TECHNOLOGY POLICY FOR CIM DIFFUSION TO SMALL FIRMS IN ISRAEL

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Abstract. Computer Integrated Manufacturing (CIM) is widely considered to be a promising strategy for any manufacturing firm facing competitive pressures. Yet in many industrialized countries, most small and medium-sized enterprises (SMEs) usually underinvest in CIM. This often leads governments in those countries to consider implementing technology policy to disseminate CIM technology to industrial firms. After reviewing basic features of effective CIM implementation and diffusion, the article examines the situation of CIM in Israel. This article considers current technology policy and the programs for assisting Israeli SMEs, and examines eight case study firms, looking at their technology and strategy for manufacturing. The article discusses the observed differences among these firms, and draws some implications for technology policy.

Key words: Israel; Technology Policy; Computer Integrated Manufacturing; Case Study; Small Firms
1. INTRODUCTION

The increasing competition for time, price, quality, and variety of goods that most manufacturing firms around the world face in developing global markets has led a growing number of developers and observers of industrial technology to suggest implementing Computer Integrated Manufacturing (CIM) in these firms to improve their competitive advantage and sustain it over the long term (e.g., Asai and Takashima, 1994; Joshi and Smith, 1994; Weatherall, 1992; Foong and Houng, 1991; Bessant, 1991). CIM is a process innovation that is not unique to certain products, and, as such, it can be a strategic weapon for any manufacturing firm—large or small—facing threats from global competition (Gupta, 1996). Although CIM has certain disadvantages specifically requiring high technical expertise, management support, and relatively high costs in the face of improvements not immediately measurable, the return on investment from CIM involves tangible benefits such as reduced floor space, higher product quality and inventory savings, and intangible benefits such as greater production flexibility, shorter throughput and lead time, and increased capability for organizational learning (Kaplan, 1986).

Despite the strategic value of CIM, small-sized and medium-sized enterprises (SMEs) usually underinvest in CIM technologies and rarely modernize their shop floor beyond occasional improvements in "islands of automation" (e.g., von Ohsen, 1992; Voegele and Binkert, 1993; Warnecke, 1993). The barriers to CIM adoption by SMEs may lie in deficient resources and skills (Rothwell and Zegveld, 1982), poor information and lack of external linkages (Rothwell and Dodge, 1991), lack of awareness of the need to evaluate all the relevant alternatives systematically (Krinsky et al., 1990), low technological expertise as a risk-averse strategy (Lefebvre et al., 1991), or an arbitrary choice of high hurdle rates for potential investments in manufacturing (Mansfield, 1993; Kaplan, 1986). Be that as it may, underinvestment in CIM technology by SMEs is not only critical for their competitiveness in global markets, but also important for the welfare of most countries due to the significant role that SMEs play (e.g., as employers) in national economies (Rothwell and Zegveld, 1982; Vickery, 1993). It is the increasing recognition of this role that has led governments in industrialized countries to address SMEs as part of their industrial policy and, in some cases (e.g., Denmark) to focus technology policy on the diffusion of advanced manufacturing technology (Vickery, 1993).

The objective of this paper is to generate an understanding of the general situation of CIM in Israel. The paper begins with a brief overview at the firm level of the technical, organizational, and strategic aspects that should be considered for effective CIM implementation. The paper then shifts its focus to
the national level to highlight the basic mechanisms of CIM diffusion to industrial firms and gives some examples from member countries of the OECD (Organization for Economic Cooperation and Development). The paper then focuses on a study of the case of Israel.

In Israel, it is quite apparent that advanced/state-of-the-art CIM technologies exist in large companies (e.g., Iscar, Intel, Motorola) and that many of Israeli companies are involved in the development of CIM technologies commercially used all around the world, especially advanced CAD/CAM/CAPE systems. Yet much less is known about CIM implementation in Israeli SMEs. Thus, this study examines Israel's industrial policy for SMEs and the perspective of eight mature SMEs in several manufacturing industries. The case study firms differ in technological capacity and strategies for manufacturing. These differences, it is argued, warrant the development of a focused technology policy that should be oriented to CIM diffusion among industrial firms in Israel. Finally, the paper discusses the findings and draws implications for practice and public policy.

