

**Current Status of Technology Adoption:
Micro, Small and Medium Manufacturing Firms in Boston**

Authors:

Pratyush Bharati
Management Science and Information
Systems
College of Management
University of Massachusetts, Boston
Boston, MA 02125-3393
Phone: 617 287 7880
Fax: 617 287 7877
E-mail: Pratyush.Bharati@umb.edu

Abhijit Chaudhury
Bryant University
1150 Douglas Pike
Smithfield, RI 02917

E-mail: achaudhu@bryant.edu

Paper Reference:

Bharati, P. and Chaudhury, A. (2006), "Current Status of Technology Adoption: Micro, Small and Medium Manufacturing Firms in Boston", *Communications of the ACM*, Vol. 49, No. 10, pp. 88-93.

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Introduction

Small and medium sized enterprises (SMEs) are important to the US economy and, in particular, to the high-tech sector. SMEs employ half of all private sector employees, generate 60 to 80 % of new jobs annually, and employ about 39% of high-tech workers such as scientist, engineers and computer workers [8, 11]. Further, SMEs play a critical role in nurturing industrial innovation constituting 40% of highly innovative firms in 2002 [9]. SMEs also play an important role in enhancing the competitiveness of an economy through the process of economic renewal by birth, death and re-structuring of economic sectors. Technology has been a critical factor in enabling SMEs to play this regenerative role in the US economy [10].

Although some work has been done at the national level little is known about the status of technology adoption by SMEs at the local level [2, 4, 13]. Accordingly, the intent of the research here is to investigate the current state of technology adoption by high-tech manufacturing SMEs in the Greater Boston area. It examines the adoption of technologies across the entire value chain, including the primary activities of manufacturing and support activities such as administration, human resource management, and design. This work has several additional purposes, one of which is to identify those factors that influence the adoption of technologies by SMEs. The degree of awareness that the firms have about various technology solutions is underscored. The data are collected and analyzed so as to emphasize the role of firm-size in technology

awareness and adoption. This assessment of adoption can aid these firms in identifying technology solutions that they maybe lacking. Beyond that this study will provide policymakers with grounded knowledge to formulate effective policies, institute fiscal incentives, and design assistance programs that are tailor-made to the SMEs population in the Greater Boston area.

The surveys were administered to 655 firms in the Greater Boston area with the assistance of Greater Boston Manufacturing Partnership (GBMP). 158 firms responded of which 135 were usable responses. The firms belonged to both discrete and continuous manufacturing serving the consumer products, electronics, machined parts, medical devices and other industries. The responses were categorized into three groups micro, small and medium enterprises. Firms employing 1-10 people were categorized as micro; firms employing 11-100, as small; and firms employing 101-500 as medium.

Value Chain Framework

The value chain “divides a company’s activities into the technologically and economically distinct activities it performs to do business” [5]. The firm’s primary activities are inbound logistics, operations, outbound logistics, marketing, and sales and service. The primary activities require support activities to provide inputs and infrastructure. Support activities are firm infrastructure, human resource management, technology development, and procurement (Figure 1).

Particularly for large firms, IT has permeated most of the value chain. It has transformed the performance of, and linkages between, value activities. The value activities have a physical and information-processing component. The information-processing captures, manipulates, and channels the data necessary to perform the activity [5, 6, 7]. SMEs in manufacturing must decide between spending resources on technology for information processing activity and on the physical value activities. The SMEs are constrained especially because of the size and revenues of the firm [3]. Since the research investigated SMEs and their usage of technologies, it was important to explain the results in terms of how they organize their activities. The value chain approach has been employed to contextualize and elucidate the role of technology in SMEs (Table 1).

Value Chain and Technology Adoption

Inbound Logistics

Inbound logistics involves actions associated with receiving, storing and supplying of raw materials. Inbound logistics is supported by supplier management and supply chain management technologies. Supplier management is the use of software to store and process supplier-related data. Supplier management is employed by a third of SMEs. Small and medium firms employ supplier management software almost equally, but only 12.5% of micro firms employ it. Supply chain management (SCM) is the use of packaged software for planning and monitoring of material flow between the firm and its suppliers and customers. SCM is used by almost a quarter of SMEs. Interestingly, SCM is one of the few software, that micro and small firms employ more of it than do the medium firms. SCM spans several activities in the value chain.

