The S. Neaman Institute for Advanced Studies in Science and Technology

Amota for Scientific Cooperation for the Promotion of Peace in the Middle East

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PREFACE

This study on "Problems in the Penetration of Advanced Production Systems and Factory Automation into the Israeli Industry" has been undertaken jointly by two teams of researchers:

a. The Ben Gurion University of the Negev, Beer Sheva:

Professor Kenneth Preiss
Professor Nahum Finger
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b. The Technion team:

Dr. Boaz Golany
Professor Ehud Lenz
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The study was coordinated by Dr. Zeev Bonen, of the S. Neaman Institute.

Draft sections of this interim reports were written by:
The Ben Gurion University Team - Executive Summary, sections 2.1, 2.2, 3.1, 4.2, 4.3, and 5.
The Technion Team - Sections 2.3, 2.4, 4.1, 4.3, 5.
Dr.Bonen - Executive Summary, Section 1, 5.6.

All sections of the report were discussed and agreed upon by both teams.
The report was edited by Dr. Z. Bonen.

EXECUTIVE SUMMARY

The competitive edge of industry nowadays depends to a considerable extent on advanced production systems and automation. Thus, it is important to understand the present status of and problems in the penetration of automation into the Israeli industry in order to recommend ways and means to facilitate this process.

Automation in industry can be considered in two phases: automation within one factory and automation between many sites and factories. Within a single factory, automation connects computer-based design and production processes between people and machines in different departments. Between factories, automation connects designers, vendors, the final production point, and the end user customer.

In the world at large, automation leads to quicker reaction to a customer's specific order, to high quality, and to production for specific orders and not for stock. Components and sub-assemblies are commonly manufactured in many countries and shipped internationally with speed and precision. This is achieved by automation of the factories, a high degree of automation between factories and technical offices, and by speedy and reliable movement of information and goods internationally.

This degree of automation is not yet widespread, but is becoming more common and is quite clearly the major direction of development.

Export products of the factories in Israel are both end user products and also components for further production abroad. There are some well-automated factories in Israel, thus demonstrating that it is possible to automate. However, even for those few well-automated factories which use computer-based communications, information is usually treated efficiently only within the factory; computer communications to customers and suppliers, a clear trend abroad, is rare in Israel. In general, the state of automation in Israel is behind the world state-of-the-art.

The time-consuming, stifling over-regulation and micro-management by government and the service sector are contrary of requirements for success in the modern industrial world. In this modern world, goods and information must move rapidly and reliably, and production work must be finished very quickly, with total quality management, and be reliably on time. If all components of the beaurocracy and service structure are not speedy and reliable, installation of automation inside industry is equivalent to installing systems to "hurry now and wait later", and will not get quality products to market with the speed needed.

This is an interim report of an ongoing study concerned with a comparative survey of automation in Israeli industry.

The report discusses world trends, gives the results of a limited survey of the Israeli metal industry, and also some recommendations on how to improve the current situation.

Automation is held back for interlocked reasons both inside the factories and also outside - in the economic environment and in the attitude of the administration and services towards facilitating automation.

Inside the factories radical changes may be required all the way from the production floor to the top management level. Such changes may require not only changes in equipment but also and more so, far reaching changes in the way work is done by various people, i.e. in the roles of personnel at all levels. This is a difficult social change involving problems of motivation and incentives on the part of management and the workers. The proper strategy for introducing CIM and FMS should be considered carefully in each case.

Outside the factory, there is not enough appreciation of the vital role of automation in creating and maintaining a competitive edge for the Israeli industry. An all out effort is required, expressed by a declared, firm government policy including suitable financial incentives and adaptation of all administrative and service support systems to the requirements of one, fast world.

CONTENTS

GLOSSARY

AGV	Automated Guided Vehicle
AMRF	Automated Manufacturing Research Facility
ARRL	Advanced Robotics Research Ltd. (University Road, Salford M5 4PP England)
AS/RS	Automatic Storage / Retrieval Systems
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CIM	Computer Integrated Manufacturing
CNC	Computerized Numeric Control
CMM	Computerized Measurement Machine
ESPRIT	European Strategic Program for Research and Development in Information Technology
FMS	Flexible Manufacturing Systems
GE	General Electric
GT	Group Technology
IAI	Israel Aircraft industries
IMI	Israel Military Industry
ISO-OSI	International Standards Organization - Open System Interconnection
MAP	Manufacturing Automation Protocol
MRP	Material Requirements Planning
NIST	National Institute of Science and Technology
ROI	Return on Investment
SBA	Small Business Administration
SPC	Statistical Process Control
TQM	Total Quality Management
WIP	Work in Process

1. Objectives

The competitive edge of industry nowadays depends to a considerable extent on widespread penetration of advanced production systems and automation.

In order to survive and flourish in the international market, Israel must not lag behind in this vital area. Hence, a major effort is required to achieve world class performance in this area.

First of all we must understand the present status of automation in Israeli industry, compare it to world status and identify the problems which impede and delay adoption of the new type of factories.

On the basis of this survey and diagnosis we try to make recommendations to all involved: Industry, Government and Academia.

2. <u>World Status and Future Trends</u>

2.1 Penetration of Automation into World Industry and Changes in Marketing and Work Methods

The automation of processes in individual industries has been followed by the installation of electronic communication between industries. This is leading to work methods and new structures, under which salesmen suggest quick reaction times for production to customers, and in some cases also suggest customer-specific configurations of products. This in turn requires fast electronic interaction on technical design and production issues between salesmen, design engineers and production personnel.

This has led to the following characteristics of the new industrial world:

a. Products are assembled from sub-assemblies and components which are produced in many countries.

b. Companies are increasing the volume of components bought from vendors, and decreasing the volume made in-house. This is done in order to decrease risk in the modern fast-changing world.

c. The method of one-time contracts is giving way to long-term contracts, with fewer suppliers. The quantity of suppliers is decreasing in some companies to 10% to 25% of the previous quantity. Such long-term vendors are selected only after a rigorous qualification process.

d. There is much technical interaction between vendors and customers, usually by electronic communication between computers.

e. The time available between getting an order and shipping the product is getting much shorter. Typical reductions, over the past 5 years, for the time allowed to get production out, for a variety of industrial sectors, are 5 years to 2 years, 6 months to 2 months, 2 weeks to 2 days. This time reduction leads to different marketing methods, and different price structures of products.

f. Because of the time reduction, every part of the industrial commercial process has to speed up. For instance, in successful countries of the Pacific rim, the time taken for goods to pass through the airport, from when the plane lands until the goods are on the road outside the airport, is less than 2 hours. Speeding up the production process requires streamlining and speeding up of everyone throughout the enterprise and in all government and commercial services serving it.

g. Under the pressure of time, there is not enough time for quality control of the product, so the approach is to conduct "Total Quality Management" on the production process of every vendor in the stream. This in turn, makes demands on the management, structure and educational level of all the workers in production.

h. Large national and international efforts are under way to standardize methods of electronic data interchange to support interactive, fast-moving, work methods. In spite of that, these technologies are not yet mature, and will cause difficulty for several years into the future.

