MANUFACTURING RESEARCH AND TECHNOLOGY

Volume 1. Flexible Manufacturing: Recent developments in FMS, Robotics CAD/CAM, CIM (edited by A. Raouf and S. I. Ahmad)
Volume 2. Computer-Aided Design, Selection and Evaluation of Robots (B. O. Nnaji)
Volume 3. Modelling and Design of Flexible Manufacturing Systems (edited by A. Kusiak)
Volume 4. Flexible Manufacturing: Integrating technological and social innovation (P. T. Bolwijn, J. Boorsma, Q. H. van Breukelen, S. Brinkman and T. Kumpe)
Volume 5. Proceedings of the Second ORSA/TIMS Conference on Flexible Manufacturing Systems: Operations research models and applications (edited by K. E. Stecke and R. Suri)
Volume 6. Recent Developments in Production Research (edited by A. Mital)
Volume 7A. Intelligent Manufacturing Systems I (edited by V. R. Milačić)
Volume 7B. Intelligent Manufacturing Systems II (edited by V. R. Milačić)
Volume 8. Proceedings of the Third ORSA/TIMS Conference on Flexible Manufacturing Systems: Operations research models and applications (edited by K. E. Stecke and R. Suri)
Volume 9. Justification Methods for Computer Integrated Manufacturing Systems: Planning, design justification, and costing (edited by H. R. Parsaei, T. L. Ward and W. Karwowski)
Volume 10. Manufacturing Planning and Control – A Reference Model (F. P. M. Biemans)
Volume 11. Production Control – A Structural and Design Oriented Approach (J.W. M. Bertrand, J. C. Wortmann and J. Wijngaard)
Volume 12. Just-in-Time Manufacturing Systems – Operational planning and control issues (edited by A. Şatır)
Volume 13. Modelling Product Structures by Generic Bills-of-Materials (E. A. van Veen)
Volume 14. Economic and Financial Justification of Advanced Manufacturing Technologies (edited by H.R. Parsaei, T.R. Hanley and W.G. Sullivan)
Volume 15. Integrated Discrete Production Control: Analysis and Synthesis – A View based on GRAI-Nets (L. Pun)
Volume 16. Advances in Factories of the Future, CIM and Robotics (edited by M. Cotsaftis and F. Vernadat)
Volume 17. Global Manufacturing Practices – A Worldwide Survey of Practices in Production Planning and Control (edited by D.C. Whybark and G. Vastag)
Volume 18. Modern Tools for Manufacturing Systems (edited by R. Zurawski and T. S. Dillon)
Volume 19. Solid Freeform Manufacturing – Advanced Rapid Prototyping (D. Kochan)
Volume 20. Advances in Feature Based Manufacturing (edited by J. J. Shah, M. Mäntylä and D. S. Nau)
Volume 21. Computer Integrated Manufacturing (CIM) in Japan (V. Sandoval)

MANUFACTURING RESEARCH AND TECHNOLOGY 21

Computer Integrated Manufacturing (CIM) in Japan

Victor Sandoval

Laboratory CIM/Logistic, Ecole Centrale de Paris
Chatenay Malabry Cedex, France

ELSEVIER
Amsterdam – London – New York – Tokyo 1994

ELSEVIER SCIENCE B.V.
Sara Burgerhartstraat 25
P.O. Box 211, 1000 AE Amsterdam, The Netherlands

ISBN: 0 444 81923 1

This book is printed on acid-free paper.

Printed in The Netherlands

"COMPUTER INTEGRATED MANUFACTURING TECHNOLOGY IN JAPAN"

FOREWORD

CIM is one of the most advanced tools for improving the economic performances and productivity of industrial systems. It is also becoming a fundamental base for designing and building the next, even more advanced generation of manufacturing systems called, at present, Intelligent Manufacturing Systems (IMS). Today, Japan is one of the more advanced countries in implementing CIM in the world. Nevertheless, the implementation of CIM in Japan presents some differences to that of Western countries.

This book, which results from a long enquiry conducted by Dr. Victor Sandoval about CIM in Japan, tries to present some of the most relevant aspects of CIM in this country, and to compare the development of CIM in the context of Japan as well as that of Europe and the United States. For doing it, this volume includes the studies of the implemented CIM systems in many companies. Among these companies figure Hitachi Ltd, Mitsubishi Electric Corporation, Toyota Motor Corporation, Toshiba, Toyo Engineering Corporation, Omron Corporation, Tokyo Electric Corporation, Fanuc Ltd., Shimizu Corporation and Nippondenso Corporation. In addition, the book includes a study concerning Intelligent Manufacturing Systems (IMS), and the basis for preparation of the so-called Future Generation of Manufacturing Systems (FGMS).

The study of Dr. Sandoval about CIM study permits a better understanding of Japanese competitiveness using advanced technology. This is an important point when the economies enter in the global world market, and when Japan is passing to the so-called "Open-CIM", a new CIM generation which combines the classical CIM and the more advanced technological advantages offered by the advances in information technology and telecommunications.

This last point is one the most interesting studied in this book, and I hope it may contribute to get out a more realistic idea about CIM. People coming from manufacturing industry, managers, engineers, officials and researchers will find in this book a rich material for knowing and understanding the crucial elements in technology development and its actual and future implementation.

Dr. Sandoval has been for many years a renowned expert in the design and implementation of advanced manufacturing technologies, including the crucial role played by information systems. He has an extensive experience of logistics systems in an international context. He was therefore one of the few specialists who could write such a book.

Professor Pierre Dejax,
Vice-Director
Laboratoire Productique Logistique
Ecole Centrale Paris

ACKNOWLEDGMENTS

The book has eight Chapters, including an introductory Chapter to present the main characteristics of CIM as it is currently implemented in Western countries, six Chapters studying Japanese CIM implementation, and a final Chapter making some comments on future perspectives.

I would like to thank all of those who contributed in different manners to this volume, especially Japanese researchers, engineers and managers, French colleagues P. Dejax, F. Benamar and H. Celikoglu, reviewers, secretaries, and Elsevier.

Victor Sandoval
Laboratoire Productique/Logistique
Ecole Centrale de Paris- France
Fax 33-1-41131436

CHAPTER 1

A GENERAL APPROACH TO CIM

This preliminary Chapter is a short outline of CIM technology, as it is currently viewed in Western countries. Some CIM aspects are described that are relevant to introduce into research concerning this technology in a country such as Japan.

The reader will find here a short summary of the technological and organizational aspects of CIM, but we consider it is important to give these details as a reference point for comparison with the particular route followed by Japan in implementing CIM.

We present in sequence a general introduction to CIM, the technology and organizational background for CIM, the approach to CIM, the creation of a CIM concept, CIM and FCIM concepts, and a short introduction to some aspects of Japanese CIM implementation.

1.1. INTRODUCTION TO CIM

As we know, the acronym CIM appeared in the mid-1980s, and means "Computer Integrated Manufacturing". At that time, computer and telecommunications technologies were experiencing a rapid steady development. Stimulated by this development, many acronyms, referencing to many kinds of productive activities, were created. Most of them contain the word "aided" as a key element; the computer is considered as a tool for aiding people.

However, the acronym CIM is an exception because the word "aided" is replaced by "integration" and people do not speak about *"Computer Aided" but* simply *"Computer Integrated"*. It is, perhaps, one of the first times that a computer is not a tool for "helping" people in their own businesses but a tool to "integrate" a system in its productive activity. So the meaning of this expression is quite different from all others.

Perhaps this is one of the reasons why many people had a rather idealistic view about the possibilities made available to mankind by CIM technology. It was not difficult to meet people who considered computer as an universal instrument able to control a factory, and starting from this point, imagined that by year 2000, factories would be entirely automated. Then factories would be in a similar position an aircraft with an automatic pilot!

But the dream had, fortunately, a short life, and soon the real problems appeared. One of them is what functional structure is needed for CIM. An answer to this question is to design a stratified model, as a pyramid, in which the levels are organized according to an increasing order.

One example of this kind of model is a four-level model that contains the following functions:

- the machine (machine and control)
- the line (control and synchronization of a set of machines)
- the workshop (control of different machining lines under the existing production constraints)
- the factory (determination of production priorities and associated constraints).

Figure 1 depicts this hierarchical structure.

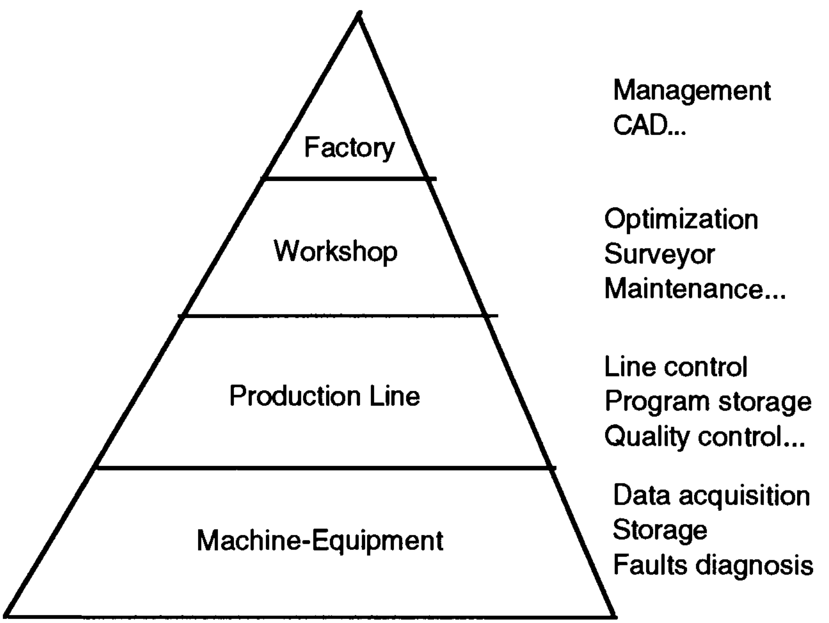


Figure 1. The CIM functional hierarchy

In parallel, manufacturers supply equipment such as programmable automated tools, computers, local networks, etc., a set forming some kind of "material" architecture (or manufacturer's CIM).

Figure 2 depicts this hierarchical architecture of equipment and tools. As we see in this example, there are five levels representing different kinds of tools.

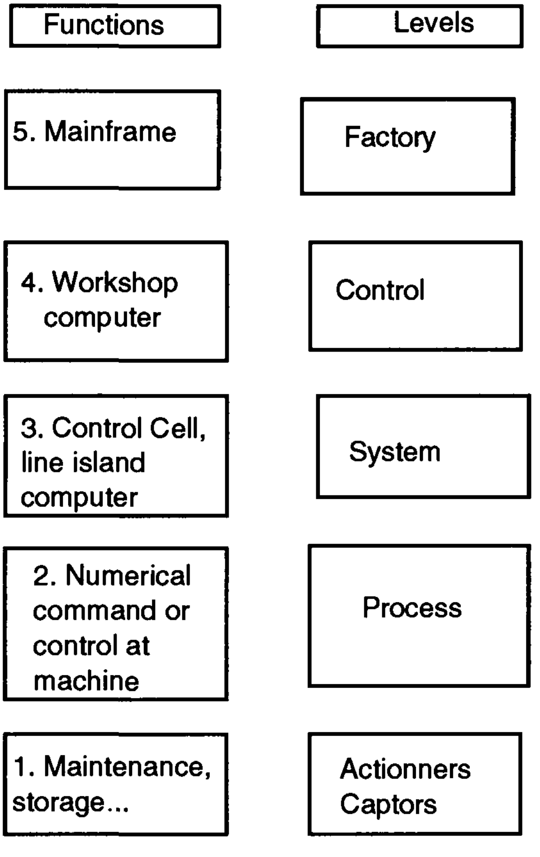


Figure 2. CIM hierarchy in terms of computer devices

Once again, workshop and factory reality is more complex, and cannot, easily, fit in to these hierarchical models. For example, computer activity is localized (artificially) at the top of these models, beside the top management. In this way, it is only possible to extract some principles about the manner in which systems function, and practically impossible to define a strong and consistent base for all CIM modelling. Under these conditions "integration by computer" is in a rather tricky situation.

In these circumstances, perhaps, a broader view considering the historical trend of industrial systems can help us to a better understanding of the meanings of CIM.

Since the industrial revolution, the industrial sector has been divided into extractive industry, transformative industry and machining industry. The common characteristic of all of them is the use of machines and particularly machine tools. These last are defined as machines activated by an energy source and aiming to shape a product by physical and chemical processes. So the machine tools have became an essential component in factory life.

The manner in which machine tools are integrated in to manufacturing industry can be used to distinguish three main periods in the entire history of modern industrial manufacturing. These periods are:

(1) the kinematic

(2) the electrical and electronic, and

(3) the computer.

During the kinematic period and mechanical transmission of movement, the steam engine played the main role. The machine tools such as weaving machines follow a set of complex movements. The coordination is realized by means of gears, cams and other mechanical means.

The electrical, and later the electronic period, saw the manufacturing and the spread of physical, thermal and chemical actuators (motors, resistances, electrodes, etc.), the motorization of handling means (conveyors, manipulators, robots,...) and, finally, the automation of production means. This is a higher degree of integration around the machine tools.

In the present period, the period in which CIM appears, hardware and software development permits a new, highest, integration of machine tools. However, this last integration goes beyond the borders of one machining process. In fact, the integration by computer affects all the activities of an enterprise. So it includes:

- production means (control, management, maintenance)
- material flows (raw materials, products in process or finished, quality)
- management of production (planning, procurement), design (products and means of production)
- aid for commerce, purchasing, marketing, finances...

Finally, in this Introduction we quoted *some assumptions concerning CIM*. Perhaps the most suitable are those made by the IIASA (International Institute for Applied Systems Analysis, Luxenburg, Austria). According to R.U. Ayres (1992) from IIASA, CIM is prompted by four linked hypotheses:

a. New manufacturing possibilities have been created by *rapid technological progress in electronics and telecommunications* (supply side of the economics equation). The rapid development of technology facilitates applications of programmable automation and CIM arises from the confluence of these supply elements (technology) and demand elements (flexibility, quality, variety)

b. in manufacturing processes involving *humans "on-line" errors result in defects*. But the market-place is unforgiving of errors and defects. Because of increasing product complexity, defective designs, components or assemblies are increasingly intolerable. This is one of the major driving forces behind the adoption of robotics and CIM.

In fact, the complexity of manufacturing increases the chances of human errors by the workforce; they cannot work at repetitive tasks (dramatically increasing) without making errors. But computers are inherently more reliable as well as faster than human, at data processing tasks. As the result, the increasing complexity in manufacturing induces an increasing utilization of computers.

c. *consumers want more choice*, which means variety and customization (i.e. less standardization) as well as *reliability and quality*, making the manufacturing process more and more complex and increasing the information-processing load in firms. The rapid introduction of new products (or new models) is becoming an increasingly important competitive strategy, and product life cycles are shortening. Both trends require greater flexibility on the part of the manufacturer, both internally and in dealing with suppliers. Thus more flexibility is needed in manufacturing technology, both to facilitate increased product variety, and to facilitate more rapid product changes.

d. there is a trade-off between *economies of scale and economies of scope* that *result from flexible automation*. If the first, in combination with price elasticities of demand, were a major growth engine for the economy for a long time in the past, it is not yet clear whether economies of scope can provide an equivalent impact at present or even in the near future.

In mass production, there is a direct conflict between minimizing unit cost and facilitating product change. The large fixed investments in dedicated "hard" automation are also a barrier to change, to the extent that the fixed capital is inflexible and not convertible to manufacturing a new or improved version of the product. But this production paradigm is in crisis.

The new paradigm for economic growth is that increasing flexibility progressively reduces the cost differential between customized and standardized products. The smaller this differential, the greater the demand for diversity and, hence, flexibility. However, this process generates savings in both capital and labour

To sum up, the increased programmability of machines improves the availability of better operating data and recognition of unsuspected regularities, suggesting new approaches to systematization and better models. As a consequence, CIM increases the integration of functions and control, generating lower costs. But CIM must permit higher quality and greater flexibility, creating more responsiveness to customer needs and wants. In turn, all this generates an increased demand for customization and shortens production runs.

1.2. TECHNOLOGY AND ORGANIZATION BACKGROUND FOR CIM

We have so far discussed the production demands for CIM. But why is CIM possible now? What are the technological factors conditioning its birth?

CIM is not a new simple technology, but in reality is based on a set of complex merging different technologies. R.U. Ayres (1992) characterizes CIM as the next industrial Revolution because the adoption of computer power in discrete part manufacturing. Computers and "smart" sensors are finally beginning to replace human brains in the factory.

CIM as a functional integration technology (see Section 1.1) also puts the emphasis on quality, flexibility and time saving. But this needs more decentralization of authority, a team approach and networking, says P. Drucker (1990). Concerning the technology background of CIM, R.U. Ayres (1992) distinguishes three categories of technologies: enabling technologies, transition technologies and technologies central to CIM (see Table 1).

In the first category are telecommunications, micro-electronics and computers. Currently, these technologies are applicable far beyond the domain of manufacturing. We must point out the rapid advances of those technologies, in particular during the last ten years. One example of this is telecommunication channel capacity, which has risen considerably during the last ten years.

Table 1
Categories of Technologies for CIM

Enabling Technologies	Transition Technologies	Central Technologies
Telecommunications	NCs	CAD
Micro-electronics	Machine tools	CAM
Computers	Programmable controllers	MRP
	Robots	LAN
		FSM

In the second category appear technologies where micro-electronic and computer devices have been applied over the past thirty years, but on a stand-alone basis. NCs machine tools, programmable controllers and robots are examples in this category.

The third category consists of technologies directly related to computer integration. The major examples of these technologies are computer-aided design and computer-aided manufacturing and design (CAD/CAM), computerized manufacturing resource planning (MRP), local area networks (LAN) and so-called flexible manufacturing systems (FMS)

FMS needs some additional comments. In fact, essentially, FMS represents a key step in the introduction of more advanced manufacturing systems including CIM technology. FMS enables links between programmable automation at the machine level and the integration of computer manufacturing at the information level. FMS is inherently designed for batch production of a family of relatively similar parts. R.U. Ayres (1992) defines FMS, based on a conventional view, as a set of CNC machines controlled by a single (mini) computer and linked by an automated materials-handling system.

This definition is important, because it *distinguishes from the flexible manufacturing cell (FMC)*. But FMS designed and built in the late 1960s and early 1970s were costly, and the benefits less than anticipated. In addition, a number of failures show the unrealistic expectations. However, the biggest failure seems to be the human dimension.

For example, workers may be familiar with manually-operated machines, controlled machines or even stand-alone CNCs, but they unable to operate FMS correctly without non-trivial amounts of special training, and firms are unable to anticipate or allow all this. FMS is thus a good example of technical and organizational implications, and this may be expanded to the more complicated field of CIM.

On the other hand, CIM is more than a simple technical problem, because the relations between organization, technologies and data processing must be considered as a single entity, following the reasoning of H. Baumgartner, K. Knischevski and H.Wieding (1991). For example, management indicates the long-term objectives, then a simplification of organization is needed and the new technologies must be integrated into the existing production structure. Thus CIM is a specific strategy for companies which is also closely linked with the long-term strategy.

From this point, CIM should be a specific concept for the company. In other words, as some authors such as H. Baumgartner, K. Knischevski and H.Wieding (1991) assume, it is not possible to reach a standard concept for CIM (see also Section 1.1). In reality, there are many factors in favour of a specific CIM concept for each company. Among these factors we can point out:

- market demands (products, quality, delays..);
- technical and economic objectives of the company (reduction of manufacturing costs, improvement of material flow, information flow..)

- degree of computerization and networking (type of hardware and software, network implementation, size of network, distributed architectures...)
- factors specific to the manufacturing conditions (formation, personnel, type of machines, type of technologies, production structure, size of company...).

Figure 3 gives an example of a CIM global view, including technical and organizational aspects. As we see, CIM is more complicated than a simple technical problem and the number of elements involved becomes quite important. At the bottom of this figure there are many techniques (CAD, CAM, CAP, CAQ, FMS, FA, computation, communication, databases, maintenance...) and their integration. This is the production or shopfloor level, in a wide sense.

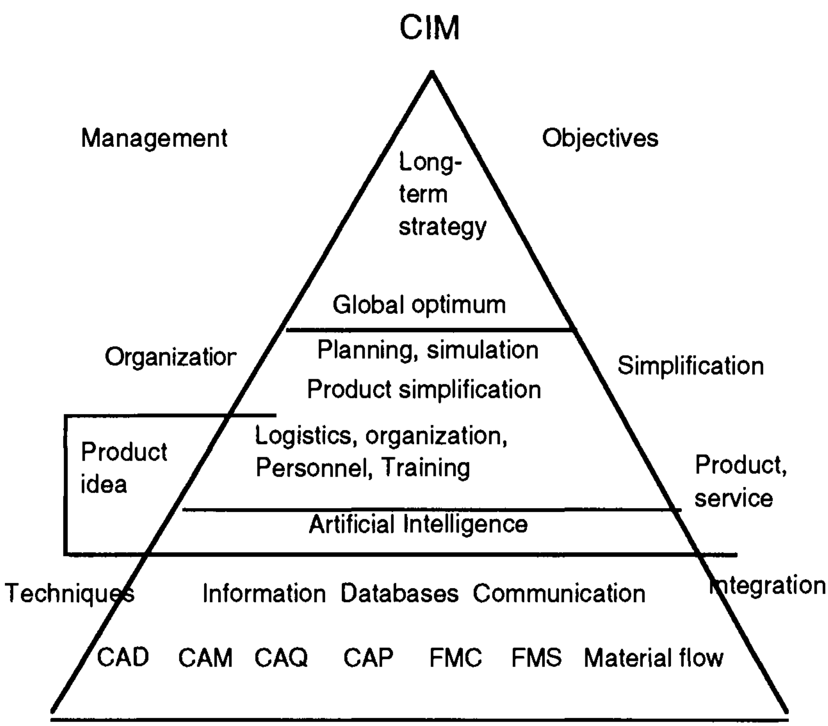


Figure 3. CIM : technical and organizational aspects

In the middle of the figure, we can see a continuum flow going from product idea to the finished product or service. This flow includes logistics, organization, personnel and training as resources involved for creating the appropriate outputs.

Finally, the higher level of this figure represents product simplification, planning and simulation that are undertaken by the organization, and simplification. The top is linked to the objectives and management (long-term objectives). CIM is at the top of this figure embracing all the above components.

1.3. IMPLEMENTING CIM

If CIM is not a simple technology or a simple new organizational approach to production systems, one important question is how to go to it, or more precisely, how to implement CIM? In answer to this question, we try in this section to advance some ideas.

First of all, the existence of a CIM project is absolutely necessary. This project must be closely related to the CIM concept (we study the CIM concept in Section 1.4). As CIM must help to improve the position of a company relative to their competitors, the CIM project must integrate all necessary criteria for reaching this general goal.

For example, from the beginning, this project may take into account these criteria as follows:

- maximum number of tasks
- maximum number of functions
- maximum duration of the project
- most difficult task to integrate
- closer solidarity between information technologies and manufacturing technologies
- largest strategic scope
- maximum money investment
- largest organizational scope

As we see, the importance of these criteria demands a strong participation of the personnel at all levels. But unfortunately in Western countries, this participation often involves only the top-level management. This situation is called top-down strategy. However, a successful CIM implementation, as we see in the next Section, requires as clear as possible a CIM concept in order to determine better planning and its corresponding scheduling.

However, whatever project, concept or planning the company has, it is necessary to think seriously about the role of CIM users, who become an essential issue for any strategy to be adopted. One possible CIM user's strategy is represented in figure 4.

According to this top down strategy (management business), there are five descending steps, each linking internal users to the external users and also to the CIM collaborators. These steps are:

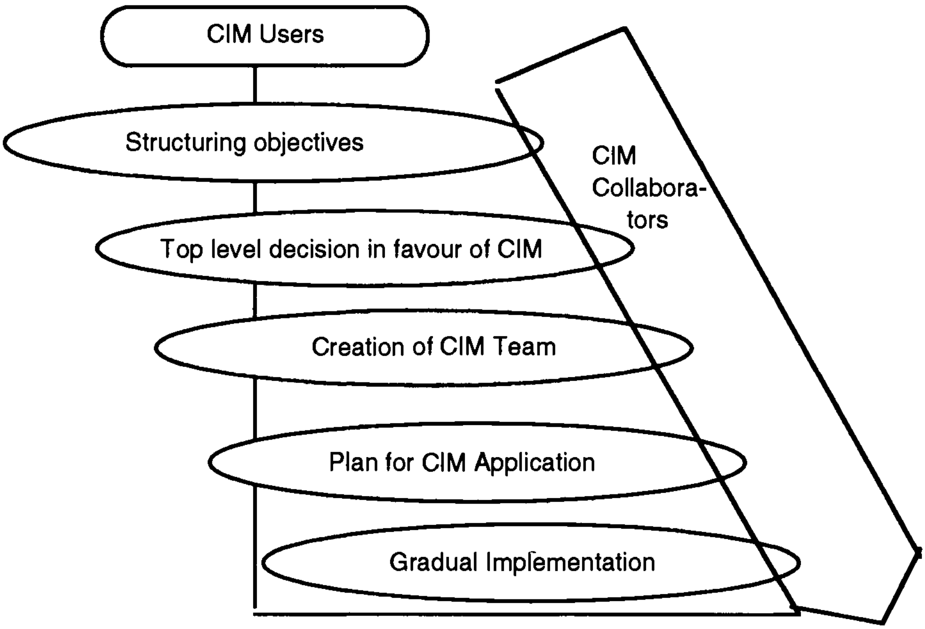


Figure 4. User's strategy

- structuring the objectives
- top level company decision in favour of CIM implementation
- creation (at the top level) of a special CIM team
- set up an application plan for CIM
- translation of the project step by step into reality.

So to implement CIM technology, the following main points can be outlined

a. Strategy for CIM, based on organization, partners and concept.

CIM implementation is characterized by a sequential decision process that should consider technical assistance, organizational modifications, manufacturing techniques configuration, data processing technology needed, personnel qualification and acceptance of CIM by personnel.

For example: the reduction of time cycle and development, including all steps of production (increase productivity), needs a decentralization of activities previously coordinated by central authority.

b. Organization for CIM.

This is a special CIM team for leading CIM business in the company. This team deals with problems such as structuring the objectives, the definition of necessary guidelines or the translation of CIM concepts into reality. In reality, success of the CIM project is principally dependent on the capacities of the CIM team to overcome complex relations and to build appropriate representation models close to the CIM strategy.

c. Collaboration with partners.

This includes the internal collaboration and the outside consultants, advisers, and suppliers of CIM components. In CIM implementation every one has a specific task to be accomplished and the CIM team must monitor the basic steps.

1.4. CREATING A CIM CONCEPT

To create a CIM concept and transform it into reality is one of the most important challenges in CIM implementation, whatever the company involved. Normally, the analysis of company strategy is an essential input in the determination of its own CIM concept. This concept must be in tune with the main CIM goal, which is to reach an economic technological optimum.

The conceptual approach requires, for example, an adequate integration of certain vertical systems or a careful study of CIM modules actually offered by CIM suppliers. But before buying or installing a CIM module, one particular point must be considered: CIM is not a simple installation of a new data processing system. CIM integrates different functions and departments previously separated. In addition, the CIM concept must be a strong support for future CIM applications and development.

But if it is extremely difficult to determine a concept available everywhere, at least the main characteristics of products must be incorporated in the CIM concept, whatever the size of project being implemented by the company. One example of this is the study of product characteristics such as life cycle, quality, complexity, cost of raw materials or stock value, that must be considered as a mandatory input in every CIM concept study.

The applications of the CIM concept can take different variants, as in the following examples.

a. CIM concept for computer aided integration concerning only one process or manufacturing conveyor.

In this case, the CIM goal is to integrate the information technology and organization starting from design, including different preparation phases, and finishing with product manufacturing itself. This is a case of integration of a single process, but the application is only possible for a component, and thus quite limited.

b. CIM concept for manufacturing-oriented systems.

Examples of this application arise in the final assembly of motor vehicle or in component manufacturing (case of vehicle engines). To apply this concept, it is necessary to consider factors such as the types of process, organization of work conditions, technology, actual automation structure, principal method of manufacturing, time cycle, range of product, product structure, and types of planning or procurement system.

c. CIM concept for large applications.

In this case the overall manufacturing, planning and product development functions of the company must be concerned in the CIM concept. This is the so-called global integration, which corresponds to the higher level of CIM concept application. In this particular situation, we can add to the factors involved in the last cases other factors such as revenues, employees, organization structure, localization, and know-how in automation or the parts to be involved in the CIM Project.

More generally, the CIM concept definition is related to the structure of the objectives, the CIM planning and the CIM realization.

i. The structure of the objectives begins with the determination of those, in particular, incorporating consideration of the actual situation, the medium and the long-term objectives, the existing possibilities, and the responsibilities for execution of the objectives. Then is needed, a problem analysis starting from the objectives and actual situation of the company with identification of defects, failures, nodal points, crucial points, strong and weak points, and determination of the real situation, the necessary profile starting from the weakest points, and the need for harmonizing with the priority objectives of the company and its achievable objectives

ii. Planning CIM implementation. The objectives must help the realization of the CIM concept, based on a broad view of the far future. In this case, the planning methodology must consider first an ideal situation, and after this a real situation. This methodology must consider, in particular, the crucial point in integration and in zones of difficulty (function structure, organization of data processing, communication) and then the general planning of manufacturing (sequence, material flow, information flow).

Figure 5 gives an overview of the situation described in point s i and ii.

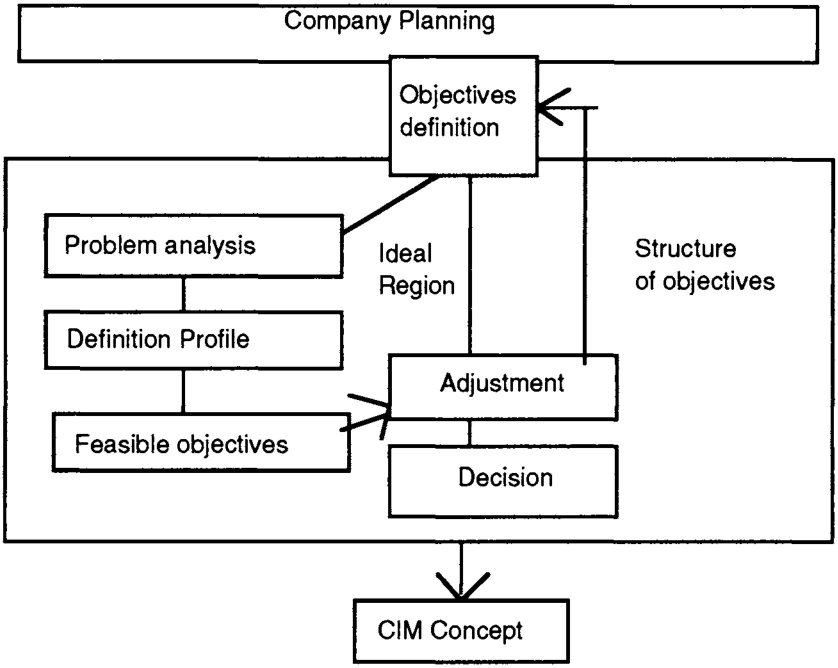


Figure 5. Structure of Objectives

To reach these objectives (corresponding to the concept of manufacturing integration), the planning may be reduced to plans of function coordinating, of organization structure, system design and of practical application. Functional diagrams according to the project phases and tasks concerned lead to the scheduling of the CIM concept.

iii. realization or practical application of the CIM concept. The main purpose is to create a space for integration. For doing it, one way is to begin by integrating the islands, then create networks of islands, replace the networks by functional fields (vertical integration) and by manufacturing fields (horizontal integration); then integrate the production field (material arriving, storage, manufacturing parts, assembly, delivery package, delivery) and functional CIM fields (CAD, CAM, CAQ, MRP, PIC, CAP).

So we have a double integration: a vertical integration and a horizontal integration as represented in figure 6. According to this figure, horizontal integration concerns at every step only one separate level in the hierarchy. For example, CAD contributes to integration of product design and design of the means to manufacture those products, when means depend on the product design, but the implication of computer aiding is different for each. Another example is CAM, which integrates at the shopfloor level.