Operations

Operations involve actions and processes associated with transforming material inputs into a finished product. It is supported by materials management, production planning, computer numerical control (CNC), and computer aided manufacturing (CAM) technologies [1]. Materials management is the use of package software for planning and control of material storage and usage in production environment. Materials management software is employed by more than half of SMEs, with 81.3% of medium-size firms, 62% of small firms, and 29.2% of micro firms employing this software. The production planning software is employed by a lesser proportion of SMEs. But this does not truly represent the proportion in micro, small and medium firm categories. More than 80% of medium firms and a quarter of micro firms employ the production planning software. CNC are microprocessor-based systems that communicate work instructions directly to the manufacturing machinery. Although more than a third of SMEs use CNC, the disparity between micro firms, small firms and medium firms is substantial, with 12.5% of micro, 38% of small and 62.5% of medium firms employing CNC. The differences are slightly less in the CAM usage among micro, small and medium firms. For the purpose of this survey, CAM is defined as the use of computers for planning the manufacturing process.

Outbound Logistics

Outbound logistics is the actions associated with the storage and physical distribution of physical goods to buyers. This activity is supported by order-processing and SCM

technologies. Order processing is use of package software to store and process customer orders. Order processing software is employed by most of the medium firms, two thirds of small firms, and about a third of micro firms. SCM is employed by fewer firms that includes only 18.8% of medium firms.

Marketing and Sales

Marketing and sales involve actions associated with advertising, promotion, pricing and selling. This activity is supported by firm website and customer relationship management (CRM) technology. Most SMEs overall and including the micro, small and medium groups have a website for marketing themselves over the Internet. CRM is use of software to store customer data for tracking and analysis of customer needs and sales activities. But the employment of IT by SMEs drops dramatically to about a quarter in the case of another marketing and sales IT, namely CRM.

Service

Service involves actions associated with providing service and assistance to the customer. This activity is also supported by CRM technology. A larger proportion of medium firms than small firms employ CRM. 16.7% of micro, 27.8% of small, and 28.1% of medium firms employ CRM.

Firm Infrastructure

Firm infrastructure involves activities associated with general management, planning, finance and accounting. This activity is supported by accounting and finance software

technologies. Accounting and finance software is employed by most SMEs overall and is also true for micro, small and medium firms.

Human Resource Management

Human resource management activities involve recruiting, hiring, training and compensation for employees. This activity is supported by human resources management software that monitors employee related data. Similar to the production planning software, a third of SMEs employ human resource management software, with about two third of medium firms, a third of small, and just 8% of micro firms employing it.

Technology Development

Technology development involves activities related to development of know-how, procedures and technology. This activity is supported by computer-aided-design (CAD) that assists engineers in their design and drafting activities. CAD is employed by a substantial proportion of SMEs (71.9%), with 41.7% of micro, 73.4% of small, and 90.6% of medium sized firms employing it.

Procurement

Procurement involves activities associated with purchasing raw materials and inputs for the firm. This activity is supported by electronic procurement systems that allow catalog search and transmission of orders to suppliers. 24.4% of SMEs employ electronic procurement, with 46.9 % of medium firms, 19% of small firms, and 12.5% of micro firms employing it.

In summary (Table 2 and Figure 2), across all SMEs, websites and accounting and finance software were being employed in significant majority, in excess of 80% of SMEs. The majority of firms, between 50-79%, had installed technologies such as materials management, order processing, production planning and CAD. A significant minority, between 30-49% of the firms, were employing human resource systems, CNC and CAM. A minority, between 0-29% of firms, were employing SCM, CRM and E-Procurement.