The changes mentioned are felt today by many industries, but are not yet universal. The trend towards decreased reaction time and improved quality is inexorable, but will take another decade to become universal.

2.2 Organizational and Structural Changes in World Industry

Organizational and structural changes in industry usually represent the industry attempts to adjust itself to its internal and external environmental contingencies.

In many ways the industrial environment has become more complex, less predictable and more rapidly changing. Markets are becoming increasingly diversified, market demands are rapidly changing, relevant information and expertise becomes more complex, the knowledge becomes rapidly obsolescent and the life cycle of many products has become extremely short.

Organizational and structural changes designed to cope with these difficulties a often affected by the immense advancements in computer and information processing technology on the one hand and by improved management techniques on the other.

Some of the more noticeable organizational and structural change trends are the following:

1. Flattening and decentralizing structures. Delegating greater authority and autonomy to the subordinate units enable them to respond quickly to environmental demands.

2. Introducing matrix and project management structures which provide better integration of high technical expertise on the one hand, with effective production planning and control on the other. Matrix organizations, although relatively difficult to manage, provide structural flexibility to handle short term and changing projects.

3. Introducing advanced computer technology to serve subunits with differentiated needs and to better coordinate and integrate different units. Subunits have been provided with local computer capacity to enhance their management and decision capacity. Computer technology has also

been also implemented to enhance the integration of separate units by providing efficient communication facilities and central data processing.

4. Encouraging the spirit of entrepreneurship and innovation within the organization. Giving greater autonomy and support to the professional levels to initiate new ideas.

5. Implementing techniques of subordinate participation in decision making such as Quality Circles to enhance motivation and better utilize their first hand experience and knowledge.

2.3 Scientific and Technological Trends

The CIM approach utilizes computer features like: information handling, machine and process control, monitoring, and data analysis to integrate the manufacturing machines, storage and handling devices, and sensors under one central controller. This approach has offered a totally different perspective on the way manufacturing processes can be organized, and it provides management with a tool to optimize and accordingly change the global rather than local output.

With the growing complexity and variety of products, and at the same time decreasing number of units per batch, flexibility becomes crucial. A partial solution is to adopt the FMS approach. However, full exploitation of the computer and automated machine capabilities is needed if the entire production process from design to service, is to be optimized. Factories which apply the CIM approach report a significant reduction in production time as a result of better organization of the production floor, better planning of resources, simpler information flow, and obviously much less set up time. Also, the number of rejected parts is significantly decreased, and at the same time the consistency and quality of production are improved. A by-product of this change is the reduction in the percentage of non-intelligent work, leaving the worker free to deal with more sophisticated and challenging tasks.

With the rapid change in global market requirements, moving into CIM is inevitable. In order to stay in the market a manufacturer has to cope with changing demands and varieties of parts, be able to produce them to a predetermined schedule and in accordance with given standards, and be able to transform the manufacturing data to remotely located factories. The use of CIM has so far been confined to a limited number of companies mainly in the machine tool and automotive industry. Widespread implementation of CIM, following the Japanese example, requires guidance and help from national resources.

Examining the possible diffusion of CIM approach, the technological trends have to be considered. These will affect the ease of its implementation, the type of users, and obviously the price/performance ratio. Some of the relevant technological trends are: improvement of existing manufacturing processes as well as implementing new processes, increased share of new raw materials in the product, development of integration software, and better material handling and monitoring.

With the constant improvement of existing machine tool performances it is expected that accuracy will increase and that more versatile and fully computer - controlled machines will be implemented; However, dramatic changes in this area are not expected. Different and new manufacturing processes are also examined. These include laser machining, water jet cutting, precision casting and forging. Significant development in any one of these areas will affect the overall rate of CIM implementation since the new technology will obviously be designed as a building block in a complete CIM structure, hence its application will be utilized to change manufacturing strategy.

Material handling devices that include robots and AGVs are important parts of CIM not only because of their ability to automate material handling, but also because obtaining precise updated picture of the manufacturing state is central to flexible automation. This information can be constantly supplied by these computer controlled handling devices. The introduction of AGVs is continuously growing, while robots continue to arrive at a fairly constant rate. The latter are introduced in places where their implementation is advantageous . An increase in their arrival rate will occur concurrently with further development of robot sensors and intelligence .

Uninterrupted flow of information that monitors the manufacturing process, is the key for successful computer integration of manufacturing. This emphasizes the sensors role in this concept. Hence, the need for development and application of reliable real-time type sensors throughout the factory floor. Three different types of sensing abilities are required: sensing of machines' condition, sensing of location e.g. parts and AGV location, and sensing dimensions and condition of the work pieces. Sensors are also required, as mentioned above for simpler application of robots in the production line. Massive effort has been devoted to the development of vision sensors and it is expected that this effort will continue. Three dimensional vision and pattern recognition have evolved over the past five years, but a reliable and more general system is yet to be developed. The new trend in neural computing has to be mentioned, with high expectations of possible breakthrough in pattern recognition and process control. Additional sensors in development are the acoustic emission sensors which monitor the machines condition and tool wear, and sensors for on-line measurements of work piece dimensions for correction of machines path during machining process. Undoubtedly, the role of automatic coordinate measuring devices role will also increase since tighter inspection is required in order to increase product quality.

The rapid development of new materials will have an impact on the application of CIM. New materials like composite materials and ceramics and new ways of fabrication like powder metallurgy, require different types of machines. For example, the shift into composite materials technology, requires automatic machines for layers and fiber handling as well as new machining processes which are still in the beginning stage. It is expected that once simpler and more automated production is achieved, the use of these materials will increase vastly and affect the entire production line. However, it has to be mentioned that CIM infrastructure components like: monitoring, measurements, process planning and analysis, purchasing, storing, and handling, will still be applicable.

With the tremendous growth of computing power no barrier is expected concerning CIM computer resources. However, a major effort has and will be devoted to the development of software. Standard communication is crucial, and several companies and countries, some of which are organized within the ISO-OSI, have already made some progress toward this goal. Over 500 companies world wide have expressed their interest in adopting Manufacturing Automation Protocol (MAP) standard communication protocol. MAP, which was initiated by General Motors, consists of a set of software and hardware specifications for factory communication based on international standards. These standards are related to an Open System Interconnection (OSI) model which allows items like computers and robots, regardless of the manufacturer to communicate at all levels. It is expected that this type of software will enable not only the integration of 'islands of automation' within a factory but also will make different factories and companies understand each other's software, paving the way for true CIM. The National Institute of Science and Technology (formally NBS) has developed the Automated Manufacturing Research Facility (AMRF) where one of its main goals is to develop and test standardized computer and machines links to enable compatibility of manufacturing equipment. In Europe, the ESPRIT program (European Strategic Program for Research and Development in Information Technology) includes CIM as one of the key areas to enhance European competitiveness. The European countries have joined forces in other programs as well (the EUREKA, the BRITE-EURAM, to name just two), in order to conduct pre-competitive research on various aspects of advanced manufacturing. These efforts on standardization of communication, networking, data bases, and CAD/CAM data is expected to further increase.