2. THE IMPLEMENTATION OF CIM

2.1. Technical Components

CIM is a strategy for integration in manufacturing that uses computer-based technology to link "islands of automation"—workstations that can operate independently from each other—into a wholly coordinated and flexible production system (Aletan, 1991). A CIM system can include several computer-based technologies such as CAD (computer aided design), CAM (computer assisted manufacturing), CNC (computer numerical control), PLC (programmable logical controller), CAQ (computer aided quality management), MRP (material requirement planning), PPC (production planning and control systems), SFCS (shop-floor control system), and SFDC (shop-floor data collection) software (Mesina et al., 1993). CIM systems can be designed to use these components and other computer-based information technologies (e.g., information-retrieval systems, electronic mail, expert systems, decision-support systems) in different configurations to perform different tasks, such as controlling individual machines, controlling groups of machines linked in cells, making interfunctional links between product design, engineering and production, and linking manufacturing control systems with management information systems. For this practical purpose, CIM components must be
interconnected and operated in an integrated way under full programmable control (Aletan, 1991). System interconnection is physically carried out by ILAN (Industrial Local Area Network)—a network of cables spread within a limited geographical area. Data communication among workstations in this network should be based on a common communication code or information standard. In this case, ILAN provides an effective (i.e., reliable and timely) intra-organizational communication infrastructure for integration of other CIM technologies (Asai and Takashima, 1994). The use of timely and reliable data communication and the sharing of a common data-base, which is possible through ILAN-based information technologies, can not only help the firm to integrate different (individual and organizational) skills and technologies so as to build its technological capacity, but can also improve the organizational intelligence, organizational memory, and organizational decision making—that is, organizational learning—in the firm (Huber, 1990).

2.2 Organization and Strategy: Other Components of CIM

The effective design and implementation of a CIM system—supporting a firm’s sustainable competitive advantage—should involve a firm-specific process through which managers choose CIM technologies, adapt them to specific tasks, decide which technologies should be integrated to what level and for what purpose, and, in the process, learn CIM by using it. This process of choice and learning is important for the firm because it enables managers and workers to inquire into the links between organizational and technical aspects of CIM so that the firm can advance quickly and smoothly down the learning curve and develop its core capabilities (Andreu and Ciborra, 1996). Moreover, this inquiry can help managers realize strategic intent (Hamel and Prahalad, 1989); that is, linking between manufacturing strategy and business strategy so that the firm can realize the full strategic value of CIM technology over the long term. Specifically, managers should consider how they are going to exploit the technology and how it is going to help the firm to compete, successfully over time, in the market place in terms of a certain price, delivery time, product quality, or degree of customization (Bessant, 1991; Kidd et al., 1991; Voss, 1988). Thus, a strategic management approach based on organizational learning, ensures that the firm implements CIM effectively by building capabilities in the context of a manufacturing strategy that is coherent with business strategy.
3. THE DIFFUSION OF CIM IN OECD COUNTRIES

As policymakers increasingly recognize the strategic value of CIM, technology policy in industrialized countries is paying more attention to the diffusion of advanced manufacturing technologies to industrial firms. While several models exist for organizing assistance to SMEs (e.g., Shapira et al., 1992), two basic mechanisms—external-influence and mixed-influence (Mahajan and Peterson, 1985)—underlie most efforts to disseminate advanced manufacturing technology in most countries. For example, diffusion policy in the US has been implemented mainly through the external-influence of change agents, usually through the direct intervention of field staff of industrial extension services and centers for technology transfer. State level programs and MTCs (Manufacturing Technology Centers initiated by the Federal-Government) typically provide direct services (seminars and workshops, demonstration sites, one-on-one field assistance), in addition to distributing technical information to SMEs (Shapira, et al., 1992). These services have been complemented by income tax credit to encourage SMEs to invest in new manufacturing technology (Poznanski, 1994). Recent developments at the state level to transfer technology to SMEs have also involved the organization of industrial networks among firms so that they can share expertise and acquire technological knowledge via interaction among themselves; yet the prevalent mechanism of diffusion in the US, as Shapira et al. (1992) suggest, has largely been on the one-on-one direct professional assistance provided by change agents; hence, external influence (Mahajan and Peterson, 1985). In other developed countries (e.g., Denmark, Austria, Switzerland, Italy), there have been explicit efforts to disseminate CIM technology through industrial extension services, which often supply a complementary range of services in areas such as funds, general management, human resources management, quality, marketing, and product design (Vickery, 1993; Massari and Salonna, 1991).