There are several significant differences and similarities between the micro, small and medium firms. When technologies are simple, such as a website, an email facility, an internet connection, and accounting and finance software, then usage difference is minimal. For instance, an overwhelming proportion of SMEs, in excess of 95%, had Internet connection and email. As technologies become more complex, the difference between the three groups become more visible. This is true for materials management, order processing, production planning, CAD, CAM, and human resources systems. In employment of technologies such as SCM and E-Procurement the medium firms are ahead of small and micro firms.

Technology and Non-Adoption

The research investigated the state of non-adoption with respect to various technologies relevant to the various elements of the value chain. For technologies not adopted, the respondents were asked to select one from the following states: no current activity, aware, interested, evaluated, and rejected. In terms of no current activity, i.e., minimal

awareness it is seen that 60-70% of micro firms are minimally aware of SCM, supplier management, CNC, CAM, CRM, human resource systems, and e-procurement. Similarly 35-50% of small firms are minimally aware of the above technology set. The medium firms are in a better position, as only 15-40% of the firms are minimally aware of the above technology set.

Drivers in the Adoption of IT in SMEs

Survey respondents were asked to identify factors that influenced their decisions to employ particular technology solutions (Table 3). According to the responses factors such as suppliers, media, vendors, and government agencies were not influential. Unlike some previous research [13], only top management and customers were seen to have significant impact on adoption decisions. Competitors and personal and professional networks seem to have some impact on their adoption decisions. The factors seem to have varying impact according to their sizes. It was observed that medium firms were more open to personal and professional networks influencing their adoption decisions than were small and micro firms. Suppliers and vendors were seen to have a stronger role for micro and small firms than for medium firms in adoption decisions.

Conclusion

Several interesting issues emerge from our survey findings. The firms were found to be more focused on building their core competencies than competencies in areas such as marketing management. The firms were more interested in employing technologies such as CAD and CNC – technologies that support core operational activities such as

production and design than technologies that support activities such as sales and procurement management. As anticipated, simpler technologies such as web, email and software packages such as accounting have a much wider application than more complex ones such as CRM and SCM.

Firm size has a significant impact on what technologies are employed. Simple technologies such as web and accounting packages are used widely across all firm sizes. Similarly, with complex technologies that are minimally employed among SMEs such as CRM and SCM, there is little differences among these firms. For intermediate technologies such as materials management, production planning, CNC, CAD, CAM and human resources, there are significant variations among the three groups, with the medium firms employing more widely than small firms and small firms more widely than micro firms.

We found that there are only two significant drivers that impact a firms' decision to adopt a technology. Top management and customers have the most influence. Factors such as vendors, media and government have very limited impact.

In terms of non-adoption, the research highlights several interesting elements. Micro firms are seen to be unfamiliar with most technologies with the exception of emails, website, internet connection and software packages relating to order processing, accounting, and CAD. Medium firms, although not widely adopting technologies such as SCM, supplier management, e-procurement and CRM, appear to be aware of these