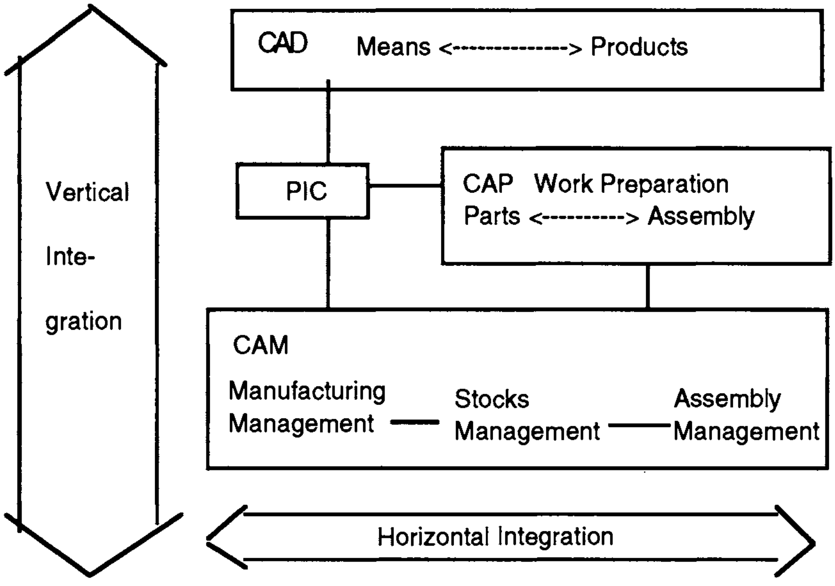


Figure 6. Vertical and Horizontal Integration

Vertical integration look at the top-down or bottom- up dimension. Then it integrates, for example, CAD, PIC and CAM, the most common being CAD/CAM. Both integrations use data exchange between management, production and leading production programmes. But data need to be more and more standardized for exchange in order to improve the overall process.

1.5. INTEGRATION PROCESSES AND TECHNOLOGIES

As we see, the integration process is based on different technologies such as CAD, CAM, MRP, PIC, or CAP. The next paragraphs give a brief description of some of these technologies.

Normally, CAD is one of the most advanced technologies in western countries because of the rapid growth, diffusion and implementation of micro-computers and distributed network communication systems. CAD deals with product design and means of production development, itself normally related to the product design development. So CAD prepares a computerized design based on product specifications. Using simulation methods, CAD facilitates estimation of the materials input for manufacturing goods.

In some cases, CAD is accompanied by CAE (Computer Aided Engineering), which can be considered as some kind of CAD for higher knowledge applications to solve the more complicated problems.

Conversely to CAD technology, CAM is a technology enabling promotion and management by computer of the production means and the direct manufacturing process. It includes the management of installations, production means, handling equipment and transport, and storage systems. In this way CAM integrates management of direct manufacturing process of parts, stocks levels and assembly lines.

MRP (Material Resource Planning or MRP2) is in an intermediate position compared with CAD and CAM. For example, MRP is linked to CAM when it is involved in the preparation of the manufacturing parts or of the assembly parts. Indeed, MRP organizes the planning, management and monitoring of different production phases, from production (supply preparation) to delivery, measuring quantities, delays and capacities.

Both CAM and MRP are linked to Production Planning, which is another important concept. We must distinguish the planning concept and the planning CIM concept. In the first case, the planning organization structure must consider two aspects: the nature of the problems, and the time cycles corresponding to the material flow path. Production planning includes the production programme, quantitative planning, management of materials, management of manufacturing, orders launching, checking orders and inventories.

In the second case, the planning CIM concept is crucial for the designing of computer systems and different procedures. Then it is necessary to create a plan, in the sense of a computer concept approach, over a long period. With this determination of global structure of data processing and automation, it is possible to describe other elements such as interfaces.

In Europe (France, for example), Computer-Aided Planning (CAP) is also used. The scope of CAP is narrower than the "planning" one. In fact, CAP is based on the results of CAD and deals with worker's planning, management of the work process, assembly planning, control planning, resource planning, simulation of the manufacturing process and assembly, and standardization and control.

Production methods are another interesting factor in manufacturing industry. In general, these methods may be classified into "pushing" and "pulling". In pushing, the supply side is the more important; whereas, in a pulling system, the more important is the demand side. The classical example of a pulling system is the Kanban principle of the Toyota Production System presented by S. Shingo (1989) and the Just in Time (JIT) production approach. The two systems may be combined.

Some readers may ask for a more extensive development of Kanban and JIT in our study of Japanese CIM, and they will be a little disappointed. This needs to a brief explanation. We think there are many misunderstandings in the approaches to both Kanban and JIT found in the literature. In our view, Kanban and JIT are simple parts of a more complex system (for more details, See Chapter 4).

Moreover, Kanban is not a universal tool, generalized to every shopfloor in Japan. For example, for similar purposes, Hitachi and Nissan Motors use other systems. Hitachi uses a method called OCR and Nissan Motors the Action Plat Method, implemented since 1989.

JIT is more a philosophy concerning the priority for the demand side in the market equation than a technique. Kanban helps JIT to perform its aims in better conditions. In addition, JIT is not a new idea but an old one. For example, a little production (of furniture and textiles) in a 17th Century in Western Europe was demand-oriented. What is actually new is the generalization of this idea to the whole economy. For this reason we do not study these systems in detail. The reader will understand our position in these pages.

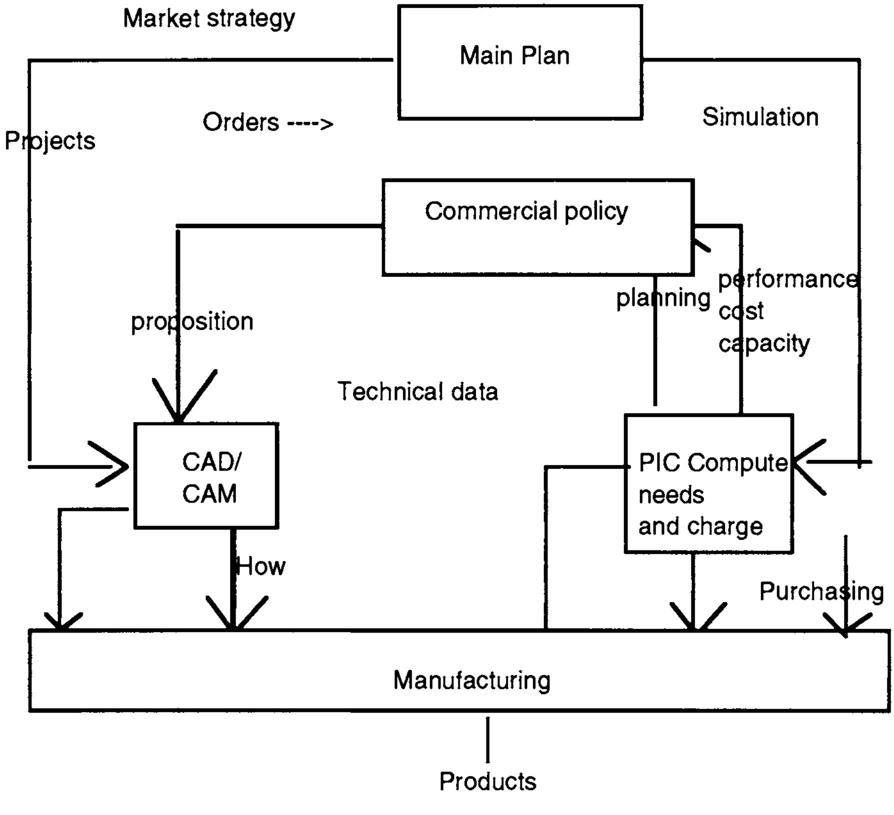


Figure 7 CIM and the architecture of information

One final comment concerns information technology and the CIM concept. IT is a main tool in advanced manufacturing systems. Without it they cannot reach the highest degree of performance. Among the themes to be studied in the CIM concept definition we have the basic structure of data processing which deals with data processing, data maintenance and data communication.

CIM needs a decentralized and reoriented hierarchy of functions, and not a simple reproduction of the existing functional hierarchy (see Section 1.1), as well as a new definition of data management in decentralized storage environments. Finally, there is data transmission which is related to the networks, protocols and computer architecture.

Figure 7 represents an example of relations between CIM and the architecture of information. But this architecture gives only a partial view of the question: it is lacking the physical flow. One key issue is the study of relations between physical and information flows. We find this problem in many situations in Japanese CIM. It is studied in particular in the case of Toyota ME-NET.

From the above development, we can now advance a more precise definition of the CIM concept. For such a definition we simply follow J.B. Waldner (1990). According to this author, the CIM concept concerns a totally automated manufacturing system in which all functions of a company (such as commercial, production, accounting or management) are integrated and controlled by computer systems.

Under these assumptions, every user must share a data base and this increases the reactivity (flexibility) and the effectiveness in responding to market demands. As we shall see, Japanese CIM reinforcing this principle shows successful achievement for CIM implementation.

1.6. CIM AND FCIM

This Section completes the above study with a short presentation of the latest development of CIM in America. This development is necessary because both the principal technological and economic competitor of Japan is America.

In America, CIM is ever more closely linked to FCIM (Flexible Computer Integrated Manufacturing). To present the concept of FCIM, we follow A. Wilson (1993) who compiled an article from several FCIM Focus articles. FCIM Focus is a quarterly bulletin for the Flexible Computer Integrated Manufacturing community in the United States.

The concept of FCIM appears in this country in the mid-1980s. It is closely related to the US DoD CALS initiative. CALS (Computer Acquisition-aided Logistic Support) was launched by DoD (Department of Defense) in 1986. For this reason the first implementations of FCIM were prepared by industry tied to the military activity. Indeed, the Department of Defense Logistics Commanders approved the FCIM Charter on 4 June 1991

They define FCIM as the integration of equipment, software, communications, human resources and business practices within an enterprise for the rapid manufacture, repair, and deliver of the items on demand, with continuous improvements in the process. (Quoted by A. Wilson, 1993).

So FCIM is a standard process for acquiring, scheduling, allocating resources, manufacturing, packaging, and distributing and repairing parts. The FCIM process, which capitalizes on modern software and hardware in an effort to produce a variety of similar products smoothly and rapidly, is designed to reduce the lead times, increase turnaround time, and decrease cost.

FCIM is a *full-cycle process which begins with identifying a part need and ends with delivery of the parts to the customer*. Its objective is simple: quality parts at a low cost in a timely manner. The customer is happy, and the manufacturer keeps its competitive edge in a crowded, competitive business environment.

So the goal of the FCIM is a continuous process improvement. In order to achieve this goal, all members of an enterprise (employer, employees, management, vendors and suppliers) must work together to eliminate policies, procedures, and processes, that do not maximize the turnaround time for the production and delivery of a part to the customer.

By implementing the FCIM concept, an enterprise can maintain its readiness within reduced budgets, capitalize on its existing resources, and reduce duplicate efforts by uniting with their vendor bases to form joint partnerships. Among its characteristics, FCIM includes the following:

(1) uses existing systems and capabilities
(2) is modular
(3) requires cultural changes
(4) is technology subject to risk

We comment on each of these points below.

(1) FCIM builds on existing systems and capabilities.

FCIM builds on existing systems and capabilities within an organization to shorten production lead times. From this point of view, every enterprise can begin the implementation of FCIM concepts. According to A. Wilson (1993) there is no need to wait until special high tech equipment can be purchased. Each facility can begin horizontal integration using its own current technology. We insist on one point: in the FCIM view the principal interest is the horizontal and not the vertical integration (for integration, See sections 1.1 and 1.4).

(2) FCIM is modular.

This means that the steps in the existing process may be automated or manual, but each step must be examined to discover more efficient and effective operating methods. FCIM is dynamic, developmental, and rapidly growing. New methods are evolving daily.

(3) FCIM requires a cultural change.

This characteristic concerns the people involved in FCIM implementation. Without a people contribution, nothing is possible in the FCIM area. In fact, people must be willing to accept new ways of thinking and new approaches to working. They must develop new time frames, establish new interfaces, and employ new skills. The intent of FCIM is to create a new environment for manufacturing products.

(4) There is a risk involved.

As in every new technology challenge there is some risk in FCIM. When any barrier to achieving this new environment is identified, it must be eliminated, whether it is due to policy, economic, or technology constraints. As a critical technology, FCIM embodies the future of the American industrial progress and must make it more competitive.

The DoD FCIM initiative emphasizes a strategy to achieve continuous improvement processes for the 21st century. The initiative begins with experiments within the Process Validation Enterprise (PVE). The PVE is an experimental environment which includes the operational functions within DoD required to acquire selected long lead-time and high-cost items from placing an order to delivery.

Seven manufacturing sites have been selected as production facilities within the experiments. These manufacturing sites, with their item or inventory managers and engineering activities, represent each of the services. The mechanics of measuring the present process has begun. After initial measurements (baselining), the iterative process of continuous improvement of both processes and technology begins.

Figure 8 depicts the PVE structure for this "joint" venture.

This partnership makes good business sense and facilitates the JLC objective of capitalizing on resources and eliminating duplicate efforts. In an ever-changing world economy with a dynamic environment of budget constraints, the DoD needs to question, examine, and radically change its most basic processes The FCIM initiative through the PVE approach is a smart path to success and achieving Quality in action.

According to Lorna Step (A. Wilson, 1993), director of the Joint Center for FCIM (JC-FCIM) which publishes FCIM Focus, understanding the current processes is the key to improvement, and the first step towards the goal. In fact, before investing in new technology, the production baseline should be measured using the PVE model.

Baselining tools, such as process modelling and simulation, are needed to document the processes, identify barriers, evaluate proposed solutions, and measure new process results as they are installed. This baseline measurement must be accomplished to empower process managers to create an environment for continuous improvement.

In fact, there are *three major thrusts in implementing* FCIM:

a. There must be a shift from decisions based on unit cost to viewing the total time and cost

b. Money must be saved through reducing logistics costs required to meet readiness goals

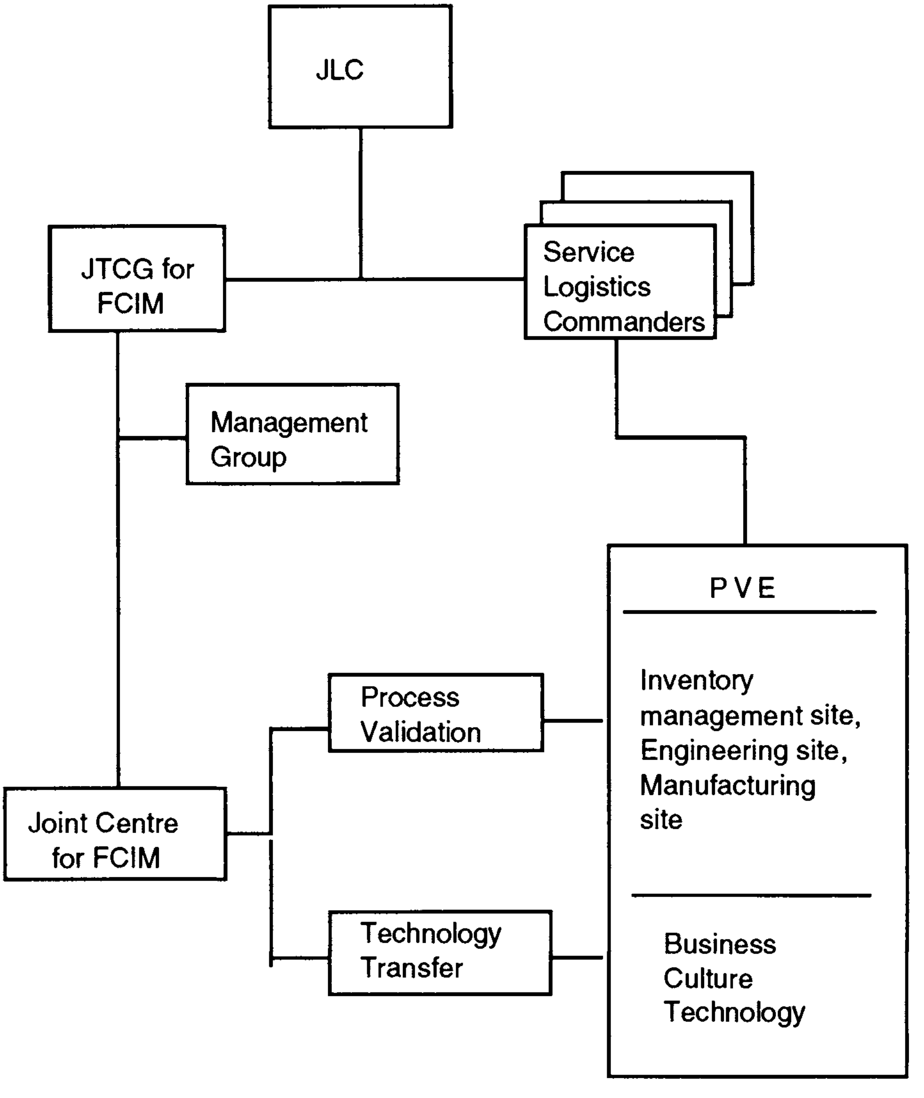


Figure 8. Joint Technical Coordinating Group for FCIM and the PVE

c. A philosophy must be established allowing users to spur on advanced technology development efforts through an implementation oriented approach. This will lead to technology solutions that are linked to users' needs.

Shorter production cycles also reduce risk and uncertainty. Thus a 300-day cycle demand is vastly more difficult to forecast than one of 30-40 days. In the latter case, the predictions would be more accurate and usage requirements could be defined. Inventories could be significantly reduced, with an accompanying reduction in carrying costs, shelf life spoilage, and obsolescence.

FCIM and RAMP.

The development of FCIM impacts on some current research programmes and, now, they are evolving to an FCIM environment. Some of these programmes began a long time ago, for example, the RAMP (Rapid Acquisition of Manufactured Parts) programme. Now RAMP is considered as an FCIM technology programme.

In 1986, the Naval Supply Systems Command realized that in order to produce repair and replacement parts for weapon systems in a more competitive manner they had to improve the process. According to the CALS-EXPO (1992), the goal was to use advanced computer integrated manufacturing technology to reduce lead time in manufacturing small batches of parts.

The original objectives were, amongst others,

- to manufacture difficult-to-obtain parts essential for increased operational readiness;
- to produce parts on demand in a responsive, cost effective and automated manner; and
- to transfer this new technology DoD-wide and to US industry.

These objectives formed the initial RAMP programme for mechanical parts as well as printed wiring assemblies.

The initial design goals for RAMP included:

- to integrate completely planning, engineering, quality control and manufacturing;
- to manufacture a high volume, high mix of parts concurrently;
- to accept an electronic input (i.e: PDES -Product Data Exchange using STEP- ISF); and
- to manufacture parts on demand within 30 days (average) of receipt of order.

The South Carolina Research Authority (SCRA) was contracted to make RAMP a reality. Following this, SCRA formed a team with Battelle, Grumman Data Systems; Arthur D. Little and Systems Engineering Associates Company in order to facilitate design and development of the Programme. The result of this work has not only met the initial objectives but also incorporates a modular, site-adaptable architecture; PDES-compatibility; and adaptability to repair operations.

Since the inception of the RAMP programme, there have been several successful tests and demonstrations of software at the RAMP Test and Integration Facility (RTIF) in Charleston, South Carolina. But success cannot be measured only by test facility results. The RAMP programme can claim success in the deployment of RAMP FCIM technology to several manufacturing facilities.

RAMP and STEP.

Let us just underline one additional point. RAMP FCIM technology is evolving in a framework of many other technologies. One of the common traits of these is the need for exchanging information between dissimilar equipment (hardware) and software. For solving this problem, one way is the development of the PDES standard. STEP (Standard Technical Exchange Protocol) goes beyond computerized geometry (the case of actual IGES and CGM).

STEP is a completely computer interpretable information model for describing any product. It supplies information about ease of maintenance, life cycle cost, assembly data, annotations, bills of material, features and solid geometry. So RAMP is using the emerging STEP standard. RAMP is demonstrating how STEP can communicate complete, unambiguous, computer interpretable product data for direct access by advanced manufacturing applications.

This means RAMP is testing STEP data models for dissimilar products. This early test effort is identifying errors and omissions in the STEP standard that are being corrected by the STEP resource model committee. For example, RAMP revealed the inability to define tolerances between the attributes of features.

1.7. INTRODUCTION TO THE JAPANESE CIM

As we see, there is no one standard CIM available everywhere and for ever. In practice there are many applications of CIM technology according to different factors such as economics sectors, nature of manufacturing process or size and location of production activity. The Japanese experience in implementing CIM is not an exception to these assumptions. Nevertheless, Japanese CIM has some interesting particularities that need a more detailed development.

Some peculiarities.

Japanese CIM, and this is one of our main issues, is one of the most important factors in creating more competitive conditions for the Japanese economy. This is a critical point to all other countries when they enter in a world characterized by an open and global competitiveness. CIM becomes a decisive factor enabling Japan to reach one of the top positions in the world economy.

On the other hand, Japanese CIM may be clearest example of how to create a flexible manufacturing system matching, at a highly effective level, consumer demand and manufacturing supply. This is less a "secret weapon" than a problem asking for an accurate inquiry. The problem for us it to know how the Japanese are implementing with success CIM technology and what are their own characteristics.

Thus this is the starting point of our inquiry about CIM in Japan. Through out this inquiry, we seek to identify what are the peculiarities, what is the role of CIM, what are the main characteristics and performances, and its contribution to the economy of companies (and of the Japan economy). Also, we are interested in questions about the future of CIM, and how CIM must be considered as an input in the evolving technology towards more and more advanced productive systems, some of them already foreshadowed.

This enquiry is not just a study supported by the existing literature (which is abundant in Japanese!), but a free searching, by open discussion and confrontation of ideas, with many Japanese CIM managers, including some wellknown specialists in this area in Japan. Also, this inquiry is completed by staying at Technology Institutes and visits of advanced factories. The purpose always remains the same: to have a more detailed picture of the CIM reality in Japan. Obviously, this kind of inquiry covers the more advanced sectors, and different sectors. This book results from this inquiry.

The Companies.

Among all companies, we were particularly interested in visiting and discussions with companies such as Hitachi Ltd., Mitsubishi Electric Corporation (MELCO), Toyota Motor Corporation (TMC), Toshiba Corporation, Tokyo Ryutsuku Center, Nissan Motors, Shimizu Corporation, and Tokyo Engineering Corporation.

Every one of these companies has some particular aspect of CIM that is interesting for readers and for building a better idea about Japanese CIM.

For example, CIM in Hitachi provides in outline a general approach to CIM, the scope of CIM and at the same time a study of the particular characteristics of Hitachi's CIM. For instance, we can point out two aspects: the Hitachi integrated planning methods for strategic information systems and the study of the Assembly Evaluation Method (AEM) and its applications to the automatic assembly line for VTR (Video Tape Record) mechanisms and in electrical appliance production (see Chapter 2)

In the MELCO case, we point out the relation between CIM and concurrent engineering that seems to be of particular importance in the CIM approach of this company. But the concept of CIM system, models and subsystems for CIM and production planning systems are also important. All of these elements contribute to create what is called a customer-oriented CIM, an application which is studied in the case of the Nakatsugawa Factory (NCIM) for ventilators production, in moulded-case circuit breakers and in the implementation of CIM/FA strategy (see Chapter 3).

The Toyota case is quite different. It is centred around mechatronic principles, a science created and developed by the Japanese. In fact, we think that the kernel of Toyota CIM is the so called MEchatronic NETwork (ME-NET). As we see, in Toyota CIM ME-NET is more important than kanban. But in reality kanban, as a part of the Toyota Production System, is related to ME-NET by mean of information technology (IT).

This study shows the need for exploring all the possibilities and, principally, the importance of IT in CIM implementation in detail and, first of all, at the workshop level of the factory (see Chapter 4).

According to the main assumption of the present Chapter, conceptual views for CIM are fundamental. So we choose three different companies in order to study this question in the Japanese CIM experience.

The first case concerns Toshiba Corporation, in which the Ome Works Factory is studied. It is perhaps one of the most impressive factories for use of more advanced technology in the manufacturing process, that we ever saw. This case is the OT-CIM (Ome Toshiba CIM). The conceptual approach is centred here around the IT underlying, principally, Steps and campaigns for OT-CIM, Database and networks. The second case, the Omron Corporation study, is concentrated on the improvement information function for CIM and the conceptual approach, step by step. Finally the third case concerns the Omron Corporation.

Another important point needs to be underlined. Japanese CIM is always taken in an historical perspective, with the use of information technology everywhere (mixing computer power and local and wide area networks profiting fully from open system interconnection technologies), the integration of bottom up and top down strategy (highly qualified CIM teams for management and shopfloor workers making CIM are priorities), the incorporation of internal and external users at the same level, a wide variety of applications and a clear CIM concept.

Another crucial point is the importance given to sales activity. In all companies it is, practically, at the same level accorded to manufacturing or database management or management of the computer centre! Sales are fundamental in the Japanese view. Sales are considered, simultaneously, as an input for the accounting system and for the manufacturing system.

In fact, the sales service represents the interface between company and customer or market. The study of customer demands prepares supply, and verifies and guides orders. In many cases, the study of market demands facilitates the development or modifications of products.

The role played by sales in CIM implementation is, perhaps, one of the most significant differences between Japanese CIM and Western CIM.

CHAPTER 2

CIM IN HITACHI

INTRODUCTION

Hitachi has a volume business estimated at 1.34 billion dollars (for the fiscal year 1990). Among the activities, this company manufactures a set of products for factory automation systems. This set of products includes:

- computers (business computers, process computers, sequence controllers, desktop computers, DDC computers, CAD/CAM, automatic drafting equipment, auto-digitizers;
- robots (process robots, welding robots, painting robots, material-handling robots, special robots);
- automatic machinery (laser process machines, wire cutters, packing equipment, automatic assembly machines, NC machine tools, plasma cutting machines, forming machines);
- inspection equipment (testers, X-ray nondestructive inspection devices, ultrasonic flaw detectors, acoustic emission equipment, parts mounting devices),
- transport (automated storage and retrieval systems, cranes, automatic carriers, hoists, transport equipment, pneumatic conveyors, lift and escalators, palletizers, depalletizers);
- instrumentation (instrumentation systems, analysis instruments, industrial measuring instruments);
- semiconductor production (dry etching machines, clean rooms, printed circuit board drilling machines, testers);
- others (inkjet printers, voice input systems, radio (mobile) telephones, closed-circuit television).

As we see, Hitachi has a wide range of production. In addition this company, like most Japanese companies, develops relevant research programmes mostly corresponding to their different areas of business activity. Among the research programmes, an important place is taken by fundamental and applied research concerning new information technologies. It is in this framework that we find the research about CIM technology.

Our interest in the research and application of CIM technology in Hitachi began when we were discussing EDI (Electronic Data Interchange) and telecommunications networks with Hitachi managers and researchers involved in this area. Then we met CIM managers and researchers, and visited the Hitachi CIM Technical Center at Narashino, near Tokyo. This Chapter results from these meetings, discussions and observations, which were among the most successful in our research on CIM in Japan.

The starting point of this chapter is an analysis of the general view of the Hitachi Corporation about CIM. Then the study is organized around the definition and scope of CIM, and an outline of Hitachi' CIM. This show us the place of CIM technology and the importance that it has in the overall activity of this company.

After this preliminary approach, we study one of the main tools in CIM realization, which is the Hitachi integrated planning method for strategic information systems. Then there is an outline of AEM (Assembly Evaluation Method) which must be thought of as a particular Hitachi contribution to CIM technology. Finally, we propose some examples of CIM implementation. These examples concern the automatic assembly line for VTR mechanisms and electrical appliance production.

2.1. A GENERAL HITACHI APPROACH OF CIM

In this section we introduce the Hitachi CIM approach. For this purpose, the discussion is turns around two principal questions: the definition of CIM, and the factors contributing to its promotion.

What is CIM?

CIM is an integrated information strategy system that connects all business activities, such as acceptance of an order, and the design, manufacture, inspection and delivery of a product, employing computers which use integrated database and communicate with one another through an information network, thus achieving high efficiency and flexibility. This definition is given in Hitachi document CIM 21 (1992).

The above definition is very instructive for our purpose and for understanding the scope of CIM not only in the Hitachi case but also in the general Japanese situation. We can summarize the main elements of this definition as follows:

a. "Integrated information strategy system".This means that information plays a key role as input for a strategy system. The whole system is integrated by information.

b. "All business activities", which means CIM concerns all activities without exception of any nature. Perhaps, this is one of the most ambitious meanings of the definition.

c. "Use database and local telecommunications networks". These elements constitute the technology kernel of CIM in this case.

d. "Efficiency and flexibility". This strategy system must achieve efficiency and be flexible.

The above discussion shows that for Hitachi, CIM has a significance far wider than the plain meaning of that simple isolated acronym. In fact, as we will see in all other cases studied in this book, there is a process of recreation or enrichment of the original definition. This process is supported by the most advanced technology operating in this company.

Thus Hitachi has combined a large number of FA (Factory Automation) systems, advanced computer technologies and information processing technology to generate a currently unique CIM system. Hitachi offers a model configured from a strategic perspective suggesting what an ideal factory and production systems of the 21st century should be, and how it should manufacture in that situation.

Why is Hitachi promoting CIM development?

The factors contributing to build up a CIM system are the linking to market needs, the technical environment and the business set-up objectives. Like many other companies in Japan and around the world, Hitachi is confronted by such problems during the recent period.

First, we point out that the market needs are to enrich product variety, enhance product quality and performance and shorten the product development cycle.

But other factors are influencing the market needs, according to the Hitachi view. Among them there are the following:

- changes in expenditures patterns (selection by wiser consumers, increasing longevity/number of working housewives, labour shortages and foreign workers)
- international changes (free trade and capital circulation, Yen appreciation, trade conflicts, rushing of New Industrialized Countries, especially in South Asia)
- changes in values (power of new generation, improvement of quality of human life, reconsideration of Japanese style of management)

Remark.

In general, these factors affect the behaviour of all companies, but Hitachi has decided to pay more especial attention to them before defining any policy or strategy in the technology area.

The technical factors are, essentially, represented by the progress in information and data processing (Improvement of information technologies

Networks - Local Area Network (LAN)/ Wide Area Network (WAN)), the progress in electronic technology (high performance, high reliability...), the standardization of telecommunications and the privatization of telecommunications. In particular, these last factors creates better conditions for using the services.

These factors create accelerating change in organizations and a new strongly competitive environment. Under these conditions, organizations must develop new tactics in order to survive. Self-induced change in a enterprise due to management innovation is then a formidable challenge. In this framework, one fundamental question is to define, as clearly as possible, new business objectives.

Table 1
Comparing CIM objectives and performances

A. Objectives of CIM
to improve high-value-added products more quickly
to improve product quality
to increase business speed
to establish customer/market-oriented organization
to establish flexible production systems
to shorten working hours
to improve working environments
B. Assumed performances of CIM
to shorten the lead-time
to improve productivity
to speed up management of order-to-production information
to improve/maintain product quality
to integrate OA/FA equipment
to integrate FA and SIS
to improve production flexibility for customer responsiveness

These factors leave companies not in an emergency situation but in a delicate position, that needs innovation and the creation of strategies better adapted far looking at the future. Under these conditions, Hitachi has set up many objectives in order to reach a new competitive position. Table 1 (A) presents summarizes these objectives. But the definition of objectives is not sufficient on its own, so the company decided to build up a CIM system. Thus the above objectives are associated with a set of performances that company hopes to reach with CIM.

We add just one comment about the new acronyms quoted above.

FA is an expression currently used in every company and one can consider it as some kind of universal step that everyone must to reach at some time. FA includes not only technologies such as CAM (Computer-Aided Manufacturing) but also a set of technologies concerning machine tools, the automation of line production, robots, all electronic devices designed for the purposes, telecommunications and network technologies, etc...