In Japan, the diffusion of advanced manufacturing technology has been heavily based on a mixed (internal and external) influence mechanism (Mahajan and Peterson, 1985), which is a more complete approach for the diffusion of knowledge among industrial firms. For example, the Japanese Kohsetsushi center (Shapira, 1992), directly through industrial extension services as in the US, not only plays an important role in helping SMEs to upgrade their manufacturing technologies, but also foments the diffusion of technology among firms by organizing several networks of firms, with each network involving about 30 local small firms, to increase the horizontal exchange of information among these
firms and to speed technology diffusion to them. The inter-firm communication that develops in horizontal networks is an effective way to diffuse innovations (e.g., Rogers, 1995; Coleman et al., 1966). Communication through networks of users involves processes of collective learning which develop through various forms of interactions, information interpretation, imitation, and sharing of experience accumulated through “learning by using” the innovations (Zuscovitch and Teubal, 1993; Hamblin et al., 1979; Griliches, 1957). The continual interaction and informational exchanges that occur among firms in a network progressively increase their collective pool of knowledge as firms pay closer attention to the joint benefits—spreading the cost of acquiring information about the relative advantages, disadvantages, and alternative modes of use of new technologies—that flow from the very process of collective learning (Imai and Baba, 1989; Hamblin et al., 1979). Over time, network learners discover the profitability of innovations faster than non-network learners (Coleman et al., 1966), and this fact can explain why firms tend to begin using flexible manufacturing systems earlier in Japan than in Europe and the United States (Mansfield, 1993).

4. CIM IN ISRAEL: THE CASE STUDY

4.1. Israel’s Technology Policy

SMEs have played an increasing role in the Israeli economy. The contribution to employment by small-sized firms (with 5-99 employees) increased from about 36% of the total employment in Israel in 1985, to about 50% in 1994 (Central Bureau of Statistics, 1995). Thus, the government has been developing its industrial policy toward SMEs. Many of the currently available policy instruments in support of SMEs include a broad range of financial services governed, in large part, by the “Law for the Encouragement of Industrial Research and Development-1984.” This Law has been implemented by the Ministry of Industry and Trade (MIT), and includes various programs which typically take the form of grants matching a percentage of expenditures in R&D projects. Grants are provided: 1) for product development projects in established firms, in startup-firms, and in firms located in selected regions of the country; 2) for projects performed by Israeli firms acting as subcontractors for customers abroad; and 3) for firms carrying out market research and feasibility studies for industrial R&D. Financial assistance is
also provided for firms establishing technological incubators, for technological incubators housing a group of R&D projects, and for individual R&D projects in incubators. Technological incubators assist start-ups in hi-tech with provision of an environment for R&D, including office services, consultation in various areas, business guidance, and training for a period of two years.

Other sources of assistance for SMEs are the Centers for the Promotion of Entrepreneurship (MATI). These centers were established in 1990 and are typically located in the large cities. The centers operate as a kind of industrial extension services, providing, on a one-on-one consultation basis, a relatively broad range of assistance, including information on legal, financial, technical, and managerial issues. These services are targeted to entrepreneurs in their initial steps in preparing and executing business plans, as well as to established SMEs. Services are 75% subsidized and are provided on a short-term basis up to a total of 170 hours. Some MATI centers operate also as business incubators for business start-ups, which receive assistance in terms of working space, office services, and business guidance for a period of two years. The system of MATI centers is coordinated by the Small Business Authority (SBA), established jointly in 1994 by the MIT and the private sector. The SBA also has the responsibility for establishing and operating funds, training, and information centers, as well as for promoting legislation and policy implementation in the small business sector.

In most of the programs available in Israel for assisting SMEs, as noted above, there is no special technology focus. Diffusion of technical knowledge to SMEs occurs generally through the external-influence mechanism underlying the services provided by MATI centers. Most of the governmental efforts to assist SMEs in Israel, as noted by Justman (1994), have focused on the individual entrepreneur, providing a broad range of advice in business and commerce, but too little specific technological assistance so as to help industrial SMEs to participate successfully, directly and indirectly as suppliers and subcontractors, in the increasing competition for global markets. This situation may rest in Israel’s traditional tendency toward a “supply” kind of technology policy—using Mowery’s typology (Mowery, 1995) for a policy that emphasizes the generation of technology more than the “adoption” and diffusion of technology. But the situation may be changing. Recent efforts to implement the Magnet Program by the Ministry of Industry and Trade (MIT) seem to be an initial step toward balancing the needs for the supply and diffusion of specific new technologies to Israeli industry.