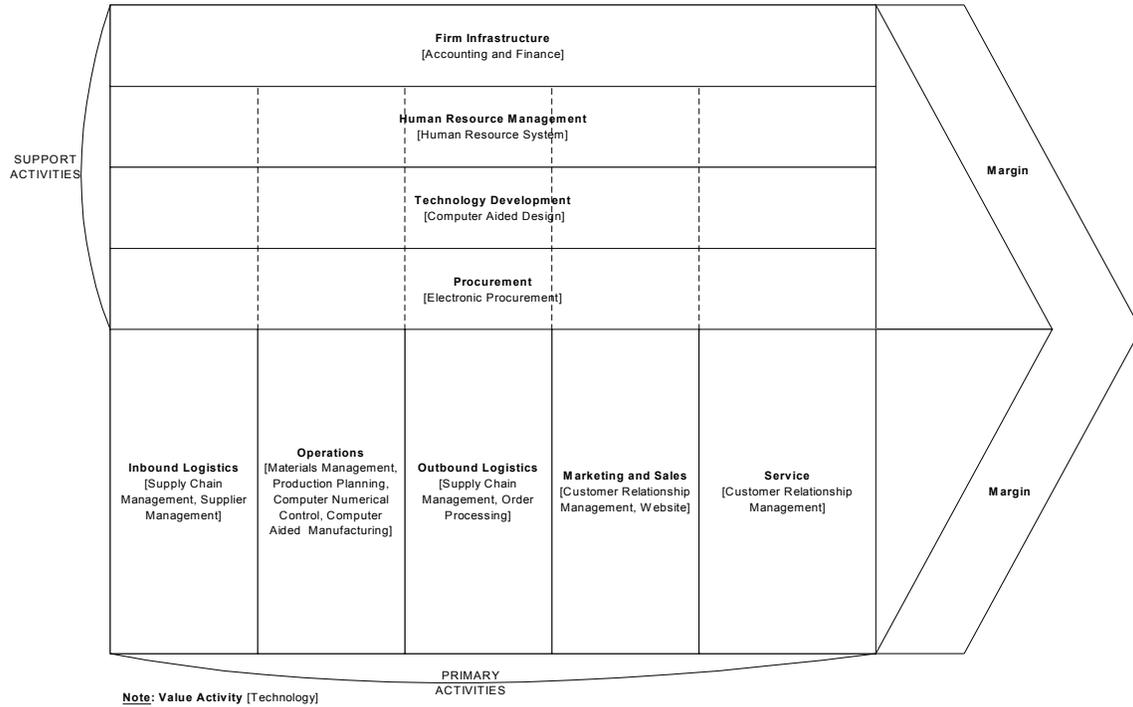
technologies. Compared to medium firms, the small firms have a lower level of awareness of technologies that support various value-chain activities.

This research provides policymakers with grounded knowledge to formulate effective policies and support systems applicable to high-tech manufacturing areas such as Greater Boston. It is evident from the study that technologies are not being adopted across the value chain even in high-tech manufacturing areas. The research brings into focus the role that the government agencies and vendors need to play in order to make this sector competitive. Since the micro and small firms are not particularly connected with professional and personal networks, it is incumbent on public sector agencies to provide the necessary knowledge and support. For instance, they could enhance their outreach programs by offering web-based knowledge repositories and demonstration laboratories. The web-based knowledge repositories could consist of technology solutions, relevant SME case studies, and best practices. The demonstration laboratories could also have a significant impact in improving the awareness and developing a better understanding of these technologies. Since SMEs are a major contributor in terms of GDP and employment, this study highlights that more empirical studies focusing on technologies important to the entire value chain should be conducted.

References

1. Ake, K., Clemons, J. and Cubine, M. Information Technology for Manufacturing: Reducing Costs and Expanding Capabilities, St. Lucie Press, Boca Raton, FL, 2004.
2. Al-Qirim, N. A. Y., Electronic Commerce in Small to Medium-Sized Enterprises: Frameworks, Issues, and Implications, Idea Group Publishing, Hershey, PA, 2004.
3. Curran, J. and Blackburn, R. A. Researching the Small Enterprise. Sage Publications, Thousand Oaks. 2001.
4. Everdingen, Y. V., Hillengersberg, J. V., and Waarts, E. ERP Adoption by European Mid-Size Companies, Communications of the ACM, April, 2000, Vol. 43, No. 4, 23-31.
5. Porter, M. E. Competitive Advantage. Free Press, New York. 1985.
6. Porter, M. E. and Millar, V. E. How Information Gives you Competitive Advantage. Harvard Business Review (July-August 1985) 149-160.
7. Porter, M. E. Strategy and the Internet. Harvard Business Review (March 2001) 63-78.
8. Small Business Administration, Small Business Resources for Faculty, Student, and Researchers, Washington, DC. May 2004. (Available on the web at <http://www.sba.gov/advo/>).
9. Small Business Administration, Small Firms and Technology: Acquisitions, Inventor Movement, and Technology Transfer, Small Business Research Summary No. 233, Washington, DC. January 2004. (Available on the web at <http://www.sba.gov/advo/>)
10. Small Business Administration, The New American Evolution: The Role and Impact of Small Firms, Small Business Research Report, Washington, DC. June 1998. (Available on the web at <http://www.sba.gov/advo/>).
11. Small Business Administration, Top Ten Reasons to Love Small Business, Small Business Administration News Release, SBA 04-06 ADVO, Washington, DC. February 13, 2004. (Available on the web at <http://www.sba.gov/advo/>).
12. Thong, J. Y. L., Yap, C. S., and Raman, K. S., Top Management Support, External Expertise and Information Systems Implementation in Small Businesses, Information Systems Research, June 1996, Vol. 7, No. 2, 248-267.
13. Yeung, J. H. Y., Shim, J. P., and Lai, A. Y. K. Current Progress of E-Commerce Adoption: Small and Medium Enterprises in Hong Kong, Communications of the ACM, September 2003, Vol. 46, No. 9, 226-232.

