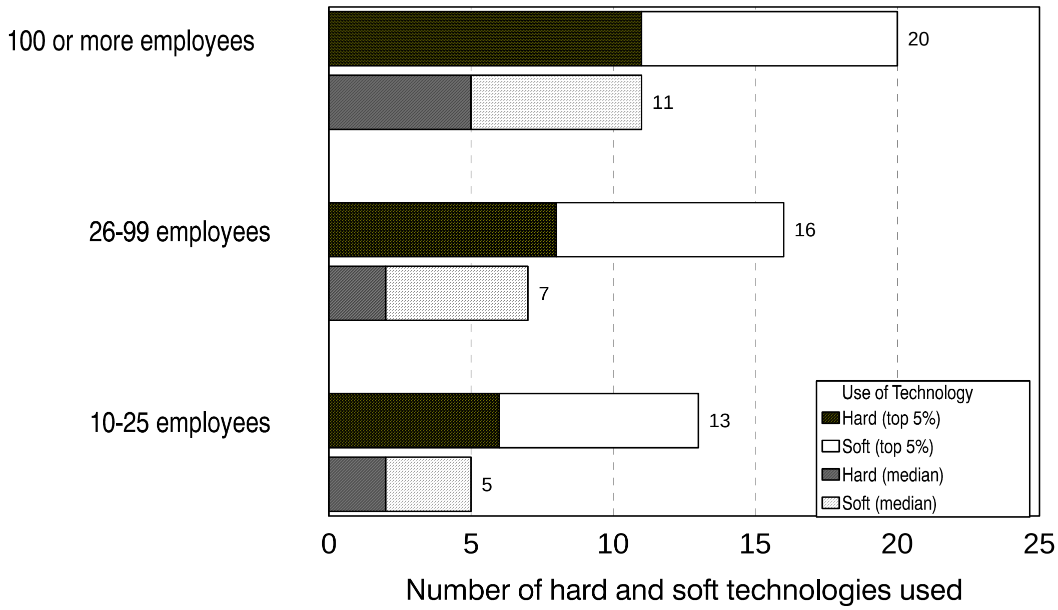
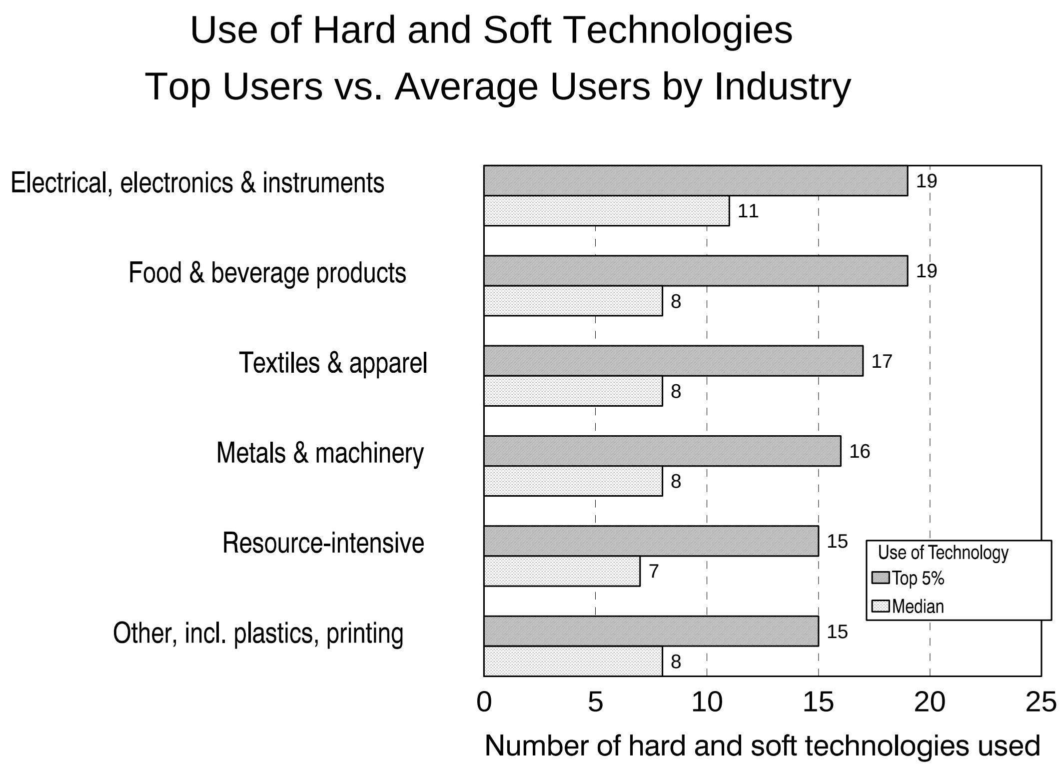
[10]The median is the mid-point, or 50th percentile, if the responses were listed in order from highest to lowest. The standard error of the mean is a measure of how widely dispersed the responses are around the mean. It is obtained by dividing the standard deviation by the square root of the number of respondents.

Figure 3

Use of Hard and Soft Technologies by Plant Employment Size
Top Users vs. Average (Median) Users



Georgia Manufacturing Technology Survey 1994 - weighted response of 1,180 manufacturers



Source: Georgia Manufacturing Technology Survey, 1994

Figure 4

Table 2.3
Use of Hard and Soft Technologies
Plants Assisted and Not Assisted by Georgia Tech Extension
1991-1993[1]

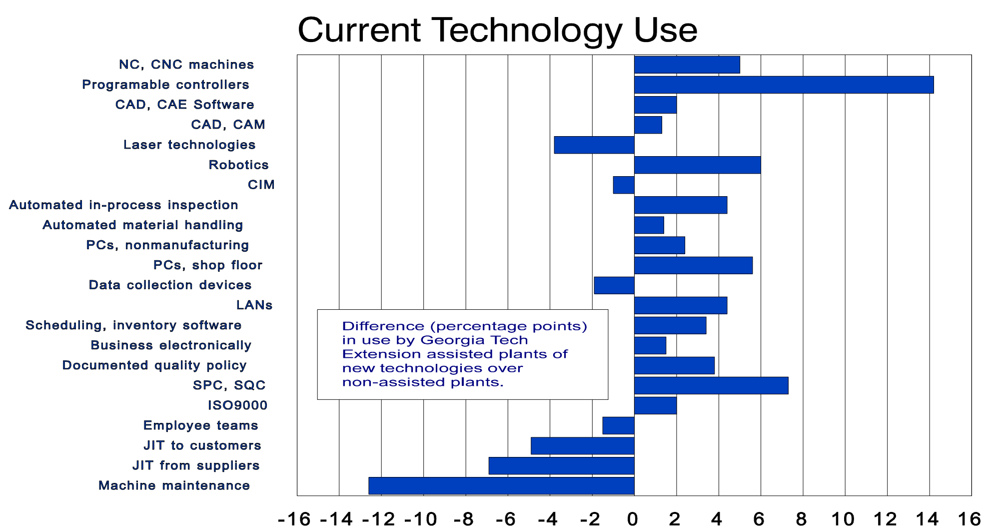
Use of Technologies and Techniques	Assisted by Georgia Tech Extension		Not Assisted by Georgia Tech Extension		GT Extension Assisted Improvement Relative to Unassisted
Number of hard technologies/ techniques	Mean	4.3 (.12)	Mean	3.6 (.04)	MORE[2]
	Median	4.0	Median	3.0	
Number of soft technologies/ techniques	Mean	4.7 (.07)	Mean	4.3 (.04)	MORE[3]
	Median	5.0	Median	4.0	
Number of hard and soft technologies/techniques	Mean	9.0 (.14)	Mean	8.0 (.07)	MORE[2]
	Median	9.0	Median	7.0	