FA is related to Office Automation (OA) and Engineering Automation (EA). In normal circumstances, the two later are also common, currently developed at every company in Japan. FA, OA and EA are the more standard expressions for describing the automation of the whole processes (in a wider sense). But this does not mean that they are the only ones. In fact, some companies develop aspects such as LA (Laboratory Automation) as an important component of CIM (see Section 6.1).

SIS is another concept now added to the first ones, which companies are now beginning to use very often in documents. To understand SIS, we consider that productive technologies are in a way encapsulated rather than linear components, in its evolution. So CIM is including FA and, in the same way, SIS is including CIM. At this point, it is convenient to underline an important distinction: SIS is aiming to create an information system as a strategic tool for a company. It is rather looking at the environment; whereas CIM is rather supporting the internal functions of company.

So Hitachi's CIM business is related to the business volume. The strength as a total CIM supplier is made up by robots, personal computers, process (control) computers, automation equipment, workstations and general purpose computers.

2.2. THE SCOPE OF CIM

One of the first interesting questions concerning the scope of CIM relates to its links with the trend of improvement of manufacturing production technology affecting the future evolution in the middle or long run. This characteristic is a common one. Indeed, every Japanese company is always looking at the future, so the short term seems to be not so essential as it is in some Western company situations.

Technology elements for CIM.

This evolving trend is constantly adding new technological elements and assuming a new shape. Indeed, CIM is inserted in a wider framework characterized by a continuous improvement of the productive system as it is presented in the CIM 21 (1992) document. Under these conditions, the following elements characterizing this trend can be clearly identified, following this order:

- FA (Factory Automation)
- CIM
- IMS (Intelligent Manufacturing System)

FA (already seen in Section 2.1) is defined by Hitachi as an in-house automated system allowing flexible production, in a factory which utilizes the latest in advanced technologies of information processing, electronics, and mechatronics to combine effectively all the processes from receipt of orders to design, manufacturing, production,inspection, and final delivery.

Remark.

A is not just an automated system but also a total approach to rationalizing a production system, based on the needs of the product market, covering all phases of the production process and requiring not just new technologies, but also new methods to implement those technologies.

In fact, automating the factory is not a simple problem. There is an infinite variety both in the goods which are produced and in the production sites where FA is to be implemented. Except in the case of brand new products and new facilities, the ordinary approach to total FA is to automate each subsystem one by one, eventually ending with total automation of the plant. So FA starts, normally, with the most critical and important production areas.

Meanwhile, it is necessary to make a distinction between Hitachi internal FA and Hitachi as a manufacturer of FA systems. For example, in this latter case, Hitachi manufactures FA products such as information processing systems, CAE/CAD/CAM systems, control systems, manufacturing/assembly systems, transfer/distribution systems, inspection/instrumentation equipment and others. But this know-how about manufacturing FA equipment is used as input knowledge in the planning of their own FA implementation.

To sum up, FA includes Flexibility and Automation. Flexibility deals with a variety of products, alternative scheduling, short delivery lead-times and small lot sizes. Automation deals with standardized products, stable production schedules, delivery lead-times and large lot sizes.

CIM concerns the integration and information circulation (info--circulation), which we called information flow (see Section 1.5). By integration is understood partial/ individual systematization, computer technologies and user-friendly man-machine interfaces. As we can see, this is rather wider than the interpretation reviewed in Sections 1.1 and 1.4. For example, a user-friendly man-machine interface is one of the key issues in the Japanese interpretation (see Section 2.3).

Info-circulation deals with the system integration through networks (LAN/WAN) and a database of management strategies. In this case, Hitachi insist on the most advanced information technologies existing in the field of networks and databases. The problem is to obtain a very fast system for circulation of information. However, information must not only circulate but also, and principally, remain available to all people concerned by it.

Finally, IMS deals with the future factory prototype that can be imagined in the present conditions. We study this problem in Chapter 7. As we see, from a historical perspective, CIM is only one step in a long run perspective of constantly perfecting productive systems and making them more complex.

The main targets.

Investigating the individual systems in manufacturing industry, Hitachi CIM managers summarize the main target as follows.

To have a strong management which can cope with the needs of tough competition, high efficiency and rationalization, in sales, development and manufacturing, by utilizing the following elements:

- engineering technology
- management technology
- environment technology
- human communication
- social balance

From this target, Hitachi considers as a decisive challenge the construction of a system with a "Leading edge", in which CIM has the main role. But to build up this "Leading edge" it is absolutely necessary to restructure the management system completely. This reorganization use of innovation in order to obtain an "enterprise of real time marketing".

So, within this context, the following aspects become increasingly important:

a. Highly sensitive sales style.

The point here is to catch market trends as early as possible. For doing so, it is necessary to establish

a1. the accuracy of the sales plan, and

a2. the sales projection into management.

This last point is related to marketing innovation, in particular effective communication with the market, and the renewal of standards, product values and market-oriented products.

b. Total optimization of physical distribution.

For achieving this, the important points to be considered are

b1. the inventory strategy corresponding to both sales and manufacturing,

b2. the consistent flow from manufacturing to sales logistics,

b3. the optimal delivery system.

This last point is related to control innovation, and in particular to:
- the integrated control,
- the unit control (gross --single),
- the high frequency control (monthly to daily) and
- the feed forward control (following --forestalling)

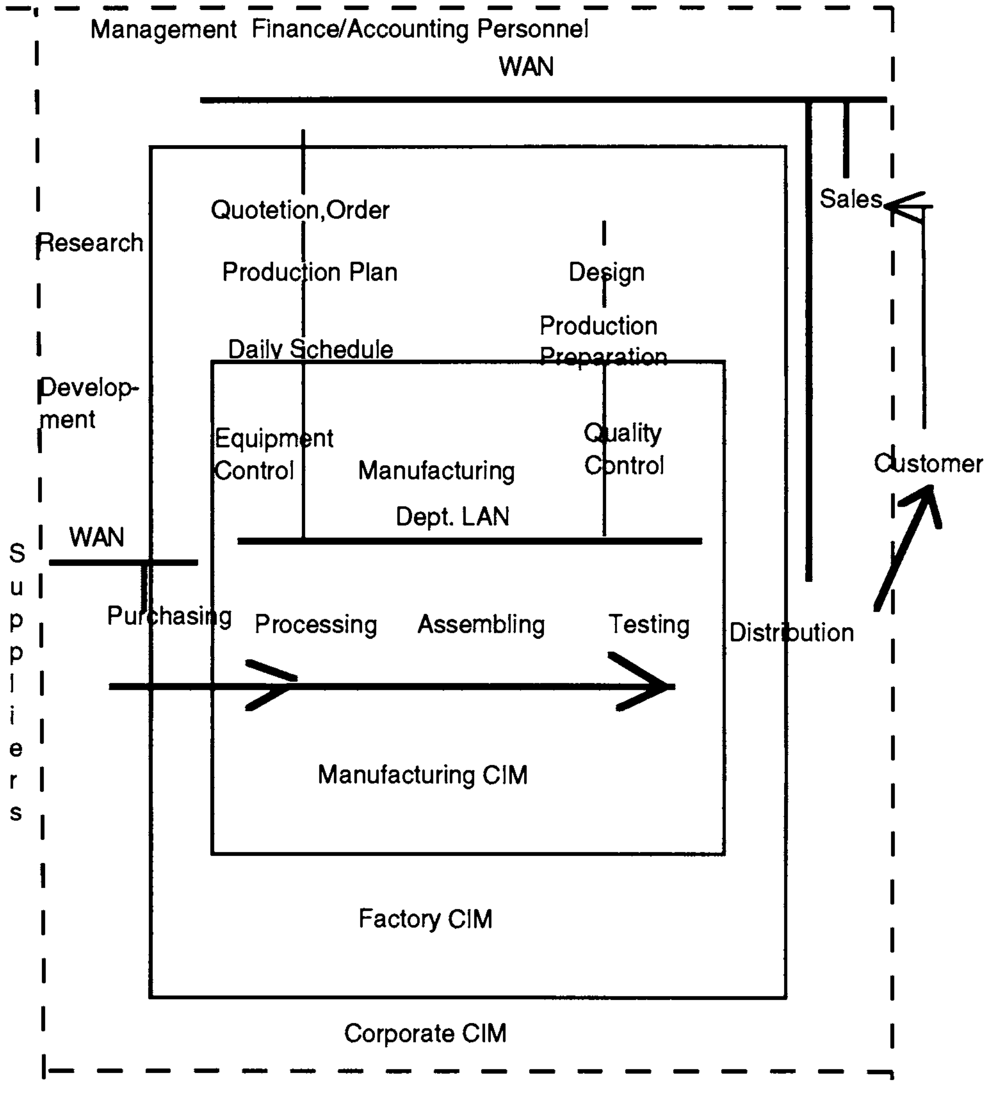


Figure 1 Scope of CIM

c. Consolidation of flexible and planned manufacturing organization.

To achieve this, two main elements are important:

- the ruling ii plant preparation of materials and machine load balancing and
- the common line indexes (time, quantity, price, etc).

d. The strategy for capital investment.

The investment policy of a company depends on all the above relations. This policy must, in particular, examine the capital investment priority and create a long-term business strategy. Investment in new information technology is particularly heavy and can sometimes involve expenditure for many years after, creating meanwhile unwanted rigidities and troubles. The problem is to prevent such troubles.

The scope of the CIM configuration is represented in figure 1.

This figure shows three levels of CIM: Manufacturing or Production CIM, Factory CIM and Corporate CIM. In this figure the arrow represent the sense in which the production flow is passing across the enterprise, the factory and the manufacturing line. So this flow goes from vendors (component suppliers) to distribution (customers).

Being coherent with the encapsulated organization of technologies, this presentation can be depicted as a nested one. Indeed, the first CIM level is the production CIM followed by the factory CIM but both of them are included in the enterprise CIM. Figure 1 shows also the links established through the networks between the different CIM levels.

It is possible to distinguish two kinds of networks:

- the local area network (LAN), which links all the components at the production CIM level, and
- the wide area network (WAN) which links the enterprise CIM, factory CIM and production CIM, and Hitachi to the suppliers and customers.

The production (manufacturing) CIM corresponds to the shopfloor level. Indeed, this CIM level includes processes such as fabrication, assembly and inspection. The interfaces between production CIM and factory CIM levels are realized by methods such as MRP (Material Requirement Planning) and by the process plan preparation.

The factory CIM level embraces the production plan that works with materials, MRP and SFC. On the other side, there is the product engineering which works with the process plan preparation. At the top of the factory CIM is the order processing which produces the inputs for the production plan and product engineering.

Finally, the interfaces between factory CIM and enterprise CIM are represented by sales and marketing, determining the input for order processing, materials and distribution. Administration, personnel, finance, research and development are included in the enterprise CIM.

2.3. OUTLINE OF THE HITACHI CIM

As we see, CIM is the total integrated system concept which promotes effective management and flexible manufacturing by utilizing all information and controlling the entire business activities (sales, technology, production, distribution, service).

Configuration of HCIM.

The total configuration of Hitachi CIM is called HICIM. Figure 2 depicts the configuration of HICIM. We can distinguish three levels: Corporate level, Division level and Factory level. One of the important points to keep in mind in this CIM configuration is the network. To understand the Hitachi networking links, we must follow CIM level by level and the relations between them. Each of these levels has its own network, hardware and software configuration.

At the centre of these configurations is the factory configuration. To understand the place of this configuration figure 2 shows, at the factory level, five factories: Power Systems/Equipment, Industrial Machinery, Home Appliances, Information and Communications, and Semiconductors. From these factories, only one configuration is depicted, that of Home Appliances.

In the case of Home Appliances, three levels forming its configuration are represented:

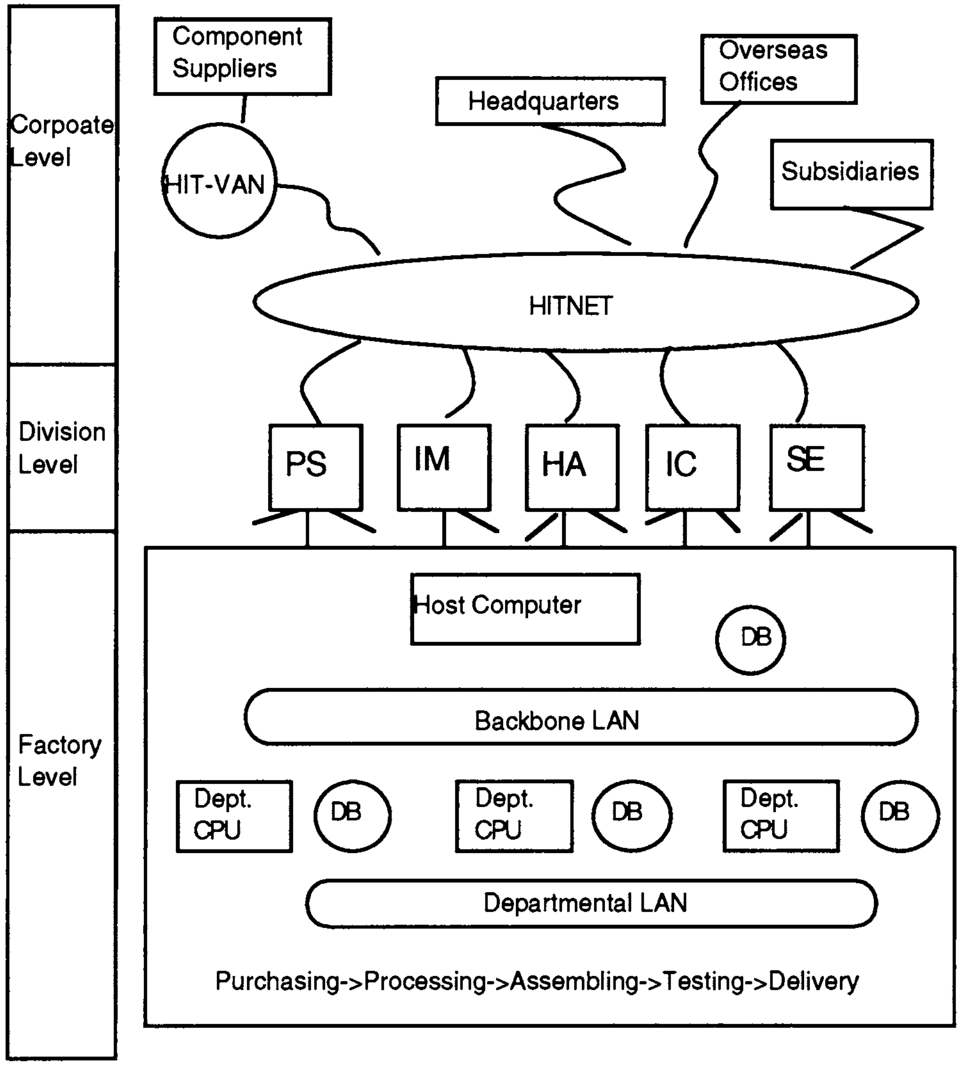
- the factory level in which we find the Host Computer with its corresponding data base,
- the interdepartmental level. The link between the top level and this level passes across the backbone LAN. Each department has its own Central Processing Unit, on-line with its corresponding database.
- the department level, having its own LAN and running the purchasing, processing, assembling, testing and delivery operations.

Assuming now that factories form divisions, this last level is connected with the corporate level by the intermediate HITNET network. This is the Hitachi Information Telecommunications Network. Through HITNET, the different Hitachi divisions are connected to the Headquarters. At the corporate level, HITNET is completed by HIT-VAN (Hitachi Value Added Network). Through HIT-VAN all Hitachi segments are connected with the component suppliers, as depicted in figure 2.

Hitachi Network and HCIM.

As is becoming common in Japanese companies, HITNET operates within two different geographies. One is for Japan itself, and the other for the overseas regions. In the case of the overseas regions, HITNET is formed by four big networks:

- HEL/LDN (Hitachi Europe Ltd./London), a submarine cable with 128kbps capacity,



PS : Power Systems Equipment; IM : Industrial Machinery;
HA : Home Appliances; IC : Information&Communications; SE : Semiconductor

Figure 2 Configuration of HICIM

- HAS/SIN (Hitachi Asia Ltd./Singapore), a communications satellite with 128kbps capacity,
- HAL/SF (Hitachi America Ltd../ San Francisco), a communications satellite with 256kbps capacity, and
- HAL/NY (Hitachi America Ltd./New York), an optical fibre cable with 128kbps capacity.

The HICIM implementation is realized following common Guidelines. These Guidelines are completed by scheduling prepared at the top level of the Corporation. The Schedule indicates precisely the steps to be followed for implementing HICIM.

The common Guidelines starting point is the official policy of the company, which consists of the reduction of lead time by a half, from orders to delivery. Also, the Guidelines summarize the goals in terms of productivity (30 % up), cutting indirect cost (30 % down) and reducing stocks in process (30 % down).

Steps of HCIM construction.

The schedule for HICIM began in the mid-1980. In general, we can identify the next two phases of its development and implementation

Phase 1, from 1987 to 1988. This phase corresponds to the policy decision and the creation of model manufacturing lines (for example, in the Hitachi Works, Totsuka Works or Kanagawa Works).

Phase 2, from 1988 to 1992. During this phase, proceedings in the corporation and the working group activities differentiated by product fields were carried out.

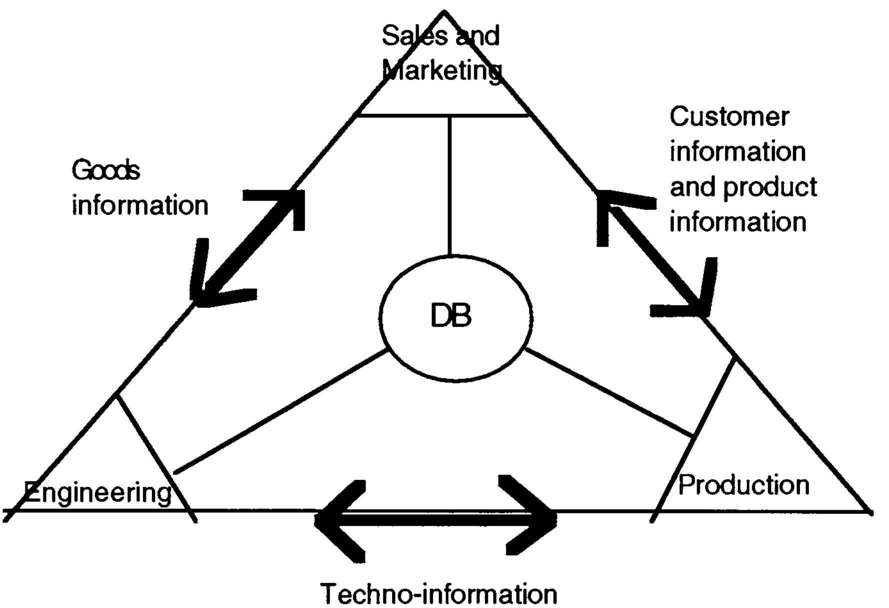


Figure 3. HICIM : Hitachi Computer Integrated Manufacturing System

A simpler representation of the CIM implementation is usually organized as a triangle, as in figure 3. In this case, the assumption is that triangle indicates the main interrelations between different segments involved in CIM, and provides a graphical view in which the following three elements are taken into account: sales and marketing services, production, and engineering, and a centralized database.

As we see in this figure, each of the elements deals with all the others. For example, sales and marketing deals with engineering and production. However, the information content is not the same everywhere, depending on the different segments involved. So, the three sides represent respectively goods information (between sales and marketing and engineering), customer information and product information (between sales and marketing, and production), and techno-information (between engineering and production).

In the centre of this triangle we can see the data base. To sum up the relations form an information flow, entirely automated, in which computer, database and networks are the main performance tools.

One general principle of CIM (applicable everywhere) is that CIM implementation differs, according to the local production conditions (see Sections 1.2 and 1.3). Thus, concerning Hitachi's local production conditions, it can be organized according to the production required and the volume of this production. The production required depends on the actual level of production based on orders, and on the forecast.

By this means, it is possible to categorize the Hitachi products, as presented in figure 4. This figure separates order-based production from forecast-based production, and links it with production volume.

Following these two dimensions, Hitachi products are separated into five categories:

- power systems/equipment
- industrial machinery
- information/communications
- home appliances
- devices

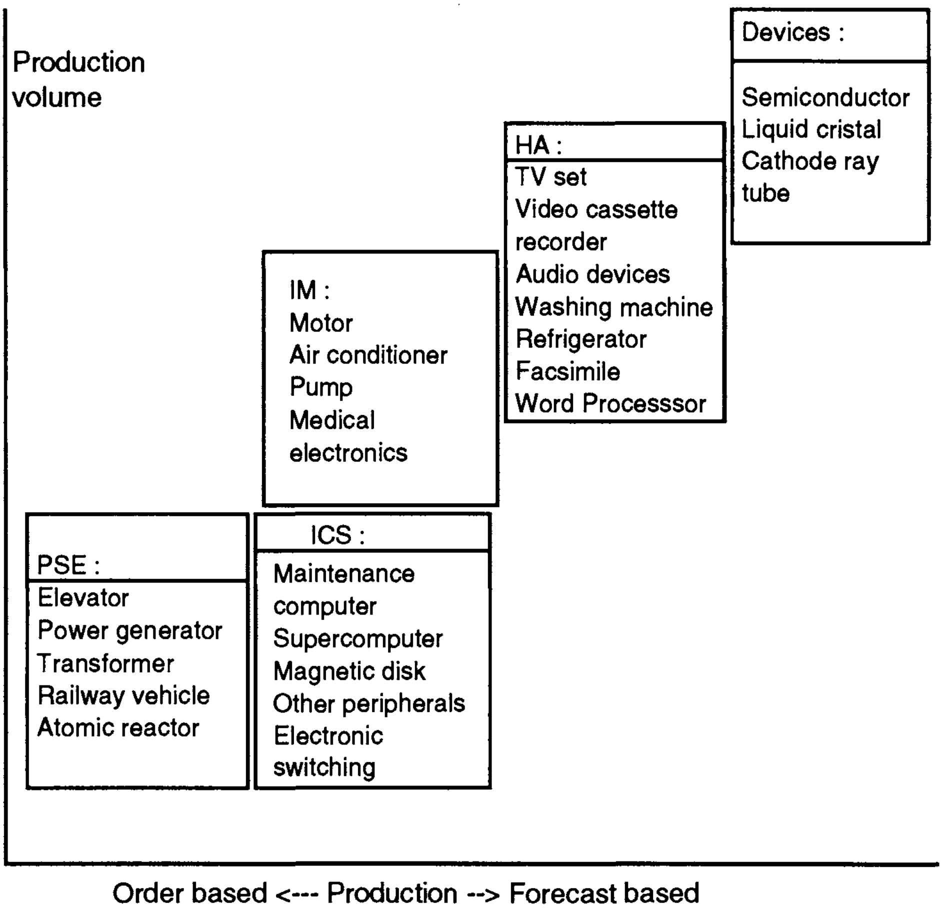
Industrial machinery and information/communications are order-based to the same degree but the production volume is higher for the first.

Remark: recall the list of Hitachi products given at the beginning of this Chapter. This is a complementary illustration for the above explanation.

All of these elements must be taken into account when we study HICIM.

Approaches and tools for CIM.

In addition, to construct a CIM system, two crucial points must be taken into consideration, as indicated in the document CIM Technology of Hitachi (1992). On the one hand, the approach to system construction, and on the other, the tools for system planning (CIM, 92). We now give some short explanations of these two points.



PSE : Power Systems/Equipment; ICS : Information/Communications;
IM : Industrial Machinery; HA : Home Appliances

Figure 4 Categorization of Hitachi products

a. The approach to system construction.

This concerns, principally, the preparation for system construction, and follows the well known top-down and bottom-up approaches. The top-down approach concerns:

- decision about objectives,
- the breakdown of objectives and measures by the so-called "objectives tree", and
- the design of a top viewpoint to provide a total optimization of the system.

The bottom-up approach deals with:

- evaluation techniques for plant activities,

- problem finding by hearing suggestions formulated by plant operators, and
- problem finding by the industrial engineering methods.

These two approaches normally run more or less in parallel. From this reality, there results a combination of Top-down and Bottom-up approaches which must promote a more advanced and appropriate CIM project, after proper study of the following points

a. setting-up a goal of the system,

b. setting-up an enhancement schedule (a practical development action plan), and

c. establishment of the project (transfer of competence)

Finally, a feasibility study on bringing together the improvements deals with:

- decisions about objectives,
- investigation of range and degree of improvement, and
- definite examination of the project.

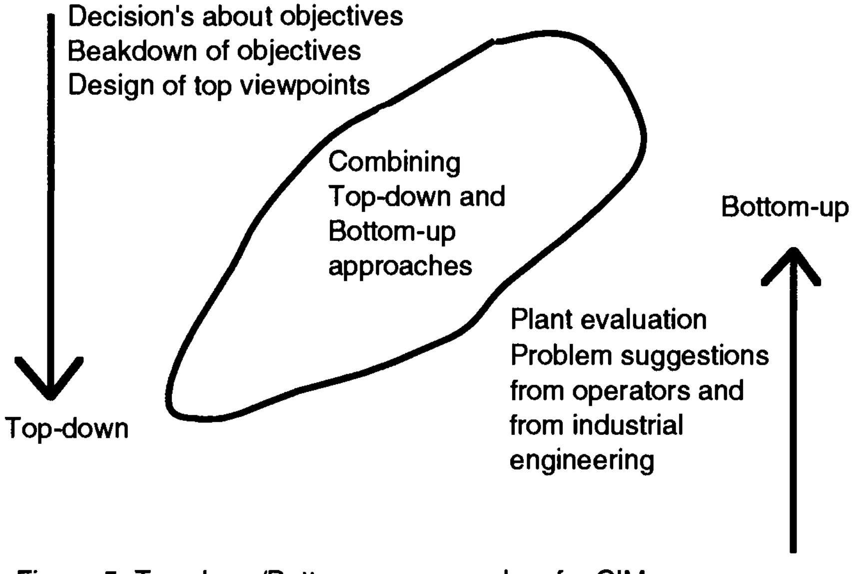


Figure 5. Top-down/Bottom-up approaches for CIM

All these elements enter into the system construction. Figure 5 gives a general view of this bottom-up/top-down approach. The region placed between both approaches represents an intermediary region, in which the two approaches are combined.

b. Tools for system planning.

These tools include the integrated planning methods for strategic information systems, the diagnosis and evaluation methods, and several kinds of simulations.

(1) The integrated planning method (to be studied in more details in Section 2.4) for strategic information systems is related to the Hitachi Plan (called HIPLAN) as follows:

- HIPLAN -SV (strategic vision), information system strategy plan
- HIPLAN - MP (master plan), overall plan for information system
- HIPLAN -AP (action programme), devising development plans for individual system

(2) The diagnosis and evaluation methods relate to:

- Plant diagnosis, this is a quantitative analysis of 93 factors and production of '"Radar Charts"
- Process diagnosis, which is a quantitative analysis of 80 factors followed by making '"Radar Charts"
- Producibility Evaluation Method (PEM), which evaluates the difficulty of processing to improve design quality
- Assembly Evaluation Method (AEM), which evaluates the difficulty of assembling products to improve the design quality

PEM and AEM are studied in section 2.5.

(3) The simulations. Complementing the analysis of points (1) and (2), many kinds of simulations are performed based upon different kinds of tools. In general, these tools can be separated into two principal categories:

(a) Exclusive Tools. For example, REPLICA (a Macro-simulation for manufacturing lines), APLS (Planning for arranging layout), and other tools for stocks and transportation

(b) General Tools: for example, individual simulations with simulation languages GPSS (see Section 2.6).

We make one additional comment concerning the outline of Hitachi CIM. It concerns the problem of the user's consciousness. In reality, CIM must be created by users themselves! This is a powerful force to be explored in any circumstances. The users consciousness extends from the simple manifestation of wants to the ergonomic problems.

Hitachi engineers have constructed an interesting chart relating the dependence on system suppliers and the activity phase of system construction. The dependence increases following the construction phase. This shows that users have become more deeply involved with the advances in CIM implementation.

So one solution to this problem is to give even more importance to the users. Some people refer to this problem as "empowering users" but whatever qualification is used, one thing is clear, it is necessary to create an appropriate organization and direct to it the problems encountered by users in the real life of CIM. The synergy between users and developers is a vital factor for the success of CIM implementation.

2.4. HITACHI INTEGRATED PLANNING METHODS FOR STRATEGIC INFORMATION SYSTEMS

Normally information systems have been used mainly for the improvement of operational efficiency. In recent years, however, there has been a move to use them as a mean of carrying out management strategies, that is, to develop new business or management methods by using information technologies as a key input. This new application is called a strategic information system (SIS).

Remark.
SIS is a matter of development in Japanese Corporations and must be considered as something more advanced than CIM. In fact, many companies represent SIS as an upper "layer" comprising CIM as an lower "layer" (see Section 2.1).

A SIS should functions in conjunction with management strategy. In this respect, special attention should be paid to the business operations and to the organizational structure, as well as to the information system. These three aspects may be combined and in order to facilitate this trend, the Hitachi Integrated Planning Procedure for Information Systems has been developed.

The three stages for planning: the HIPLAN procedure.
This procedure consists of three stages covering company activities from the macro to the micro level. Based on various methodologies and concepts, the procedure breaks down activities into finer steps (see tools for planning, Section 2.3) to study the procedure in more detail. We present, firstly, a conceptual view of this procedure and, secondly, a graphical view.

There are three main stages of this procedure

a. Strategic system vision
In the first stage, the management strategy is clarified and the information system strategy that supports it is worked out. The corporation's forward look should be defined, and the strategic conception formulated. The idea is to fill the gap between the concept and reality as fully as possible during this time.

b. Master plan
The second stage involves implementation of the strategy throughout the organization, and development of the master plan for SIS. In the master plan, the framework of the total business operation and that of the total information system should be worked out. And the strategy should be broken down within the framework, thus creating the objective or goal for each business operation and system.

c. Action programme

In the final stage, the business operations procedure for achieving the goal is sought and system requirements are determined. The action programme is applied to each system defined in the master plan for finalization of the system requirements, which are the primary input to the system design process.

As we see, the information system becomes one of the key business resources for this company. The planning, especially the planning of management strategies, needs to take into account the maximum of data at every level, starting from the higher level and going down. HIPLAN (Hitachi's planning system), using information technology to support business, is designed to do it.

Providing a total solution, HIPLAN supports all aspects of business from planning to the implementation of different strategies. In addition, its business experts are able to improve and modify the actual work done by business. So HIPLAN, which consists of three different level approaches (see Section 2.3.) meets the requirements to construct SIS. For example, each outcome of a strategic vision study is published as a book or brochure.

More accurately is the use of actual information about sales. In fact, POS (Point of Sales) data are collected to create graphs of actual sales achieved for each item of merchandise. This information allows comparison at any time between reality and forecasting, and by the way to adjust this last as soon as necessary.

Figure 6 gives a general graphical view of the planning procedure described. The planning steps are represented on the left side of this figure; the central ellipse represents what we call the main content corresponding to each step. Interacting directly with the planning structure is the Designing Information System Infrastructure. This system receives any information input between the two first steps and gives an information output before the last step begins. Finally, we find the implementation of SIS.

The planning tools for factory.

Another important factor related to SIS and CIM concerns the planning tools for factory automation systems.

As we know, FA systems are more flexible and complex and the need for reduced planning and set-up times has become more acute than ever before. To meet these needs, various planning and evaluation tools based on sound scientific methods must be used. In general, these methods are linked with the needs assessment, the system planning and the system operation.