A global approach to manufacturing that emphasizes the end result - customer satisfaction - rather than optimizing local process, has became dominant. It has been found that product quality is one of the main components required to achieve customer satisfaction, and therefore much more attention is paid to quality improvement. Quality improvement is an all - embracing concept, it encompasses strategic planning, management of technology, introduction of automation and new processes, control, and monitoring, and it can not be overemphasized as the key for success.

2.4 Economic Implications

The introduction of CIM and automation into existing and new factories alike carries important economic benefits. However, the task of quantifying these benefits is far from being trivial, as some of the benefits are either of qualitative nature or start to influence the company's balance sheet years after the introduction of the new technologies. On the other hand, the new technologies require significant capital investment, as well as other expenses, such as those related to the consequent changes in the workforce. Nevertheless, many industries have already realized that CIM and automation are crucial elements in maintaining the survivability of the company. In other words, even without achieving increased profits, companies are moving into the new era of automation since they realize that without such a move, their days in the ever more competitive markets of the future are limited.

The discussion of the economic implications can be categorized by the different parameters which influence the economic and financial situation of the company. On the 'positive' list, we see the following parameters:

The Rate of New Products Introduction - modern consumer markets are characterized by a large turnover in the types of products offered. Whether it is a result of a new technology made available, or a new fashion, companies must adopt to this dynamic environment. CIM and automation are prerequisite factors in providing the flexibility needed in order to make the necessary adjustments in the products line in short time spans.

Planning and design Lead Time - Integrated CAD/CAM systems, and in particular the advanced tools of computer graphics which are now available (e.g., the Origami CAD/CAM system for the sheet metal industry developed at the Mechanical Eng. Faculty at the Technion) have contributed to drastic cuts in the time required for the planning and design stages of new products.

Throughput Time - FMS, combined with associated computer packages that manage the automated shop floor shorten the throughput time by monitoring the production processes and providing instantaneous corrections in case of irregular performance.

Inventories Reduction - As the other stages of the production process become shorter and more flexible, the inventories of both WIP and final products have to be reduced to prevent them from becoming bottlenecks for the entire system. New storage policies and systems, mainly in the form of AS/RS, have set new standards on the size of required inventories, the accuracy of monitoring inventory levels and other dimensions which are all related to reducing the overall investment in inventory.

Reduction of Direct Labor - As the shop floor becomes more automated, the proportion of direct labor involved in the company's operations decline. This phenomenon decreases the company from dependencies on issues of labor relations, increases production flexibility (work in three shifts, performing difficult or monotonous jobs without breaks, etc.) and allows quick adjustments (relocations, changes in the work contents, etc.).

Reduction of Production and Inventory Space - As a consequence of the reduced inventories, the decline in the size of the direct labor involved in production and the introduction of new and sophisticated transportation devices, automated plants are becoming compact in their overall size. This is a crucial factor which offers management the flexibility to locate such plants even in areas where land is scarce and expensive.

Improved Quality - The trend towards automation has boosted quality management in many ways. Since the automated system must monitor itself and be able to take action when things go wrong, techniques such as SPC were introduced for these tasks. Thus, defects are detected in early stages and corrective action taken.

Moving now to examine the 'negative' list, we find:

Rate of Return on Investment - The economic Achilles' heel of CIM and automation is in the area of evaluating the ROI rates associated with it. Typically, these investments include state-of-the-art equipment and technologies which require experiments and development of integrated systems before full installation is possible. This characteristic increases the size of the required investment, the risk involved in the investment and the time it takes before the investment pays itself back.

Increased Employees Emoluments - Although direct labor is reduced, the overall investment in the workforce usually increases as the portion of non-direct labor (which is typically much more expensive to recruit and maintain) increases.

Increased Maintenance Costs - Maintenance bills grow in parallel, or sometimes, in a larger rate, with the price tags of the new equipment. As explained above, the new systems require some experimentation and this applies to the maintenance teams as well. Also, prices of spare parts, Maintenance contracts on computer hardware and other elements of the automated system have all become rather expensive in recent years.

3. Opportunities and Threats for the Israeli Industry

3.1 Background

A concentrated effort by Israeli industry to adopt advanced technologies and novel organizational and managerial techniques will help in positioning it as a potential competitor in global markets. To do so Israeli companies must be able to identify new markets, quickly penetrate them and establish themselves as quality leaders in these markets. These new markets are characterized by:

* more diversified, shorter lived products
* fast, flexible custom production

The system characteristics required for success in such markets are:

* Fast response to customised production orders.
* Total quality assurance.

The achievement of these characteristics requires comprehensive changes in the entire manufacturing process; these will be discussed in detail in par. 3.2.

Dangers

The fast pace of change in the world means the unless we make a concentrated, focused effort by industry, government and academia, we are going to be left far behind and uncompetitive.

3.2 Influence on Manufacturing Scope of Activities

In order to be competitive, new ways and manufacturing technologies must be adopted for the entire manufacturing process, from the product concept, through development and design, manufacturing, service and marketing. These new automation and computer integrated manufacturing technologies have already been successfully introduced in the advanced industrial nations, with support from governments and major investment in research and development programs. The Israeli industry cannot afford the threat of joining too late this new industrial revolution.

The aim of these advanced, Computer Integrated Manufacturing technologies, is to increase productivity, improve quality, reduce costs, and make new products available to the marketplace faster than the competition. In order to achieve this aimed competitive advantage, all aspects of the manufacturing activity must be influenced: R&D, engineering design, production, marketing, and distribution.

Opportunities for competitive advantage need to be created by introduction of new products. This is in particular true for the large segment of the Israeli industries that manufactures for the military markets. With the political changes in Europe, and a global detente, these markets are shrinking, and there is a need to find and compete with new products for the civil and consumer markets in order for these industries to survive. The threat of changing markets will require reevaluation of research and development efforts for development of new products, and reassessment of the entire manufacturing system, and its suitability for the manufacture of civilian goods. While the military industries have the human resources, technology and skills to produce high-quality products, some of their production lines are designed for mass-production of large quantities of the same product, using dedicated automation. The consumer market today is characterized by the proliferation of product variety, coupled with a faster pace of new product introduction. This has led to shorter product life cycles. As a result, some of the existing production systems, which were designed for hard automation used in mass-production, are no longer adequate. These production systems will have to be modified or replaced by flexible, general-purpose automation systems.

Research and Development of new products for the consumer market is a must in order to achieve a competitive advantage. Such new products may achieve a competitive edge either by some innovative idea, being protected by patent rights, or by the ability to bring the product to the market before the competition. Thus R&D efforts and expenditures must be devoted to development of new and improved products, but equally or even more to the improvement of process technology, manufacturability, and improvement of the manufacturing system. To meet this challenge, there is a need for highly skilled human resources, both on the R&D and engineering level, and in manufacturing. This need for a highly educated and skilled work-force bears, along with a challenge, an excellent opportunity for the Israeli industry, in view of the skill and education level of the new immigrants from the USSR, and the need to retain in the country skilled young engineers and technicians.

In order to meet the challenge of the world-wide changes in manufacturing, and compete in this new environment, there is a need for major changes in the manufacturing systems structure, including introduction of new technologies, methods and standards of production, and new skills.