The Magnet Program was established by the MIT in 1992 to build the technological base of the whole Israeli economy (Ministry of Industry and Trade, 1995). To achieve this objective, the Program brings research institutions (universities and government laboratories) and industrial firms into consortia
to promote: 1) local R&D to develop new pre-competitive technologies; and, 2) transfer of technologies from foreign sources to local potential users. The MIT helps organize these consortia and subsidizes their members (firms 66%, and universities 80%). The members in consortia are either collaborators in R&D projects in specific technologies (e.g., satellite communications, digital communication, gallium arsenid/MMIC), or associated users interested in sharing expertise and learning a particular new technology. By the end of 1995, ten consortia for R&D were formed and several other R&D consortia were under formation (particularly in the area of food technology, software development, special coatings, and multimedia). Consortia for technology transfer and diffusion are few. So far, two consortia of this kind were formed, both involving about 60 members interested in the area of electronics. A new consortium of this type is under formation in the area of information technology.

While the Magnet Program seems to provide an appropriate infrastructure for the diffusion of CIM among SMEs, consortia for this purpose have not yet been organized. The kernel for such organization may become the recently developing CIM laboratories in Israeli universities, though these labs are still in the developing stages and are much more dedicated to educational and research purposes than to industrial applications (Rabinowitz et al., 1997). Along with this lacuna in national infrastructure for CIM, there is a lack of financial instruments dedicated to encouraging the adoption of CIM technology by SMEs. As noted above, most of the available financial instruments of Israeli technology policy, which are provided by “Law for the Encouragement of Industrial Research and Development-1984,” are focused to “supply” technology rather than to “demand” technology (see Mowery, 1995). Thus, current policy for technology infrastructure in Israel has, at best, an underdeveloped mixed-influence mechanism of diffusion for CIM to SMEs. The actual situation of CIM in the small firm sector is examined in the following section.

4.2. The Case Study Firms

During the first half of 1996 a multiple-case study of SMEs was conducted. Its aim was to identify the various manufacturing strategies and technological capabilities in SMEs, to understand the ways in which those strategies and capabilities were related to each other, and to determine the actual situation of CIM implementation in these firms. Firms were selected purposefully (Gummesson, 1991) from an initial list of SMEs that was assembled using the Kompass (1995) business guide. The criteria for
inclusion in this list were age (more than ten years old), firms that sell in foreign markets, and those operating in competitive manufacturing industries (e.g., plastics, electronic equipment). These criteria helped identify a relatively mature, hence presumably more experienced, group of firms that typically manufacture under competitive pressures. These conditions are most favorable for the adoption of CIM as a strategic weapon (Gupta, 1996). Thus, we expected to learn from this group how firms responded to competition. Firms from that initial list were then contacted to negotiate access (Gummesson, 1991). Ultimately, data (Table 1) were collected on eight firms. Their names were disguised to preserve anonymity. Data were collected from semi-structured interviews with top managers and on-site visits to manufacturing plants. Since the interviewees were asked identical questions (available from the authors upon request), some consistency was achieved across interviews that enabled comparisons across cases. All the interviews were conducted in the interviewee’s office and lasted between two and three hours. On-site visits were made to complement the interviews, observe process technologies actually used by each firm, assess routines of equipment maintenance and operations management, and cross-check data collected in the interviews. Reliability of the data was also cross-checked by the fact that two researchers were always involved in every case who immediately transcribed field notes after each interview and visit.

**Table 1. Description of the firms studied**

<table>
<thead>
<tr>
<th>Firm</th>
<th>Year of starting production</th>
<th>Main products</th>
<th>Number of local competitors in main product markets</th>
<th>Total sales in 1995 (million $)</th>
<th>Exports in 1995 (%)</th>
<th>Employees</th>
<th>Typical number of shifts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1980</td>
<td>Plastic cans and bottles</td>
<td>48</td>
<td>7</td>
<td>10</td>
<td>75 (70)</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>1964</td>
<td>Irrigation equipment</td>
<td>8</td>
<td>37</td>
<td>65</td>
<td>110 (30)</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1983</td>
<td>Electronic equipment</td>
<td>24</td>
<td>12</td>
<td>40</td>
<td>85 (70)</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>1971</td>
<td>Plastic precision parts</td>
<td>40</td>
<td>8.5</td>
<td>70</td>
<td>90 (70)</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>1978</td>
<td>Canned fruit, Natural juices</td>
<td>30</td>
<td>40</td>
<td>60</td>
<td>100 (60)</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>1982</td>
<td>Adhesive tapes</td>
<td>5</td>
<td>10</td>
<td>50</td>
<td>50 (80)</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>1966</td>
<td>Metal products for electronic industries</td>
<td>17</td>
<td>14.5</td>
<td>30</td>
<td>65 (80)</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>1971</td>
<td>Faucets</td>
<td>14</td>
<td>5</td>
<td>25</td>
<td>80 (60)</td>
<td>3</td>
</tr>
</tbody>
</table>