[1]Analysis controls for plant size and industry classification. Standard error of the mean is in parenthesis.
[2]5 percent chance of no difference between assisted and not assisted by Georgia Tech
[3]10 percent chance of no difference between assisted and not assisted by Georgia Tech

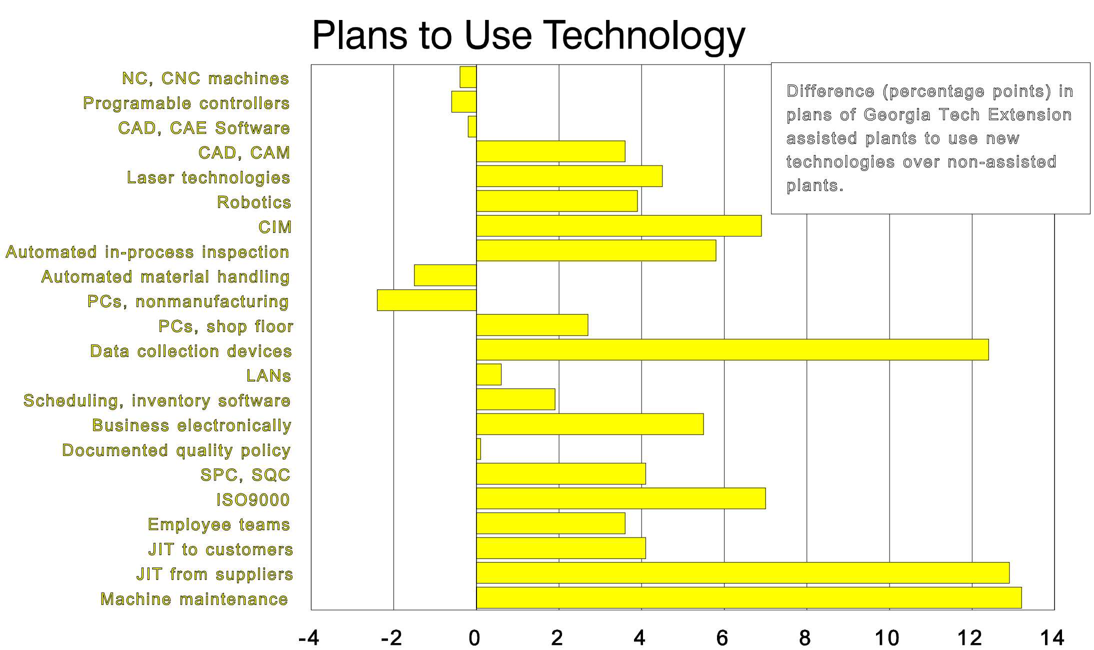
The survey also asked general managers to indicate whether they had significantly changed the layout of machines or activities in the plant to improve process flow and/or throughput. More than half of the respondents reported having changed plant layout. By employee size, 63 percent of firms with at least 100 employees reported changing plant layout, compared to less than 42 percent of firms with 10 to 25 employees.

Figure 5

1994 Current and Planned Technology Use,
Georgia Tech Extension Assisted v. Non-Assisted Plants



1991-1993 = period of assistance/non-assistance



1991-1993 = period of assistance/non-assistance

Decisions about Plant Investment

With Georgia known for being a "branch plant state," one potential obstacle to technology adoption might be that plant investment decisions are made out of state. Respondents were asked to indicate whether theirs was the only plant in the company. Fifty-two percent reported that their plant was the only location. Of the 48 percent that are part of other plants, only 16 percent report that plant investment decisions are made outside of Georgia. Thus, for 84 percent of the plants investment decisions are made in the state and could potentially be influenced by in-state program efforts.

Research and Development

General managers were asked whether four types of research, development, and engineering activities are conducted at the plant. (See Table 2.4.) Roughly two-thirds responded that these activities are conducted at the plant: manufacturing, engineering, and process improvement; customized design of existing products; new product development or prototyping. Only 32 percent of the plants conduct research to commercialize new technologies. Research, development, and engineering activities are more prevalent among larger plants. Customized design of existing products and new product development is prevalent in all industry groups except for food products industries. Commercializing new technologies is more likely at plants in textile and apparel, metals and machinery, and electronics and instruments industries. Georgia Tech-assisted plants are substantially more likely to report conducting manufacturing engineering and process improvement activities than plants that did not receiving assistance from Georgia Tech.

Table 2.4
Research, Development and Engineering Activities by Industry
(percent conducting activity)

Research and Development Activity	All Re-spondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
Manuf. engineering and process improve.	67.9%	61.5%	72.0%	64.4%	76.8%	87.9%	55.8%
Customized design of existing products	66.5%	47.2%	65.7%	67.4%	70.5%	73.3%	66.1%
New product develop. or prototyping	64.6%	56.5%	71.3%	58.4%	69.3%	74.4%	62.5%
Research to commercialize new tech.	31.6%	26.4%	37.6%	26.1%	36.6%	40.4%	28.8%

Table 2.5
Research, Development and Engineering Activities by
Georgia Tech Extension Assistance
(percent conducting activity)

Research and Development Activity	Assisted by Georgia Tech Extension	Not Assisted by Georgia Tech Extension
Manuf. engineering and process improvement	80.4%	63.7%
Customized design of existing products	68.8%	65.7%
New product develop. or prototyping	70.7%	62.5%
Research to commercialize new technologies	35.1%	30.4%

Section 3
Customer Relationships

The survey included several questions about the number and nature of customer relationships, subcontracting and outsourcing, defense dependency, and inter-firm activities. The responses to these questions are summarized below.

How Manufacturers Compete

General managers were asked whether they rarely, sometimes, or often compete on the following factors: low price, quality, uniqueness, and short delivery time. Nearly 84 percent reported competing on high quality often. More than half indicated competing often on short delivery time and uniqueness. Less than one-third of the respondents said they often compete on low price, although 44 percent reported competing sometimes on low price. Firms with 10 to 25 employees were less likely to report competing often on low price (23 percent) than were larger firms (34 percent), and more likely to report competing on uniqueness (63 percent) than were larger firms (50 percent).

Customer Relationships

The survey asked general managers, "How many customers does it take to account for 75 percent of your sales?" The average (median) plant reported having 18 customer relationships. Three-fourths of the plants sold to 50 customers. Only 5 percent of the respondents reported that one or two customers accounted for 75 percent of sales. Number of customer relationships was unrelated to the plant's employment size. Resource-based industries and those in the printing and miscellaneous industries tended to have more customer relationships than plants in other industry groups.

Nevertheless, roughly 80 percent of the respondents indicated that they had major customers--not many diverse ones. These respondents were then asked whether four questions about the nature of customer relationships described their situation rarely, sometimes, or often. Nearly seven of 10 respondents reported that often major customers have established quality performance requirements. Four in 10 respondents said that often they have two or more customers with different quality requirements. Three in 10 respondents indicated that often major customers give short-term contracts. Only two in 10 respondents reported often receiving direct assistance from major customers to improve quality or solve technical problems. Another 43 percent said that they rarely get direct assistance from major customers.