Inflexible labor union policies, are a potential obstacle in the way of introducing the needed changes in the structure and skill level of the work-force. There is a major need for more cooperative and flexible labor-management relationship in the process of introducing new technologies, changing production methods, and retrofitting existing manufacturing facilities, with all their implications of retraining and restructuring the work-force.

Another major difficulty in implementing the change is the existing industrial infrastructure. This existing infrastructure is frequently far from ideal for the introduction of some of the new production and automated material handling facilities. If a decision is made to implement the changes in the existing manufacturing facility, there is a major challenge in doing so with minimal interruption to the manufacturing activities.

The Israeli industry faces marketing difficulties, and limited markets due to political constraints. Even in established markets, in which the technological advantage of Israeli products have been demonstrated and accepted, there is a constant threat posed by political instabilities, which threat distribution and support systems.

A very basic problem addressed by the Computer Integrated Manufacturing technologies, is the problem of new product transition from design to manufacturing. Better coordination between design and manufacturing has a major impact on the product development cycle, product development and manufacturing costs, and product quality. At the root of such coordination, for which the terms of "Design for Manufacture" or "Concurrent Engineering" have been coined, is the use of factory-wide advanced computer systems, manufacturing data-bases, smart algorithms, and communication networks.

This computer technology is the tool for better factory-wide coordination and integration. In general, the problem of full coordination and integration still awaits solution. The existing computer tools have typically created "islands of automation". Integration of the various tools available from CAD/CAM, CNC, FMS, AGV, or AS/RS system vendors requires a deliberate and focused effort on part of every single user. Such integration efforts are done individually, by the different users, and the integrated systems, when developed, serve the individual plant, with very few transferable benefits.

There is a need for generic solutions in the area of systems integration. This need presents a unique opportunity for the Israeli industry, in the area of systems design and software development of the needed generic integration tools.

For the individual manufacturing plant, the new technologies present an opportunity to penetrate unique markets, such as the aerospace industries or telecommunications. The ability to demonstrate to potential customers a fast development-to-manufacturing cycle, an efficient manufacturing system, and quality assurance practices built into the production process, are necessary to penetrate such markets. Several examples of competitive marketing edge achieved by Israeli firms that have adopted the new manufacturing technologies have been encountered during the survey. These examples will be discussed in detail in the next section.

4. Difficulties in The Introduction of Automation Technologies

4.1 Survey and Industry Study - the Metal Industry

4.1.1 Introduction

The approach adopted in this survey of CIM Technologies and Automation in the Israeli Industry, was that of a detailed, bottom-up study of selected plants in the Metal sector. The plants and industries visited are representative of the Israeli metal manufacturing sector. They include both small, medium and large plants, in the public and private sectors. All plants visited were targeted for the study based on some evidence that they have approached the introduction of automation and CIM technologies. Our bottom-up approach focused on the production system itself: its organization and level of integration, elements of automation and CIM technologies implemented, management policies and strategies for introduction, difficulties, and achievements.

In general, we found that there are different levels of automation and integration, and different approaches in the management strategy to implement the system, from a step-by-step, bottom-up approach, fueled further by initial success, to a top- down design of an entirely new, automated computer-integrated facility. However, for all the plants visited, the driving force for entering the new technologies was the need to increase productivity and product quality, and reduce manufacturing costs, in order to maintain a competitive edge and penetrate new market segments.

This section will briefly summarize the plant studies for each of the plants visited, and conclude by a discussion of common findings, problems and concerns.

4.1.2 Plant Visits

Carmel Forge - Haifa

Background: Carmel Forge Ltd. main production line is devoted to aeronautical parts which can be subdivided into engine parts vs. body parts, rotating vs. non rotating parts, and cold vs. hot parts. The plant, which is jointly owned by the Israeli Kur concern (58%) and United Technologies (42%), employs 220 workers and has an annual sales of $20M (96% export). Among its major clients are Boeing, Pratt & Wittney and General Electric. The plant was constructed in the early 1960s for the dual purpose of providing forged parts to the Israeli auto manufacturers and providing employment to the population in the area. Towards the late 1960s, as the local car industry failed, Carmel Forge moved out of the so-called "black forge" processes and entered the aviation market with the Kfir project. As the level of sophistication and the frequency of technological changes increased, it became apparent to the plant management that the installation of CIM and automated systems is a necessary condition to economic survival.

CIM and Automation: Advanced systems were introduced into isolated "islands" which are currently not integrated. These include:

* Fully automated rolling cell which include a mechanical manipulator which transfer parts into and out of the rolling machine, external control unit with 2 micro computers which offer real time cell control.
* Computer controlled thermal processes with real time monitoring through sensors.
* CNC system with a number of machines programmed via the Pasters software.
* CAD unit which is based on two Apollo work stations.
* Semi automatic quality control system which includes one CMM.

Special Characteristics and Difficulties:

* Extreme quality requirements due to aviation safety regulations
* Difficulties in acquiring new clients. Carmel Forge needs accreditation from each new client and this entails a difficult and costly procedure.
* Difficulties in penetrating the European markets due to governmental protection of European companies
* Difficulties in securing credit for planned capital investment (especially in light of the financial difficulties of Kur)
* Delicate labor relations, work force is unionized and job retraining is hard to enforce
* Unsuitable infrastructure (buildings, internal roads, storage areas, communication lines, etc.)

Achievements:

* Major increase in production and sales (50% in sales in the last year alone)
* Ability to hold on to prime clients in an ever increasing competitive market.

Israel Aircraft Industries - "Shahal" - Lod

Background: Shahal Ltd. is a subsidiary of Israel Aircraft industries (IAI). It is organized as an autonomous financial entity but, it shares common data and information bases, sales, advertising, etc.with the parent company. The company, founded in 1965, manufactures hydraulic systems and servo actuators for aircraft, ships, and tanks. Originally, the main product was hydraulic systems for aircraft landing gears, especially for IAI aircraft. Looking for new markets, Shahal gradually switched to other aircraft manufacturers (Boeing, ATR, Airbus) and to new users like tanks and ships manufacturers. Following the cancellation of the Lavi project in 1987, and the consequent loss of work orders, Shahal faced difficult financial situation and had to initiate a comprehensive recovery program. As a result of this program the number of employees decreased from 900 to 520 over the course of three years, and export increased to about 70% of the total $38M sales.

CIM and Automation: About 40 machine tools, constituting the machining shop, have been recently organized in cells to optimize machining of similar parts. Group Technology concepts were applied in determining the association of parts into the cells and in organizing the software that manages the shop floor. The machine tools are computerized and are based on Japanese manufacturers like Makino and Okuma. As income increased, the company has lately started to invest in up-to-date machines. The CAD software, which runs on DEC's VAX machine, is based on special in-house developed programs as well as on commercial available programs like Euclid, Transformation of manufacturing data to the machines is done manually and requires additional programming of the machines. Process management program collects process data and runs MRP every alternate month, and MSC every week.