*The numbers in parentheses are % employment on shop floor out of total employment in the firm*
Findings: We found that case study firms clearly differ, as Table 1 indicates, in technological capacity and strategies, something that is not surprising given that these firms are relatively mature, operate in competitive industries and sell in international markets (see Nelson, 1991). Tables 2-3 summarize the main findings.

Table 2. Technological Capacity

<table>
<thead>
<tr>
<th>CIM technologies implemented¹</th>
<th>Firm 1</th>
<th>Firm 2</th>
<th>Firm 3</th>
<th>Firm 4</th>
<th>Firm 5</th>
<th>Firm 6</th>
<th>Firm 7</th>
<th>Firm 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLC</td>
<td>PLC</td>
<td>PLC</td>
<td>CNC</td>
<td>PLC</td>
<td>PLC</td>
<td>CNC</td>
<td>CNC</td>
<td></td>
</tr>
<tr>
<td>PPC</td>
<td>PPC</td>
<td>PPC</td>
<td>PPC</td>
<td>PPC</td>
<td>PPC</td>
<td>PPC</td>
<td>PPC</td>
<td></td>
</tr>
<tr>
<td>CAD</td>
<td>CAD</td>
<td>CAQ</td>
<td>ILAN</td>
<td>SFCS</td>
<td>CAQ</td>
<td>CAQ</td>
<td>CAQ</td>
<td></td>
</tr>
<tr>
<td>CAQ</td>
<td>SFCS</td>
<td>SFCS</td>
<td>SFCS</td>
<td>SCFS</td>
<td>SFCS</td>
<td>SFCS</td>
<td>SFCS</td>
<td></td>
</tr>
<tr>
<td>SFDC</td>
<td>ILAN</td>
<td>ILAN</td>
<td>ILAN</td>
<td>ILAN</td>
<td>ILAN</td>
<td>ILAN</td>
<td>ILAN</td>
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</tr>
</tbody>
</table>

| Innovativeness in manufacturing technology | 6 | 5 | 4 | 3 | 3 | 2 | 2 | 2 |
| Utilization of CIM technologies       | 1.14 | 1.52 | 0.67 | 0.63 | 0.50 | 0.45 | 0.38 | 0.42 |
| Autonomous service and upgrading of equipment | P | P | P | P | P | N | N | N |
| System integration                   | P² | P³ | P⁴ | P⁵ | N | N | N | N |
| Evaluation of CIM alternatives       | N | N | N | N | P | N | N | N |

¹ For list of abbreviations, see § 2.1.
² Shop floor – No programming capacity
³ Some machine cells
⁴ Shop floor – No programming capacity
⁵ Firm considers full system integration

P = Partial capacity  N = No capacity
Table 3. Strategic Coherence

<table>
<thead>
<tr>
<th>Firm</th>
<th>Business Strategy</th>
<th>Technology Strategy for Manufacturing</th>
<th>Strategic Coherence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Challenge the competition of local producers. Growth in existing market segments. Compete on quality, price and speed. Increase profitability.</td>
<td>Develop full-system integration. Develop automatic maintenance management capacity. Reduce costs and cycle time and increase quality through process innovation.</td>
<td>F</td>
</tr>
<tr>
<td>4</td>
<td>Challenge the local competition by product differentiation. Increase market share in international markets. Increase profitability. Speed response to changing customer needs.</td>
<td>Add computer control to the whole shop floor. Consider full-system integration. Retain capacity for manual-operation of machines.</td>
<td>P</td>
</tr>
<tr>
<td>5</td>
<td>Growth by diversification and exports. Compete on quality, price, and speed. Increase profitability.</td>
<td>Seek external expertise to evaluate CIM systems Seek the integration of production control and quality control system. Reduce costs and cycle time, and increase quality through process innovation.</td>
<td>P</td>
</tr>
<tr>
<td>6</td>
<td>Differentiate products and markets. Increase share in local and international markets. Compete on quality, price, and speed. Increase profitability. Reduce bargaining power of buyers.</td>
<td>Add computer control capability to current workstations. Reduce costs mainly by reducing inventories.</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>Develop market segments. Compete on speed, price, and quality (products and services). Increase profitability.</td>
<td>No intention to achieve full integration in production. Develop automation of inventory. Improve product quality.</td>
<td>N</td>
</tr>
<tr>
<td>8</td>
<td>Meet the increasing demand in existing product markets. Compete on quality. Increase profitability.</td>
<td>No intention to integrate workstations. Increase production capacity mainly by decreasing set-up times and improving current practice. Increase product quality.</td>
<td>N</td>
</tr>
</tbody>
</table>