Table 3.1 presents these customer relationship descriptions by industry. The vast majority of general managers reported that their customers have quality requirements, commonly within the electronics and instruments industry group. This industry group was also most likely to report having two or more customers with different quality requirements. Short-term contracts figured most strongly in the textile and apparel, resource, and metals and machinery industries. Manufacturers in electronics and instruments industries more often received direct assistance from customers; resource industries least often.

Table 3.2 shows that by employee size, larger plants have more stringent quality requirements. However, plants in the 25 to 99 employee range have rates of multiple customers with different requirements similar to plants with 100 or more employees, yet at the same time, have higher rates of short-term contracts than these large plants and lower rates of direct assistance from customers. To some extent, they appear to be in a quality squeeze--they have to meet the same standards as larger plants, but under more time constraints and with less help.

Table 3.1
Customer Relationships by Industry
(% responding "often")

Customer Relationships	All Respondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
Major customers have estab. quality req.	68.5%	77.4%	71.8%	62.6%	69.3%	84.9%	66.2%
Two or more cust. have diff. quality req.	41.1%	39.8%	40.5%	38.3%	39.4%	54.7%	44.4%
Major customers give short-term contracts	30.7%	19.7%	36.0%	33.4%	35.1%	19.4%	22.5%
Major customers directly assist us	19.5%	27.1%	20.6%	13.2%	20.4%	29.5%	22.6%

Table 3.2
Customer Relationships by Employment Size
(% responding "often")

Customer Relationships	All Respondents	10-25	26-99	100+
Major customers have estab. quality req.	68.5%	58.1%	68.2%	77.4%
Two or more cust. have diff. quality req.	41.1%	28.9%	44.6%	44.8%
Major customers give short-term contracts	30.7%	33.5%	32.4%	25.2%
Major customers directly assist us	19.5%	16.5%	18.5%	24.0%

Subcontracting

Forty percent of the respondents reported that the plant usually subcontracts or outsources manufacturing work. This percentage does not differ by employee size. By industry, food products manufacturers rarely subcontract (less than 14 percent) whereas more than half of metalworking/machinery and electronics/instruments manufacturers engage in subcontracting or outsourcing work.

Of the plants that subcontract or outsource work, the mean percentage of production value subcontracted is roughly 16 percent. Nearly half of this subcontracted work goes to Georgia firms, one-third to firms in other states, and the rest to firms outside the United States. Subcontracting plays a larger role for electronics and instruments industries (32 percent) than for firms in other industry groups. Manufacturers with 25 or fewer employees subcontract a higher percentage of production value to Georgia firms (mean=9.6 percent) than do manufacturers employing 100 or more workers (mean=5.3 percent).

Defense Dependency

Whether a manufacturer is defense-dependent is not straightforward because several government agencies have defense-related authority and because the degree of defense-dependency hinges on the percent of sales or value of shipments to these agencies. The questionnaire asked managers to indicate whether the plant shipped products to any of four agencies or firms: federal defense agencies, prime contractors, subcontractors, and U.S. Department of Energy (DoE) facilities or contractors. In all, 28 percent of Georgia manufacturers said they shipped to any of the four agencies or firms, 19 percent said they shipped to federal defense agencies, 17 percent to subcontractors, 16 percent to prime contractors, and 9 percent to DoE facilities or contractors. (See Figure 6.) More than 40 percent of metalworking/machinery and electronics/instruments industries shipped products to defense agencies, compared to less than 26 percent of manufacturers in the other industry groups. Manufacturers assisted by Georgia Tech (33 percent) were also somewhat more likely to ship products to defense agencies than those not assisted (26 percent).

In most cases, the percentage of sales or value of shipments to defense agencies was small. The median percentage of sales shipped to defense agencies was 5 percent. Only 25 percent of firms shipping to defense agencies had 10 or more percent sales in defense-related work. A few manufacturers depended heavily on defense agencies, however. For 5 percent of firms shipping to defense agencies, these agencies accounted for at least 65 percent of their sales.

Use of Inter-firm Networks

The survey asked respondents to indicate whether or not they currently participate, or were interested in participating, with other manufacturers in several different types of inter-firm activities. More than half of all respondents said they currently participate in at least one type of inter-firm activity. Figure 7 shows that the most common inter-firm activity was identification of shared industry problems and needs, in which 45 percent of manufacturers participated. Nearly 20 percent of firms took part in cooperative design or cooperative manufacturing. Thirteen percent engaged in cooperative training. Nine percent participated in quality assurance/ISO 9000 user groups, although an additional 40 percent of respondents said they would be interested in participating in these groups, the highest level of interest for any of the inter-firm activities. Respondents were least interested in cooperative marketing; 68

percent of manufacturers said they were not interested in participating in this activity.

Participation in inter-firm activity is related to plant size. (See Table 3.3.) Only 39 percent of firms with 10 to 25 employees current participate in any inter-firm activity compared to 64 percent of firms with 100 or more employees. Participation in activities such as identification of shared problems and needs, training, and quality assurance increases with employment size. By industry, the majority of plants in all but the metalworking/machinery industry group engage in some form of inter-firm activity; only 43 percent of metalworking/machinery industry group plants participate in some form of inter-firm collaboration. (See Table 3.4.)

Table 3.3
Participation in Inter-firm Activities by Employment Size
(% currently participating)

Inter-firm Activities	All Respondents	10-25	26-99	100+
Identification of shared industry problems	45.2%	34.5%	44.0%	61.3%
Cooperative design or new product dev.	19.8%	21.0%	18.4%	20.7%
Cooperative manufacturing	19.5%	21.7%	17.7%	19.8%
Cooperative training	13.0%	10.4%	12.1%	17.8%
Quality assurance/ISO 9000 user groups	8.8%	3.5%	8.0%	16.8%
Cooperative marketing	10.8%	11.6%	9.0%	12.8%

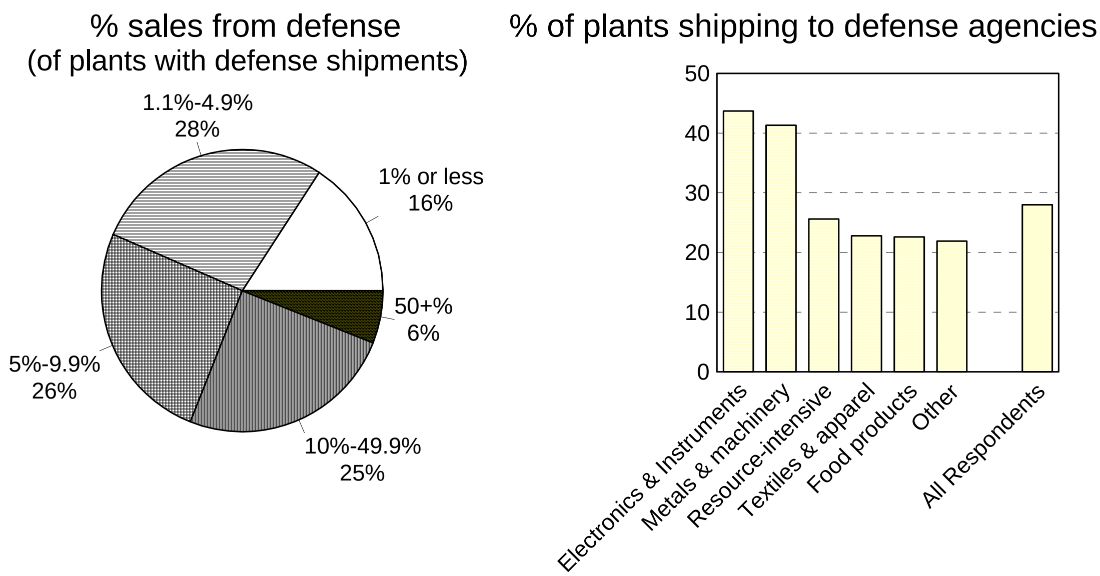
Table 3.4
Participation in Inter-firm Activities by Industry
(% currently participating)