Special Characteristics and Difficulties:

The company is connected to the main division for financial sources, sales, management and design software, and computer resources.
High quality requirement due to aviation and military standards.
Major effort is devoted to acquire new overseas markets.
Equipment in the factory is usually utilized in two shifts.

Achievements:

Reorganization of the company included also the adoption of the Group Technology approach. All the parts were classified into groups and subgroups according to size, geometrical features, use, and production process. Accordingly, the factory floor has been organized into 5 FMSs that minimizes part travel through the factory. Also, worker responsibility and involvement have increased since a small and closely located group is now involved in the production of a complete product. Production management became simpler, and overall productivity has substantially increased.

ISCAR - Tefen and Ma'alot

Background: ISCAR factories in Tefen and Ma'alot are relatively new. The firm, whose headquarters are in Naharia, decided to construct these factories in these locations as part of the general effort to move factories into the new industrial park in the mid Galilee. The factory in Ma'alot is the older one and was used as a test bed for a new concept in automation and integration. Tefen's factory was built utilizing the experience of the prototype in Ma'alot and is supposed to become fully productive during 1990.

Ma'alot Saw factory produces circular saws of different sizes. The common geometrical features of the products simplified the implementation of the fully automated production line. All the machines are computer controlled with high emphasis on monitoring, loading and unloading. An AGV is used to move the products form one machine to the other. Except for the initial loading of the raw material on special jigs, the entire movement of the products through the production process is automatic. Only a few operations are performed manually, and those require six workers in a shift. The process is controlled by a central DEC computer, and operates in three shifts.

Tefen cutting tool factory produces a variety of cutting tools. It's design is based on the Ma'alot model, and the objective is to make it fully automated. As a new factory which is still in its start up stage it was designed in a top-to-bottom manner and with a minimum number of workers. The main production process is the pressing of the raw material, fed as a powder, into a cutting tool shape. Loading and unloading is performed by robots, where one robot is attached to each pressing machine. An AGV travels between the rooms and transfers the product to the thermal treatment section and to the AS/RS devices.

CIM and automation: Even though various kinds of automation have been applied in other factories in Israel, this factory is unique in its level of integration of the entire process under a central computer. It is clearly the most advanced factory in Israel in terms of CIM and automation, and at the for-front of automated factories world wide. The process in both factories is controlled by DEC computers, and the software is was developed as an in-house product by a joint team of Digital and Iscar. The AGV was originally ordered form a German company but was redesigned and the software to run it was rewritten by Iscar's engineers.

Achievements:

* The highest degree of automation in Israel.
* The number of workers is extremely low.
* The model of automation developed in Ma'alot was the key to penetrate into the Japanese market where Iscar's saws are now sold.
* The software system to run the automated shop floor was developed as a generic instrument which is now marketed to other companies so as to recover the R&D costs that were invested in it and even generate profits from it.

Israel Military Industries - P Plant - Haifa

Background: Located in Haifa, the factory was founded in 1949 as a section of Israel Military Industry (IMI). Over the years the number of employees increased from 33 to about 2200, and the original line of shells was changed to include a variety of products. Export to foreign countries is the main source of income, about 75% of the total $200M sales. As with other sectors of IMI, the P plant became in the last year a separate entity with independent authority over profits and investment considerations. Following the global decline in demand for armaments, major effort is currently devoted to penetrate civilian markets, which account today only for 1% of the total sales.

CIM and Automation: The plant P produces armament parts which are mainly made out of metal. Metal processing include metal cutting, metal forming, welding, coating, and thermal treatment. There are about 350 machine tools in the factory with about 140 CNC machines. Standardization of CNC machines started in 1977 based on GE equipment. However, In 1981 the factory switched to Japanese manufacturers especially Okuma and Mazak, which dominate the factory today. No robots are employed and loading and unloading are performed manually. Robots are applied to complicated and hard-to-reach drill tasks. The design and construction of the automated systems was done by various external agents. For example, an important manufacturing line, in which hard automation is employed, was designed by the Swiss company Bodmer Ltd. while in another section of the plant, a custom made equipment was designed and built by a M.I.R - a small Israeli company who specializes in this area.

Special Characteristics and Difficulties: Most of the products are in large quantities for which flexible manufacturing is not advantageous. Introduction of new technology that requires different skills causes difficulties, since retraining of the workers is not easily accepted. Quality control consumes about 20% of the product cost, and different, more automated approach, has to be adopted.

Achievements: The product quality is high and it is recognized as such by many foreign armies.

The hard automation is suitable for many operations in the factory and it is successfully implemented.

"Chromagen" - Kibbutz Sha`ar-Ha`amakim

<u>Background</u>: Chromagen Ltd. is a large Israeli manufacturer of water tanks and boilers. Its products, some 3000-4000 boilers a month, come in different sizes and fit a variety of water heating systems. The plant is owned by (and located in) Kibbutz Sha`ar-Ha`amakim, and most of its 20 full time employees are kibbutz members.

<u>CIM and Automation</u>: Hard-wired automation was introduced into the plant in the 1970s mainly in the form of conveyors and some work stations with fixed operations. The advances of the last few years included the introduction of flexible automation (through programmed control units) to replace some fixed automation units, and an investment in a fully automatic welding system which was supposed to perform all the welding tasks required for the boilers. Today, flexible automation is successfully practiced in most parts of the production line (post-welding, cleaning, coating, polyurethane injection, etc.)

<u>Special Characteristics and Difficulties:</u>

* The state of the art in robotic welding technology on cylindrical bodies seems to be short of the plant's requirements. In spite of the efforts and money which was invested in the automatic welding system, it still can not function as planned and hence, it is only partially (and manually) operated.
* The plant engineers had difficulties in finding reliable information sources in Israel with which they could consult on issues such as the selection of equipment and suppliers. As a result, costly (and avoidable) errors were done at this stage.
* Chromagen is a small scale plant and, like most of the industry in the Kibbutzim, does not have a strategic goal to become a much larger plant. Hence, management faces severe problems in obtaining the funds when a need to invest a considerable amount in new technology arises.

Achievements:

* During the last 4 years the plant was able to double its production volume (from 1300 boilers a month in 1985 to more than 3000 today) without increasing the workforce.
* The programmed control units helped to reduce the number of rejected boilers.

Telrad - Lod

Background: Telrad Telecommunication & Electronic Industries Ltd. is a manufacturer of telecommunication systems and products, for commercial markets, telephone companies, and the military. The company belongs to Kur. About 40 percent of total production is for export, with customers in over 30 countries.

CIM and Automation: In the early eighties, the plant management started to define a strategy for Integration and Flexible Manufacturing Systems. This initiative stemmed from technological changes in telecommunication products, from a predominantly mechanical systems to electronic systems. The result of this change was an average reduction of the production life-cycle for specific products from about 20 years to two years ! The strategic planning team presented a design for a flexible manufacturing system capable of manufacturing in small lot sizes, which allows fast introduction of new products. This top-down approach to system design defined a hierarchical system, with three levels: management systems at the top level, CAD/CAM systems at the intermediate level, and shop floor systems.

The implementation of the systems was accomplished in a bottom-up manner, by a gradual change of the production facilities on the shop-floor, within budgetary constrains and existing infrastructure.