F = Full  P = Partial  N = No

1. Technological Capacity: Five aspects of technological capacity were assessed for each firm:

(One) Innovativeness in manufacturing technology: Firms were ranked according to the number of CIM technologies implemented, as shown in Table 2. This scale was suggested by Lefebvre et al. (1991)
as a proxy for gauging the extent of innovativeness of SMEs in manufacturing technology. As Table 2 shows, firm 1 is the most innovative, and firms 6-8 are the least innovative.

(Two) Utilization of CIM technologies: For each firm, the number of technologies implemented per 10 employees in the shop floor was calculated. This is a rough measure of the relative extent of utilization of CIM technologies by each firm, as suggested by Mansfield (1993). As Table 2 shows, this indicator is higher for firms 1-2 than for firms 6-8. The reader should bear in mind that the relative number of technologies implemented by each firm is only a very crude indicator of the extent to which the firm utilizes these technologies, since the size and importance of a particular technology (e.g., CNC), can vary greatly across firms. This might be a limitation of the present analysis, and thus, the results for this indicator should be treated with caution. Yet, these results get some validation when they are cross-checked with the qualitative data shown in Table 3.

(Three) Capacity for doing autonomous service and upgrading of equipment: We found that firms 1-4 were quite capable of maintaining, and even upgrading, their equipment independently from suppliers. Engineers in Firm 1 know how to improve automation and maintenance systems, and they often do so. The firm has signed contracts with suppliers only for equipment service in case of total breakdown. Firms 2 and 3 typically perform the upgrading of most of the software they use in production by themselves, but require the services of suppliers for hardware maintenance. Managers in Firm 4 have tried to become increasingly independent from suppliers by providing regular technical training to their personnel. Often these firms have purchased standard equipment from a single source so as to reduce the variety of brands and makes installed and help their technicians to develop their own standards of maintenance. Apparently these firms are trying to reduce the bargaining power of suppliers (Porter, 1980). In contrast to these cases, firms 6-8 have notably less capacity for autonomous service, maintenance, and upgrading activities. Firm 6 reported often getting both formal (through contracts) and informal assistance for its regular maintenance tasks from a key software supplier in Israel, as well as regular assistance from foreign equipment suppliers through their agents in Israel. Firm 7 also receives regular maintenance assistance from suppliers and often some help from external consulting engineers to solve most problems with equipment. Firm 8 has signed annual contracts according to which it (the firm) is responsible for the maintenance of most mechanical parts, and the supplier is responsible for the service of all the electronic components of equipment. Interestingly, the production manager in this firm noted that the dependence of the firm on its suppliers that these contracts formalize hinders the firm from developing its own technical capacity.
(Four) Capacity for system integration: Although no detailed data could be collected so as to specify the particular links among different technologies and their exact level of integration in every case, we assessed the capacity of each firm to bridge “islands of automation” based in part on the presence/absence of ILAN infrastructure as a prerequisite of such integration, and in part on the presence/absence of links among different functions in the firm. Thus, the present analysis is somewhat limited in that it does not specify the level of integration of the different CIM technologies. Table 2 shows our findings. None of the firms studied have achieved full factory integration to the extent of linking management systems functions and shop-floor operations to a central data base. Only firms 1-3 have ILAN technology as an infrastructure enabling them substantial operational integration on the shop floor. In Firm 3, for example, several manufacturing functions (metal works, special coatings, electronic assembling, and engineering), which are housed in separate buildings, are linked together and share a common data communication channel. For these firms, set-up times often take a few minutes. In contrast, firms 4-8 have no communication infrastructure (i.e., ILAN) on the shop floor, and most workstations in these firms operate as “islands of automation.” In Firm 8, for example, the programming of single production batches is typically made in a computer room first, then copied onto a diskette and moved into a portable computer, which is then used in an upcoming shift to set-up the machines for the next production run. Sometimes set-up times took days in this firm.