Inter-firm Activities	All Respondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
Identification of shared industry problems	45.2%	51.8%	46.2%	46.3%	33.9%	46.6%	52.0%
Cooperative design or new product dev.	19.8%	16.4%	18.1%	20.7%	17.3%	33.3%	20.1%
Cooperative manufacturing	19.5%	14.1%	20.7%	18.7%	14.7%	27.3%	24.5%
Cooperative training	13.0%	13.2%	10.3%	16.2%	7.8%	13.0%	16.2%
Quality assurance/ISO 9000 user groups	8.8%	12.8%	10.3%	8.3%	9.0%	19.1%	3.8%
Cooperative marketing	10.8%	13.4%	9.1%	11.5%	10.7%	12.9%	10.2%

Figure 6

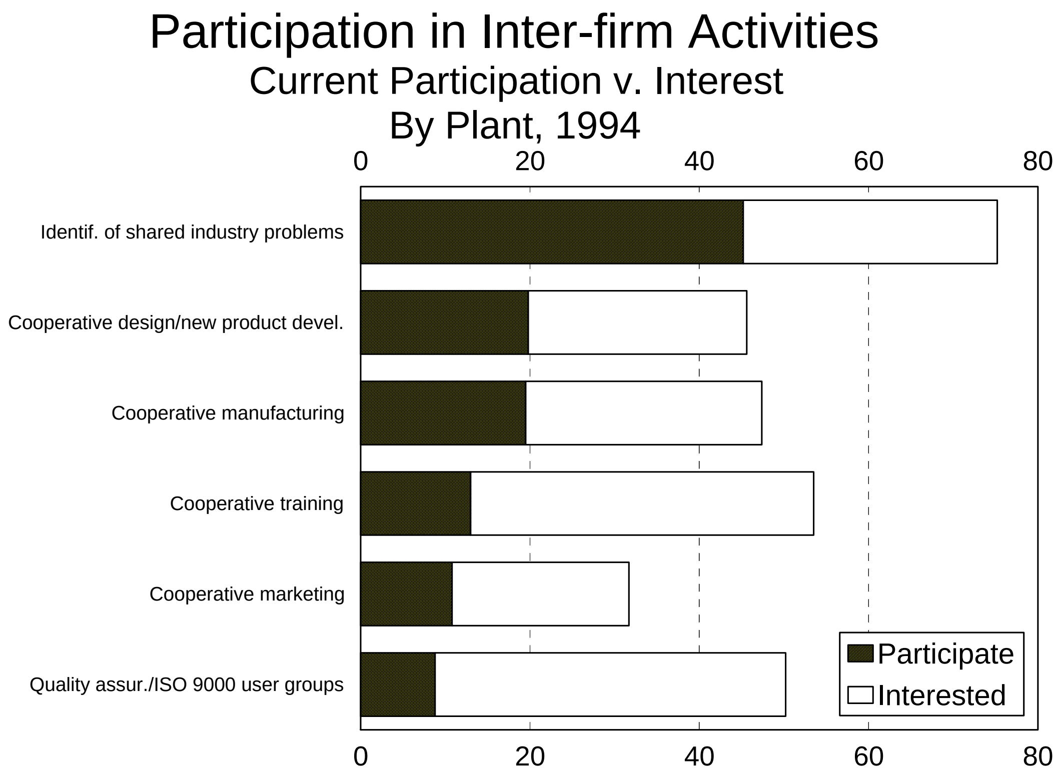
Shipments to Defense Agencies

% of plants shipping to defense agencies and % of sales from defense



Georgia Manufacturing Technology Survey 1994 - weighted response of 1,180 manufacturers

Figure 7



Georgia Manufacturing Technology Survey 1994 - weighted response of 1,180 manufacturers

Section 4
Use of Information and Assistance Sources

Obtaining information and assistance is a critical factor in maintaining competitiveness. Yet it is difficult to measure because information and assistance can, depending on the manager, come through a network of formal and informal channels. Information and assistance also can come into the plant via multiple employees. It is particularly hard to obtain accurate information about use of public and non-profit programs because of the traditional negative reaction private firms have to "government."

We asked "In the last two years, has your plant received assistance from a public or non-profit program?" and included examples. The results showed that a substantial portion of Georgia's manufacturers rely on public or non-profit sources for information and assistance. Twenty-seven percent of manufacturers received assistance from a public or non-profit program in the last two years. Organizations most commonly used were Georgia Tech and Georgia Power Company, each used by roughly 10 percent of the firms responding. Less than 5 percent of firms used the Small Business Development Center (SBDC), technical institutes, or federal laboratories or other federal technology programs.

Use of private sources (e.g., consultants, vendors, or other private organizations) is even more common. Forty-seven percent of manufacturers received assistance from one or more private sources. The vast majority of firms that received assistance from public sources also used private sources. Seventy percent of all manufacturers assisted by public/non-profit organizations also received assistance from private sources. It is possible that public sources act as a resource link to private organizations in some instances, although the causal direction is not proven.

Differences exist in the nature of service provided by public/non-profit and private firms. By type of assistance received, public sources are most likely to be used for environmental matters, training services, production or technology assistance, and energy audits. Private firms are more often used for environmental matters, production or technology, training, and management assistance.

Public/non-profit assistance tends to be of shorter duration than private assistance. Thirty-six percent of private organization customers received more than five days of assistance compared to only 11 percent of public/non-profit customers.

Forty-five percent of manufacturers have not received assistance from public, non-profit, or private sources. Table 4.1 illustrates how size plays an important role. The mean number of employees in 1993 of manufacturers not receiving assistance is 62 (median=25); the mean number of employees of firms assisted by Georgia Tech is 162 (median=65); the mean number of employees of firms receiving private assistance is 172 (median=70). By industry, food products manufacturers are more apt to report being assisted by either private organizations or Georgia Tech. Respondents in electronics and instruments industry show the greatest tendency to use private organizations. (See

Table 4.2.) Figure 8 further examines Georgia Tech's service penetration by showing the percentage of firms using Georgia Tech's Industrial Extension Service by two-digit SIC, along with the number of establishments in each of these SICs in the state.