Highlights of the implementation included: Management commitment, at all levels, to follow the integration strategy, and introduce it as a new work culture in the plant. New technologies, with regard to both processes and materials, have been developed. These are necessary for successful implementation of automation technologies. For example, robotic painting of high quality could not have worked without introduction of electrolytic metal sheet and electrostatic painting.

The software systems for major modules in the two top levels are purchased packages (MM3000 and PM3000, Unigrafix). Integration is not complete (all integration modules had to be developed in-house). Software for specific tasks, such as finite capacity planning, can not be acquired off-the-shelf, and it is difficult to link them with the packaged software.

Special Characteristics and Difficulties:

* Labor relations - as in Carmel Forge.
* Production Management systems, including the MRP II, lag behind current needs and bring about forced delays. For example, those systems do not have finite capacity planning ability and, as a result, inappropriate schedules are sent to production.

Achievements:

* Workforce in the mechanical and plastics departments.: reduced from 270 persons, working in one and a half shift, to 150 persons, working in three shifts.
* Design time: Mold design time reduced from 3 months to 2-3 weeks.
* Marketing: Large export contracts were made possible thanks to the ability to demonstrate to the customer a product Design-Modify-Manufacturing cycle with the new system.
* Improved product quality
* Flexibility and capability to manufacture efficiently in small production lots.

4.1.3 Discussion - Industrial and Economic Aspects

The implementation of advanced manufacturing technologies and automation systems is approached by different methods and strategies in the plants surveyed. There is the Top-Down approach, in which an integration strategy leads to development of an entirely new facility, implementing the ideas of "Factory of the Future" and integrating all the automation elements on the shop-floor, taken by Iscar. Another approach is that used by Telrad and Shahal, in which there is an overall, top-down strategy for introducing flexible automation, Integration, and new manufacturing technologies, but the implementation is done bottom-up, one step at a time, within the constraints of budget, the existing infrastructure, and labor union contracts. There are also bottom-up approaches, to solve specific production problems by introduction of technologies such as programmable controllers, control computers, or robotic work-stations. In this approach, a specific production problem is solved first, creating an "Island of Automation" in the plant. Attempts at integration are taken only at a later stage. This type of approach was found in Carmel Forge and Chromagen. It is necessary to consider carefully at the beginning, the suitable approach for a specific factory.

The type of production, its variety, and market needs, affect the degree of flexibility in the automation approach. Flexibility and flexible automation, which is achieved by the use of general purpose CNC machines and robotic systems, is in general less efficient than a tailored, dedicated automation. This is manifested in the considerable amount of dedicated automation systems in IMI "P" plants, and much more flexible automation technologies in the other plants visited, which are characterized by larger product variety, and relatively small batch sizes.

In all the plants visited, instrumental to success of the automation projects was recognition of the need by management, and high commitment, both by management and by a very dedicated implementation team, to introduction of the new systems. In all cases, the introduction of the new automation technologies did require a large investment, which was not supported by external (government) sources. Another characteristic attribute is that the planning and design of the new systems was done, in its majority, in-house, without external support for system analysis, selection of equipment and vendors, or system installation. This was due mainly to lack of such reliable support body, which could consolidate expertise and knowledge, and transfer it.

The introduction of automation and advanced manufacturing technologies had a major impact on the human resources. There is a need for new skills with the introduction of the new manufacturing systems. The introduction of such systems also means a reduction in the number of direct production workers needed to produce the same quantities of products. There is a need for retraining programs on all levels. The new environment does create new and more challenging job definitions and responsibilities. For example, the move to flexible manufacturing cells, such as partly done in "Shahal", requires more versatility and responsibility from the cell operators, which are now in charge of the entire manufacturing process, and all the different types of production facilities in the cell. This change in responsibility, from a single machine or process, to the entire cell, creates more involvement and motivation, but also requires new skills.

In all the plants surveyed, Iscar being an exception, systems implementation was performed taking the "Bottom-up" approach. As a result, elements of automation were created on the shop-floor, with integration of these elements being partial, and encountering difficulties. Frequently, a manual link, or other specifically tailored solution was used to transfer the necessary data from one "automation island" to another, such as from the design department to the CNC machines or to the inspection coordinate measurement machines. The source for this difficulty is due to incompatibility between different software and hardware vendors equipment, lack of complete standards for interfaces, or lack of knowledge which interfaces to require when selection of equipment is made. This problem is not unique to the Israeli industry, and it exists world-wide. Interface standards are being formed, but their acceptance and implementation by equipment vendors is slow.

A related aspect, which represents a major portion of the investment required for implementation of the new technologies, is software and software development. In all the plants visited, software needed for integration and creation of interfaces between systems had to be defined and developed in-house, as a specifically tailored solution. In one case, of "Shahal", even the more general Group Technology and Computer-Aided Process Planning software was developed in-house, with a major investment, due to the feeling that available software packages in this area cannot be tailored for the specific needs of Shahal.

4.2 Communication Difficulties

Automated manufacturing requires electronic computer-based communication between all the components of the manufacturing cycle. The technology of computer communication is still new and immature, and that leads to operational difficulties.

Data sent from one computer to another should be passed quickly through the network, and the reading equipment should be able to read the data and use it correctly. This can be done reasonably well if all the software processes in the system have been obtained from a single vendor. When dealing with automation within one factory, that is feasible. However, the trend now in automated manufacturing is for data to be transferred between many computers at the sites of the customer, the designer, the production planner (who decides where production is to be done and schedules supply of components and materials), the production site, and the various vendors. This widespread large number of players will inevitably need to use many different kinds of computers and software.

Difficulties of exchanging data between different systems can be illustrated by well-known difficulties with exchanging data between word processors. The file of data for a document includes not only the letters of the text, but also symbols which control fonts, underlines, page breaks, etc. These symbols are different for different word processing software, and a document prepared on one system cannot be simply read into another system; it has to be converted by special conversion software which translates those symbols as needed. For text documents which include graphics, and for documents which include engineering drawings, there are many more control symbols and many more types of entities to represent than for a simple text document, and the format and conversion problems are much more complex.

There is currently much activity in Europe and in the US, and internationally, regarding standards for electronic exchange of technical data. These standards are still changing, and it is likely to be several years until they are stable enough to permit a mature technical data exchange technology. A company wishing today to arrange communcation between diverse computer systems within its own organisation and to vendors and customers, cannot simply order a system by quoting an internationally-accepted standard. That will be possible only some years from now. The option of not installing connectivity now implies that the company will remain disconnected, when the world is moving to working by computer connectivity, and so is not good. The only solution now feasible to install connectivity is to rely on expertise of people who are aware of the technical problems, and of the discussion in progress in the relevant standards committees, and who can therefore best guide the technical solutions taken so as to provide maximum connectivity now, and also in the future as standards and methods change and mature.