(Five) Capacity for doing systematic evaluation of CIM: No firm, irrespective of the number and kind of technologies already implemented, did a systematic evaluation of CIM. Even Firms 1, 2 and 3, the most innovative of the firms in this study, did not plan for CIM. Firm 5 is an exception; it indicated the possibility of planning for CIM depending on results of an upcoming evaluation of flexible manufacturing systems by external experts. Firm 6’s CEO and chief production manager did not consider, nor do they intend to consider, planning for CIM, even though integration in manufacturing has been a strategic objective for these executives. Although Firm 7’s CEO was aware of the CIM strategy, he did not evaluate CIM systems, nor did he intend to do so in the future. Firm 8’s executives were all aware of the CIM strategy, but they also showed no interest in pursuing manufacturing integration as a strategic option. These CEOs indicated their strong skepticism about finding any good financial justification for CIM technologies.

2. Coherence in Strategic Profile: Table 3 summarizes the strategic profile of each firm in terms of its business strategy and technology strategy for manufacturing. We assessed the coherence of each profile with CIM strategy as a reference. A fully coherent profile results from managers who apparently
understand the technologies that are important to their business in the long term, so that they can be able to frame key strategic issues in relation to technology (Burgelman et al., 1996). Thus, a competitive business strategy that builds on the recognition of the strategic value of implementing CIM can be said to be coherent.

Virtually all the firms in this study try to compete for quality, price, or speed, and seek to improve profitability. This reflects the similar competitive pressures that they often face, mostly from international counterparts. Changing local and international market conditions typically induce these firms to reduce uncertainty in manufacturing. They have typically achieved this by deploying massive employment on the shop-floor (about 60% of total firm employment on the average) and maintaining full capacity production most of the time, typically in three-shift production schedules. Yet, these firms differ in the coherence of their strategies, as Table 3 shows. Firm 1, for example, nicely integrates the terms of its business strategy (competitive price, speed, and quality) with the outline of its technology strategy for manufacturing as if it were pursuing the strategic advantages of CIM (i.e., integrating CAD, SFDC, and other CIM technologies through ILAN). Firm 8, in contrast, competes in the markets on similar terms (e.g., set-up times), but with much more basic technology (i.e., CNC) arranged on the shop floor as independent workstations. This firm has apparently no coherent strategic profile, since it does not pursue the benefits of CIM for business competition.

5. SUMMARY AND CONCLUSIONS

As of 1996, we find that some of the case-studied SMEs are quite innovative in process technology. These firms have implemented advanced CIM technologies, although they have not yet achieved full system integration. These firms apparently have learned that sustainable competitive advantage can be achieved by linking the various aspects of CIM implementation, as well as manufacturing strategy, with business strategy. The firms showed a manufacturing strategy that is coherent with business strategy, a greater utilization of technology relative to employment on the shop floor, and a manageable relationship with equipment suppliers, which apparently was intended to reduce the suppliers' bargaining power. While these firms may need some specific assistance to carry out the full integration of their production
technologies, it seems that they are building capabilities to realize the strategic value of CIM over the long term.

In contrast, we also find that there are less innovative SMEs competing in international markets with standard CNC machines and software for production planning and control systems (PPC). Apparently, these firms have responded to competition with non-integrated workstations, although developing competitive pressures may have required that they adopt CIM as strategic a weapon so as to build a sustainable competitive advantage over the long term. Thus, unless these firms develop more advanced technological capabilities to achieve corporate system integration, they may continue to exist for only a while, or for as long as they do not face much of a threat from competitors who are technologically more advanced and strategically more coherent.

The differences we find among these relatively mature firms in their technological capacity and strategic profile can be even greater among younger SMEs across the whole Israeli economy. Greater differences mean relatively more incompetent SMEs, more young firms with incoherent strategies and ineffective technical capacities that can combine so as to increase the tendency of these firms to fail early. This undesirable outcome for the national economy finds support in empirical evidence on the "liability of newness" hypothesis, which suggests that the highest mortality rate occurs among the youngest firms (e.g., Singh et al., 1986; Freeman et al., 1983).