Table 4.1
Use of Assistance Sources by Employment Size
(percent using source)

Assistance Source[1]	All Respondents	10-25	26-99	100+
Unassisted	42.4%	61.8%	38.6%	20.9%
Assisted by private organizations	45.9%	29.3%	47.3%	67.0%
Georgia Tech extension assisted	25.3%	16.4%	27.7%	34.0%

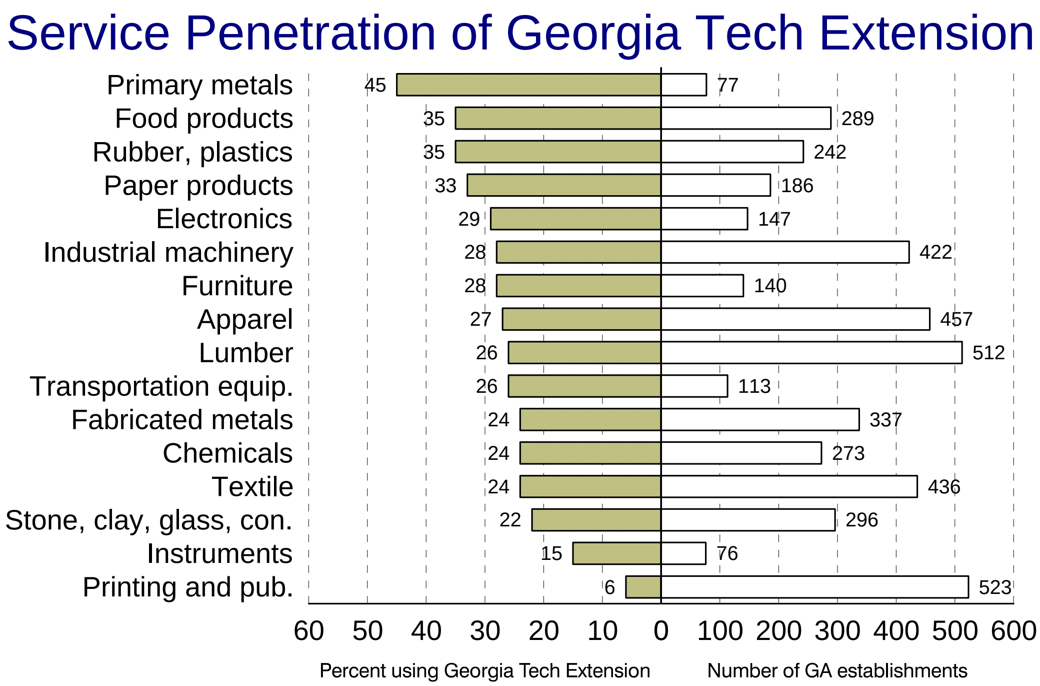
[1]Firms assisted by Georgia Tech extension may also be assisted by private organizations.

Table 4.2
Use of Assistance Sources by Industry
(percent using source)

Assistance Source[1]	All Respondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
Unassisted	42.4%	27.6%	38.8%	44.1%	46.1%	32.3%	46.6%
Assisted by private organizations	45.9%	50.1%	48.3%	45.3%	39.4%	56.1%	47.5%
Georgia Tech extension assisted	25.3%	34.9%	25.5%	25.9%	28.0%	24.2%	18.4%

[1]Firms assisted by Georgia Tech may also be assisted by private organizations.

Figure 8


Service Penetration of Georgia Tech Extension
Primary metals 45 77
Food products 35 289
Rubber, plastics 35 242
Paper products 33 186
Electronics 29 147
Industrial machinery 28 422
Furniture 28 140
Apparel 27 457
Lumber 26 512
Transportation equip. 26 113
Fabricated metals 24 337
Chemicals 24 273
Textile 24 436
Stone, clay, glass, con. 22 296
Instruments 15 76
Printing and pub. 6 523
60 50 40 30 20 10 0 100 200 300 400 500 600
Percent using Georgia Tech Extension
Number of GA establishments

Section 5
Business and Economic Outcomes

The survey form included several questions that are part of the national measures used by the National Institute of Standards and Technology to assess manufacturing performance. This section will examine survey responses to these questions and examine differences between firms assisted and not assisted by Georgia Tech.

Respondents were asked to report or estimate these measures for 1991 and 1993. To handle the wide variability in how firms operate, researchers focused on the change between 1991 and 1993 rather than absolute numbers in each year.

Several factors additional influence the results. An economic downturn affected operations in 1991. Respondents may have felt an incentive to inflate improvements in operating characteristics (judging from the large number of firms with improved figures for 1993), although it would be unlikely that they could guess how other manufacturers in the state would have responded. Researchers attempted to check for this positive bias by calculating several ratios and contacting firms whose responses seemed unreasonable or extreme for verification. Nevertheless, results should be viewed in comparison with one another rather than as stand-alone performance measures.

Intermediate Operating Characteristics

Survey respondents provided information on the following intermediate operating characteristics:

- percentage of employees at this location using a computer or programmable machine control on a weekly basis as part of their jobs
- manufacturing or production lead time--the number of calendar days between production start and end
- scrap (or yield loss) rate
- percentage of product shipments customers rejected for defects or not-to-spec conditions
- amount spent on training for all employees at this location.

The average (median) manufacturer had the following operating characteristics:

- 17 percent of employees used computers weekly in 1993, 5 percent more than 1991
- 10 days lead time, unchanged from 1991
- 3 percent scrap rate, unchanged from 1991
- .5 percent customer reject rate, unchanged from 1991
- $224 training expenditure per employee, $35 dollars more than 1991.

Note that scrap and customer reject rates already were very low in 1991. Thus, little improvement in the average manufacturer could be expected. The top 5 percent of manufacturers have more than four times the rate of computer usage, one-tenth of the lead time, one-sixth of the scrap rate, a reject rate of virtually nothing, and twice the training dollars spent per employee compared to the average manufacturer.

Table 5.1 reports operating characteristics for 1993 by employment size. The tables show the mean change and standard error (indicative of the degree of dispersion around the mean). They also include the median and the weighted average for the top 5 percent firms on each measure. (We do not know if these firms are the same across each measure.)

Several of these operating characteristics are related to the size of plant[11]. These include percentage of workers using computers, manufacturing lead time, customer reject rates, and training expenditures per employee. The top 5 percent of plants have similarly low scrap rates, manufacturing lead times, and customer reject rates, regardless of size.

Table 5.2 shows the change in operating characteristics from 1991 to 1993 by employment size. Overall, larger plants tend to show greater improvement on these operating measures than do plants with 10 to 25 employees, except for change in customer reject rate. However, the top 5 percent of plants with 10 to 25 employees have changes in scrap rate and a reject rate similar to, if not better than, those with more than 25 employees.

Tables 5.3 and 5.4 present operating information by industry group. Electronics and instruments manufacturers have significantly higher computer usage than firms in other industry groups and tend to have among the lowest scores on scrap and reject rates. Food products manufacturers have low lead times and reject rates as well. Regarding percent change from 1991 to 1993, electronics and instruments manufacturers exhibit greater improvement than do other industry groups in the percentage of workers using computers. Their manufacturing lead time has decreased faster than all but metals and machinery manufacturers.

One general observation is that manufacturers in groups with already good operating characteristics--larger plants, those in electronics and instruments industries--appear to have improved to a greater extent than their counterparts in other size and industry classes.

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[11]Difference in means among the employment size groups is significant at the 95 percent confidence level.