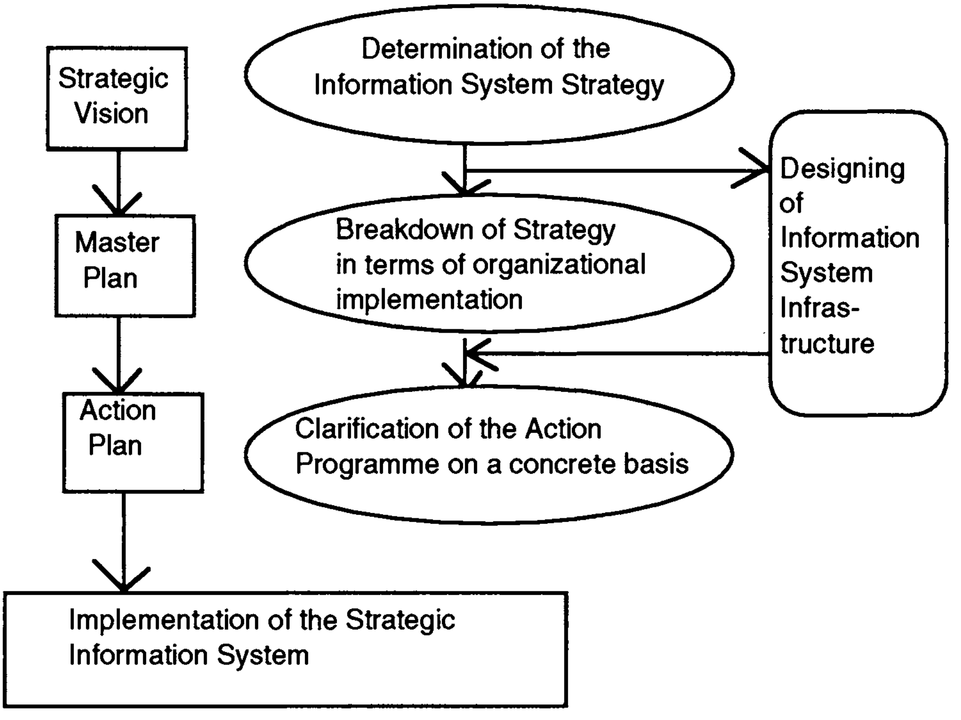


Figure 6. Hitachi Integrated Planning Procedure

As an example of needs assessment, we can mention the factory diagnosis. The factory diagnosis is an important element in promoting factory automation. This is true for the factory at the beginning of the automation era and even more so for a factory having already reached a certain degree of automation. This diagnosis involves a process of analyzing the various aspects of a particular factory, and clarifying the problems to be dealt with.

In order to solve such problems, a particularly effective method of analysis must be applied. Then diagnosis tests should be easy to carry out, and provide results for concrete data. The diagnosis will bring out the weakest points of the existing system and by planning to begin the automation process here, it will be possible to achieve a more efficient system.

Linked with the factory diagnosis and planning system, Hitachi has developed the Assembly Evaluation Method (AEM), one of whose first versions was published in Journees de Microtechnique (1988) (see next Section). AEM must be qualified as a typical Hitachi input for a planning system. AEM is the result of the know-how developed uniquely by Hitachi which can quantitatively measure at the design stage, the assembly potential for a particular product.

Planning procedures are currently examined by engineers to improve the efficiency of the existing methodologies. One direction of this research consists of the development of tools based on the most advanced artificial intelligence and neural network. For example, one of these tools is the development of an "Intelligent Manufacturing Planning System" as presented by M. Watanabe et al. (1991). That system is designed for supplying customized products on the required time schedule.

The system consists of a sales support system and a production management system having the following characteristics:

- the sales expert system uses a photo-realistic environment model created by a three-dimensional image processing of pictures that helps in design appearance evaluation, and in the choice of product specifications to fill the functional requirements;

- the neural-network based estimation system projects the delivery date quickly and accurately, by learning the past manufacturing performance pattern. This pattern consists of variable product specifications and indexes of the manufacturing conditions;

- the production planning system adjusts the manufacturing operations to cope with dynamic changes in manufacturing conditions and product specifications. The adjustments are realized by high-speed simulation with a graphical interface to display manufacturing conditions and direct coordinations. A method of determining the lead time is proposed which is combined with newly developed production planning, based upon a similar method to the MRP (Material Requirements Planning) method.

The intelligent manufacturing planning system is designed by engineers as a user-friendly strategic information system, and it is applicable to a large variety of customized products. It is necessary to understand by this not only a simpler facility to perform planning but also a facility incorporating what are considered essential aspects such as, for example, the ergonomic aspects.

The starting point of this system is the criticism of the conventional MRP system and the Capacity Requirements Planning (CRP). In the system proposed by Hitachi engineers, the two steps of MRP and CRP are unified and handled simultaneously in order to determine the component production lead time. The production planning generator consists of the MRP calculation module and a lead-time setting module, cooperating to generate a production plan that takes into account only the load on each shop and the capacity of each shop.

By this method, the MRP logic generates components requirements level-by-level of shop flow, while the conventional MRP logic generates the parts requirements level-by-level of the parts structure. The MRP calculation module generates the requirements quantity and the completion date in final assembly shop. Following this process, the module sums up the amount of work each shop has to complete on each day (called the completion shop load).

The lead-time setting module receives the completion shop load and calculates the lead time from the completion shop load and capacity of the shop. The MRP calculation module receives the lead time and determines the parts release date for the final assembly shop. In this way, generation of the production plan takes account of the load on each shop and the capacity of each shop is achieved.

Remark: from the point of view of Concurrent Engineering (CE) principles - CE is also called Simultaneous or Parallel Engineering - , it is not difficult to recognize some of them here. In particular, we must underline the capacity to detect the problems and to anticipate the solutions of some at an earlier stage of preparation, that means, in principle at the stage of product design.

Applying this, Hitachi has achieved

- a substantial improvement in shortening the lead times for development,
- savings of time and work through a more efficient assembly model, and
- increasing product reliability.

2.5. THE ASSEMBLY EVALUATION METHOD (AEM)

AEM is related to another method, the Producibility Evaluation Method (PEM) presented in the document Hitachi Producibility (1992). The application range of PEM covers products such as VCRs, CD players, washing machines, vacuum cleaners, circuits breakers, rotary compressors, automobiles and automotive parts.

The PEM and AEM methods.

PEM prepares drawings or samples, proposes assembly sequences and methods, proposes machining methods and calculates evaluation indices. The simple steps of the PEM evaluation procedure algorithm are the next:

(1) prepare drawings or samples, PC with PEM program, and minimal basic product data

(2) propose, firstly, an assembly sequence and assembly methods, and simultaneously, propose the machining methods

(3) calculate evaluation indices

(4) Judgement; therefore, if the results issuing from (2) and (3) are good, then producibility is accepted; if the results are not good, it is necessary to improve product design for better producibility, and then to begin a new iteration.

The main characteristics of the PEM method are the following:

- an accurate quantitative evaluation (ease of assembly, machine-producibility and producibility evaluation scores. Assembly, machining and total cost ratio)
- a rationalized theory and easy analysis (assembly and machining are analyzed by a similar simple system)

- a correlation between scores and operation cost ratio (scores are correlated to operation costs based on layer fashion assembly and flat surface machining)

In general, PEM improves product design for better producibility, which means the aptitude to produce something. Producibility is ex ante in the production process and should not be confused with productivity, which is, as everybody knows, a measure of the output (or ex post).

The consequences are very important, as just one example will show. Factory automation (FA) may be facilitated because an improved easy-to-produce product can be manufactured by a simpler and more economical production system; automation of assembly and machining is realized early, and the design period is reduced (completed with fewer developmental design changes, since evaluation and producibility improvement can be achieved at an early stage).

The AEM is an effective method, created by Hitachi to improve the design quality for better assembly producibility. It is widely used by the Hitachi group, but also by many well known companies around the world. Using this method, at the early design stage, the product design quality can easily be analyzed quantitatively. So it is easier to discover the weaknesses in the design's assembly producibility.

This discovery is important for the overall activity because it helps to improve the whole process. As is well known by CE engineers, the quality design improvement affects the cost of assembling products directly, and in this way contributes to achieving more reliability at lower cost. When this quality is assured at the early stages of design, the positive effects are fully evident.

In order to facilitate design improvement, by identifying weak points in the design at the earliest possible stage, AEM uses the following two indices:

(1) the assembly evaluation score E, which is used to assess design quality, or the difficulty of assembly operations;

(2) the estimated assembly cost ratio K, used to project assembly costs.

Although the ultimate target is cost reduction, a cost index alone cannot express whether the design quality is good enough, or identify the causes of bad producibility. Thus, a quality index is also required as a tool for design improvement. AEM is included in the larger process of the assembly and design improvement process, and is not an isolated tool, as shows in figure 7.

The beginning of the improvement process is the product design step. This step is concerned with preparing product concept drawings, making prototype drawings, preparing product design drawings and receiving samples. The assembly evaluation concerns the degree of difficulty of assembly, the operations and the approximate assembly costs.

Finally, different kinds of comparisons are made, in particular, comparisons of various concepts against various companies' products. Here functions the Product Assembly Range, which identifies points to be improved, estimates the effects of this improvement and facilitates the design improvement.

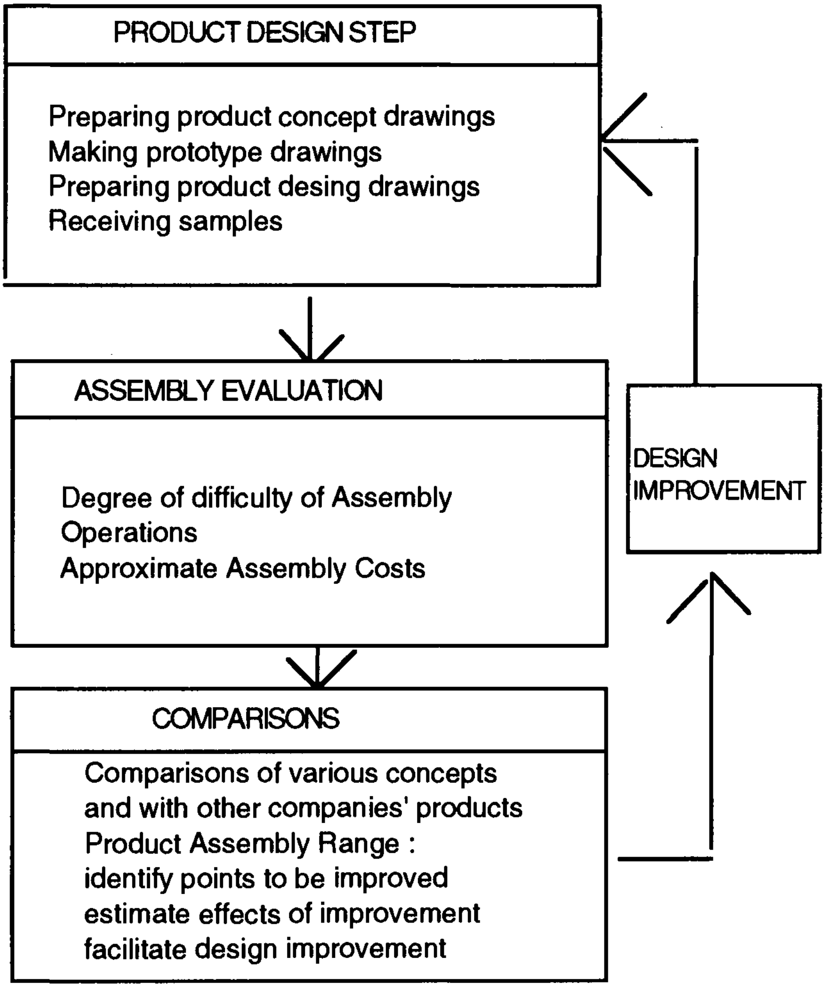


Figure 7. Assembly Evaluation and Design Improvement

Evaluation of the ease of assembly can be carried out with conceptual drawings. Then completed product design drawings, samples, or prototypes can be evaluated with greater accuracy. Practically, the AEM provides sufficiently accurate results from the information available at the early design stage. Evaluation results can also be used to compare alternatives or to compare a competitor's model to one's own.

Design improvement is performed by reviewing the evaluation results and the improved design is again submitted to the assembly evaluation process in order to evaluate quantitatively the effects of the improvement. These iterative steps facilitate design improvement activities.

Formalization of AEM.

From the mathematical point of view, the AEM theory of evaluation is structured on the following principles, according to the Hitachi New Assembly Evaluation Method (1991)

(1) Assembly operations are categorized into approximately 20 elemental operations X, and each of them is assigned a symbol mark (referred to as an AEM symbol) which clearly indicates the content of the operation. Among these operations, the easiest one is chosen to be a basic elemental operation.

(2) With each of these elemental operations X a penalty score is associated. So that the penalty is proportional to the relative increment of difficulty (i.e., assembly operation cost Cx or operation time T x), they are correlated with each other through the shop rate. After this, the cost C represents the case of that particular operation related to the difficulty of the basic one T.

All this is expressed by the equation:

$$\mu_x = f_1(C_x) = f_2(T_x) \qquad (1)$$

To the basic elemental operation the least (e.g., zero) penalty score is given.

(3) Besides the operation elements mentioned earlier, factors which also influence the difficulty of the entire assembling operations are extracted as coefficients, i.e., n: influence of a succession of elemental operations for a part.

(4) The part assembly evaluation score Ei is defined so that it decreases when the attaching difficulty of a part, i.e., assembly operation cost Ci increases. The sum of the penalty scores of _mij for a part "i" is modified by the coefficients, then subtracted from the full score (e.g., 100 points) and thus, a part assembly evaluation score Ei for the part "i" is calculated using the equation (2):

$$E_i = f_3(C_i) = 100 - g(\mu_{ij}, \partial_{ij}, \ldots) \qquad (2)$$

where g(µij, ∂ij, ...) is a function which increases when the sum of the elemental operation costs for the part "i" increases.

(5) "The total assembly evaluation score E" for a product or an assembly is defined so that it decreases when the assembly operation cost C of a product or an assembly increases. The E value is obtained by using the figures or the number of parts N and the part assembly evaluation scores Ei for all the parts:

$$E = f_4(C) \qquad (3)$$

$$=f_4(\Sigma_i C_i) = f_4 [\Sigma_i f_3^{-1} (E_i)], \text{ which gives } f_5 (E_i,N), \tag{4}$$

where $i=1, ,N$; $C= \Sigma_i C_i$; N: number of parts.

(6) The assembly operation cost ratio K is calculated.

$$K=C/Cs \tag{5}$$

Therefore, the total assembly operation cost and operation time are calculated from all the parts assembly evaluation scores Ei and the number of parts N, by a simple equation (6):

$$C = \Sigma_i C_i = \Sigma_i f_3^{-1} (E_i)=f_6(N, E) \tag{6}$$

Even if the AEM is successfully practised in the Hitachi Group and outside, it is normally a matter of research to improve its performance. The research lies in answering the requirements such as:

(1) The improvement of cost estimation accuracy: AEM users wish to evaluate the assembly operation cost of individual parts in the evaluated assembly.

(2) The necessity of being combined with the Machining-producibility Evaluation Method (MEM). To unify the AEM and MEM, the evaluation accuracy must be improved so that the assembly evaluation score, machining-producibility evaluation score, assembly operation cost, and machining operation cost can be combined upon a part-basis evaluation.

Thus the new AEM is developed based, particularly, upon the following improvements:

(1) The influence of dimensional accuracy, configurational accuracy, the size and mass of parts, the repetition of operations, the length of a screw, etc. on operation cost is taken into account;

(2) Formulae and constants are thoroughly reviewed, and reconstructed more precisely. The use of a personal computer helps the installation of more sophisticated formulae and precise constants. The new AEM unified the two formulae for cost calculation used in the conventional AEM

(3) The contents of the elemental operation symbols are reviewed, and their definitions clarified. This reduces the user's subjective influence on the analysis and the evaluation accuracy is improved while the features of the conventional AEM are preserved.

Finally, ease of assembly is an abstract concept, and thus difficult to measure directly. For this reason, the assembly cost is used as an indicator of the AEM's accuracy. The estimated assembly cost ratio K and the actual assembly cost ratio C/Cs are compared. If the deviation (the evaluation error) of K from C/Cs is small for many products, then it is reasonable to conclude that the approach used and the conditions are acceptable.

2.6. THE AUTOMATIC ASSEMBLY LINE FOR VIDEO TAPE RECORDING (VTR) MECHANISMS

As an example of CIM, an automatic assembly line for VTR mechanisms is presented in this Section. This assembly line, 88% of whose stations are automated, consists of 52 dedicated automatic assembly machine stations, 11 robot stations, and 9 manual assembly stations.

The AEM method and VTR mechanism.

The recent improvement of robot technology allows robots to contribute to the realization of flexible automatic assembly. Thus various technological attempts to utilize robots for automatic assembly have been already performed. But if this robot promise exists, not many robot installations have been achieved so far in mass-production automated assembly lines.

Among the reasons which explain this particular situation, T. Ohashi et al (1991) consider two:

- the assembly speed of robots is considerably slower than that of dedicated assembly machines, and
- robots are still relatively expensive.

So in order to develop a flexible automatic assembly line in which robots are effectively installed, these authors propose a systematic approach, from product design improvement to facility development. As we study in the next Chapter (Sections 3.1 and 3.2), this approach is quite similar to that of Concurrent Engineering. This kind of approach means taking into consideration many new aspects, normally, which influence the costs of robot construction and its implementation.

The production design of a product plays a very important role in the automation of assembling, the product's life and its quality. If the structure of a product is not easy to assemble, assembling facilities must be more sophisticated and dextrous, and hence expensive, and nevertheless the failure rate of assembly stations becomes high and the performance of the whole line will be low. Therefore, the product design needs to be thoroughly reviewed and a mechanism suitable for automatic assembly should be developed.

For example, in the case of VTR (Video Tape Recorder) mechanism, most of the parts, such as pressed parts, moulded parts, rubber belts and coil springs are assembled from the top, with an easy attaching movement. Owing to this design improvement, these parts can be attached by pick and place units or relatively simple assembly robots, as mentioned later.

For product design reviewing, the analytical design improvement procedure AEM (see Section 2.5.) is used. In this particular case the AEM analyses assembly structure using 17 symbols and gives an idea to designers and production engineers how easily products can be assembled. In addition, as we already know, it points out the weaknesses of the design from point of view of assembly.

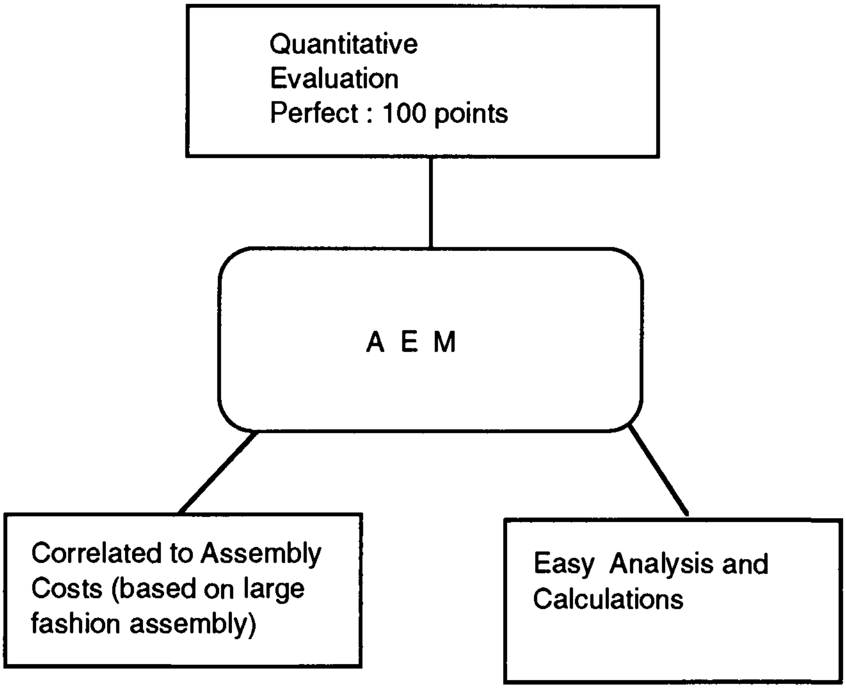


Figure 8 General idea of the AEM

Figure 8 gives the basic ideas of AEM used in the VTR mechanism example. These ideas are:

- quantification of difficulty of assembling by means of 100 point system evaluation indices. Everybody can easily infer the difficulty of assembly operations starting from the indices;
- easy analysis and easy calculation which makes it possible for designers to evaluate the assembly of the product in the early stages of designing
- assembly evaluation indices are correlated to assembly cost.

Fairly accurate cost estimation is then easily provided. By means of the evaluation and improvement iterations, designers can improve the product design very effectively at the early stages of the development. The results of design improvement simulations are presented in appropriate tables.

Table 2 presents an example for design improvements applicable to the case of the VTR mechanism. The columns represent respectively the purpose of simulation, the means for achieving it and the part name involved in that simulation. For example, the loading motor assembly needs a stabilization of the parts positioning, and the means to perform it is to prepare a positioning guide portion. The washer is needed to prevent jamming, and the means to do it is by increasing the parts thickness.

Table 2
Example: design improvement in the VTR Mechanism

Purpose	Means	Part name
Reduction of number of parts	Utilize parts	Tape guide
Stabilize parts positioning	Prepare positioning guide portion	Loading motor assembly
Easyn handling	Prepare parallel portion for gripping	Capstan motor assembly
Easy insetion	Prepare chamfering	Screw
Prevent etranglement	Use connecter to eliminate lead wires	Loading motor assembly
Prevent jamming	Increase parts tickness	Washer

Performance simulation of automatic assembly.

The same tables or others appropriate present for every part concerned by a simulation the drawings corresponding to both different stages; first, the drawings before design improvement by simulation, and second the drawings after design improvement.

Finally, the figures for the assembly improvement are presented in tables containing the number of parts and the assembly evaluation ratios according to the new or the previous mechanism. These last tables also permit some cost-benefits analysis of simulation operations.

The line performance simulation is another important aspect of automatic assembly. In fact, the following evaluations and the feedback of the results to the system design are necessary:

- to determine the capacity of the assembly line to achieve the intended amount of production;
- to identify the stations producing bottlenecks in the assembly line;
- to determine better buffer sizes between stations;

- to study the influence of machine troubles of individual stations on the line output

In order to evaluate these items, an assembly line simulator was developed using GPSS (General Purpose Simulation System), a simulation language based on queuing theory. Input data for simulation flow programming are presumed, based on the actual result of an automatic assembly line for tape-recorder mechanisms having a similar line structure.

After several of trial simulations for the automatic assembly line for the VTR mechanisms, buffer size distribution is determined. The simulation is started with the initial condition that all the assembly line is empty. After the line operation reaches a steady condition, statistical data are calculated for some hours of operation (for example, two hours).

When the expected line tact time for the planned assembly line structure shows that the line would be able to achieve the intended performance, the assembly machine specifications as well as the assembly line structure are determined. Then different comparisons (pre-estimated average line tact time, actual line tact time or calculated line tact time) are performed.

When we consider the flexibility of the automatic assembly line, it is possible to distinguish various degrees of flexibility in it. These levels go from the simple to the most sophisticated. Although flexibility of the line is an important target for CIM achievement, it can however create new problems that need some special attention from the management of the company.

In fact, there exists some correlation between flexibility and cost; the more flexible the line, the more expensive it become. Mass production assembly lines usually produce a relatively small number of standardized models and their minor variations for some period (for example, one year or two), and after this are modified. But the cost is quite different in the flexible systems.

At the beginning of the development of an automatic assembly line, one looks to have one which can be adaptable to those old model changes, layout changes, and partial changes. Accordingly, quick, easy changes of parts supply and assembly operations are required. Besides, the facilities are desired to be reused with minor modifications and to be lined up in a short period, because the production of new models usually increases very quickly.

Taking these points into account, the automatic assembly line for VTR mechanisms must satisfy the following assumptions:

- individual assembly machines should be simple;
- reprogramming of each station should be easy, and it should be performed for all the stations simultaneously;
- maintenance and repair should be performed without influencing the whole line operation;
- component parts supply systems should be easily changed

Figure 9, at the end of this Chapter, shows an example of the layout of the automatic VTR assembly line.

This line consists of 86 modularized assembly stations, of which 56 are dedicated assembly machines such as a pick and place unit, coil spring fitting machine, rubber belt fitting machine, screw-driving machine, etc, and 11 are assembly robots (with 3 degrees of freedom). Inexpensive, variable-stroke pneumatic pick and place units are used for chassis loading and unloading operations. Subassemblies which require complicated attaching movements are attached manually at 9 stations.

The chassis, assembly parts and subassemblies are contained in flat magazines or buckets and supplied by automated guided vehicles from automatic warehouses and preparation rooms to each station. Production control is carried out by a Hitachi mini-computer L-320 and process control computer H-08.

The automation rate for VTR mechanism is calculated by the ratio "(Number of automized stations/Number of assembly stations) * 100)". In 1991 this rate was 88 %; to-day the rate is about 100 %.

The robot station.

Finally, some particular comments about the robot station are necessary.

(1) The robot station consists of a basic machine, an assembly robot A3020 developed in Hitachi, and a magazine handler. The basic machine is a modularized direct feed, free cycle type. This modularized structure is important because it allows layout changes in such a way that the number of stations could easily be increased in accordance with increasing production. This responds to the variation in demand for the line.

(2) Individual stations can be developed and adjusted at various places by different makers simultaneously, so that quick line-up is becoming possible. As the robot station does not need an X-Y table for magazine positioning, the magazine handler can be smaller and thus, less expensive than before.

(3) The robots are used delicate and precise subassemblies for of complicated shapes or parts supplied from flat magazines. Supported by the design improvement process, the robots required for this line can be relatively simple and cheap. Based on the attached movement estimated by the AEM (see Section 2.5), the subassemblies to be attached by the robots are chosen.

Despite this improvement from of the AEM, some subassemblies or parts require very intricate attaching operations that must be able to be performed by high function robots. This is a matter of very complicated robots. However, such complicated robots are not economic and so they are not implemented. As a result, these operations continue to be performed manually.

As the assembly speed of the robot is not as fast as that of dedicated assembly machines, the robot station cycle time is intended to be shorter and not disturb the line balance. The robot is placed in such a position that the assembly path is the shortest. For operator convenience, a palletizing function is developed to simplify the teaching operations. In this function the operator needs only to teach the position of the first corner of the magazine. The robot calculates all the other positions of parts in the magazine by itself, based on the magazine dimension data.

The flexible automatic assembly line implemented for VTR mechanisms is operating as well as intended. After completing the automatic assembly line, the conclusions of the development can be summarized as follows:

- assembly labour is reduced to 1/6 i.e. 150 fewer workers
- area of assembly shop is reduced to 1/3
- quality improvements
- re-adjustment rate of the final assemblies is reduced to 1/5.

2.7. A CIM SYSTEM FOR ELECTRICAL APPLIANCE PRODUCTION

In this Section we present an example of a CIM system applied to electrical appliance production. This example concerns an Integrated PCB (Printed Circuit Board) Assembly Production System developed for use in any Electrical Appliances production studied by H.Onari and Y. Matsumoto (1992). The first question is to tackle Production CIM, with the aim of shortening manufacturing lead-times and the efficient production of a wide range of goods.

As the use of electronic devices extends to a wider range of manufactured goods, printed circuit board (PCB) assemblies are being produced in greater quantity and diversity. But at the same time both the part packing densities and the complexity of PCBs is rapidly increasing.

As we know (see section 2.1), conventional production methods are not sufficient to meet these new demands. Then problems such as increased lead-time, demand for manpower or decrease in production line utilization ratio occur.

In order to solve these kinds of problems a highly automated flexible production line is created with a computer integrated information system for design. For achieving this project, integration of the management and production functions is one of the main tools.

The CIM system generates all assembly line data automatically. It derives this information from design and scheduling data, distributing it to each production cell via an on-line computer network.

The system has the following three components:

a. A Computer Aided Manufacturing (CAM) system.

This system creates production data directly from Computer Aided Design (CAD) data. Various CAD systems are normally used. In particular, optimized NC data for an insertion and mounting machine is created. But a manual placement process is also planned and graphical instruction sheets are produced.

b. A fast response Scheduling system.

This system uses Material Requirement Planning in order to synchronize assembly operations and parts preparation. The optimization of job order planning minimizes setup times for switching between different PCB runs. All this permits increasing of the production utilization ratio.

c. Line control system.

The system is based on a JIT progress control system and group control system using mini MAP (Manufacturing Automation Protocol). The on-line process management controls work progress, using real-time factory feedback data.The data management distributes control data to production cells via group control stations. The reliable automation system uses high precision assembly machinery such as an odd-shaped part mounting robot cell, chip mounter and inspection cell.

The CAM system automatically generates NC data and other associated data for the assembly line. This is achieved through CAD/CAM integration. CAD data from many different systems are first translated into a standard assembly data format These data are taken by NC to produce appropriate NC data for a variety of insertion and mounting machines, and manual operation instruction sheets created.

In addition to this, the process assignment and the placement sequence for manual operations are created. For manual assembly, processes must be assigned which take into account line balancing. The placement sequence is determined to ease assembly operations, to ensure high product quality.

The resulting instructions for the operator are displayed in a graphical format on visual display units at the assembly stations. Parts to be assembled are displayed, and colour coding using to indicate those parts placed, not yet placed and next to be placed. Part names and numbers are also shown.

A Quick Response to Market production system embodies a joint Sales and Production CIM system which consists of a Sales Support System, highly Efficient Production System for a wide range of products and an interface between Production and Sales. The basic challenges of such a system are the integration of Production and Sales.

For activating this system, a decision support system is required, allowing quick response to changes in both market and production. This system is based upon on-line information exchange via a computer network between sales offices and factories. The Sales support system must be able to present product specifications to match order inquiries, and swiftly determine corresponding delivery times and prices.

The challenge for a high efficiency production system for a wide range of products is the realization of a single part lot sizing regime. To achieve this aim, advances will be required in small lot sizing and high product variety manufacturing systems and in flexible production facilities which allow for easy introduction of new products and which have readily adjustable capacity.

The challenge for the interface between Sales and Production is the creation of a real time management function. This requires the ability to handle the scheduling of production from assembly down to material purchasing, while taking into account the real situation in the factory.

The benefits of CIM.

Finally, we summarize some problems and some benefits issuing from CIM implementation. Among the problems, the following are important:

- the changes in production data sent by different department;
- the need for an integrated supervision and control system to manage several new relations;
- the computer system must be easy to upgrade, so that it can track the gradual improvement made to the equipment;
- the coordination of data following a CPU system fault condition is difficult, because the tracking method is not robust enough to ensure consistency between the data and the disposition of the actual materials;
- the system must remain flexible, despite the changes which go hand-in-hand with a steadily growing system;
- the control of a large number of robots;
- determining how best to automate the quality assurance line, given the large number of items requiring direct human intervention

Hitachi CIM Technical Centre.