The Government can play an important role to ease these differences and their negative consequences for individual firms, and for the national economy as a whole, by implementing an aggressive technology policy that should be explicitly oriented to the diffusion of CIM to SMEs. This policy can improve the productivity and competitiveness of industries, as previous studies in developing countries have suggested (e.g., Ebel, 1991). In Israel, however, we find that current technology policy is underdeveloped as far as the diffusion of CIM technologies are concerned, although in other areas of advanced technology, particularly in microelectronics (Shaphir, 1993) and plastics (Yinon et al., 1993), there have been promising efforts to implement a diffusion-oriented technology policy. In contrast to these technological fields, the area of CIM is lagging; the lack of organizational networks for learning about new manufacturing technologies among SMEs in different industries is limiting the diffusion of CIM. The lack of special financial assistance for CIM technology adoption also limits the diffusion of CIM technologies to SMEs even more. Thus, Israel seems to need a focused diffusion policy for CIM to SMEs. The mechanisms for diffusion should involve a mixed-influence diffusion type so as to maximize the scope and rate of CIM adoption among SMEs. On one hand, the provision of direct assistance to
SMEs on the basis of one-on-one industrial extension services, like those provided through MTCs in the US and through existing MATI centers in Israel, are essential to transferring technology with professional commitment to individual SMEs. On the other hand, diffusion policy should encourage the organization of SMEs in networks of potential CIM users, who then can exchange information among themselves, advance manufacturing technology, and, in the process, solve many of the problems that they may encounter in CIM implementation.

There are some issues that policymakers, service providers, and network organizers should keep in mind in planning for such a mixed-influence diffusion policy for CIM. CIM as a strategy cannot be fully implemented in a firm without first introducing basic information technologies; for example, by establishing ILAN-based intra-organizational communication infrastructure. Such an infrastructure is required to implement and integrate additional CIM technologies effectively in a SME. This can improve the reliability and timing of data communications within the firm and can thus drive the firm through an improved organizational learning process (e.g., Huber, 1990). Better organizational learning, in turn, can help the firm to develop higher coherence between its manufacturing and business strategies so that the firm can be aware of the strategic advantages of CIM technology and become motivated to further pursue the systemic integration of the organization (e.g., Voss, 1988). Learning about information technologies for manufacturing, directly through service providers or indirectly through inter-firm relations within networks, constitutes an expanded way to increase the SME's demand for CIM developments. Thus, the implementation of CIM in SMEs would typically require the long-term commitment of external agents (central and local governments) to support (not to manage) the provision of services and operation of networks on a continual basis so as to effect learning and sustain the resulting technology demand. Limited subsidized consultation time as currently practiced by MATI centers would not be sufficient for an effective diffusion policy for CIM.

Also, and related to the above, practitioners and policymakers should be aware that effective diffusion programs should help SME's managers to shift their relatively conservative ways of thinking about investing in manufacturing technology. Such programs should encourage managers to evaluate technological alternatives according to improved management accounting systems, such as activity-based-costing (Cooper and Kaplan, 1990), and, therefore, according to strategic considerations and long-term goals for their businesses (Kaplan, 1986). This should also imply a change in managers' views of their firms under CIM strategy: a firm becomes a pool of resources and competencies (not only of products and markets) which must be identified, selected, developed, and protected to gain and sustain a
competitive advantage over time (Prahalad and Hamel, 1990). All these changes will require the development of training centers for CIM at the local and national levels, and probably the involvement of university CIM labs, which should provide industrial firms with a comprehensive array of courses and demonstration sites for hands-on exercises. To reiterate, just few hours of seminars and workshops about CIM would be insufficient.

The Israeli Government should also consider linking the technology-transfer type of consortia within the Magnet Program, the CIM labs in universities, the system of MATI centers, and the administration of the SBA as an appropriate organizational infrastructure for further development and implementation of a CIM diffusion policy in Israel. Such an organization can also be complemented by “diffusion-oriented” policy instruments (Mowery, 1995), such as government-mandated technology transfer, subsidies for the adoption of specific industrial technology (e.g., grants and tax allowances for investment in flexible manufacturing technologies, robotics, ILAN), institution of technical standards for industrial data communication and computer-based integration of manufacturing equipment, and subsidized industrial extension for CIM oriented services. It is reasonable to expect that new organizational arrangements and instruments of diffusion policy for CIM would proliferate in Israel as developing global competition inevitably hits industries and SMEs with increasing force.

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