Table 5.1
Operating Characteristics by Employment Size
1993

Operating characteristics	All Respondents	10-25	26-99	100+
% workers using computers				
Mean	27.2	19.4	22.9	23.5
Standard error	0.47	0.64	0.64	0.78
Median	17.0	10.0	12.0	13.0
Top 5 %	90.0	75.0	90.0	80.0
Manufacturing lead time				
Mean	16.0	14.4	16.1	17.7
Standard error	0.40	0.55	0.57	1.04
Median	10.0	7.0	10.0	10.0
Top 5 %	1.0	1.0	1.0	1.0
Scrap rate (%)				
Mean	6.0	6.0	5.6	5.8
Standard error	0.15	0.23	0.23	0.31
Median	3.0	3.0	3.0	3.0
Top 5 %	0.5	0.0	0.1	0.3
Customer reject rate (%)				
Mean	1.1	1.1	1.2	1.0
Standard error	0.03	0.06	0.05	0.06
Median	0.5	0.5	0.5	0.5
Top 5 %	0.0	0.0	0.0	0.0
Training dollars per employee				
Mean	894	608	894	1234
Standard error	109	88	128	344
Median	224	204	200	283
Top 5 %	1733	1400	1733	1809

Table 5.2
Change in Operating Characteristics by Employment Size
1991-1993

Operating characteristics	All Respondents	10-25	26-99	100+
Change in % workers using computers				
Mean	9.9	5.0	10.7	9.9
Standard error	0.27	0.55	0.70	0.62
Median	5.0	0.0	5.0	5.0
Top 5 %	40.0	25.9	60.0	30.0
% change in manufacturing lead time				
Mean	-2.9	-7.5	-13.5	-19.5
Standard error	0.19	1.83	1.16	1.63
Median	0.0	0.0	0.0	-25.0
Top 5 %	-60.0	-53.3	-66.7	-66.7
Change in scrap rate (%)				
Mean	-1.3	-1.0	-1.4	-1.5
Standard error	0.05	0.14	0.10	0.16
Median	0.0	0.0	0.0	-0.9
Top 5 %	-6.0	-10.0	-7.0	-5.0
Change in customer reject rate (%)				
Mean	-0.7	-0.4	-0.4	-0.6
Standard error	0.04	0.08	0.06	0.07
Median	0.0	0.0	0.0	0.0
Top 5 %	-4.0	-4.0	-2.5	-3.8
Change in training dollars per employee				
Mean	188	80	198	301
Standard error	44	14	19	166
Median	35	2	38	66
Top 5 %	707	583	992	720

Table 5.3
Operating Characteristics by Industry
1993

Operating characteristics	All Respondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
% workers using computers							
Mean	27.2	11.9	15.0	20.2	21.5	37.2	31.4
Standard error	0.47	1.15	0.72	0.67	0.84	2.20	1.04
Median	17.0	4.3	7.0	10.0	10.0	25.0	20.0
Top 5 %	90.0	50.0	65.0	75.0	84.2	100.0	90.0
Manufacturing lead time							
Mean	16.0	8.1	16.9	13.1	26.2	21.3	10.1
Standard error	0.40	0.97	0.78	0.60	1.37	2.12	0.36
Median	10.0	3.0	10.0	5.0	14.0	10.0	7.0
Top 5 %	1.0	1.0	2.0	1.0	1.0	2.0	2.0
Scrap rate (%)							
Mean	6.0	6.8	3.9	7.7	4.6	4.8	5.5
Standard error	0.15	0.76	0.18	0.33	0.25	0.99	0.21
Median	3.0	2.5	3.0	4.9	3.0	2.0	4.0
Top 5 %	0.5	0.0	0.1	0.1	0.1	0.1	0.5
Customer reject rate (%)							
Mean	1.1	0.8	1.4	0.9	1.3	0.9	1.4
Standard error	0.03	0.12	0.09	0.04	0.08	0.16	0.09
Median	0.5	0.3	0.5	0.5	0.5	0.1	1.0
Top 5 %	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Training dollars per employee							
Mean	894	1508	1178	678	973	517	836
Standard error	109	585	465	103	285	91	126
Median	224	171	209	207	213	278	278
Top 5 %	1733	2857	1667	1704	1389	1600	2273

Table 5.4
Change in Operating Characteristics by Industry
1991-1993

Operating characteristics	All Respondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
% workers using computers							
Mean	27.2	11.9	15.0	20.2	21.5	37.2	31.4
Standard error	0.47	1.15	0.72	0.67	0.84	2.20	1.04
Median	17.0	4.3	7.0	10.0	10.0	25.0	20.0
Top 5 %	90.0	50.0	65.0	75.0	84.2	100.0	90.0
Manufacturing lead time							
Mean	16.0	8.1	16.9	13.1	26.2	21.3	10.1
Standard error	0.40	0.97	0.78	0.60	1.37	2.12	0.36
Median	10.0	3.0	10.0	5.0	14.0	10.0	7.0
Top 5 %	1.0	1.0	2.0	1.0	1.0	2.0	2.0
Scrap rate (%)							
Mean	6.0	6.8	3.9	7.7	4.6	4.8	5.5
Standard error	0.15	0.76	0.18	0.33	0.25	0.99	0.21
Median	3.0	2.5	3.0	4.9	3.0	2.0	4.0
Top 5 %	0.5	0.0	0.1	0.1	0.1	0.1	0.5
Customer reject rate (%)							
Mean	1.1	0.8	1.4	0.9	1.3	0.9	1.4
Standard error	0.03	0.12	0.09	0.04	0.08	0.16	0.09
Median	0.5	0.3	0.5	0.5	0.5	0.1	1.0
Top 5 %	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Training dollars per employee							
Mean	894	1508	1178	678	973	517	836
Standard error	109	585	465	103	285	91	126
Median	224	171	209	207	213	278	278
Top 5 %	1733	2857	1667	1704	1389	1600	2273

Do manufacturers assisted by Georgia Tech show greater improvement than those not assisted by Georgia Tech? Table 5.5 presents operating characteristics by firms assisted and not assisted by Georgia Tech. The analysis controls for employment size and industry, although factors other than Georgia Tech assistance may have resulted in the operating characteristic impacts presented here. Georgia Tech-assisted manufacturers show significant improvement compared to plants not assisted by Georgia Tech in percentage of workers using computers at least weekly and change in scrap rate. Georgia Tech-assisted plants were also a bit more likely to have lower customer reject rates than those unassisted by Georgia Tech.

Table 5.5
Operating Characteristics
Plants Assisted and Not Assisted by Georgia Tech Extension
Change 1991-1993

Operating Characteristics	Assisted by Georgia Tech Extension		Not Assisted by Georgia Tech Extension		GT Extension Assisted Improvement Relative to Unassisted[a]
Change in scrap rate	Mean	-1.1	Mean	-1.1	**MORE[1,3]**
		(.12)		(.05)	
	Median	-.3	Median	0	
Training $ per employee	Mean	133	Mean	212	SAME
		(72)		(56)	
	Median	37	Median	34	
% change in manufacturing lead time	Mean	-9.1	Mean	-9.6	SAME
		(1.29)		(.73)	
	Median	0	Median	0	
Change in customer reject rate	Mean	-.8	Mean	-.6	MORE[2]
		(.07)		(.05)	
	Median	0	Median	0	
Change in % workers using computers at least weekly	Mean	10.1	Mean	8.3	**MORE[1]**
		(.49)		(.25)	
	Median	5	Median	2	

[a]Controlling for industry and employment size. Standard error of mean in parenthesis.
[1]5% chance of no difference between assisted and not assisted by Georgia Tech
[2]20% chance of no difference between assisted and not assisted by Georgia Tech
[3]Although the means are similar, the greater variance among Georgia Tech assisted firms results in more having improved scrap rates (53%) than do unassisted firms (44%).