4.3 The National Environment for CIM and Automation

4.3.1 Infrastructure

Infrastructure includes many different items:

a. Incentives

Almost all industry in Israel is of a size which in the Europe or the USA would be considered small or medium size and unable to finance research and development in automation and the restructuring required. Governments finance that work. The implication of this fact for Israel is clear.

b. Culture

All leaders and journalists who influence public opinion should be educated to understand and cope with the new ideas of a modern industrial plant. In particular, they have to realize the indispensable importance of speed in getting work done. Whoever cannot react quickly will lose markets, whatever his costs are.

c. Services

Emphasis on reducing time in all operations, e.g.:

1. Goods to move through the airport within 2 hours of a plane landing.

2. Elimination of all time-consuming government and commercial bureaucracy.

All beaurocratic interaction with commercial and industrial day-to-day activity should be conceptually viewed as being part of real-time operational control of a dynamic system, just as the air force is managed. The existence and timing of all such bureaucracy should be made to fit such a concept.

d. Communications

Need for reliable 64 Kb computer communication as a standard,with faster speeds available, to North America, Europe, Pacific rim industrialized countries.

e. Unique Support Systems

Like other advanced segments of the industry, CIM and automation require a variety of unique support systems that will constitute a friendly environment into which new entries will find it easy to penetrate. Although this topic was not thoroughly checked in this survey, it is possible to point out at least three relevant areas of infrastructure whose existence may contribute to a more rapid development in the field.

* Suppliers of special CIM equipment who keep close contact with their counterparts abroad and can offer quick (off-the-shelf) solutions to local problems.
* Software development companies who gain experience in this line of application and can employ their skills, together with generic software modules, to create custom made solutions in reasonable lead-time. (See the example of the cooperation between Iscar and Digital mentioned in 4.1.2).
* Hardware design specialists who can design and build custom made work stations at various degrees of automation level in a reliable and timely fashion. (See the example of the equipment that was developed by M.I.R for IMI and is mentioned in 4.1.2).

f. Education and Training

The work force should be brought up to a modern educational standard, capable of statistical quality control (for instance, them Demming method) in their work.

4.3.2 Standards

1. Industry will need access to technical expertise to define practical product data and technical document communications solutions, even though standards for electronic data interchange of product and production data

are evolving and immature. This is a more complex problem than interchange of a regular data base data, such as in banks.

2. Israel must not attempt to define national standards for communications and industrial data interchange. National policy will have to decide which standards to adopt, European or USA or both.

3. Currently, no representatives from Israel are active on European and other significant international bodies dealing with interchange specifications for technical and industrial data. As a result, Israeli industry has no access to up-to-date knowledge as to directions of technical development in these fields, and preparations they may wish to make lag behind industry abroad. Also, because there are no representatives, even where the way is open, the standards are not influenced by any special problems Israel may have. There are individuals in Israel with strong technical knowledge in these fields, and this resource is not utilised. Plans and budget should be made for at least 30 representatives travelling to at least 3 meetings a year, with a national responsibility and a systematic method of reporting and dissemination of data in Israel.

4. Standards for exchange of Hebrew text data should follow from and be compatible with, internationally-accepted standards.

5. Whoever waits for stable standards until moving to electronic data interchange will be be disconnected from international industrial and retailing markets. Computer system companies are not able to solve all these problems in spite of their claims. Industries therefore need access to expert individuals who understand these standards and the difficulties in using them. This cannot be funded by individual industries, but has to be organized and catalyzed by a suitable public function.

4.3.3 Regulations

A review of all regulations which affect movement of information and goods, must be undertaken, so that these regulations will support efficiency measures of services (par. 4.3.1c).

Current accounting practice derives from days of slow moving commerce and in many technical details inhibits introduction of fast-moving automated methods. There is currently debate in progress on this issue among organisations of auditors in several countries, especially in the USA. The professional accountancy bodies in Israel should join that discussion in the US and elsewhere without delay, so as to introduce changes in Israel compatible with methods abroad, and which will encourage rather than inhibit modernisation of automated production facilities.

5. <u>Conclusions and Recommendations</u>

5.1 General Conclusions

There is no doubt that CIM and FMS can make large contributions to rapid response, quality improvement and cost reduction.

The analysis of the case studies which were investigated in this survey leads to the conclusion that several 'necessary' conditions have to be present for the penetration of CIM and automation into shop floors in the Israeli industry. However, these are certainly not 'sufficient' conditions since numerous cases can be found in which the necessary conditions prevail but CIM is still lagging behind. The conditions which were identified are:

- Top-level managerial recognition of the potential embedded in CIM and its importance to the vitality of the plant.
- Existence of some outside pressure (e.g., performance of relevant competitors).
- The presence of at least one person, high enough in his managerial rank, who is totally devoted to the concept and works continuously to push CIM projects forward.

It should be noted that the company's financial situation is not mentioned above. The survey included profitable companies as well as others which suffered significant losses in recent years and in spite of that fact invested in CIM. It seems that when the conditions mentioned above materialize, the needed funds can be found.

5.2 Recommendations to Governmental Agencies

A National Center for Advanced Production Systems

The Trade and Industry Ministry should take the initiative of establishing a Center for Advanced Production Systems (CAPS). The center will get some seed budget from governmental sources and the majority of its income should be provided by collaborating organizations - mainly, companies which have interest in the subject. The British initiative in founding the Advanced Robotics Research Ltd. (ARRL), a company which runs their National Advanced Robotics Research Center, can serve as an example for CAPS. ARRL was instigated by the UK Department of Trade and Industry in 1988. The government provided an initial budget of 5M pounds sterling which was matched by the dozen of collaborating organizations which started the company. These organizations, including leading industrial companies and universities, are shareholders of the company. They will have access to its patents and discoveries as well as the right to profits which will be generated by the company's activities. Of course, appropriate modifications and adjustments to the Israeli environment will be required to employ this model for the creation of CAPS. The objectives of CAPS may include:

- Developing new technologies and distribute them among its participants
- Constructing and maintaining data banks/library
- Encouraging collaborative ventures between academia and industry
- Providing consulting services to non-participant organizations
- Managing 'start-up' projects, by helping to select equipment and suppliers providing installation teams, etc.
- Establishing standards
- Developing public awareness

Close cooperation between CAPS and Academia is important. Hence, it should be located in close vicinity to an appropriate technological university.

Cooperation with the Common Market

As the turning point of 1992 is approaching, the Trade and Industry Ministry, The Ministry of Science and Technology, together with officials of the Foreign Affairs Ministry, should look for ways to collaborate with activities which are already undertaken, or are already scheduled to start, jointly by the member countries. This cooperation may include:

- Joint ventures
- Workshops and Study Programs
- Agreements on knowledge transfer
- Participation in standardization committees

International Scientific Cooperation Agreements

Automation and CIM projects should be included in bilateral and other international R&D cooperation agreements, negotiated by the Ministry of Science and Technology.

A particular goal may be the admission of Israel into the EUREKA initiative. This joint effort, launched by the European countries in 1985, has already produced hundreds of successful high- tech projects, the majority of which in the areas of robotics and production automation.