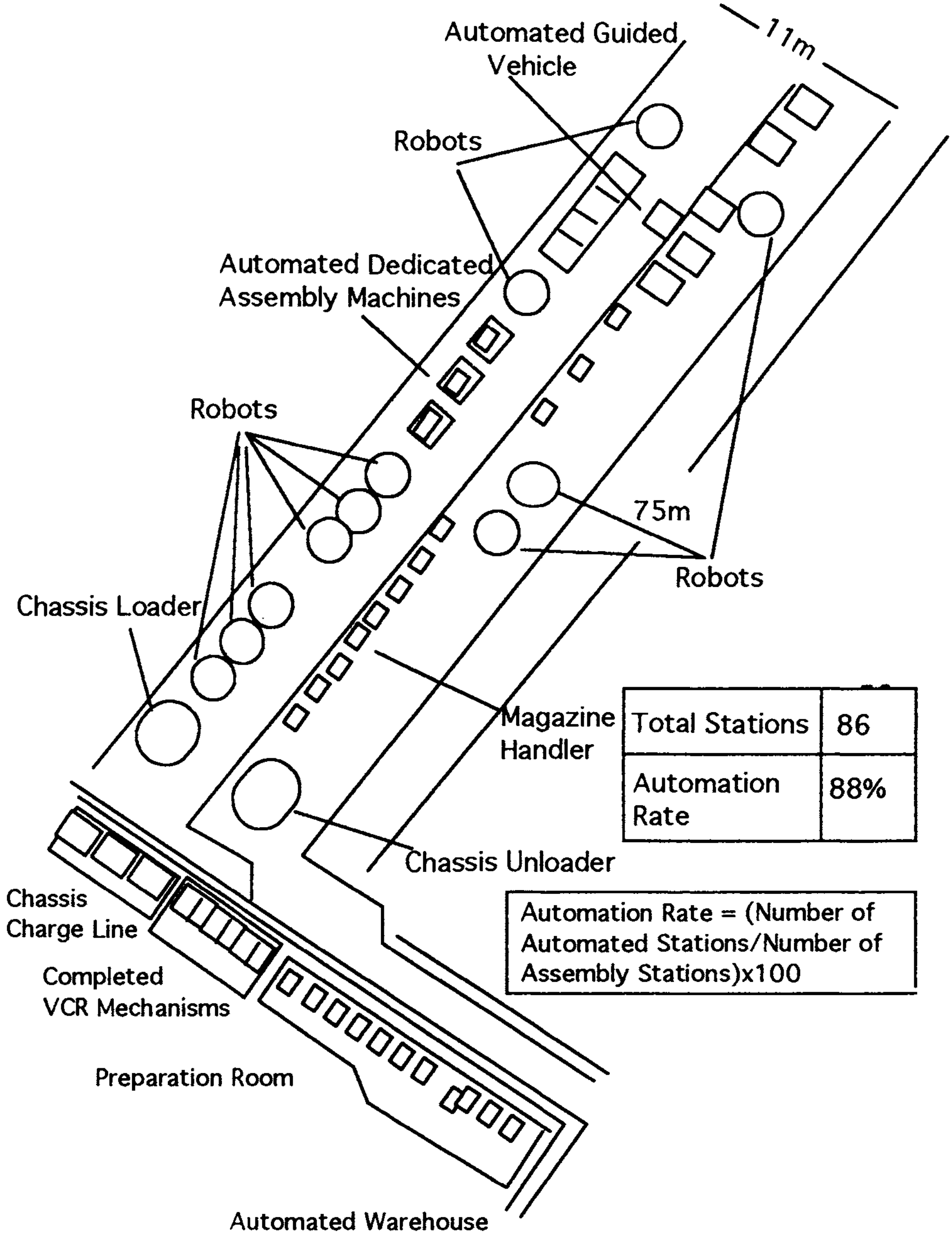
One final point is interesting to quote. It concerns the Hitachi CIM Technical Centre, created as research and a learning centre. This center is created to exhibit advanced technology, to be seen and experienced by as many people as possible. The centre exhibits and demonstrates actual apparatus and introduces such advanced systems as information processing OA system, CAE, CAD system, operation management and control system, goods distribution system, FA system, VAN system and so forth, that make up CIM.

The centre has the following CIM displays:

- a CIM presentation corner which shows how seriously Hitachi is wrestling with CIM, the total technology power of the Hitachi group, the CIM concept and configurations of CIM systems as well as the centre itself, by use of high resolution video equipment such as VTRs and laser disks that provide necessary information;
- an engineering technology corner, which presents Hitachi system engineering technology, system design concepts, and the manner in which Hitachi is tackling CIM. It also introduces system configuration techniques and demonstrates simulation;
- a CAE/CAD and management corner. This corner introduces EA, OA production management system and other systems of such sections as sales,

production management, design, materials and delivery. Examples of some systems are demonstrated by use of actual apparatus;

- a shop management and control corner. This corner introduces to FA system, a unique Hitachi system design based on the CIM concept in manufacturing industry by use of actual apparatus. It also introduces such a system used in the fields of production management and control system, a POPs system, an all-out instrumentation system, etc, by using actual apparatus;
- an assembly line corner: this presents a demonstration of a marking system by using an actual line;
- an SMT (Surface Mount Technology) assembly line corner, which presents actual line demonstrations of a PC board surface mount system.



Total Stations	86
Automation Rate	88%

Automation Rate = (Number of Automated Stations/Number of Assembly Stations)x100

Figure 9 Automatic Assembly Line for VTR Mechanisms

CHAPTER 3

CIM AND CONCURRENT ENGINEERING: THE MELCO CASE

INTRODUCTION

We first give some information about this company, and then we try to relate our subject to this important company. MELCO is the contraction of Mitsubishi Electric Corporation, one of the companies belonging to the Mitsubishi Group. MELCO is a world leader in manufacturing and marketing electronic and electrical equipment. Its operations are focused in four key areas: information, telecommunications and electronic systems and devices; heavy machinery; industrial products and automative equipment; and consumer and other products. It has a network of 111 subsidiaries and 30 affiliated companies.

Thus in the space development field, MELCO has taken a leading role in the construction of more than 100 larger-scale satellite communications earth stations worldwide. As the prime contractor for Japan's National Space Development Agency (NASDA) Japan Earth Resources Satellite-1 (JERS-1), MELCO created a synthetic aperture radar for the on-board observation system. Activities in communications and information-processing focus on such dynamic areas as videoconferencing, cellular telephones, facsimiles, optical-fibre and digital transmission networks, and computer satellites.

Activities in electronic devices concentrate on state-of the-art facilities and flexible manufacturing techniques to produce a highly competitive range of semiconductors, application-specific integrated circuits, and other electronic devices. In industrial equipment, MELCO's leading-edge factory automation equipment spans computerized numerical controllers, electric-discharge machines, CO2 laser beam processing machines, programmable logic controllers, and frequency inverters.

But one of the most active edges of activity is research/development, where the main interest subjects are electronics, new energy sources, industrial equipment and systems, and home electronics. The company intensifies research into semiconductors, and information processing and communications. MELCO is presently constructing a synchrotron radiation facility, to stay ahead of future semiconductor needs.

At Hitachi we were very interested in a global approach to CIM, but in the MELCO case we find not only this general aspect particularly relevant but also some peculiarities that are interesting for Western researchers and engineers. Among these peculiarities we can quote the importance accorded to the concurrent engineering approach and its relations with production planning, global CIM and CIM systems.

Although many engineering researchers have already been working on concurrent engineering for some years, this approach is only now becoming increasingly popular, in Western countries. One of the reason is, probably, the rapid development of the technology research stimulated by the American CALS Initiative (in Chapter 1, we presented CALS related to FCIM).

As CALS is now taking the official name of CALS/CE/EDI, CE is assumed to play one of the principal roles in many research and application programmes. In America, are taking place the first Conferences on concurrent engineering. Some societies such as American CE Society and the European CE Society (ESOCE) are actively promoting concurrent engineering.

But, curiously, concurrent engineering was created by the Japanese at the beginning of the 1980s, as Suzue (1992) says. In the previous Chapter, we presented some references to concurrent engineering when we were studying CIM in Hitachi. It seems that the Japanese were the first to encounter problems requiring a concurrent engineering solution, and solve them.

In the MELCO case, CIM is presented by managers and researchers as something related to concurrent engineering. But the concept is somewhat adapted to the realities of this company, and one aim of this Chapter is to describe it.

This Chapter begins with a conceptual presentation of CIM and continues by studying CIM models and subsystems, production planning systems and CIM, and application of production planning systems. After this, we present two cases applying CIM: the case of the Nakatsugawa works (customer-oriented CIM of ventilators) and the case of customer-oriented CIM in moulded-case circuit breakers. Finally, we study the implementation of CIM/FA strategy.

3.1. THE CIM CONCEPT AND CONCURRENT ENGINEERING

Manufacturing companies are currently under strong pressure to supply goods, related services and information that more faithfully answer their customer's requirements, increase the degree of satisfaction of both employees and stockholders, and protect the environment. For these reasons it is very important to construct lean production systems that can respond flexibly to business demands minimizing the waste in all company activities, following D. Roos et al. (1990).

Towards a definition of Concurrent Engineering.

New information technology is playing an important role in this challenge. Nevertheless, until recent years, the introduction of FA linking to the EDPS (Electronic Data Processing System), with computer-aided design (CAD) and computerized engineering (CAE) of design departments, sales information systems of sales departments and flexible manufacturing systems of the manufacturing departments, were characterized by three aspects:

1) to be veritable islands of automation;

2) to cause many redundancies; and

3) to produce conflicting processing situations among individuals, and between them and isolated systems.

If computer network technology and database technology appear as fundamental technology tools for solving this kind of problem, one even more important factor to emerge from this situation is the realization that departments in companies have common goals. This means that they must work together as a whole in order to reach the optimal solutions, and not separately.

In the MELCO approach, both CIM and concurrent engineering are main concepts that can contribute to creating better conditions for improving this kind of cooperation. In fact, the spirit itself of CE corresponds fully to this challenge. But what is Concurrent Engineering?

J.Smith (1990) quotes from the Military Handbook (American DoD, 1988), though an earlier definition advanced by IDA Report (1986). She defines Concurrent Engineering as a systematic approach to creating a product design that considers all elements of the production life cycle, from conception through disposal of production: the design of products, their manufacturing, and all other required life cycle processes such as logistics support.

With concurrent engineering technology, the definition of product, of the manufacturing process, and of all other necessary life cycle processes must be made simultaneously. It is an integrated design approach that considers every aspect to produce a more robust design. Then concurrent engineering is a cooperative concept for every productive system. Emphasis is put on three ideas:

(1) efficiency;

(2) increased quality; and

(3) reduced cost.

Concurrent Engineering is thus an opposite concept to the traditional approach of engineering which is a sequential one. Figure 1 depicts the sequential engineering process and the concurrent engineering process. As we see, to exist and to be effective, concurrent engineering needs absolutely to be a cooperative process. But this cooperation is not evident, and goes against many old and bad ingrained habits; mentality must be changed, in parallel with the engineering process.

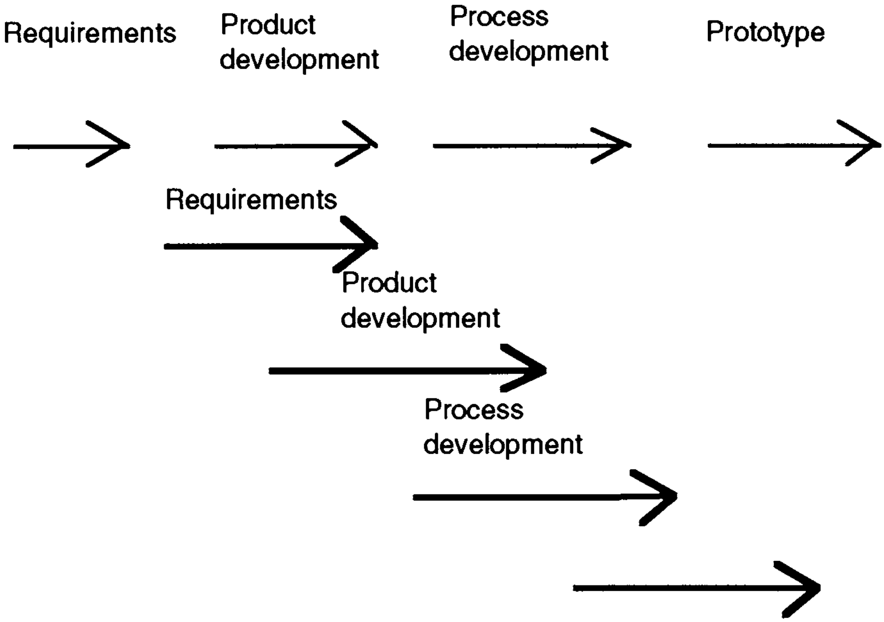


Figure 1. Comparison of sequential and concurrent engineering

Dimensions of Concurrent Engineering.

From the above definition, D. Carter and B. Baker identify four key dimensions of concurrent engineering. These four dimensions are:

- organization, concerning essentially teams such as development teams. For example, these last must embody the responsibility and the authority for their design decisions, and work in a cooperative manner;

- communication infrastructure, which is a crucial point to link people and all processes taking place in the company;

- requirements, that means to pay attention to the customer requirement for products and its satisfaction as a main company strategy;

- product development, that concerns, principally, the design process, the components libraries and the optimization of product development.

These dimensions are associated with the five forces of change. The forces of change proposed by these authors are:

- technology: that means companies "need to change the way they view, choose, and use technologies in developing a product"

- tools: that means paying attention to continual evolution of tools and the increasing matching of tools and evolving technology
- tasks: that means paying attention to the increasingly complex tasks of which individuals are capable through the evolution of automation
- talents: that means paying attention to the necessary new skills for the workforce, in particular the new higher skill division of labour which is emerging and will affect all companies
- time: that means, principally, the need for engineer time and to reduce total cycle time.

Even if these authors insist particularly on the design aspect of concurrent engineering, we think their presentation of dimensions and forces of change of concurrent engineering can serve as a reference point for a better understanding of the MELCO CIM and concurrent engineering case.

In particular, concurrent engineering as a cooperative concept for research/development design must revolutionize products and production systems. In fact, production systems themselves must be thought of in a radically different manner. Many of their present activities are entering into the critical path following this approach. And one problem for managers and engineers is to find a better adaptation to this new challenge

According to the quoted definition itself, concurrent engineering will push simultaneous and parallel development of the entire production process, from marketing, conceptual design to the product itself, including the manufacturing process, manufacturing system and sales system. Concurrent engineering must exploit many potentialities of computer models and tools to plan even shorter times and optimize development results.

MELCO, Concurrent Engineering and CIM.

Now, what is the relation between concurrent engineering and MELCO CIM? We try to answer this question.

According to MELCO, the CIM system is a production system which can produce in a virtually stationary state, creating and selling the same or similar product with the same or similar processes. In other words, one can create a system that uses computers to increase production response to a level that, on the one hand, rivals the speed at which the market changes and, on the other hand, minimizes mechanical losses and redundancy within the production system.

So the CIM system is a production system that provides a sales information system and parameters to integrate various factory automation systems, such as automatic design systems, automatic assembly, sheet metal FMS and automatic inventory. As we see, this MELCO CIM approach is quite convergent to the concurrent engineering approach to the productive process (in the MELCO interpretation).

Figure 2 gives a graphical representation of this MELCO idea. We can see that concurrent engineering creates a design linking two main elements: on the one hand, sales, and on the other hand, the manufacturing process. Then, as I. Toshio (1992) says, concurrent engineering is producing inputs for both innovative products and a CIM innovative production system. So, the MELCO view is radically different from the Western definition of CIM,but they are not totally different.

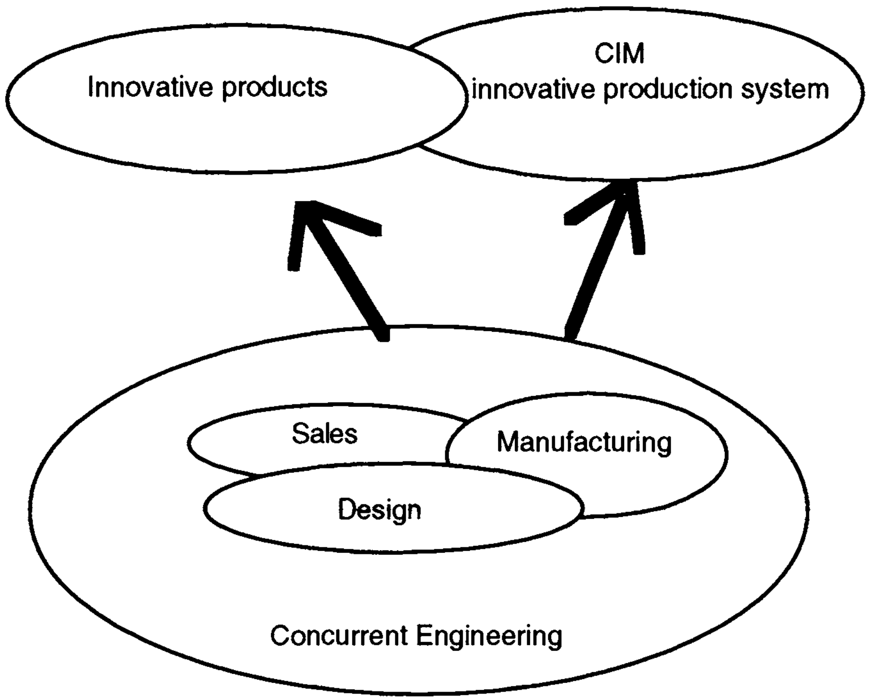


Figure 2. Concurrent Engineering and CIM

CIM and concurrent engineering behave as means to improve the performance of computerized operations. By this method MELCO plans to reach the border of human creativity, interacting with complex machines via computers and networks linking computers. And as in the human beings perspective, the creativity can determine "what to do" from various sources of information.

This environment allows users in different departments inside the company to process up-to-date. That means accurate data are flowing through and being stored in the CIM system and the computer system for concurrent engineering. This set of technical tools encourages them to generate more and more information.

In addition, a client-server system needs to be implemented as an effective method. By using software tools on the market that enable easy automation of a series of processes in the client-server environment, users with even a little know-how can test and evaluate systems for themselves. This is extremely significant, because it enables every user to generate information automatically and then improve productive operations.

We know that one of the goals of CIM is to improve and to shorten time of delivery. Another objective for CIM, in the MELCO view, concerns the rationalization of factors such as the reduction in opportunity losses and total logistics costs. With the CIM system everyone involved can put the customer in first place and give even more importance to the leanness of not just his own workplace but also the entire production system. CIM is then a technology involving individuals in the framework for global production.

Just one additional comment: Given the importance of the logistics, MELCO is one of the first to appreciate the relations between CIM and logistics: CIM must contribute to reduce the logistics costs. Unfortunately, we do not know new form of the logistic concept which, in our view, must be different in a CIM environment. The classical logistics is not entirely adapted to this new environment.

3.2. THE CIM MODELS AND SUBSYSTEMS

If a general concept for CIM exists, this is not the case when we assess the CIM models. This distinction is important, and as we saw in Chapter 1, there is no one universal model for all CIMs but many CIM systems. MELCO CIM confirms this assumption.

The kinds of CIM systems.

Studying the MELCO case, I. Toshio (1992) distinguishes several kinds of CIM systems. So, according to the required lead time and the product design needs, in MELCO it is possible to find three types of CIM:

(1) production-to-stock

(2)variant mass-production

(3) job-order production

These systems are represented on a graph showing required lead time and product design time. The product design may be predetermined, or after order. In turn, the required lead time may be short or long. Figure 3 depicts this situation.

Looking at this figure 3, three types of CIM may be characterized, as follows:

- the production stock, for which the required lead time is short and the product design is predetermined

- the job order production, for which the required lead time is long and the product design is executed after order

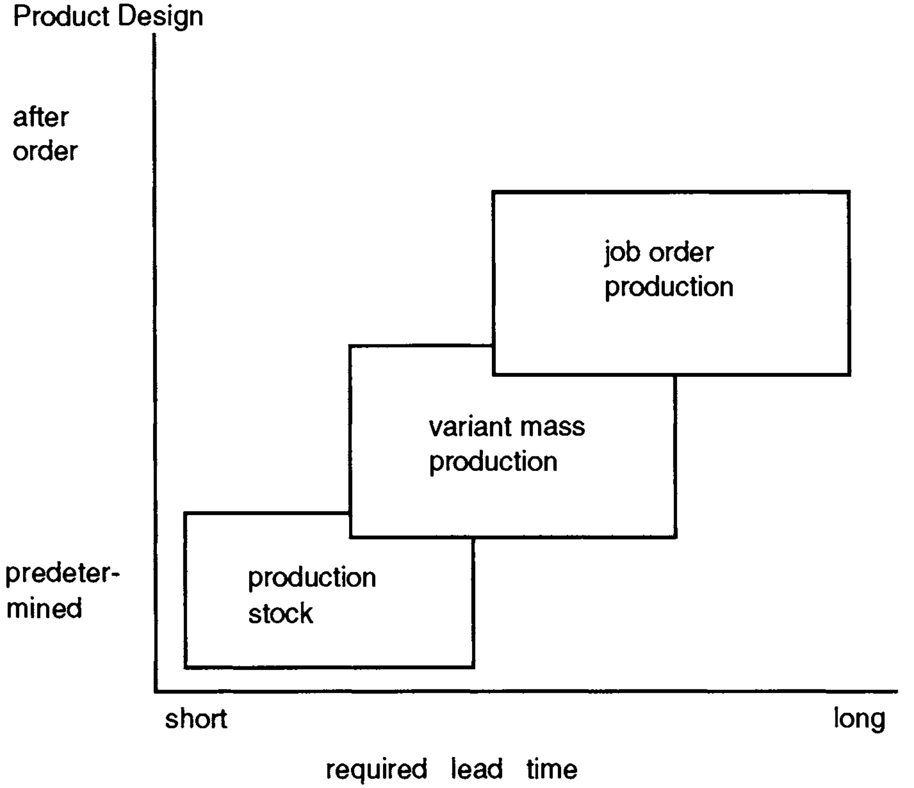


Figure 3. Types of CIM systems

- the variant mass production, which is in an intermediary position compared with the other two.

Subsystems and kinds of CIM.

In order to implement CIM, it is necessary to define different kinds of subsystems that are related to the CIM systems. To study each CIM system we follow design, sales and manufacturing views, as presented before. This classification is coherent with the global function assumed by CIM technology in the MELCO case.

Figure 4 presents these subsystems according to the three last CIM categories and following the design, sales and manufacturing points of view. For example, "production to stock" uses CAD/E technology for design, sales information system for sales and FA for manufacturing. "Variant mass production" uses AD/CAD technology for design, sales information system for sales and FA and FMS for manufacturing.

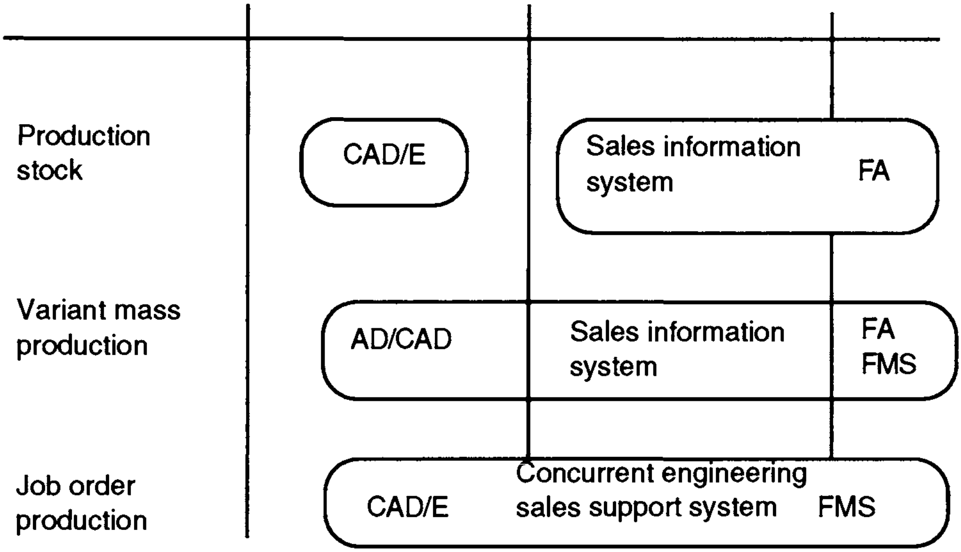


Figure 4. Typical subsystems of CIM systems

The importance of design, sales and manufacturing and the application of these CIM systems also depends on what kind of production is involved. For example, in the case of "production to stock" system, where development has already been completed and customer needs are gauged by market research, manufacturing and sales are designed to follow demand trends. This is a typical case of demand-oriented production.

In the case of MELCO CIM, industrial electric appliances and air conditioners each require a line-up of products with differing specifications such as capacities, and the customer insists on on-time delivery. We study more accurately this kind of problems in the case of Toyota CIM (see Chapter 4). For instance, we insist that MELCO people concentrates forces in constructing a CIM system for such a product.

The "variant mass-production".

In the case of "variant mass-production" system, the products are manufactured having more or less standard configurations to variant designs, according to the already known customer specifications. At MELCO this system covers products such as elevators and medium-size motors.

In addition, in a CIM system for "variant mass-production", it is important to consider a factory automation system provided with auxiliary functions. Among these auxiliary functions, the following are important:

- a sales support system that supplies the customer with estimated prices and delivery dates, processed from parametrized product specifications;
- an automatic planning system that inputs product specification parameters; and
- a production management system that can vary the manufacturing schedule with changes in computer-aided manufacturing (CAM), FMS (Flexible Manufacturing System) and repeating delivery dates.

The "Job order production".

"Job order production" takes care of manufacturing products whose specifications are determined by consultation between customer and designer. This covers a large range of products such as large generators and plant control systems. As, in this case, each order has many parts requiring simultaneous development, concurrent engineering becomes an important tool for creating an appropriate CIM system.

Comment: in this last point, we note analogies with some Western programmes applying the more advanced technologies such as CALS or other major industrial projects, as quoted by CALS Euro Conference (1992).

Semiconductors are a field that extends over the present CIM classifications. Products such as micro-computers have a large demand for quicker delivery, and thus demand a more appropriate construction of job-order CIM. But some other MELCO products, such as medium-sized motors, have characteristics of both the "production to stock" and "job-order" types of production, and need another adapted CIM system.

The "production-to-stock".

In CIM for "production-to-stock" manufacturing there is a strong demand for market -driven production. In this case a technology for CIM construction is essential. I. Toshio (1992) quotes at least two important problems in this case:

(1) the technology for CIM system implementation answering to defined targets is essential; and

(2) the importance of developing subsystems to a level where they can be integrated to construct a CIM system that makes full use of all these technologies.

Concerning the first point, the problem is to construct a manufacturing system that can follow variations in product models and quantities, reduce delivery times by implementing small-batch, multi-cycle production, rebuild a production planning and management system, shorten the setup time of facilities and then review this manufacturing process. Indeed, a particular emphasis is placed on technologies relating to details such as design for manufacturing.

Concerning the second point, the problem is to put each subsystem in a situation such that they can satisfy the new roles in a CIM- concurrent engineering environment. As we see in the preceding paragraphs, one of these subsystems is a sales information system that can completely and rapidly collect data on details such as customer orders and product inventories. Another subsystem is a manufacturing system, which requires factory automation that can accurately fulfil various orders for many different products within a short manufacturing period and can rapidly give information on the status of these orders.

In this way, we are approaching the question of a production planning system. As a result of the above development, a production planning system (see Section 3.3 for planning) that links, accurately, sales and manufacturing subsystems becomes one of the most important tools for building correct CIM system. But this question leads to another: the question of people involved in CIM at every internal level of the company.

Generally, CIM strategy must associate as closely as possible people working in a company. To achieve this target, MELCO headquarters (engineering and manufacturing) have formed a CIM construction team. This team has a comprehensive knowledge of distribution, production management and production technology as well as business.

In reality this team, in contact with the manufacturing and personnel departments of factories, are working to achieve a company-wide CIM system project.

3.3. THE PRODUCTION PLANNING SYSTEM AND CIM

A production planning system within the production to stock CIM system must be able to provide optimal, and rapid, production instructions in order to meet changes in consumer demand. A production plan is the tool for this purpose. Following this view, one definition of a production plan is a plan that determines the specifications, quantities and delivery dates of products to be manufactured in order to respond to customer demands.

The content of production plans.

The content of production plans can be divided into two main categories with different applications and times scales:

(1) the first category sets necessary resources, such as facilities, man-hours and materials, and their timings, to provide long-term planning extending over one to six months until final assembly, and

(2) the second category finalizes the timing of production steps, and is determined closer to the date of final assembly.

With production planning for production to-stock manufacture, the feasibility and economics of each product are evaluated and determined with respect to production demands predicted from marketing data such as sales trends and inventory. We need consider separately two elements:

(1) the forecast correctness of production requirements, and

(2) the changeable range of production plan.

The sources of production requirements that form a base for production planning differ according to the time involved. In the long term, the main source is forecasting study from economic trends and demand forecasts. In the short term, the sources of data come from inventories and advance orders.

Forecasting needs a special comment. We know that the accuracy and reliability of forecasting is, in general among other factors, linked to the time dimension. Furthermore, estimation methods have more or less application according to the time dimension. So, in normal conditions, forecasting is more accurate and precise in the short term than in the long term. This kind of problem is always emerging when we study planning, and we find it in the MELCO case and also in the Toyota case (see Chapter 4).

For instance, confirming the above assumptions, in the MELCO situation we can consider the example of refrigerators. Although one can forecast demand for refrigerators in general up to three months in advance, it is difficult to forecast demand accurately for a specific model. But over one week, it is possible to predict the demand for that model with a high degree of accuracy, based on advanced orders, inventories and back orders.

The prediction model must be well able to take correctly into account the demand based on the forecast and the changes becoming necessary according to the order variations. This must allow a redefinition of refrigerator demand at every scheduled point within a certain period.

As we see, an important problem emerging in this production planning is the variations within certain limits. So there exists a certain range in which variations are taking place. The range of variation for production planning is then changeable over the time. This is wider in the long term than in the short term. Normally, this range narrows gradually as the final assembly date approaches.

This occurs because constraints acting over the preparations leading up to the actual production became. Among these constraints, the following are interesting to underline:

- the component parts,
- the progress towards the final assembly date,
- the taking into account of lead time, and
- the current status of this production preparation.

Production planning cannot avoid these constraint conditions without the risk of generating, for example, losses in productivity or undesirable delays.

Deliberate decision-making: long and short range.

One important element intervening in this production planning is the deliberate decision-making that should coordinate constraint conditions on the changeable ranges of production plans, to narrow them gradually as production demands change, and to ensure that customer demands are satisfied within feasible limits. The role of deliberate decision-making varies following the long range or the short range supported by the difference between strategic planning and operational planning.

During long-range planning, in which strategic views prevail, the deliberate decision-making process proposes and reconsiders production demands centred on forecast requirements and determines strategies taking into account the necessary available resources. A consensus must be reached between the different departments concerning the decision process and its results.

During short-range planning, in which the operational views prevail (factual based, partial optimum, rapidity), the deliberate decision-making process focuses on individual problems which decision-makers are facing. As we see, the data for the deliberate decision-making process change according to the period of the planning process.

In addition, the deliberate decision-making process for planning is supported by computer. Nevertheless, the role of decision-making and computer is not the same for the long-term planning and the short-term planning. The problem is then to know what role (and how) must be attributed to both man and computer during the production planning process. As in the precedent analysis, we need to distinguish two situations

(1) deliberate decision-making for the long range.

In this situation, the role of the computer is to supply data to promote better deliberate decisions. The data must not only be output in a standardized format, the decision-makers themselves must be able to perform versatile analysis in an interactive manner, using the forecasts as starting points.

In this case, each department must be aware of what the other departments are doing, in order to avoid any confusion generated by their own subjective forecasts. At this point, it is convenient to provide a centralized forecast and available information to everyone. To do this, the client-server computerized architecture is a good method.

(2) deliberate decision-making for the short range.

In this second situation, an area should be automated by computers in order to obtain accurate and flexible solutions to the huge number of demands. If some problems could occur, it is necessary to issue flexible executable instructions in order to solve the problems referring to the constraint conditions linked to the production planning changes.

An effective method is a constraint-oriented problem-solving approach, in which methods of solving problems are placed in a hierarchy, and the region where problems should be solved is subjected to detailed constraint condition checks to obtain a solution. When this method cannot find the solutions, then the role of the man is to intervene in order to obtain some solution.

Figure 5 presents the roles of man and computer in production planning. The region under the diagonal line represents the computer intervention area in solving production planning problems. As the figure 5 shows, the role of the computer is increasing when the planning production process is passing from the long range to the short range plan. Conversely, the man role is decreasing over this same period of time.

At the beginning of the planning production process, man is intervening on multiple data analysis/forecast, strategic decision and consensus making but gradually this intervention diminishes until the moment in which, finally, man is only intervening in problems concerning emergency action. Conversely, at the beginning of the production planning process, the computer works, principally, on database operations, and gradually its intervention covers the problems such as automated problem solving and emergency warning.