<u>Business and Economic Outcomes</u>

Ultimately, manufacturing practices should have a broader effect on a firm's performance and on the larger economy. This section looks at several of these "outcome" measures:

- employment
- average wages
- annual sales
- sales per inventory (inventory turns)
- change in export percentage of sales
- value added per employee (productivity).

Several of the measures were calculated from questions in the survey. For example, average wages were determined by dividing figures for payroll by the number of employees. The inventory turns measure resulted from dividing annual sales by total inventory on hand in a typical day. Value added per employee derived from combining payroll with expenditures on purchased materials, parts, and services and subtracting the total from annual sales. These calculated measures may be subject to more error than those obtained directly from questions asked.[12]

The average (median) manufacturer had the following outcome measures:

- 42 employees in 1993, up 7 percent from 1991
- average wages of $22,460, an increase of 6 percent from 1991
- annual sales of $4 million, 20 percent higher than 1991 sales
- $13 sales per inventory in 1993, up 6 percent from 1991
- virtually no exporting activity, unchanged from 1991
- value added per employee of $27,078, a 9 percent increase over 1991.

The top 5 percent of manufacturers had four times the number of employees, paid nearly twice the wages, had 3.5 times the sales, engaged in significantly more exporting, had 50 percent more inventory turns, and had four times the value added per employee of the average (median) manufacturer. Again, the same firm did not necessarily rank in the top 5 percent on all measures. Exporting activity in particular is

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[12]Because of this potential for errors, which is particularly high for value added per employee (because it includes more components), the analysis collapsed the lowest and highest 5 percent of the responses for value added per employee.

concentrated in a few manufacturers.

Tables 5.6 and 5.8 present outcome measures by number of employees. All measures are associated with employment size.[13] Manufacturers with 100 or more employees tend to have higher wages, sales, exporting activity, and value added. They also show higher growth rates for export sales and inventory turns. However, larger plants have slower rates of employment growth, sales growth, and value added per employee than do plants with less than 100 employees.[14]

Tables 5.7 and 5.9 display outcome information by industry.

- Electronics/instruments manufacturers have relatively large workforces, high average wages, and high value added per employee. Their growth rates for employment and value added per employee are lower than are those of other industries.
- Food products firms also have large workforces and high value added per employee, as well as high sales, relative to other manufacturers.
- Resource industries had the highest inventory turn ratios. Their growth rates for number of employees and value added per employee were also very high, although the growth in number of employees is from a small base.
- Manufacturers in metals/machinery industries had the lowest value added per employee, and their growth rate on this measure was among

[13]Difference in means among the employment size groups is significant at the 95 percent confidence level.

[14]Note should be made of the underlying "ecological" trends by size, as smaller firms tend to have lower survival rates over time (small units may grow faster in any given time period than larger units, but subsequently many of these small units will go out of business at a more rapid rate than the large ones).

the smallest. Their employment base grew at a higher rate than did those in other industries, although their average wage grew less than that for other industries.

- Textile and apparel manufacturers had the lowest average wage, although it grew somewhat faster than the rate for other manufacturers. Likewise, its exporting growth rate was relatively high.

Table 5.6
Outcome Measures by Employment Size
1993

Outcome Measures	All Respondents	10-25	26-99	100+
Employment				
Mean	120	16	55	379
Standard error	4.86	0.11	0.53	17.94
Median	42	16	50	247
Top 5 %	500	25	98	900
Payroll per employee (average wage)				
Mean	22460	20531	22946	24592
Standard error	192	295	288	449
Median	21000	20800	21045	22083
Top 5 %	40000	38008	38133	45714
Sales (000s)				
Mean	23110	472	9184	80081
Standard error	2020	1203	308	8664
Median	4000	1300	5500	5500
Top 5 %	80000	6000	30000	243000
Export percent of sales				
Mean	6.5	5.2	7.1	7.6
Standard error	0.29	0.48	0.47	0.56
Median	0	0	0	2
Top 5 %	33	25	50	30
Sales/inventory (turns)				
Mean	124	73	171	112
Standard error	17.57	13.06	37.44	25.60
Median	13	14	13	13
Top 5 %	200	192	225	150
Value added per employee*				
Mean	46004	34550	47546	61496
Standard error	1161	1458	1819	2986
Median	27078	21467	30000	42143
Top 5 %	200000	108333	200000	2000000

*The lowest (less than 0) and highest (over 200000) 5% of responses have been collapsed.

Table 5.7
Outcome Measures by Industry
1993

Outcome Measures	All Respondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
Employment							
Mean	120	252	188	78	101	238	68
Standard error	4.86	27.7	9.54	3.56	17.52	34.03	3.63
Median	42	61	95	36	33	70	30
Top 5 %	500	1100	650	295	300	755	271
Payroll per employee (average wage)							
Mean	22460	20882	18405	23183	24099	29519	22648
Standard error	192	917	379	346	421	844	4001
Median	21000	18833	17085	21595	23118	28923	21529
Top 5 %	40000	39409	30884	45000	40000	46528	39292
Sales (000s)							
Mean	23110	96758	28355	16758	21191	36008	7507
Standard error	2020	30555	2980	1142	3726	7139	448
Median	4000	14200	4808	4575	3800	7100	2600
Top 5 %	80000	266000	100000	65000	54941	135000	35000
Export percent of sales							
Mean	6.5	8.8	6.3	6.0	8.7	8.1	4.4
Standard error	0.29	1.39	0.64	0.52	0.75	0.99	0.55
Median	0	0	1	0	0	5	0
Top 5 %	33	50	30	33	50	41	15
Sales/inventory (turns)							
Mean	124	68	75	172	36	42	232
Standard error	17.57	13.2	20.04	40.33	4.75	9.52	61.88
Median	13	20	12	14	10	10	24
Top 5 %	200	178	131	125	180	394	385
Value added per employee*							
Mean	46004	69978	41242	55512	34547	61121	37891
Standard error	1161	6578	2991	2269	1880	5744	1997
Median	27078	44335	19167	36111	23333	39800	30500
Top 5 %	200000	200000	200000	200000	116000	194182	159333

*The lowest (less than 0) and highest (over 200000) 5% of responses have been collapsed.