Figure 1: Value Chain with Technologies



Adapted from [5, 6]

Figure 2: Technology Employed for Value Activity

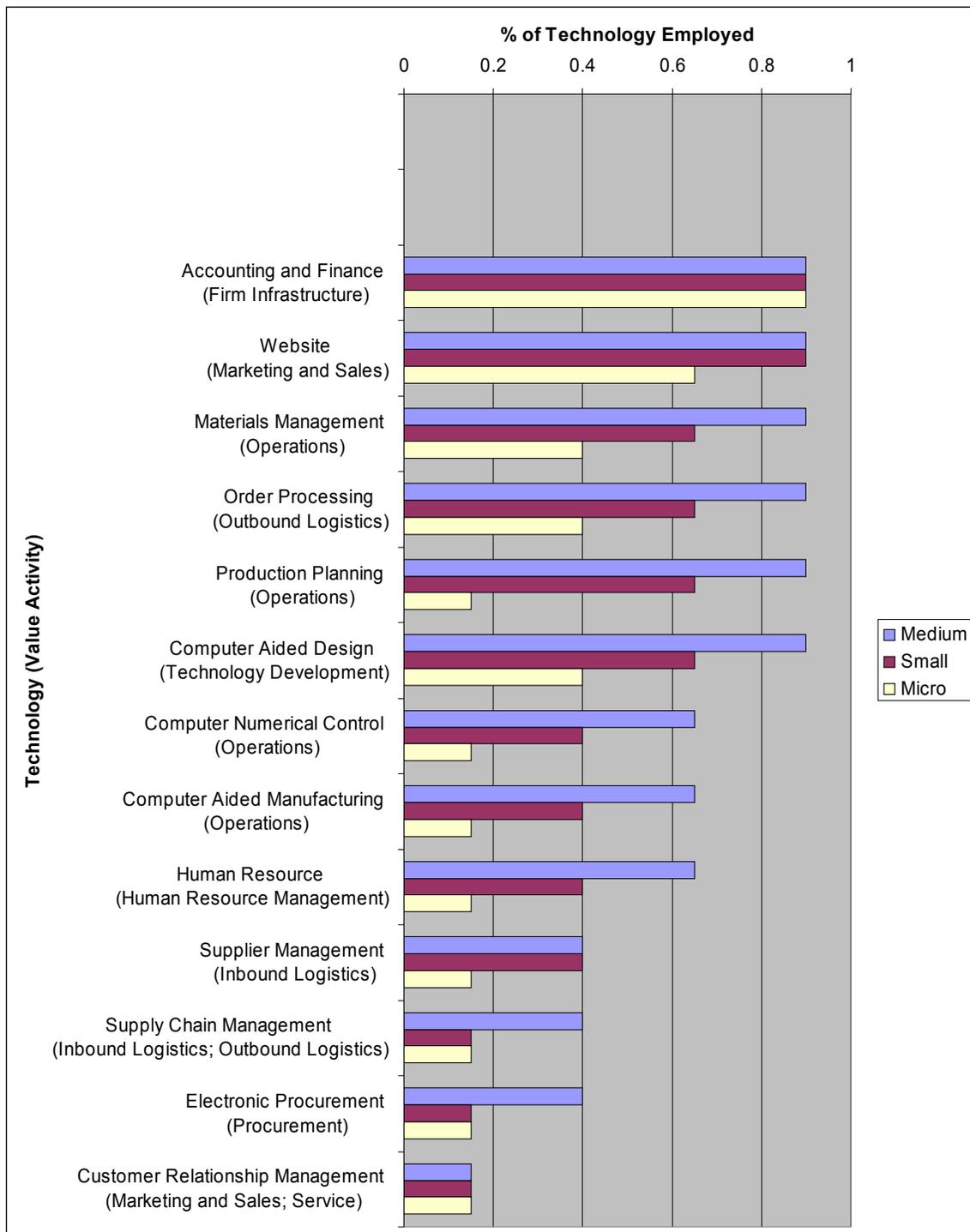


Table 1: Technology Adoption in the Value Chain

Value Activity	Information Technology	All SME (1-500)	Micro Firms (1-10)	Small Firms (11-100)	Medium Firms (101-500)
Inbound Logistics	Supply Chain Management	23.70%	25.0%	25.3%	18.80%
	Supplier Management	33.33%	12.5%	38.0%	37.50%
Operations	Materials Management	60.74%	29.2%	62.0%	81.25%
	Production Planning	57.78%	25.0%	55.7%	87.50%
	Computer Numerical Control	39.30%	12.5%	38.0%	62.50%
	Computer Aided Manufacturing	37.78%	20.8%	36.7%	53.13%
Outbound Logistics	Supply Chain Management	23.70%	25.0%	25.3%	18.80%
	Order Processing	71.11%	37.5%	73.4%	90.63%
Marketing and Sales	Customer Relationship Management	25.93%	16.7%	27.8%	28.13%
	Website	88.15%	70.8%	91.1%	93.75%
Service	Customer Relationship Management	25.93%	16.7%	27.8%	28.13%
Firm Infrastructure	Accounting and Finance	91.11%	83.3%	93.7%	90.63%
Human Resource Management	Human Resource	34.07%	8.3%	30.4%	62.50%
Technology Development	Computer Aided Design	71.85%	41.7%	73.4%	90.63%
Procurement	Electronic Procurement	24.44%	12.5%	19.0%	46.88%

Table 2: Technology Adoption for each Value Activity