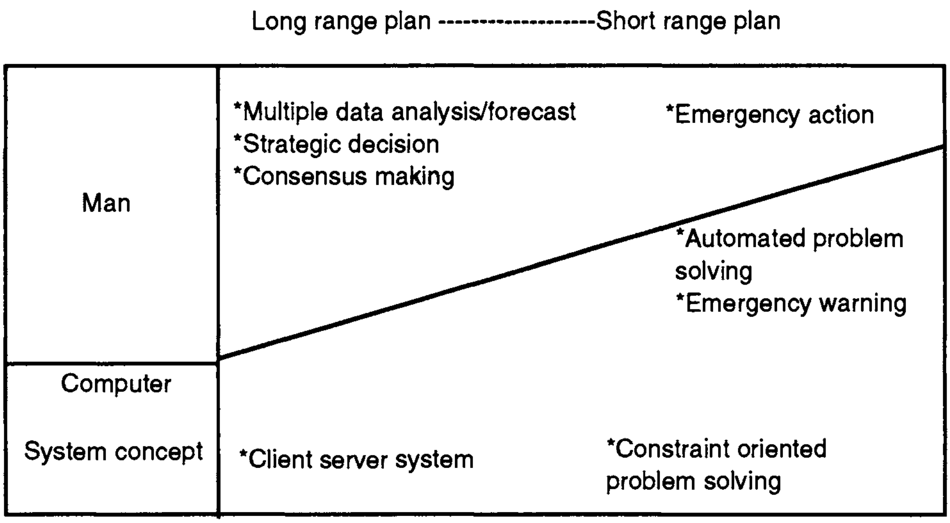


Figure 5. Roles of man and computer in production planning

It is important to point out that from the system concept viewpoint, both man and computer are operating with different system approaches according to the situation in which they actually are, the long-term range planning or the short-term range planning. In the first case, a client-server system is operating. In the second case, the constraint-oriented problem solving is operating. The first system concept is commonly used by other companies for similar purposes. In particular, we meet the client server system in Toyota CIM (see Chapter 4).

3.4. AN APPLICATION OF PRODUCTION PLANNING SYSTEM

In the previous section we have presented the production planning system and CIM in MELCO. This Section is dedicated to less theoretical developments. We introduce the decision-making process relevant to production planning and the relationships between man and computer in those processes in the case of production-to-stock systems of CIM MELCO systems.

The example of production-to-stock systems concerns ventilators. According to I. Fukuda (1992), ventilators represent a 700 million yen market in Japan. A large numbers are installed in the kitchens and sanitary spaces in offices and homes. There are over 200 types of ventilators having different applications, ventilating capability and exhaust function. There are strong market demands for manufacturers to deliver quickly a range of several types of ventilator.

The problem is then that customers need to install ventilators following the progression in building work processes. To solve this problem and then to meet correctly the demand for ventilators, MELCO decide to build a market-driven CIM system that I. Fukuda (1992) calls "Customer-oriented CIM in the ventilator business".

The steps of planning.

In this MELCO ventilator CIM system, production planning consists of four steps that determine progressively finer details. These four steps are:

(1) annual plan

(2) aggregate production plan

(3) semi-monthly production plan, and

(4) daily plan.

Note: Do not confuse these sequential planning steps with concurrent engineering, which is a simultaneous production tool for product design, incorporating many aspects of the life cycle of a product.

Figure 6 gives a general idea of these four steps.

We comment on each of these steps in the next paragraphs.

a. Annual plan.

Every year a long-range annual production plan for up five years ahead is proposed, as part of the operations strategy based on macro-economic trends. This plan determines resources planning, such as product development planning and investment. Stand-alone personal computers are used to draw up these plans, and to collect and analyze various types of data including external databases.

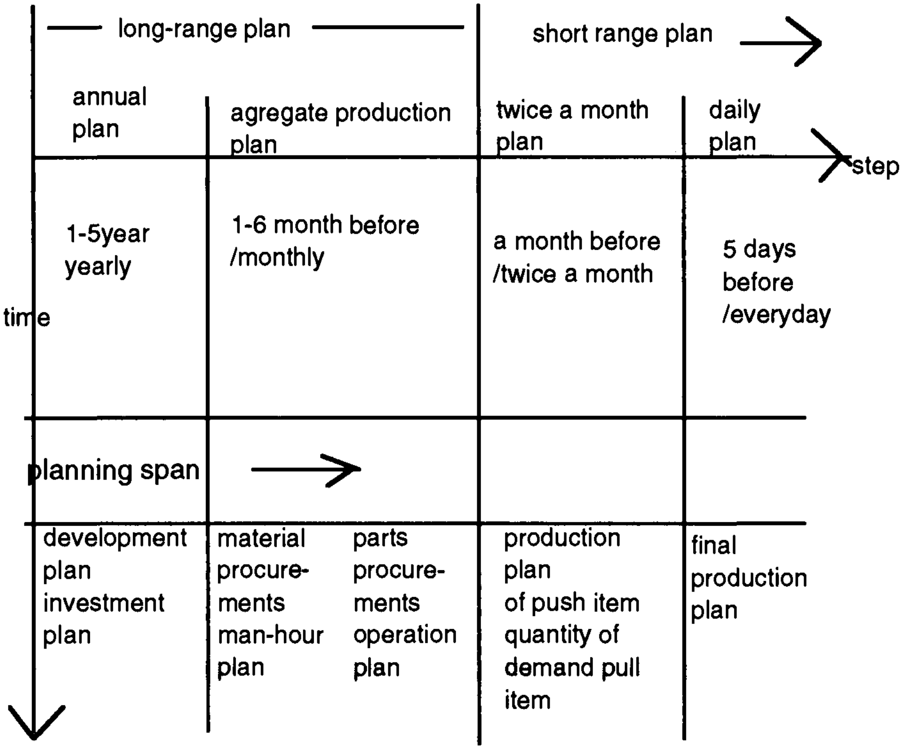


Figure 6. General idea of production planning steps

b. Aggregate production plan.

A production plan is proposed each month for one to six months ahead, based on estimates of the model demand. The quantities and rates of increase/decrease of these demands are calculated from estimates seasoned by actual sales results from the past few years and sales trends. Following this, a revised plan is automatically calculated that satisfies general limitations of resources that have already been allocated, such as product inventory status and production capabilities. This revised plan comprises the previous month plans plus additions for one month and six months ahead.

When it is necessary, the operations departments can also change these planned values by interactive processing. When all these data are ready, the management department takes this data, creates load allocations that contain more and finer details than the automatically calculated plans, checks and adjusts man-hours, and by this means, long-range materials procurements and macro capacity plans are estimated.

c. Semi-monthly production plan.

This plan indicates the scheduled assembly dates of large-lot push-models for the next half-month. Only the scheduled quantities of demand-pull models are given. The semi-monthly production plan determines the production schedule and operations planning for special parts which require more than five days. As we see, both push items and demand pull items appear here, giving the production plan of push items and quantity of demand pull items.

At this stage, the MELCO ventilator CIM system is giving an original approach concerning the links between supply and demand (we also find this in the Toyota case, see Chapter 4) or, in other words, we find here the classical situation of just-in-time production. Nevertheless, the above approach is quite different from approaches quoted by A. Satir (1991) concerning the operational planning and control issues.

For example, A. Satir (1991) quoted a paper comparing push and pull systems in a cellular manufacturing environment (written by B. Durmusoglu, pages 115- 132). This article describes a good link between both push and pull approaches at the cell level in the factory, but the operational, and even more the strategic planning, concepts are completely lacking.

d. Daily plan.

A production plan for the next five days is automatically decided upon every day. The daily plan determines the production amount and quality required, assigning priority from models that are forecast as accurately as possible to run out, from among the demand-pull models as indicated in the semi-monthly production plan which is, in turn, based on the previous day's Japan-wide orders and inventory information. As Production quantities of demand-pull models vary within a certain range, this plan must cope with variations in demand.

The next step is the matching of pull-demand models issues with push-models. For doing it, production quantities of planned push-models are adjusted in answer to changes in the production quantity of demand-pull models, in order to maintain the operation planning.

The results of planning and CIM.

In this CIM system, a distributed schedule management system on a personal computer client-server system is developed. This system can receive the daily plan and adjust the production schedule and actual production results of each line in the factory, and allows accurate production that can respond flexibly to changes. This is an innovative factory automation system that enables revolutionary production design of motors and unmanned production line, comments Toshio (1992).

What are the results of the above described planning production systems and CIM system for ventilators?

The results can be summarized as follows:

- a reduction of the schedule, from 40 days to 5 in the best situation;
- the improvement of prompt deliveries;
- a reduction of the final product inventory to one quarter, and halved distribution costs;
- a rebuilt planning system that enables MELCO to increase planning accuracy, and
- the strategic timings are shortened.

Continuing with the application of production planning in the MELCO CIM system, we add some developments about another product: air conditioners. In general, the principles studied above are applied in this case.

Air conditioners for large spaces such as buildings have seen a rapidly increasing demand. One part of this growth is in small and medium size models, for use as individual distributed air conditioners. There are hundreds of types of air conditioners manufactured to respond to the customer demand and low-energy conditioning characteristics. They can be separated into several classes but, in general, they depend overall on whether they are floor-standing or ceiling concealed cassette types.

In the production planning system for air conditioners for buildings and commercial use, deliberate decision-making frames are arranged to provide a supply of products required by customers with minimum product inventory and within demand timing, taking into account changeable ranges of accuracy of production demands and production planning.

In this particular case of air conditioners, the decision-making period for production quantities in the production planning system is divided into three steps:

(1) the first step determines the production quantity for each large group one month before final assembly, based on requirement estimates;

(2) the second step determines the production quantity for each small group two weeks before final assembly, based on actual sales results, inventory status and advanced order data;

(3) the third step determines the final production quantity for each model one week before final assembly, based on inventory status and highly reliable advance orders.

The group configuration can take into account changing patterns of customer orders and for this reason is not greatly affected even when order changes occur. Actual sales results, inventory status and order data are collected directly in the factories into a database using for this purpose a sales information network.

The production planning in the first step is strongly affected by strategic decisions made by humans, but in the second step onwards, decisions are automatically indicated by means of computers. In the second step, the production quantity for every large group is made closer to the target inventory, based on past sales results and advance-order data.

During the third step, the production quantity for every small group is broken down into production quantities corresponding to each model, based on inventory status and highly reliable order data, in such a way that the minimum necessary inventory for each model be not less than the safety-level stock.

We now takes a practical example.

The production planning process runs as follows:

(1) it assumes that during the first step there are two groups of air conditioners to be produced: A (with amount 120) and B (with amount 190);

(2) during the second step, the group A is divided into smaller groups, for example A1 (with amount 70) and A2 (with amount 50);

(3) during the third step, the smaller group A1, for example, will be separated into product item and quantities as follows: Product A11 (30), Product A12 (40). In this last case, the work is performed completely by computer.

The system was designed to ensure that component parts were common, as far as possible. It was also designed to rebuild manufacturing lines and reduce lead times to incorporate the processing of different parts components that could not be made common (such as printing of model codes on the corrugated cardboard used for packaging). A similar system is also applied for night-time rate electric water heaters.

This method of dividing production planning into several decision steps is called a multi-step production planning system. It is a key technique for constructing the CIM system. As all CIM systems are closely related to the distribution, it also developed a company-wide system for monitoring distribution. This system uses data to check on the sales information system and production planning system in the future, to increase customer satisfaction with smaller inventories and fewer distribution resources.

What are the benefits of the introduction of this production planning system? They include

- a reduction in safety-level stocks
- prevention of sales losses due to inventory run-out, and
- lightening of the load on production planning staff.

3.5. THE CASE OF THE NAKATSUGAWA WORKS (NCIM) FOR CUSTOMER-ORIENTED CIM OF VENTILATORS

In Japan "works" means a production site including more than one factory. So we keep this word in the following developments.

In the above section, we studied a general approach of production planning and its application to ventilators production, with reference to a specific product but not to a specific factory. In this Section we study more precisely the implementation of the CIM system for ventilator production within the framework of a precise production centre: the MELCO Nakatsugawa Works.

The significance of NCIM.

After some years this centre is developing a CIM system named NCIM (which results from the contraction Nakatsugawa and CIM). Within this framework the CIM was introduced at the Iida Factory (which is one part of the Nakatsugawa Works) in April 1991. As we have studied in Section 3.2, 3.3 and 3.4, the concept governing this implementation is to approach customers by linking production and sales.

The Iida factory produces a wide variety of ventilators. Whether or not the information links between manufacturing and sales exist, MELCO engineers call this "approaching customers and producers environment" and they then propose a contraction NCIM meaning "Nakatsugawa Customer In Manufacturing", which is an equivalent to the "Nakatsugawa Computer Integrated Manufacturing". The idea is to have a manufacturing system as a simple "supermarket" in which customers are served.

According to I. Fukuda (1992), to realize this CIM system, the following aspects were taken into consideration:

- change of production method. That means the introduction of small-batch multi-cycle production and changeable volume production;
- improvement of production planning method. That means the adoption of step-by-step planning method, to improve accuracy of production planning;
- reconstruction of computer-aided production, planning and control systems;
- improvement of line capacity, which includes shortening of set-up times.

The general goal of the CIM system (to shorten the lead time) is broken down into several sub-aims to which correspond different approaches. Some of the NCIM approaches can be explained from the point of view of system design and constructing the total effective system (see Section 3.1 about concurrent engineering). The cutting down policy responds to the adaptation of CIM implementation strategy to the local conditions or the nature of local production.

We now give an overview about CIM sub-aims and the set of associated approaches, as used for the NCIM implementation. In order to shorten total manufacturing lead time, there are the following NCIM approaches:

- "sales and distribution information system (network)" and "computer-assisted production planning" for improving accuracy of production planning;
- "ADPP (Automated Daily Production Planning System) and distributed schedule management system" for shortening lead time between plan and production;
- "line support system", "shorten set-up time item change" and "improvement of line capacity" for introducing small batch multi-cycle production;

- "improvement line capacity" which combines with the earlier approaches for increasing flexibility of production capacity.

STEPS method and NCIM.

All these approaches need a system design methodology allowing a higher flexibility and adaptation of production capacity and production line. This methodology is called "STEPS" which means "STEp-by-step Production System". The STEPS method is linked with all previous approaches presented earlier.

The production planning method "STEPS" for customer-oriented CIM is a concept of the total production system to shorten manufacturing lead time. There are three progressive STEPs:

- STEP1: make quantitative goal. Examples of NCIM are: lead time 5 days; inventory 09 month in final product; prompt delivery ratio 95%;
- STEP2: analyze sales information and break down the goal. Examples of NCIM are: classification products items; decide changeable-width of production plan and production frequency satisfying quantitative goal made;
- STEP3: make specification of subsystems. Examples of NCIM are: cycle of production plan is daily; production volume of some line is X/day; set-up time in the item change is Y minutes ...

To make a production plan, it is necessary to make decisions about "products items", "date of production" and "product volume of each item". Figure 7 gives a graphical view of this STEPS concept.

According to this figure, in the STEPS method these three elements have changeable width at first, and the width is narrowed down step-by-step. That means the production plan is decided step-by-step from uncertain plan to certain plan. The production volume of each item is not clearly decided, but some constraints which are necessary to prepare for production are decided. For example, total production volume is necessary for a man-hours plan, or maximum production volume is necessary for the ordering of some parts.

The traditional method needs negotiation between the manufacturing and sales departments when production plan changes occur. But in the NCIM case, the STEPS method makes the "rules of production plan change" clear, and the concept of STEPS is important for the design of a customer-oriented production system which is totally effective.

But the improvement of production planning for shortening the lead time is nothing without changing (or at least adapting) production methods. In order to improve the production methods it is important to analyze the production conditions and diagnose the pros and cons existing in real operation processes.

The Iida factory is producing about 220 varieties of ventilators. These items are classified into two groups, following the indications given by the sales analysis. The groups are called " A group" and "B group". The items of the first group are sold constantly, with little variation of demand. Conversely, the items of B group have a large demand variation. These items are sold irregularly and it is difficult to predict the demand for them. In addition, delivery troubles are in the B group. So, one solution is to maximize flexibility in the B group production plan.

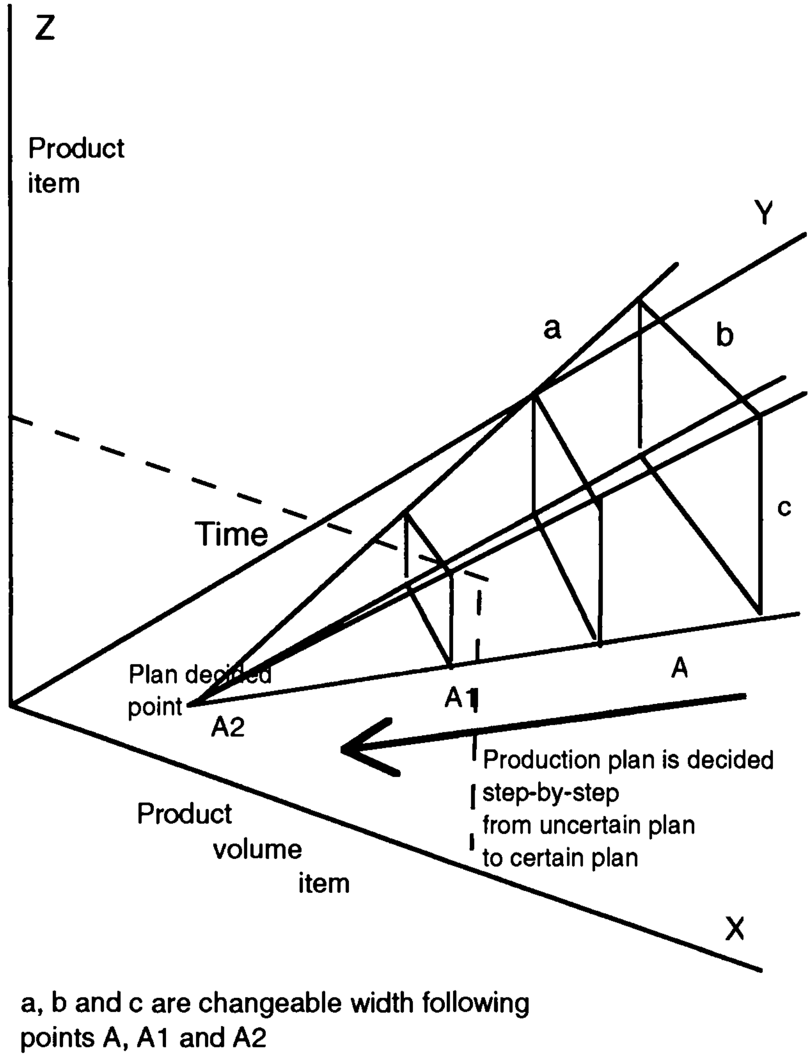


Figure 7. Generalized concept of STEPS
(STEp-by-step Production System)

The production system must be adapted to the changeable volume production under the following conditions:

- twice a month plan (15 days in advance):

(1) temporary production volume, with changeable-width;
(2) periods of production (in 1/4 month units) are indicated;
- daily plan (five days in advance):
(1) date of production;
(2) sequence of production;
(3) final production volume is fixed.

Items in B are "demand-pull manufacturing items". A is a small-batch multi-cycle production; B is a changeable volume production. To enhance changeable width of B there are stocks of bottleneck parts. A simulation-based approach was used to estimate the relation between stock volume of bottleneck parts and service level to customers.

But changing production method and production planning improvements need an appropriate information system, which is now becoming a real factor of production. This is a key issue for reconstruction of computer-aided production planning and control systems. How this problem is solved in the NCIM context, we try to explain below.

NCIM functions and benefits.

An overview of NCIM information system is given in figure 8.

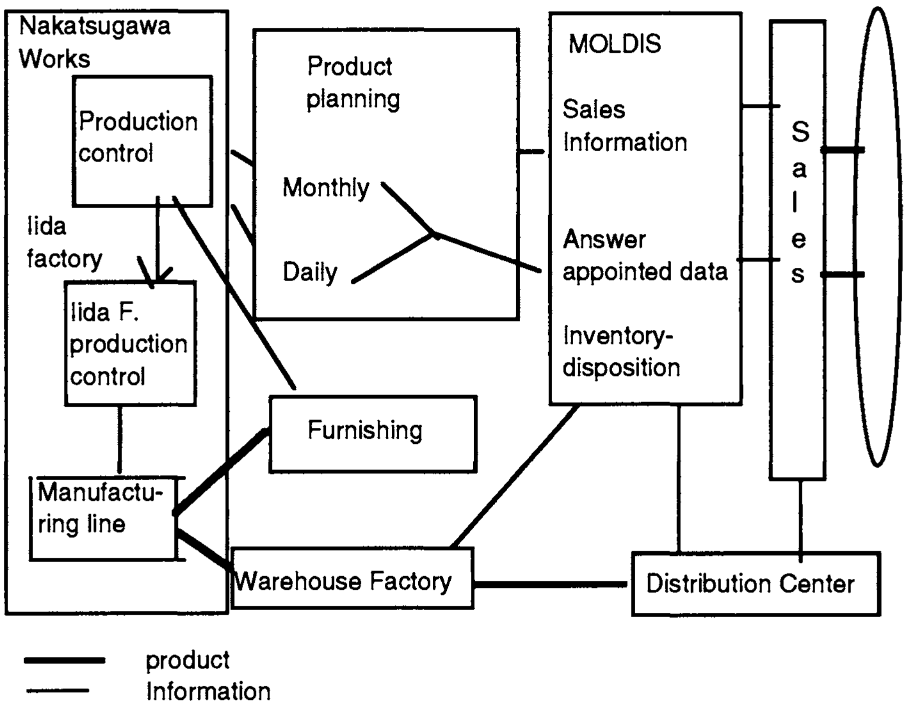


Figure 8. Outline of NCIM Information System

This figure shows two main flows (physical product and information flows) going to the customers and many information links, particularly the MOLDIS Network (MELCO On-Line Distribution Information System). On the left side we see the Nakatsugawa Works and the production control system. Below is the Iida factory, with its own production control. In the centre is the production planning system, operating monthly and daily. On the right side there are MOLDIS networks linking production planning, Nakatsugawa, sales and the distribution centre.

The NCIM information system runs as follows:

- from sales information input to the terminals of sales branches, computers automatically generate the production plan (twice a month) and daily plan;
- these data are sent to the manufacturing line and vendors; through the production control system as production instructions;
- receiving inventory data from each distribution centre, a detailed supply request is sent to the factory warehouse;
- when products are out of stock, the predicted date of delivery is sent to customers
- finally, production planning and instruction systems estimate monthly production and plan the daily ventilator items to be assembled, 5 days ahead of time

As we know, the final production planning of STEPS is the daily production planning. It decides production plans automatically from sales information (inventory, back orders, etc.) received from the sales and distribution information system. A heuristic method is used to solve manufacturing constraints (production capacity, materials, lot size, etc...) and to satisfy customer demand.

Heuristic methods are often used in Japanese companies to solve this kind (and also other kinds) of problems, whereas Western companies frequently use sophisticated methods such as those issued from operations research, or computer-aided decisions, or artificial intelligence. In other words, heuristic methods probably have potential a development and application advantage beyond what we assume at present.

It is interesting to observe that the Iida Factory and manufacturing line are inserted in a wider information network. In this framework, the schedule data are downloaded from the Nakatsugawa Works to the Iida Factory via an M80 (office computer of MELCO). Based on these data, the entire Iida Factory is controlled by computer. This entire system is adapted to support the production system in NCIM (small-batch multi-cycle, changeable volume production).

Under these conditions, the distributed schedule management system prepares the production schedules of workshops in the factory, that is the final assembly lines, receiving information about production plans from the

Nakatsugawa Works. Each schedule is managed by shop-side PCs connected with PCs LAN. It is a cooperative system between men and computers.

The line support system is located under a distributed schedule management system (PC-LAN). Its functions are to:

(a) receive the newest schedule data (items, sequence of assembly) from the upper system;

(b) when set-up, display work instructions;

(c) when set-up, send set-up data to programmable controllers of each unit;

(d) check the performance and activity of automated stations;

(e) monitor and track the production line flow.

What are the benefits of NCIM for MELCO?

The introduction of small batch multi-cycle production changes the production style of ventilators, and follow benefits in consequence. Some examples of benefits are:

- Axial flow fan type:

(1) the number of items/day for axial flow fan type rises from 6 items/day before CIM to 30 items/day after CIM

(2) the lot size passes from 2500-40 before CIM to 200-20 after CIM.

- Radial flow fan type:

(1) the number of items/day for radial flow fan type rises from 8 items/day before CIM to 32 items/day after CIM

(2) the lot size passes from 2500-40 before CIM to 800-20 after CIM.

- in addition, NCIM reduces the manufacturing lead time (that is the time between production plan and final assembly) from 40 days to 5 days.

To sum up there is an improvement of productivity of assembly lines and other machines. Other improvements are shortening of index time (for example, incorporating servo-mechanisms, double-head units or programming of concurrent motion), shortening set-up times (setting-up, automatic set-up...), reduction of stopping and shortening stop times (productive maintenance of machines and dies, warning systems), synchronizing and directly linked lines (just-in-time, automation of M/H and parts supplying) and, finally, establishing a total productive maintenance.

3.6. CUSTOMER-ORIENTED CIM IN MOULDED-CASE CIRCUIT BREAKERS

In this section we present another example of the MELCO CIM system. It concerns moulded case circuit breakers, where faster delivery and lower price have been required. For solving this problem, a CIM system was introduced in the Fukuyama Works in August 1991. The system uses automated production line computer integration to control production activities, based on a customer-oriented concept (K. Kojima and T. Okazaki, 1992).

A moulded-case circuit breaker is a power distribution and protection device. When trouble occurs, it breaks the circuit quickly and protects it and connected equipment from fatal damage. For CIM in this case, it is necessary to improve market adaptability and manufacturing methods. How is it realized?

In order to reduce inventories and to meet various customer needs, the strategy is to improve production planning methods and reconsider computer aided production planning. Production planning for every half day is decided as the result of analysis of sales and inventory information. Each production plan is decided in the morning or afternoon two days before the final assembly. So each item must be manufactured in two days from market request.

There are standard and customer-made types of moulded-case circuit breakers. Customer-made types are those produced according to the customer orders and standard are produced according to the inventory volume. Nevertheless, the first type has a production priority. The inventory covers several volume categories in which standard types will be produced.

The production method is changed far the introduction of small-batch production. More than 17 types per day can be produced on the new line: so the minimum lot size is about one third that of the previous ones. But the introduction of small-batch production decreases the productivity because of the setting-up for a type change, and complicates the production control.

The manufacturing lead time is reduced to three days (that is, time from production planning to shipping) by a change of policy, to produce almost all MELCO parts rather than purchasing. Then only the raw materials remain to be ordered twice a month, according to the production plan requests

The CIM system is a fully automated production line, from sub-assembly to final assembly, followed by testing. Sales information from the MELCO On-line Distribution Information System (MOLDIS) is sent to the host computer in the Fukuyama Works. A production plan of the final assembly line is automatically generated, based on sales and inventory information, in the host computer in a similar manner to that already studied in Section 3.5. The plan instructs to lower computers and generates the schedule, considering the yield by the production control system. The schedules instruct sub-unit assembly line by turns.

The production control system monitors the number of units being manufactured, number of parts supplied and equipment status in real time, and can report them to the host computer promptly (and the delivery date to the customer quickly). The lower system has good real-time performance in which the more detailed items are managed and the control cycle is shorter.

The key parts are processed and assembled at the sub-unit assembly line. They are stored in the automated warehouse located in the middle of the line. Then these parts are supplied to the parts feeder using three AGVs (Automatic Guided Vehicles), in synchronism with the production progress. This automated production line is designed in order to shorten transportation.

Another factor that makes small-batch production possible is the realization of automatic set-up within a cycle time. According to schedule, set-up and inspection data are automatically sent to a memory card. When set up, the memory card passes through the final assembly line. The equipments read the next production data from the memory card, and carry out automatic set-up. Fully automated production lines depend on production design for manufacturing, as we saw in the first Sections of this Chapter.

Finally, the configuration of the production control system is an important element in the CIM implementation at the Fukuyama Works. This configuration of the production control system is arranged to:

- instruct the production schedule;
- send set-up and inspection data to the memory card;
- monitor and track the production line flow;
- gather and manage quality information;
- control the AVGs and the automated warehouse

All equipment of the production line is connected to the PC LAN (Programmable Controller). Through this network, users can see the number of products manufactured and the equipment conditions. The standardization of equipment error codes and protocol is settled from the equipment design step. This an important factor to construct the production line successfully and to improve the rate of operation.

All products undergo five kinds of inspection. The faulty products would be automatically rejected from the line, and the error conditions would be printed out. All information concerning quality inspection is gathered in real time and analyzed statistically, in order to check the quality. In this quality control, FA-computers are connected through the FSM-bus. One is located for the sub-unit assembly line, one for control of the automatic warehouse and the AVGs, two for the final assembly and testing line, and three more FA-computers are used for monitoring equipment and quality control.

As in the general MELCO approach, the production control system is constructed step-by-step. If one FA-computer fails, it has no influence on the others because of the distributed and not down-sized processing system. The FA-computer runs multi-task and can respond quickly in order to gather all quality information in a few seconds.

3.7. THE IMPLEMENTATION OF THE CIM/FA STRATEGY

To end this Chapter we make some additional comments concerning the implementation of CIM/FA strategy. For doing it, we follow the case of the MELCO Nagoya Works (NW). The manufacturing strategy of NW searches for increasing quality, reduction of delivery time and lowering of cost by use of the CIM concept, FA strategy, MPS strategy and OA strategy.

CIM/FA and communications networks.

FA strategy aims are:

- the construction of a continuous flow FA line;
- an automatic production system that balances the man-machine combination;
- the expansion of a Network between system (MAP); and
- the practical use of products in the FA production line.

OA strategy aims are:

- increase of the administration benefit by the total information system;
- real-time processing in order to unify the production; and
- information flow and the construction of the corporate network (see MIND and MELNET Networks).

Finally, the MPS activity aims to establish the CIM base. The JIT production system aims for the customer just-in-time production system, the construction of a high productivity production line, the execution of improvement activity in the FA production line and the execution of visual control by an OA system.

In order to link all these points, there are three main telecommunications networks:

- MIND (Mitsubishi Information Network by Digital technology);
- MELNET (Mitsubishi Electric Local Area Network;
- VAN network

Figure 9 shows the position of MIND and MELNET. We now present a brief description of this figure.

At the bottom level is the MAP network connecting devices from the FA production line, POP and FA controller. In the level above is MELNET B10 which is a LAN bus type network. MELNET B10 connects MAP network, quality control and factory control. A higher MELNET level is represented by MELNET R100, which is a main route LAn connecting different existing factories in the Nagoya Works (factory A, factory B, etc.) and shipping control.

MELNET R100, in turn, is connected to the engineering information system containing mechanical CAE, electrical CAE and product software design, and to the common host computer in which are located the administration information system, production information system and, principally, one of the most important tools for this centralized system, the common database. This last contains administration information, engineering information and production information.

The MIND network provides connections between the Nagoya Works, other works, head office, branch offices, outside database and main CAE centre. Finally, through the VAN network, MIND users can connect subcontractors, banking facilities and products transferring.