Table 5.8
Change in Outcome Measures by Employment Size
1991-1993

Outcome Measures	All Respondents	10-25	26-99	100+
% change in employment				
Mean	17.4	17.7	19.8	13.0
Standard error	0.89	2	1.12	1.22
Median	7.1	6.7	10.5	3.3
Top 5 %	85.7	80.0	100.0	83.0
% change in payroll/empl. (avg. wage)				
Mean	8.1	7.4	8.7	8.3
Standard error	0.36	0.6	0.64	0.56
Median	6.1	5.9	5.8	6.7
Top 5 %	38.5	39.6	37.9	37.1
% change in sales				
Mean	36.1	36.1	41.1	26.6
Standard error	1.42	2.57	2.44	1.58
Median	20.0	20.0	22.5	17.6
Top 5 %	130.3	130.8	157.7	90.5
Change in export % of sales				
Mean	0.6	0.2	0.7	1.1
Standard error	0.08	0.13	0.11	0.21
Median	0	0	0	0
Top 5 %	5.0	5.0	6.0	7.5
% change in sales/inventory (turns)				
Mean	16.7	12.3	13.7	29.3
Standard error	1.37	2.64	1.21	3.87
Median	5.9	2.1	6.8	8.2
Top 5 %	96.9	80.0	95.0	141.2
% change in value added per employee*				
Mean	17.6	19.0	17.5	15.3
Standard error	1.36	2.37	2.00	2.92
Median	9.1	10.8	9.2	6.8
Top 5 %	170.0	170.0	139.2	169.2

*The lowest (less than -90%) and highest (over 170%) 5% of responses have been collapsed.

Table 5.9
Change in Outcome Measures by Industry
1991-1993

Outcome Measures	All Re-spondents	Food Products	Textiles, Apparel	Resource Industries	Metals, Machinery	Electronics Instruments	Plastics Printing Misc.
% change in employment							
Mean	17.4	9.9	21.4	15.5	21.7	9.7	16.3
Standard error	0.89	2.32	3.38	1.42	1.62	2.63	1.11
Median	7.1	0	0	7.1	10.0	0	13.3
Top 5 %	85.7	87.5	84.6	100.0	100.0	70.0	80.0
% change in payroll/empl. (avg. wage)							
Mean	8.1	8.4	9.2	8.1	7.4	8.2	7.6
Standard error	0.36	1.59	0.88	0.69	0.7	1.35	0.77
Median	6.1	7.6	7.1	5.9	4.0	5.6	6.7
Top 5 %	38.5	37.0	54.0	38.4	33.4	33.3	38.3
% change in sales							
Mean	36.1	41.5	33.3	37.6	40.0	25.6	30.0
Standard error	1.42	14.39	2.73	1.91	3.9	3.81	1.45
Median	20.0	11.6	18.2	22.5	21.0	15.9	22.7
Top 5 %	130.3	158.8	200.0	130.8	140.0	124.7	100.0
Change in export % of sales							
Mean	0.6	-2.2	1.0	0.8	0.6	0.4	0.8
Standard error	0.08	0.81	0.15	0.14	0.16	0.32	0.09
Median	0	0	0	0	0	0	0
Top 5 %	5.0	4.0	7.6	5.0	5.2	6.8	5.0
% change in sales/inventory (turns)							
Mean	16.7	36.5	10.0	16.0	17.4	26.6	13.7
Standard error	1.37	13.35	1.91	1.92	2.58	13.4	1.83
Median	5.9	7.9	2.9	5.5	7.14	-4.6	6.4
Top 5 %	96.9	110.0	72.4	87.5	108.4	130.0	106.9
% change in value added per employee*							
Mean	17.6	4.3	10.0	22.3	13.5	10.9	25.0
Standard error	1.36	4.73	3.41	2.43	3.08	6.43	2.80
Median	9.1	9.1	6.9	10.2	2.6	0.9	12.3
Top 5 %	170.0	101.5	170.0	165.3	169.2	137.0	170.0

*The lowest (less than -90%) and highest (over 170%) 5% of responses have been collapsed.

These outcome measures can be viewed as a benchmark against which operating characteristics and practices may be evaluated. Value added per employee is a particularly important measure in this regard. An analysis of the previous operating characteristics and value added per employee shows that manufacturers with higher computer usage and lower scrap rate in 1993 also had higher value added per employee in 1993. This relationship was statistically significant[15] controlling for employment size and industry group. Lead time and customer reject rates did not have a strong association with value added per employee, in part because these rates were low and showed little variation. Training expenditures per employee in 1993 exhibited a negative relationship with value added per employee in 1993, although conceivably training expenditures may have a positive effect in time.

How did Georgia Tech-assisted firms fare on these measures? Table 5.10 shows that Georgia Tech-assisted manufacturers had greater gains in employment and average wages than those not assisted by Georgia Tech. Georgia Tech-assisted firms tended to have higher annual sales than unassisted firms, but because their base sales size was high, the percent change from 1991 to 1993 was not significantly higher than unassisted, lower sales-producing firms.

Value added per employee was lower for Georgia Tech-assisted than for unassisted manufacturers. The implications of this finding are unclear. For example, Georgia Tech-assisted manufacturers could have sought assistance because of productivity problems. Improvement in these problem areas may take more time to be revealed in the numbers. Also, without knowing what type of assistance Georgia Tech provided to these firms, it is difficult to assess likely outcomes.

The implication that firms who invest more in technology and quality may accrue faster sales and employment growth but also be less profitable (measured here by value added) is something we will probe further in future analysis. At least one other study (in Britain) has a similar finding that firms adopting lean production

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[15]Significant at the 95 percent confidence level.

methods grew faster but were less profitable.[16] At least in the short term, this suggests that being a "best practice" company is not cost-free. However, we would hope, in later analyses, to identify tangible longer-term benefits.

[16]Nick Oliver and Gillian Hunter, *The Financial Impact of Japanese Production Methods in UK Companies,* Judge Institute of Management Studies, (Working Paper 1993-1994 No. 24), Cambridge University, Cambridge, UK, 1994.

Table 5.10
Outcome Measures
Plants Assisted and Not Assisted by Georgia Tech Extension
Improvement in 1991-1993 Change

Performance Measure	Assisted by Georgia Tech Extension				Not Assisted by Georgia Tech Extension				GT Ext. Assisted Improvement (change) over Unassisted[a]
	1993		Change		1993		Change		
Employment	Mean	163	Mean	22.4	Mean	104	Mean	15.6	**MORE[1]**
		(8.36)		(2.60)		(5.65)		(.77)	
	Median	65	Median	7.7	Median	36	Median	7.1	
Payroll/ empl. (average wage)	Mean	22,297	Mean	10.1	Mean	22,443	Mean	7.4	**MORE[1]**
		(362)		(.82)		(219)		(.39)	
	Med.	20,828	Median	6.7	Med.	20,963	Median	5.9	
Sales (1993 in millions of dollars)	Mean	40.5	Mean	37.9	Mean	16.9	Mean	35.4	SAME
		(6.31)		(3.35)		(1.24)		(1.52)	
	Median	6.6	Median	20.0	Median	3.6	Median	20.0	
Export % of sales	Mean	8.0	Mean	.8	Mean	6.3	Mean	.5	SAME
		(.55)		(.24)		(.34)		(.07)	
	Median	1	Median	0	Median	0	Median	0	
Sales/inventory ratio (turns)	Mean	138.6	Mean	14.6	Mean	109.9	Mean	17.4	**LESS[1]**
		(39)		(1.55)		(17.31)		(1.79)	
	Median	11.3	Median	5.6	Median	14.7	Median	5.9	
Value added/ employee	Mean	44,742	Mean	8.5	Mean	45,204	Mean	21.2	**LESS[1]**
		(2,103)		(2.42)		(1,268)		(1.63)	
	Med.	24,890	Median	2.3	Med.	29,343	Median	11.1	

[a]Controlling for industry and employment size. Standard error of mean in parenthesis.
[1]5% chance of no difference between assisted and not assisted by Georgia Tech