Information Technology	Value Activity	Most (100-80%)	Majority (79-50%)	Significant Minority (49-30%)	Minority (29-0%)
Accounting and Finance	Firm Infrastructure	Medium Small Micro			
Website	Marketing and Sales	Medium Small	Micro		
Materials Management	Operations	Medium	Small	Micro	
Order Processing	Outbound Logistics	Medium	Small	Micro	
Production Planning	Operations	Medium	Small		Micro
Computer Aided Design	Technology Development	Medium	Small	Micro	
Computer Numerical Control	Operations		Medium	Small	Micro
Computer Aided Manufacturing	Operations		Medium	Small	Micro
Human Resource	Human Resource Management		Medium	Small	Micro
Supplier Management	Inbound Logistics			Medium Small	Micro
Supply Chain Management	Inbound Logistics and Outbound Logistics			Medium	Small Micro
Electronic Procurement	Procurement			Medium	Small Micro
Customer Relationship Management	Marketing and Sales and Service				Medium Small Micro

Table 3: Technology Adoption Drivers

Drivers of Technology Adoption	All SME	Micro Firms (1-10)	Small Firms (11-100)	Medium Firms (101-500)
Customers	63.4%	58.33%	65.8%	59.38%
Competitors	37.3%	45.83%	32.9%	40.63%
Suppliers	24.4%	25.00%	29.1%	12.50%
Vendors	25.2%	25.00%	30.4%	12.50%
Government	17.0%	8.33%	21.5%	12.50%
Mass Media	15.6%	16.67%	15.2%	15.63%
Personal & Professional	35.6%	25.00%	35.4%	43.75%
Top Management	86.7%	87.50%	93.7%	68.75%