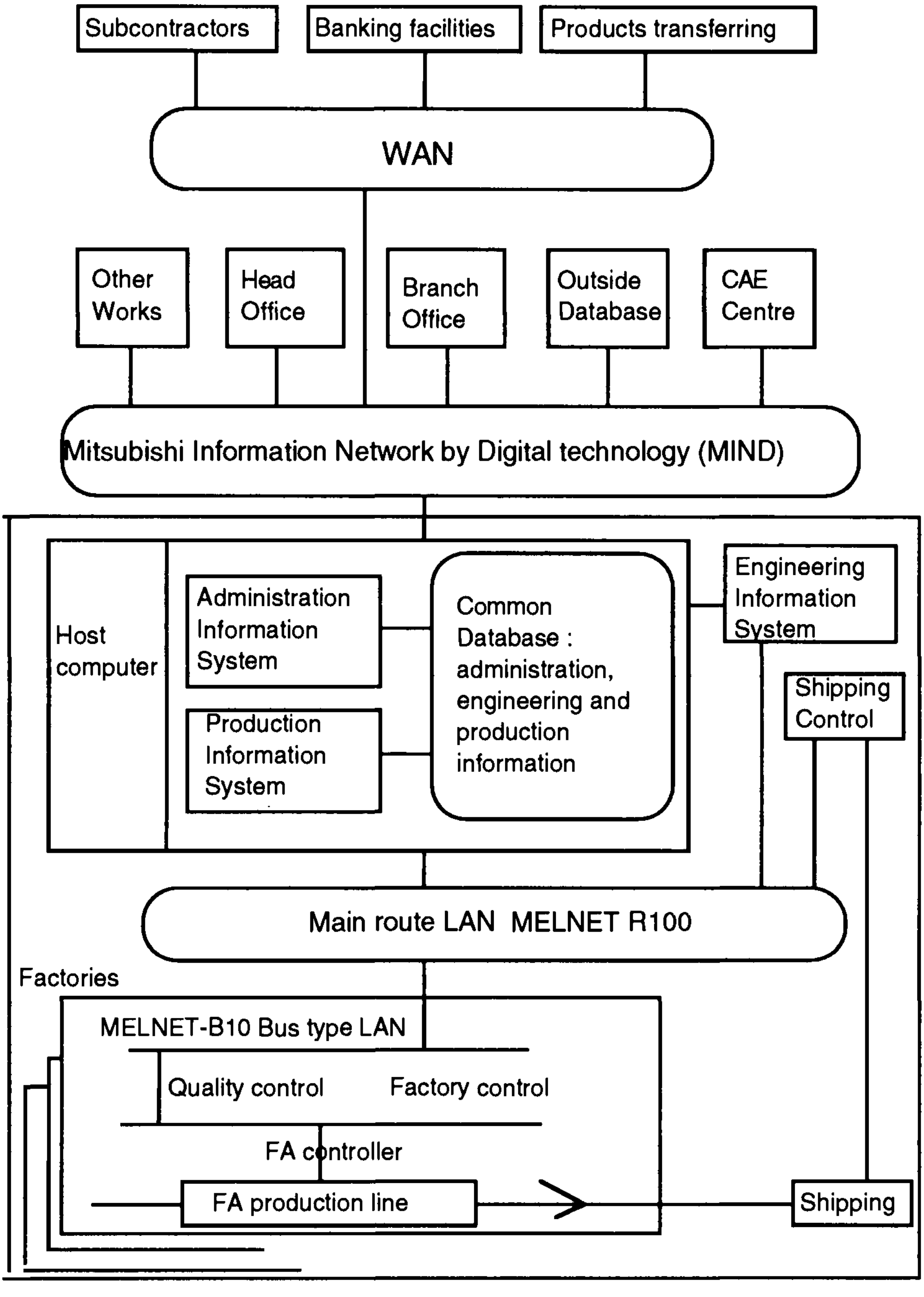


Figure 9 Database Integration and Network (Nagoya Works)

CIM, FA and MAP Protocol.

A production planning system, positioned as a core system, is being integrated with the CAD/CAM system, production control and plant operation system. FA-networks link FA- computers at the area level with FA-controllers in cell-level controllers. They play an important role in CIM implementation. Nevertheless, MAP installations are not increasing in Japan, and MELCO has decided to develop their own FA/MAP system.

The objective of configuring this model network is to prove its feasibility in the application field and to help the evolution of MAP networking applications. MELCO participates actively in MAP standardization, in making its own FA/MAP network it intends to contribute and to improve this standardization and not to be separated from the MAP community.

Figure 10 (see at the end of this Chapter) depicts the factory-level system architecture. At the bottom of this overall architecture are the production line and the control level. The production line is characterized by the material flow passing across receiving, fabrication, warehousing, assembly, test and inspection and, finally, shipping. The control level has PC, NC, RC connected by a controller bus.

As figure 10 shows, the factory-level system architecture is organized into three distributed architectures:

- factory-management or factory (host-computer)
- area level or FA-computer level (OA-network, FA computer, FA network)
- cell-level or FA-controller level (FA controllers)

This architecture involves three types of networks:

- OA network connects factory level and area level (Ethernet type or Token Ring)
- FA-Network connects area-level and cell-level. MAP or Ethernet type of networking is applied. In the case of the FA/MAP, MAP is applied.
- factory backbone network for interconnecting OA-networks and FA-networks

The architecture for the FA/MAP model involves FA-computers and FA-controllers, and the FA-Network which interconnects these computers and controllers. As we saw in Sections 3.1 and 3.2, this architecture is based on the client-server model and is assigned to be a CIM model factory. The system requirements, containing functional and networking requirements of the FA/MAP, are to be abstracted from those defined for this model factory.

The objectives of this system are:

- to exclude all losses from the manufacturing process, from order-entry to product-delivery;
- to shorten the production cycle and production lead time;
- to stabilize product quality;
- to raise management quality level.

The translation of these objectives into the FA/MAP model system progress via several functional requirements such as production-program data processing, parts-warehousing data processing, fabrication data processing and management, assembly-line program control, point of production data processing and management, facility management data processing and management, quality control data processing and management, or parts despatching data processing and management.

In turn, these functional requirements are decomposed into sub-functions, all of which are assigned to either an FA-computer or an FA-controller, according to the client-server model considered. An FA-computer should be a server, and FA-controllers should be clients. Based on this assignment, the networking requirements were defined containing five key items transmission direction (up or down), transmission frequency (times/day), kind of transmission (message or file), data volume (bytes/time) and required response time.

Concerning the design architecture, if it should be based on MAP networking, the application layer protocol has two choices: MAP/MMS and OSI/FTAM. The conclusion was that the MAP/MMS should be more suitable for requirements on real-time message exchanges. In fact, MAP/MMS furnishes the function of acknowledge on transmitting data/message, so it is more convenient for real-time applications. Although MAP/MMS can provide 86 services, MELCO introduces only 12 basic services.

The entire software architecture implementing this network architecture is constructed onto the software system on an FA-computer (CPU (Central Processing Unit) and the firmware on an MAP-interface board (full seven layers are implemented by the firmware ported by this MAP-interface-board). A modem is also mounted on this board, and the board is connected to an FA-computer CPU by an internal bus/channel.

The FA/MAP model, consisting of network and software architecture, has been applied to the CIM model factory, from which the system requirements had been abstracted. The system has operated satisfactorily from the beginning of 1991.

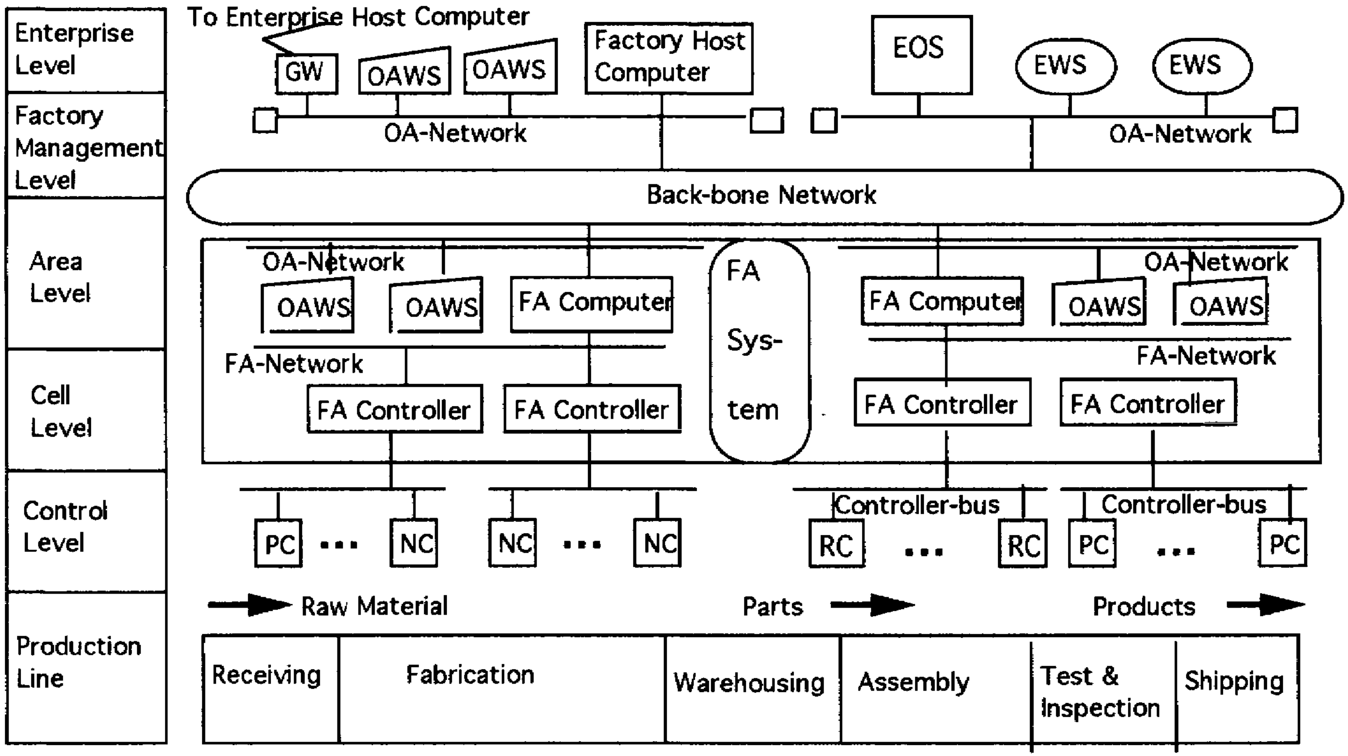


Figure 10 The Representative Factory-level System Architecture

CHAPTER 4

THE KERNEL OF TOYOTA CIM: MECHATRONIC NETWORK (ME-NET)

INTRODUCTION

To write a special Chapter about CIM in Toyota is a rather complicated exercise. On the one hand, Toyota and its productive system is well known all around the world. Many research institutes, especially in the USA and Europe, have studied or are now studying this system because of its high level of performance. On the other hand, Toyota is always a very innovative company, and for this reason is constantly creating strong conditions for improving its own productive system.

CIM constitutes an important part in the development of the new production means and facilities to overcome the increasing competitiveness in an ever more open, more global, market. Toyota is very attentive to all changes now occurring in the field. But one thing is clear in this strategy: the technology challenge. Toyota is investigating and creating its own solution for CIM implementation during recent years.

A good example which confirms the above development is the case of the Teiho Plant in Toyota City, near Nagoya In the Teiho Plant, the more advanced technologies are used by the research/development teams in order to perfect the actual means of production and to experiment with new means of production. From this point of view, the Teiho Plant has a main laboratory for manufacturing sophisticated advanced production means such as robots or other tools, including mechatronics devices (see Section 4.2).

This innovative capacity which characterizes Toyota is a source of inspiration for most companies in Japan itself. So the advances made by Toyota are studied promptly and accurately by managers and researchers from these companies (competitors or not). These are some reasons for devoting the present Chapter to CIM in Toyota. But there are other reasons that we think are also important. One of them is the research and implementation, especially at the shopfloor level, of the so-called "Mechatronic Network".

The "Mechatronic Network" is perhaps one of the better examples of how Toyota introduces the technologies at the shopfloor for improving the overall performance of its CIM. For this reason we consider ME-NET as the kernel in the future Toyota CIM.

We study successively a general approach to CIM in the context of Toyota, a general presentation of ME-NET, the ME-NET position in CIM, a technical presentation of ME-NET, the communications functions of this network and some perspectives of ME-NET. This Chapter is principally organized around the ME-NET Toyota network.

4.1. A GENERAL APPROACH

Providing outstanding products swiftly and at low cost - this is the most important question of production at Toyota. In order to respond to the increasingly sophisticated and diversified needs of customers, Toyota strives for state-of-the-art production technologies and to establish a flexible production system. As Toyota (1991) says, by constant efforts to automate production systems, the company intends to transform the production process into one that offers a creative challenge for the human labour force.

In fact, automobile manufacture involves bringing together tens of thousands of parts needing an assembly line control (ALC) which can control this complicated process. Computers and robots are utilized in each production line, bringing quality to the auto making process at the system level.

But this system also encourages suggestion schemes and voluntary quality circles,to sharpen the talents of employees and faster innovative ideas. At every level of the company, people is very active in promoting this kind of activities. CIM is inserted in this constantly improving automobile manufacturing process.

CIM and Planning methods.

The Toyota CIM approach has some similar aspects to other Japanese CIM models. As there, an important aspect is to have a high performance planning system. However, in designing this planning system, Toyota distinguishes more clearly than others, the two main flows: material flow and information flow. The Toyota CIM model is then more closely related to this distinction.

As the starting point, we find the demand side considered in the current economic sense. The problem is to know how this demand will evolve in the near future. The forecasting of car demand is thus one of the most crucial elements to which the Toyota productive system must be adapted.

The forecasting of car demand and changes in consumer wants is accurately estimated by the sales department following the consumer's demand changes as closely as possible. The knowledge of the real state of demand is based upon surveys and econometric estimation. In particular Toyota, like the other car manufacturers in the world, follows attentively the evolution of car registration. It is well known that registration of cars is one of the most reliable ways for estimation of the total number of cars.

This information is currently set against the orders to produce cars, and it is one important input in the production planning process. This is the main guide for production, without planning it is impossible to say what kind, what quality or amount of production is needed. Like other Japanese manufacturers (see Chapters 2 and 3), Toyota distinguishes several kinds of plans:

a. long term production plan.
b. annual production plan.
c. monthly production plan.
d. 10-days production plan.
e. daily plan.

The annual plan contains specifications about the in-house and external manufacturing, and an intermediary production capacity plan. The monthly production plan contains a short-term production capacity plan (that covers various production arrangements). Finally, the daily plan contains an assembly sequence plan. We note that the 10-days production is, practically, a determinant indicator about both the amount and the quality of production.

Indeed, the methodologies employed to determine the production figures differ according to the plan involved. Thus production figures in the annual plan are determined from market research, but monthly and 10 days production are planned to conform to the forecastings. And finally, daily production schedules are determined entirely from orders.

Levelling in Toyota production system.

So at any time the system is handling accurate information which enables it to compare the manufacturing of cars and the evolution of demands for cars. This confrontation is called (in Toyota jargon) a levelling plan. The aim of the levelling plan is to perform a constant adjustment of plan, in order to reinforce the matching between production and consumption.

According to Shingo (1989), production levelling is one of the pillars of the Toyota production system. The production processes must be arranged to facilitate production of the required quantity at the required time, with necessary workers and equipment. To prevent the vicious circles, it is necessary to make the flow as level as possible, by rounding down peaks and filling in valleys. Indeed, Toyota's order-based production schedule corresponds directly to actual demand, or in other words, the Toyota production system is an order-based production system (Shingo, 1989).

But to match demand and orders correctly, it is even more important to have a flexible manufacturing capacity, and to adapt this capacity to ordered production, which means having a flexible capacity on the supply side. It is in this context that we find, for example, the kanban system.

The kanban system is a method of control designed to maximize the potential production system, as well as a system with its own independent functions (Shingo, 1989). Nevertheless, there exist some misunderstandings about what kanban really is, and what is its role.

Shingo (1989) wrote "some people imagine that Toyota has put on a smart new set of clothes, the kanban system, so they go out and purchase the same outfit and try it on. They quickly discover that they are much too fat to wear it! They must eliminate waste and make fundamental improvements in their production systems before techniques like kanban can be of any help. The Toyota production system is 80 percent waste elimination, 15 percent production system and 5 percent kanban"

So, there is a confusion between the basic production principles at Toyota and kanban. This last is a technique to help implement these principles. According to T. Ohno (1987), kanban is a simple means for achieving just-in-time. So, probably, the confusion comes from the term "rules of kanban" used to refer to principles of production as well to kanban. Kanban is an essential technique (it is not a principle of the Toyota production system) for control.

Trying to eliminate this confusion, Shingo (1989) considers the distinction between principles of production and rules of kanban in terms of the following three functions of management:

- planning, which establishes the system and objectives;
- control, to ensure correct execution of the plan;
- inspection, which compares execution to plan so that one or the other can be corrected or adjusted if necessary.

And he concludes: "the above cycle of organization, control (including execution), and inspection moves forward like steps on a stairway. The Toyota production system is the planning function; kanban is a control function" (Shingo, 1989). So among the basic principles of production, we have: the waste of over production, just-in-time (which really means "timely", "well-timed", or "just on time"), separation of worker from machine (which comes down to automation).

In physical terms, Kanban is a simple card containing some data about manufacturing process parts.

Normally, three tags fulfil the main functions of the system:

- Identification tag, indicates what the product is;
- Job instruction tag, indicates what should be made, for how long, and in what quantities;
- Transfer tag, indicates from where and to where the item should be transported.

One example of a kanban card is given in appendix 1 at the end of this Chapter. This card contains information that copes with the store address, the destination plant name, the bar code, the supplier name, the part number, the kanban number, the quantity/ container and the dock code. As we see, this information is principally designed for the circulation of components and parts inside the factory, and between factories and suppliers.

For car assembly, three main types of kanban are used (see figure 1, at the end of this Chapter):

- in-process kanban. This type acts principally in machining attaching and supplier parts;

- minimization of stock kanban, principally used in stamping (transportation units), in casting/forging and in plastic moulding parts provision;

- the kanban between shops, for example between stamping and welding or between casting/forging and machining attaching, or even between machining attaching, plastic moulding and supplier and painting completion and completion cars. This kanban is used for transportation of parts and components.

One additional element, playing an important role in Toyota CIM, needs a special comment. That is the remote identification of cars. In fact, the remote identification of cars is becoming more and more a fundamental input that completes the information handled by the planning system. This last information comes from classical sources of collection, such as regular surveys or special consumer's panel enquiries. But now identification is becoming crucial for getting more accurate information about the life cycle of cars.

In addition, identification is relatively closer to the FA (Factory Automation) flexibility, the performances of logistics and the social infrastructure. In short, according to the Toyota engineer's approach via the route of identification, FA and logistics, all manufacturing of cars become a part of the social infrastructure, as Takano and Kawabata (1992) say.

4.2. MECHATRONICS

Searching for more flexibility of the production capacity, one of the most important points in Toyota CIM is probably that concerning the so-called ME-NET (MEchatronics NEtwork). In our view, the Toyota mechatronic research development leading to the ME-NET corresponds perfectly to the policy of this company, in supporting both demand and supply side. Supply must be prompt and flexible, and tools such as ME-NET can contribute to achieve it.

As ME-NET has a great importance for the success of the Toyota production system, before we study the main development of ME-NET, in the next Sections, we think it is necessary to make a short presentation of mechatronic concepts. This Section is dedicated to this target. For the moment, we add just one final comment: in our opinion, ME-NET must become as famous as kanban is to-day for the ordered-production system of Toyota. Indeed, all manufacturing companies should must interest in it.

The birth of "Mechatronic".

The name Mechatronics (Mechanics and electronics) was coined by Japanese in the mid-1970s to describe a new technology fusion. The word has rapidly spread all over the world within the last several years. Mechatronic technology makes up the basis not only consumer products (such as recorders or compact disks) but also manufacturing systems. It is an advanced technology to create energy-saving, resource-saving and high intelligence systems by integrating mechanics, electronics and software.

In 1971 the slogan "Electro-mechanical integration" was often used to promote the merger of machines and electrical devices that was then a weak point of Japan. The question was then to save energy, material and cost. Under such serious conditions, energy and resource-saving products with intelligence were developed. These products required the following advanced technologies:

- precision mechanisms;
- software control by micro-computers;
- high quality and low cost production technology, for highly precise mechanical and electrical devices.

Under these conditions the word "mechatronics" appeared. M. Kajitani (1993) explains the development steps leading to mechatronics as follows:

a. at the beginning there was the mechanical technology that dealt mainly with the problems of energy and material;

b. after this time, the progress of semiconductors, especially integrated circuits, made possible integration of machines and electronics in only one body. This is the beginning of the electronic age;

c. at this stage, the system could not yet have intelligence. The next revolution began with the appearance of micro-computers. Small and cheap micro-processors were installed in machines, so that a machine could think and make a decision by itself. This is the age of information technology, especially software technology;

d. the mechanical technology has changed to mechatronics by merging information-processing functions.

Figure 2 gives a symbolic illustration of the mechatronic roots.

As we see, one of the most important key-words in mechatronics is information or software, not electronics. However, mechatronics is also a mechanical technology required by advanced information systems and societies. In such ground, the added value is enhanced by information. In reality information, which is invading all human activities, is more and more the only factor contributing to increase added value of all things. We propose some examples explaining this statement.

The added value of materials and energy can be obtained by software such as processing methods. Furthermore, energy-saving and resource-saving are the most basic additions of value, because we have a limited amount of natural resources. As M. Kajitani says (joining one of our old points of view expressed in one of our draft papers about the "information society" some twelve years ago), hardware of information systems cannot have any value without software. So software is an important source of added value.

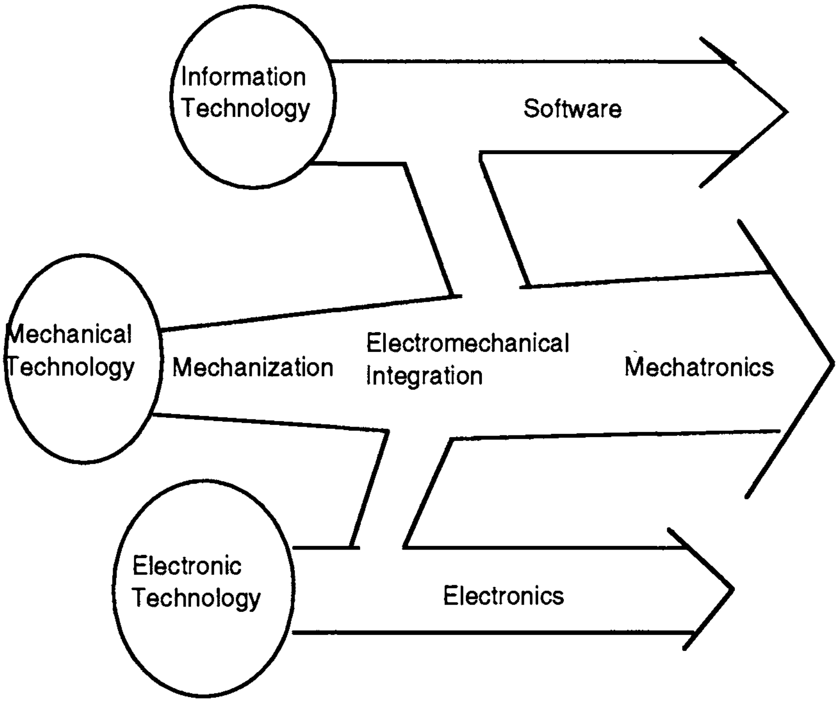


Figure 2. Flow into Mechatronics

The key concepts.

Information and machines are related through different aspects. One example is the advancement of the control function of machines. These control information functions are required by new cars. These electronic cars have 20 or more micro-processors installed. In this particular case, information is necessary for all machines or systems to control themselves. This way, all machines and all elements will have intelligence because the equipment uses micro-processors.

To present a concept of mechatronics, M. Kajitani (1993) proposes two basic concepts: the system concept and the interface concept.

a. The system concept.

The system concept is organized around four internal functions. The main function of one system is the operation function. This is a function to perform the purpose of the system, that means, the function to convert material, energy and information. The power function handles energy, lubrication, cooling and so on, which are required for the normal operation of the system. The next function is the control information function which controls the entire system, playing by this means the functions of the brain and senses of humans.

In addition to this, the component elements of the system must be arranged at predetermined positions in space and must be built up into one unit. In many situations, mechanical and geometrical architecture has, also, a great influence on the functions and performance of the system. Then to handle these problems, the structural function is introduced as another function of the system. Finally, there is the waste function, that means, an anti pollution function which has, in Japan, a real importance in all productive systems. This is one of the ways of coming to "clean" manufacture.

b. The interface concept.

The interfaces are very important in mechatronics. In fact, dealing with a compound system, various technologies and elements having different properties such as mechanisms, electronic devices, software, etc. are combined with each other. In this situation, most of the design of the system is the design of interfaces. "The thinking method of the system in view of the interfaces is called the interface concept" (M. Kajitani, 1993).

Toyota, like other manufacturers in Japan, has developed a research programme on mechatronics. Nevertheless, this research programme is not only oriented to the construction of electronic car devices but also to the investigation of improvements for their own manufacturing process in factories. ME-NET must be considered as a part of this programme. However, ME-NET is founded not only on the mechatronics technology but also on the networks technology.

The most advanced developments in the technology of networks are used by Toyota for this purpose. Toyota is paying special attention to the local area network technology, in particular to the lower layers of the OSI model, and to the MAP technology. The problem is to combine mechatronics and networks to improve the actual FA system and enhance CIM technology as well.

4.3. A GENERAL PRESENTATION OF ME-NET

The automation of automobile production lines consisting of manned standardized operations, such as fitting and assembly lines, requires a large-scale compound system constructed with combinations of very highly sophisticated mechatronic equipment from a wide variety of makers to ensure ease of maintenance, high quality and high equipment operation rate.

The development.

In order to produce highly efficient operation of such a system, Toyota developed a system network called ME-NET. ME-NET is the inter-connection system among FA users, as Takano and Kabawata (1992) write. ME-NET results from the research/development programme that began in the early 1980s. During this period three different types of networks were built:

- M-NET (Module Network): a development programme running from 1985 to 1987
- U-N (Unit Network): a developing programme running from 1985 to 1987
- ME-NET (Mechatronics Networks) is the continuation of those programmes from 1990 (it was introduced into the Toyota factories in 1992).

Figure 3 shows the evolution of these types of networks from 1980 to the present day. All these related to each other (see figure 3).

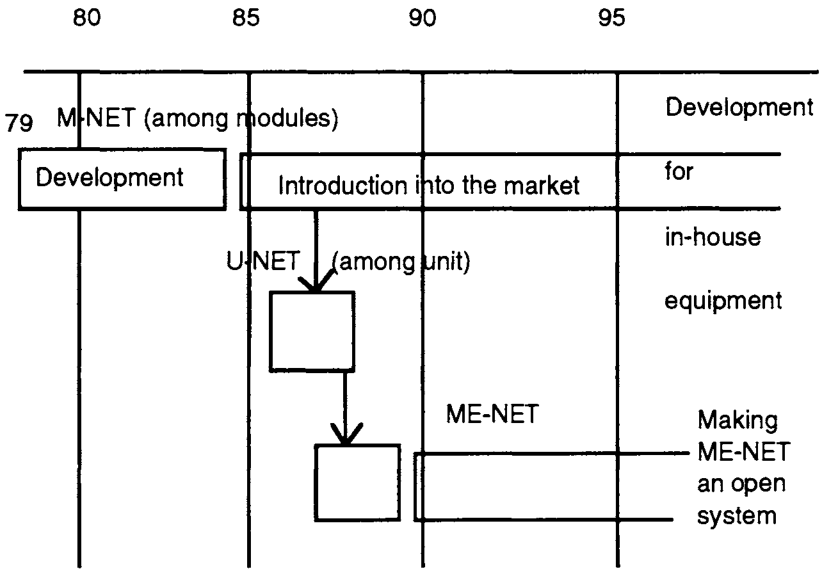


Figure 3. The ME-NET development

The M-NET (Module Network) is designed to link different modules, and the U-N (Unit Network) is designed to link different units among them. Finally, ME-NET results as a development and completion of the previous ones. Its goal is to improve the performance of the network, especially at the physical level in all factories. In other words, Toyota is creating a standard model for its own production system; GM did a similar thing with MAP (Manufacturing Automation Protocol) (see Section 4.4.) during the 1980s.

Note that M-NET and U-NET were developed only for in-house equipment, while ME-NET is developed for an open system environment. This last is now possible because of the advances made in the field of information technologies, namely, the network, the micro-computer and the software technologies that have been improving since the mid-1980s.

The ME-NET construction at the Toyota Laboratory, in the Teiho Plant, began between 1987 and 1990. The basic principles of ME-NET development are founded on diverse experience in preventing recurrence of both major and minor line shutdowns, and on the basic principles of the Toyota production system (see Section 4.1). The question is to find a solution able to conciliate to prevent a shutdown, while keeping the principles of production the system Toyota.

The goals and requirements.

Table 1 shows the main roles for which ME-NET development is designed. It is possible to distinguish three areas: abnormality monitoring, abnormality removal (essential in the Toyota system), and production control. The problems encountered differ according to the areas involved.

Table 1
ME-NET roles

Abnormality monitoring	Person	Safety	Man-made disaster prevention
	Product	Quality	Inconsistency among measurement data
	Equipment	Operation	Condition of systems equipment and machines
Abnormality removal	Maintenance		Defect tendency and cause analysis and preventive maintenance
Production control	Production instruction		Vehicle family and programme determination and jig and tool change
	Record summing-up		Production condition control and operation rate, and record summing-up

On the one hand, abnormality monitoring can concern man, product or equipment respectively related to safety, quality or operation. On the other, abnormality removal concerns principally maintenance, which influences defect tendencies and is related to the analysis and preventive maintenance. Finally, production control concerns production instruction and record summing-up. Production instruction is related to vehicle family (in the Toyota system, several types of cars can be manufactured in the same assembly line) and programme determination, and jig and tool change.

According to this description of failures of the system, the main goals of ME-NET can be summarized as follows:

a. to ensure high reliability and maintenance for a large-scale production system functioning as a central nervous system automation. To achieve this, it is necessary to link robots, programmable controllers (PCs) and vision controllers from various makers on line, via a single cable and permitting one-touch connection.

b. to monitor the system continuously so as to provide a prompt remedy for abnormality by visualizing information controlled by ME-NET (see table 1) and providing highly functional, real-time communication.

c. to position ME-NET as an open system, to allow mechatronics equipment from various manufacturers to be linked thereto by means of an inexpensive high-speed data communications interface, with simple system design and operation of the automation system, so making it available to as many users as possible.

As a consequence of these goals there is a set of requirements that ME-NET must fulfil. So there are many different requirements but, in general, two sets of requirements are distinguished: the equipment system requirements and the requirements for the network which are closely related to them.

A. The equipment system requirements.

These requirements are:

1. ensure safety
2. ensure high product quality
3. ensure low product cost
4. ensure the target production volume
5. ensure equipment reliability
6. remove equipment failure as soon as possible
7. be accurate and prompt in issuing instructions for manufacturing plans and summing up achievements

B. Requirements for network.

The consequences of the equipment system requirements at the network level can be summarized as follows:

1. improvement of reliability with electronic control system
2. quicker failure removal

3. simplification of equipment by reducing wiring

4. implementing communications among different types of equipments including machines, robots, vision controllers and NCs (Numerical Controls)

5. permit creation of a simple system change,via switching or like means

ME-NET is thus an ambitious project, which is concentrating many efforts at the Research Laboratory in the Teiho Plant. At the beginning, this research programme was oriented to the development and standardization aspects in order to increase the number of ME-NET users. For achieving these aims of ME-NET, the following guidelines are established as priorities:

- technical development for down sizing and the provision of higher functions;
- project reorganization and improvement of the current organization;
- standard systems construction for certification tests;
- demonstration at various exhibitions;
- registration of command codes (currently some 100 companies);
- follow-up research on application to practical lines;
- standardization of the installation method: handling of cables, connectors, interfaces, programmes and so on;
- education: system designers, coordinators and maintenance and service people encompassing different makers and compound systems consisting of different types of equipment

4.4. ME-NET POSITION IN CIM

As we see, ME-NET is principally linked to factory automation of the Toyota plants. But this factory automation is one of the main components for improving CIM. Since 1992, Toyota is implementing ME-NET in all its factories, while ME-NET is enhancing the whole Toyota production system.

The Open System Interconnection (OSI)-ISO model.

ME-NET is designed with reference to the field bus in the OSI model (Open System Interconnexion) - the International Standardized Model ISO for open systems (ISO, 1978). The OSI model standard is clearly accepted by companies and manufacturers of telecommunications and computer devices all around the world as a reference model. This model is now increasingly used by the open communication systems with higher real-time properties.

Compatibility between heterogeneous equipments can be ensured by defining interconnection standards that govern the behaviour of each item of equipment. Then every equipment to be connected is considered as an open system, if the interconnection standards are respected. The first aim of ISO is to define a standard network architecture. It is the Reference Model for the Interconnection of the Open Systems (commonly named ISO/OSI Model).

This architecture follows the principle of layered structure. For the purpose, it is necessary to consider the following elements:

- N-sub-system: one element belonging to a hierarchical division of one system having interactions only with upper or lower elements of this division
- N-layer: sub-division of OSI architecture formed by sub-systems of N-rank
- N-entity: active element of one sub-system (N)
- N-service: capacity of the N-layer (and lower layers) for furnishing service to N+1 entities localized at the border between the N-layer and N+1-layer
- N-facility: element belonging to an N-service
- service access point (SAP): point where N-services are given by an N-entity to the N+1-entity. The service data unit (SDU) passes across the SAP
- N-protocol: set of rules and formats (semantics and syntax) determining the characteristics of communications between N-entities when they are performing the N-functions. The management of protocol is realized by the Protocol Data Unit (PDU).