Accelerated depreciation on capital

The government should recognize the important role of introducing the newly emerging manufacturing devices as a necessary condition to the long term economic growth of the country. Accelerated depreciation on the relevant equipment was used by the Japanese government during the last two decades in developing factory automation in that country. Soon, it became one of the most important vehicles in encouraging industry to introduce the new technologies into the factory floor. In Israel, as in the Japanese case, this form of subsidy should be offered without regard to the geographic location of the plant. Otherwise, many of the well established plants which are located in central areas and which are unable to relocate themselves, will be denied access to this important means.

Providing other (long term) financial tools

The government should find the means (Loans, Investment Programs, etc.) to provide the industry with sufficient investment incentives to introduce CIM processes and plants. This government action is particularly essential for small and medium size companies which are not able to accumulate enough financial backing of their own for that purpose. Some of the financial instruments used by the American SBA may be studied and adopted towards this goal. Further, it is recommended that investment incentives which are directly connected to the capital required for CIM, will be offered regardless of the geographical location of the plant. This indeed contradicts the government general intention to encourage investment in development areas but, it will allow companies which are already located in non development areas, and for which relocation is not economic, to move into the new era of CIM.

Providing Computer Communications to Peripheral Regions

Modern industry requires high intensity reliable electronic communications and movement of goods nationally and internationally within hours, therefore manufacturing industries not situated in the center of the country are critically disadvantaged. The government should ensure that the communications infrastructure to regions in the North, South and East of Israel have the same speed and reliability as in the coastal region, and that manufacturing industries in the outlying areas be connected to the Tel Aviv exchange, at government expense.

5.3 Recommendations to Industry

Joint ventures with Foreign companies

Companies which manufacture elements of automatic systems should be encouraged to launch joint ventures with foreign companies in order to expand their markets and be able to offer complete and more attractive systems to their clients. An example to such a move is the recent agreement signed by Robomatics Ltd. (owned by the Israeli concern Klal) and the Japanese concern Shiboya to create a joint company which will take on the marketing of Robomatics' systems (mainly, automatic cutting and welding systems which are based on advanced laser technology) in the Automative industries in Japan and in other Far-Eastern countries.

Cooperation with the Academia

An important area of cooperation between industry and academia on CIM and automation matters which is almost non existing in Israel, is by joint applied research. Efforts in that direction can be launched and monitored within the CAPS framework. The German experience in operating the Fraunhofer Institutes, were the funds invested by the industry are matched by the government and the institute charter is deliberately geared towards applied research, can be studied and perhaps applied in Israel.

Encouraging in-house R&D activities

Most of the funding offered today by the office of the Chief Scientist at the Department of Trade and Industry is channeled to encourage new products with promising prospects in the market. We recommend that in order to help developing CIM and automation in Israel, some of these funds will be devoted to the creation of new, CIM related, processes, and not just products. This will encourage the in-house R&D activities of the companies working in this field by offering them seed money to start develop new processes which will later be integrated in their regular operations.

Commercialization and Knowledge Transfer

Israeli companies which acquired particular knowledge and expertise in specific areas of automation should be encouraged, through financial incentives, to share the knowledge with other Israeli manufacturers, of course, with the appropriate safeguards that this action will not be used against them by direct competitors. For example, the unique experience of Chromagen in automatic welding might be of help in other metal factories (some within the Kibbutzim's industry). Every effort should be taken to achieve quick commercialization of the new technology so as to guarantee the continuation of investment in R&D.

Human resources management

The introduction of CIM into shop floors has a profound impact on the workforce at all levels of the plant. Management has to consider the financial aspects of the change as well as its implications on work relations, motivation and stability. Training and education programs for existing staff (retraining, job enhancement, job enrichment) have to designed and implemented. Selection of new employees on the basis of their fit to the new requirements and, at the same time, reductions (e.g. through forced retirement) in unskilled labor has to be undertaken.

5.4 Recommendations to Academic Institutions

Curriculum changes

The rapid changes in the real world of production, in particular, the introduction of FMSs, the evolvement of MRP into MRP II, the contrasting 'pull' vs. 'push' approaches, require some drastic changes from the "classical" curriculum which is still taught in most schools. Courses have to be updated and new courses constructed. These changes should affect all the Israeli engineering schools. Within these schools, different departments will have niches in which they can contribute to the development of the area. In particular, the departments of Mechanical and Industrial Engineering will have to be responsible for most of the required changes. Emphasis should be put on developing laboratories with state-of-the-art equipment. These laboratories will serve the dual purpose of preparing the students for the conditions which they will meet later in industry and serving as an instrument in developing new technologies.

Feasibility studies

Teams of researchers, consisting of experts from diverse areas (e.g., production, control theory, computers, economics, marketing and finance) can work together in exploring new avenues for development of automation and investigate the probability of success from the different aspects of their respective interests.

Students' projects

Students should be encouraged to undertake projects of practical nature in the industry. These projects will provide the students with on-hands experience while, at the same time, it may improve the performance of existing automatic systems.

Cooperation with industry

Cooperation can take place in many forms including those which were mentioned above, i.e., joint ventures through CAPS, feasibility studies, supervising students' projects, etc.

On-going Monitoring of Activities abroad

Academic survey teams should be encouraged to monitor the activities taken by research institutes as well as governmental and industrial agencies abroad. The monitoring should be performed via the professional literature, visits and personal contacts with the relevant persons abroad. Government should fund periodic reports on developments abroad. These reports should be widely distributed (in Hebrew) to increase the access of various groups to this vital information.

5.5. Proposals for Projects

5.5.1 In Israel

The projects listed below are such that they either have relevance only to Israel, or rely on specific knowledge that has already been accumulated at home and carries relative advantage over other alternatives such as joint projects with entities abroad.

* Continuation of the current study (see par. 5.6).
* Preparation of a master plan and specifications for the creation of CAPS based on experience with similar centers abroad.
* Development of generic AGVs which can be easily fitted for particular tasks.
* Development of automated assembly systems which can be integrated into various configurations of overall production systems.
* Development of expert systems for a variety of needs (e.g., tool selection, production scheduling).
* Development of hierarchical software packages capable of managing an automated plant from the tactical levels of periodic production and inventory planning through the operational level of running the shop floor.

5.5.2 Collaboration with the U.S.

The collaboration can take effect through individual agreements between pairs of research institutes in the two countries or, through a bi-national fund which will be dedicated to this purpose. It should be noted however that, at present, The NSF is blocked to Israeli scientists (while not in the U.S.) and the existing Bi-National Fund is dedicated to pure research in the exact sciences and does not fund activities along the lines required here. The projects suggested below are such that some relevant expertise exists in both Israel and the U.S. and can be pulled together in a relatively easy manner.

* Development of decision support systems, each dedicated to particular segment of the industry, which will offer alternative generic solutions for systems integration. Interdisciplinary teams with experts in systems design and software engineering can develop the needed generic integration tools.
* Development of new approaches to communications in FMS multivendor environment in order to integrate the different intelligent devices into one working system.

5.6 Future Program for this study

This is an ongoing study. The program for the next year should include:

1. An in-depth survey of the national environment for CIM and automation. (Infrastructure, Standards, Regulations).
2. Extension of the production floor survey to other sectors (beside the metal industry).
3. An industry wide survey of the behavioral and organizational aspects.