The technique for structuring the OSI model is the layer technique. According to this technique, one system is composed of an ordered set of sub-systems. The adjacent sub-systems communicate across its common border. The set of sub-systems having the same rank of order N forms the N-layer. One or more N-entities belong to every N-sub-system.

Each layer is then defined by protocols (for communications purposes between its homologue) and services (for relations with upper or lower layers). Every N-layer (with the sole exception of top layer) furnish N-services to the N+1-entities of the N+1-layer. The top layer is assumed to represent all the possible utilizations of services furnished by the lower layer.

The OSI has seven layers. These seven layers are: physics, network, data link, transportation, session, presentation and application. The field bus in the OSI model corresponds to the so-called lower layers, that is physics, link and network layers. We make a brief presentation of these layers.

- The physics layer gives the mechanical, electrical, functional and procedural means necessary for activation, retention and deactivation of physical connections for transmitting bytes between entities of data links
- The data link layer gives the functional and procedural means necessary for the establishment, keeping and liberation of connections of data links between entities of the network and the transfer of service data units of data links
- The network layer manages the routing of information from one link to another or from one local network to another
- The transportation layer permits a transfer of transparent data between two users whatever the number of networks crossed by communications, managing the resources in order to optimize them
- The session layer manages the dialogues and the data interchange between users

- The presentation layer manages the representation of information that application entities are presently communicating between them
- The application layer gives all OSI services to be used directly by the application process

The ME-NET, OSI-ISO Model and MAP.

ME-NET must also be compared with MAP, created by GM (General Motors) during the first part of the 1980s. MAP is designed for different applications including the CIM technology, and has a similar architecture to that of the OSI Model. To understand the MAP model it is useful to start from a hierarchical model which should be comparable with the real hierarchy of the existing functionalities in the manufacturing companies.

The real architecture made up of machines and equipment,cells, workshops, factories and, finally, the body of the entire enterprise. Figure 4 depicts five levels of abstraction. The MAP model is constructed by abstraction of this reality, using the basic principles of the OSI Model.

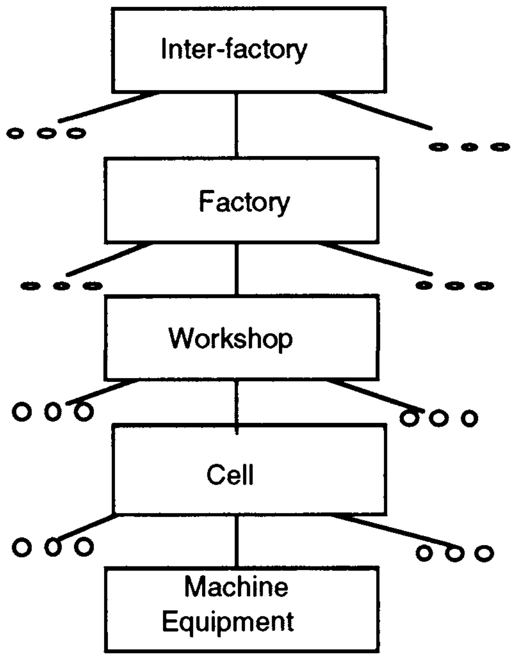


Figure 4. Level of abstraction for MAP

So at the bottom level there is some equipment or machine for performing some parts of the manufacturing work. The equipments are organized into cells, coordinating activities and synthesizing information. This organization differs according to the manufactures involve, but we can define it as an equipment set, cooperating in order to manufacture some product at its final stage. A cell has a high degree of automation of successive operations. Control and command coordinate the different activities.

Then cells are organized into workshops which manage their resources according to the principles of production planning. The workshops are organized into factories. Normally, at the top level, we have a company grouping many factories. At every level it is necessary to connect different kinds of equipments, but they are often constructed by different manufacturers.

The aims of MAP are to define a set of standardized protocols to be implemented, validated and tested on every equipment in order to obtain an inter operability involving the computers, programmable equipments, automates or other terminals used in the cells, workshops and factories belonging to the same enterprise. This inter operability concerns the whole manufacturing system.

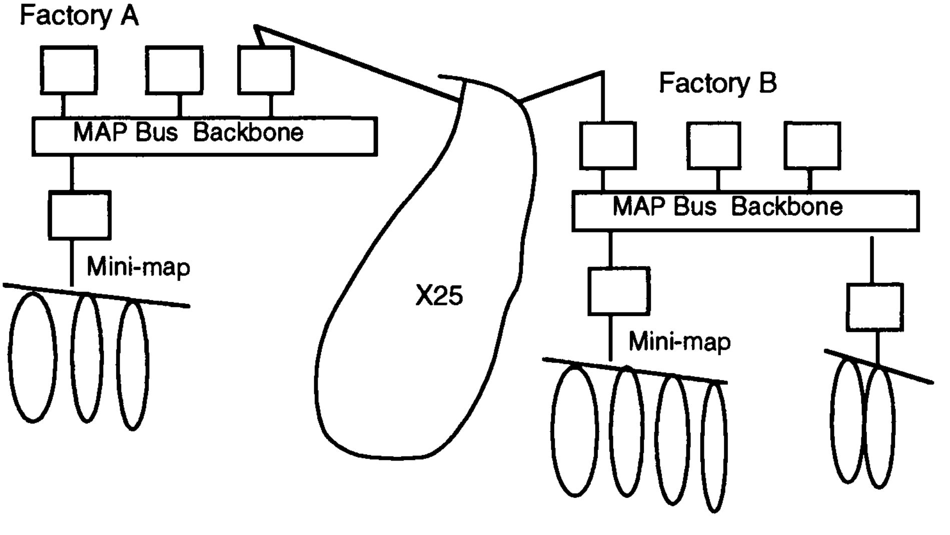


Figure 5. Inter-factory network

The MAP architecture for one company is characterized by the backbone networks connecting its different sites by the gateways or by a public switched network such as X25. Inside the Factory, each backbone corresponds to the necessary functionalities at this level. The backbone is connected to the networks existing at the shop or cell level. These last ones are called Mini-MAP networks and they are connected to the backbone by bridges. Figure 5 gives a general idea of MAP and Mini-MAP.

MAP and Mini-MAP are thought of as the important tools for integrating the manufacturing system in GM. Indeed, MAP should become the central nervous system for an eventual implementation of CIM technology. Toyota, like many other manufacturers, uses MAP and Mini-MAP in its factories, but nevertheless the research/development team try to build a more complete network especially at the shopfloor level. In reality, ME-NET must be considered as a subset of MAP or, more precisely, as a subset of Mini-MAP, as we can see in figure 6.

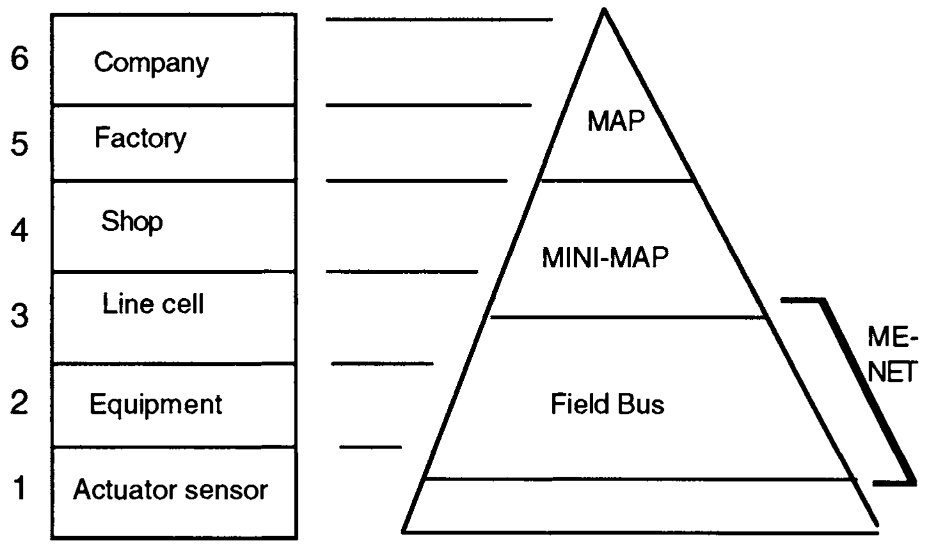


Figure 6. ME-NET position in CIM

Figure 6 shows the ME-NET position in the CIM environment of Toyota. We can see six levels, beginning with the actuator sensor at the bottom level and followed up by equipment, line cell, shop, factory and finally company (or Corporate) at the top level. This figure represents also the levels of MAP and MINI-MAP architectures. As we see, the position of ME-NET covers only one part of the three first levels or the so called "physical levels" of MAP.

Figure 7 depicts the position of ME-NET, the Mini-MAP and MAP networks, in a simplified architecture corresponding to the Toyota factory. At the top we find the MAP network, and in an intermediary position, we find the Mini-Map network. The ME-NET network is at the bottom of this figure. Different devices are linked by a tree ME-NET, both in the same hierarchical position.

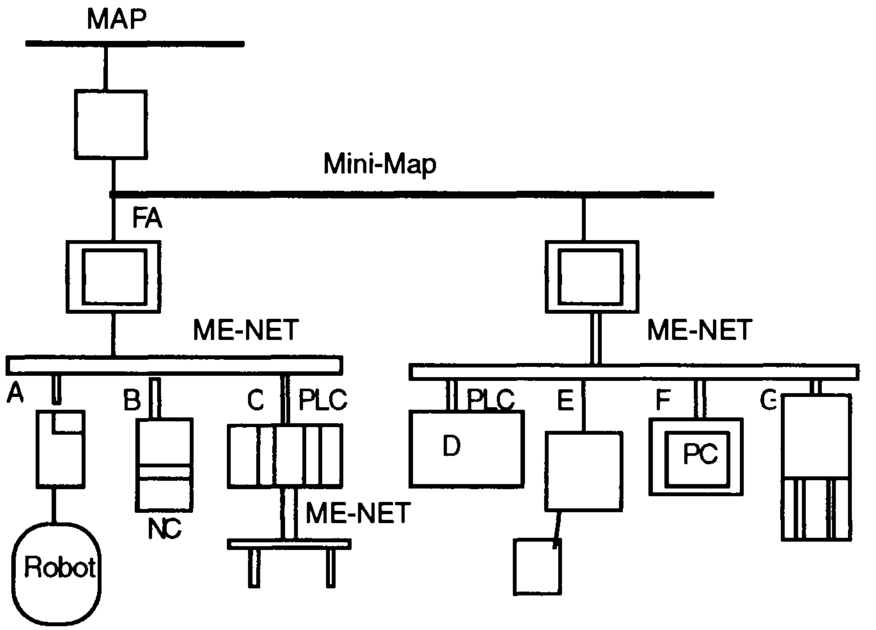


Figure 7. Position of ME-NET in MAP and Mini-MAP framework

Between ME-NET and Mini-MAP a PC is installed, but ME-NET is linking different devices such as robots, NC, PLC, ID or even PC. The continuation of ME-NET under PLC does not need a PC, it is linked directly. So, the ME-NET is a complementary tool or, if one prefers, a slighter development more at the ground level of MAP and Mini-MAP. Obviously, this kind of architecture needs some important software development and more simplified interfaces.

4.5. TECHNICAL PRESENTATION OF THE ME-NET

ME-NET is provided with the function of cyclic scanning transmission called data link (see Section 4.5.), for subtle control required at the field bus level. This function is available to users without their being conscious of communicating with someone, as if they were operating conventional parallel I/O (Input/Output) transfer. ME-NET provides another communication function called computer link as well. Only the connection of an FA computer, for instance, permits information exchange among ME-NET specifications.

The figure 8 gives an example of network configuration of communications. Six companies can use ME-NET connecting PC, Robots, Vision Controllers, Nut Runner Controller and Host Computers, and can exchange information through the network. In particular, we see an example of communication between company A (system monitor) and company F (nut runner controller).

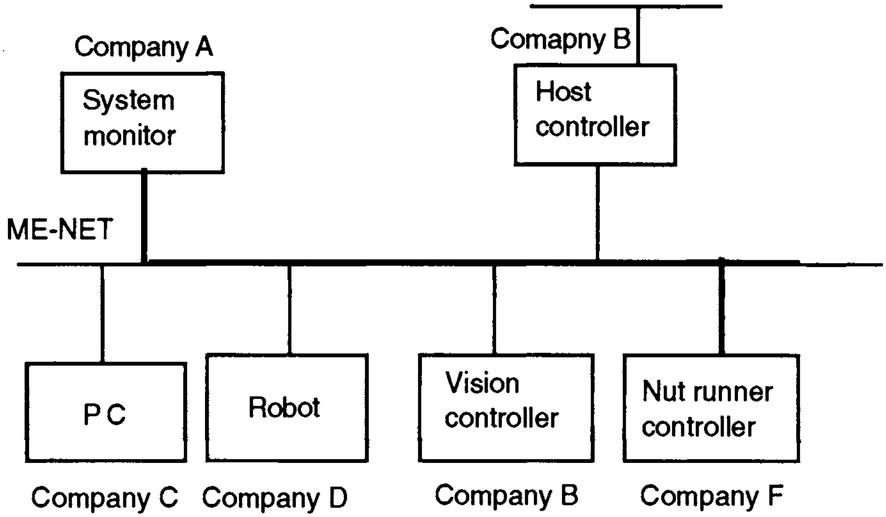


Figure 8. Example of Network Configuration

Some specifications of ME-NET are:

- communication access method: token passing
- communication network type: bus, token bus
- modulation method: phase continuous frequency modulation (carrier band)
- transmission rate: 1.25 Mbps
- transmission code: NRZI (Non Return to Zero Inverted)
- frame structure: in accordance with HLDC (High Level Data Link Control) frame
- transmission level: +8.75 dbm (075Omega) (0.75v)
- receiving level: - 17.5 dbm (075Omega) (0.037v)
- communication media: JIS C3501 75Omega coaxial cable (Trunk: 5c2v, Dropper: 5c2v)
- total length of cable: Trunk: up to 1km Dropper: up to 40km
- connection: BNC Connector
- branch: T branch (BNC T connector)
- number of nodes: max. 64 pcs

So as communication method, ME-NET uses the token bus method, which is one of the methods specifying access to communication lines by respective stations. This is supported by the same standard used by MAP (IEEE 802.4, Institute of Electrical and Electronic Engineering) (ISO, 1980).

The token bus method uses special data (called a token) which must be authorized to open the transmission right. The token continually travels through the stations linked into a bus like information. So stations in need of transmitting data to the circuit can do it when they hold the token.

An example of data transmission to the communication circuit in the ME-NET environment is as follows: basically the token flows from a larger to a smaller station number. If the station having received the token has data to be transmitted, it carries out transmission and transfers the token to the subsequent station. If the station having received the token has no data to transmit, it transfers the token to the subsequent station.

By this means, the token bus has the characteristics that the network response rate does not deteriorate seriously in the event of an increased communications load. In practice, Toyota considers that this method corresponds very well to its FA data networks needs.

In its position as the method of the field bus, ME-NET has specifications of its own network (including physical properties), excluding the token bus algorithm in IEEE 802.4 which was referred to in determining the specifications for the sake of reducing the size and cost of the communication control section.

Why were these specifications adopted by Toyota? Although MAP and the like use the special-purpose LSI (Large Scale Integration), called a normal token bus controller (TBC), ME-NET has been developed to enable the use of a generic serial communication controller (SIO) instead of TBC, to meet the need for low cost. So the frame design is founded on HDLC supported by SIO, and the coding method is NRZI (Non-Return Zero Inverted).

One problem arising from this application is that the token bus algorithm processing has to be executed by the CPU. Indeed, the capacity of software becomes clearly an important limit when this method has to be approximated to TBC, because of the limited processing rate and hardware capacity.

To solve this problem, it is possible to obtain an equivalent function to TBC by adopting the following measures:

- the provision of a special-purpose CPU for the token bus, so decentralizing the load and preventing deterioration of the processing rate;
- a partial simplification of the token bus algorithm specified in IEEE 802.4, to the extent that its functions are kept intact, thus allowing the algorithm to be executed with generic SIO

4.6. COMMUNICATIONS FUNCTIONS IN ME-NET

The communications functions specified in ME-NET are the data link and computer link.

(a) Data link

One of the features of ME-NET specifications is the data link, some kind of application of the so-called cyclic scanning transmission method.

A special memory area is allotted to the respective stations. The area is divided into two parts: one of them is for transmission at a given station, and the other for receipt from other stations. Each station transmits its own data, and stores data received from other stations. The communication mode following this structure is shown in figure 9. This method has been in use for communications between PCs (one needs this method only for the parameter command).

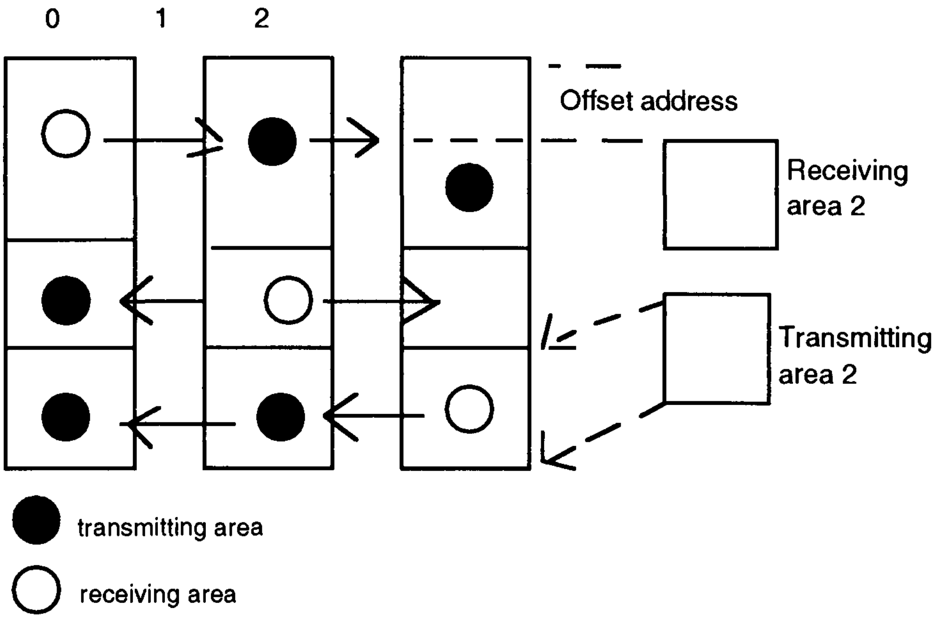


Figure 9. Communication mode of the Data Link

Remark: With the offset address of slave station 2 on the master station specified slave station 2 receives data on only a part of the area.

One advantage of this method is that the users can exchange data with other stations without being conscious of communicating with them. In addition, there is no need for using complicated procedures concerning the protocols. ME-NET has succeeded in broadening the application of this method ranging from PCs to robots, NCs and any other type of control equipment.

A problem posed with the data link is ascertaining a method to connect, without complicated procedures, different types of equipment from different makers with different internal architectures (for example, memory arrangement, address system or memory capacity). In the ME-NET the memory address transferred via the network is mapped to the real address of the respective equipment, giving then a one to one correspondence between transmitting and receiving memories within the data link.

This address information (as to which area at each station is allotted as data link area) and system information as to the data link, including the amount of transmission data of respective stations, are controlled exclusively at the master station (station Number 0) as a data line parameter, and distributed to slave stations at the time of the initiation. Thereafter, the stations cyclically transmit data only. This has made possible high-speed data exchange in the data link.

Even if the data link receives data from all stations as a rule, it is often impossible to secure all areas required for the data link since the internal data is limited by the use for robot controllers and others purposes. To overcome this difficulty, a function was added so that only a specified partial area is taken to the given station. Normally, users have communicated with others from their PCs via an I/O unit. ME-NET can be connected to such equipment without drastic change in the controlling principle.

ME-NET requires two memory areas for the data link. They are the relay and register links. The relay link is used principally for transfer of ON/OFF information, and has a total of 2048 points (256 bytes) of area. The register link is used principally for transfer of numerical information and has a total area of 2048 bytes.

(b) Computer link

The computer link specifies the communication between FA computer and other equipment, consisting of a processing request (command) and the response of its results. The computer link does not indicate scanning transmission, as does the data link. Commands are sent only on request. Equipment having received the command executes the specified processing and responds to the sender, returning the results of processing. The computer link operates even during operation of the data link.

Computer link commands consist of basic and optional ones. The basic ones are a group of commands intended primarily for PCs, providing functions and reading and writing data, and setting and resetting the timer. As in the data link, the memory address in the network, and those of the respective equipment, are mapped on the equipment, thus allowing a simplification of procedures.

Table 2
Example of registration of optional commands

Maker Code	Model Code	Function Code	Maker Name	Model Name	Function Name
AA	A	A	OO Co.	Robot Controller	Reading program, step and tool numbers
		B			Reading world coordinate
		C			Reading joint coordinate
		D			Reading approach direction
		E			Reading servo monitor
AD	A	A	DDCo.	Vision Controller	Reading status
		B			Resetting measurement data
		C			Starting measurement
		D			Reading measurement data

Optional commands are an outstanding feature of ME-NET. The reason for these optional commands is linked to the future development of ME-NET. In fact, an increasing number of various types of equipment will be connected to ME-NET in the future. As a consequence, it is probable that the needs from users will increase in number. To cope with these future needs, ME-NET introduced an approach of providing optional commands.

The optional commands are registered according to specified format. Once registered as specified, optional commands are given new functions (specific to the equipment involved). Each command consists of four Upper Case English Letters (2 for maker code, 1 for model code and 1 for function code), designed to allow command names to overlap and to give a simple form for registration control.

N. Takano and Y. Kawabata (1992) present an example of registration of optional command (see Table 2 for detail). The introduction of optional commands meets a wide variety of needs from users. There are two maker codes AA and AD, the model code A, the maker company name, two model names (robot controller and vision controller) and the function name. The AAAA code has six functions A,B,C,D, E and F. The code ADAA has four functions.

Another important point is the ME-NET interface. The connection of different types of equipment to ME-NET requires a special interface to that equipment. Figure 10 presents the general architecture of the ME-NET interface, which is divided principally into two sections: one for communication control, and the other for bus interface.

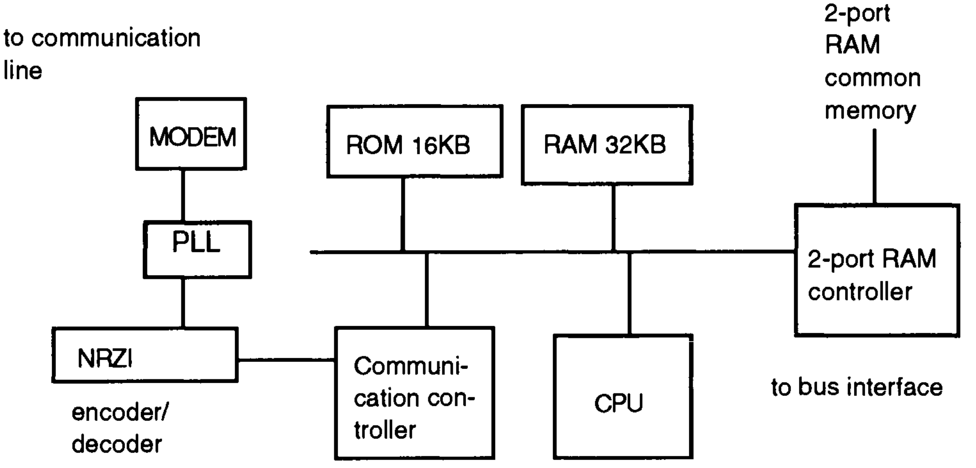


Figure 10. Standard communication board architecture

The communication control section exercises a subtle control over communication operation and maintains the token bus. The bus interface section mediates between the communication control section and the internal memories of equipment connected.

Used for data exchange between these is the 2-port RAM (common memory) as we see in figure 10. The bus interface sets transmitted data on the 2-port RAM. Data received are set by the communication control section on this RAM.

The ME-NET secretariat has developed a standard board for the communication control section. Using the board, equipment manufacturers can shorten the period for developing an ME-NET interface. The CPU is V40 and the communication controller mPD72001, a generic controller. This combination provides the token bus capability of processing.

One of the most difficult tasks in putting ME-NET into practical use is who coordinates and maintains the system to be connected to various types of mechatronic equipment, when manufacturers handling ME-NET equipment receive orders from users. There are more than 100 manufacturers and users who join ME-NET, by connecting their mechatronic equipment and systems thereto.

This situation is creating some challenge for ME-NET participants. For example, if they want to reduce the problems with the system with which their equipment is connected (and normally searching for improving this system), they need to maintain cooperation with other manufacturers, meeting user needs and leading effective coordination. Then equipment suppliers and system integrators must understand user needs as well as possible, and educate them in consequence.

Education becomes important for users; they should be able to improve the system to a level where a greater number of different models of different makers are linked. Project members are instructed to study system management via practical experience of initiating the system in ME-NET commercialization activities.

4.7. BENEFITS AND PERSPECTIVES OF ME-NET

ME-NET is a challenge for TMC. It permits an important increase in automation of material and information flow, principally at the shopfloor level. At present the main results are:

- ME-NET reduces considerably (see figure 11) the hierarchy of the system. This is an important point, because it normally grows drastically and becomes very complicated with the increasing number of components of a given system, as Su (1992) shows.

- the reduced hierarchy due to simplifying the construction of the network system permits a drastic reduction in its cost. So ME-NET represents only 35% of the cost of one classical network. The most important reduction in cost input corresponds to the construction cost of the network. The next most important factors in cost reduction are the interface costs and the programming controller, that are cut by a half.

ME-NET is now developing at the commercialization stage. In 1993, Toyota has decided to implement ME-NET in all their own factories. In addition, more than 150 Japanese manufacturing companies are currently participating in tests and training, in order to establish connections and to implement this network. So ME-NET becomes a de facto standard for communications between heterogeneous equipments in the automobile manufacturing, and by extension, may be in the manufacturing world, assuring higher performance than that of the classical MAP or Mini-MAP.

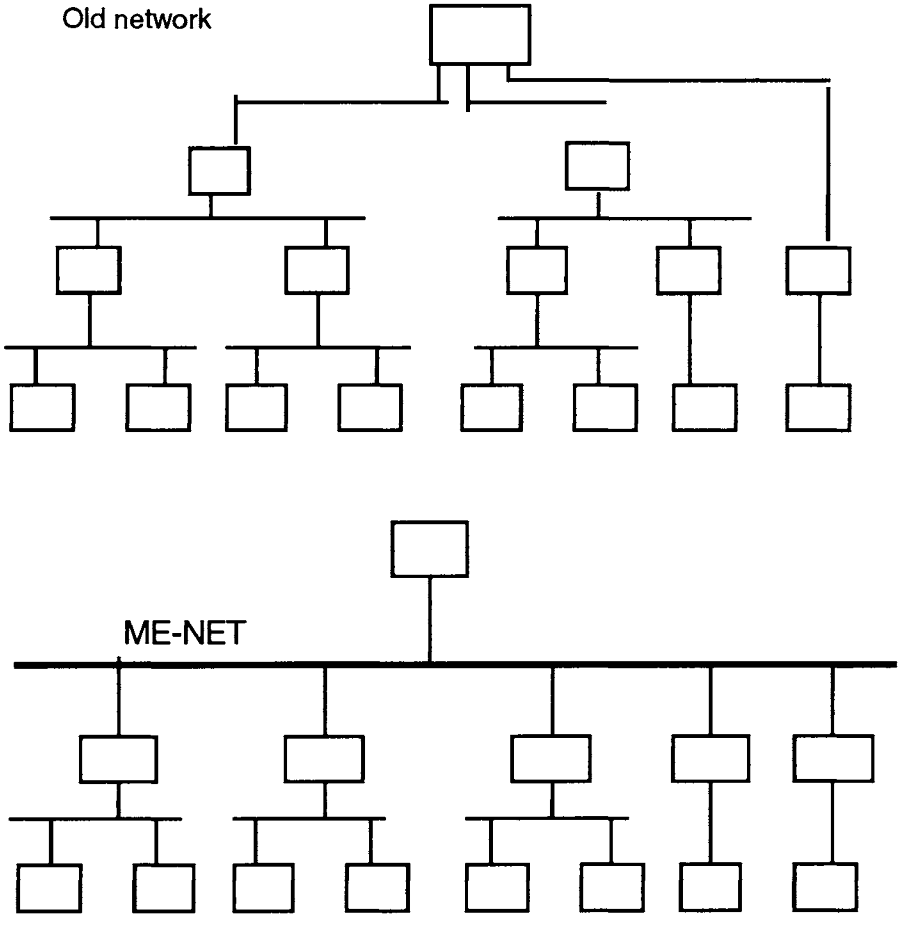


Figure 11. Hierarchies of old network and ME-NET

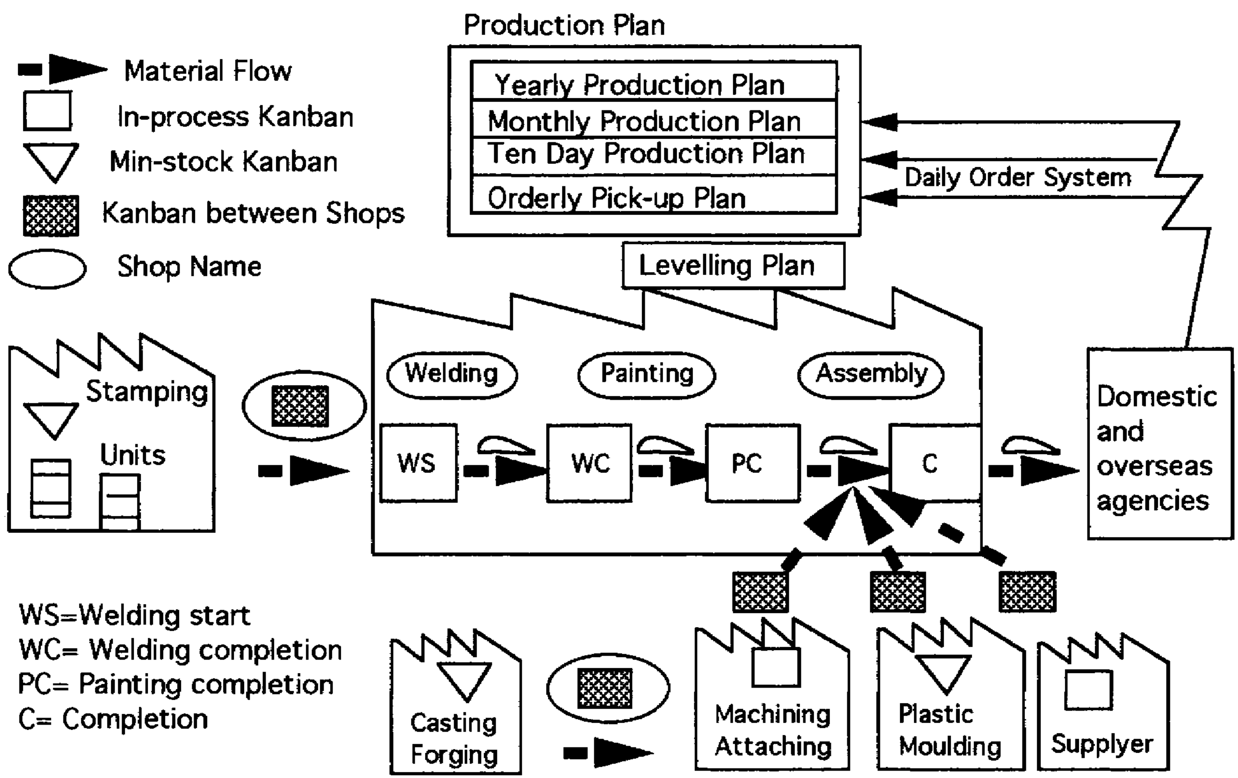
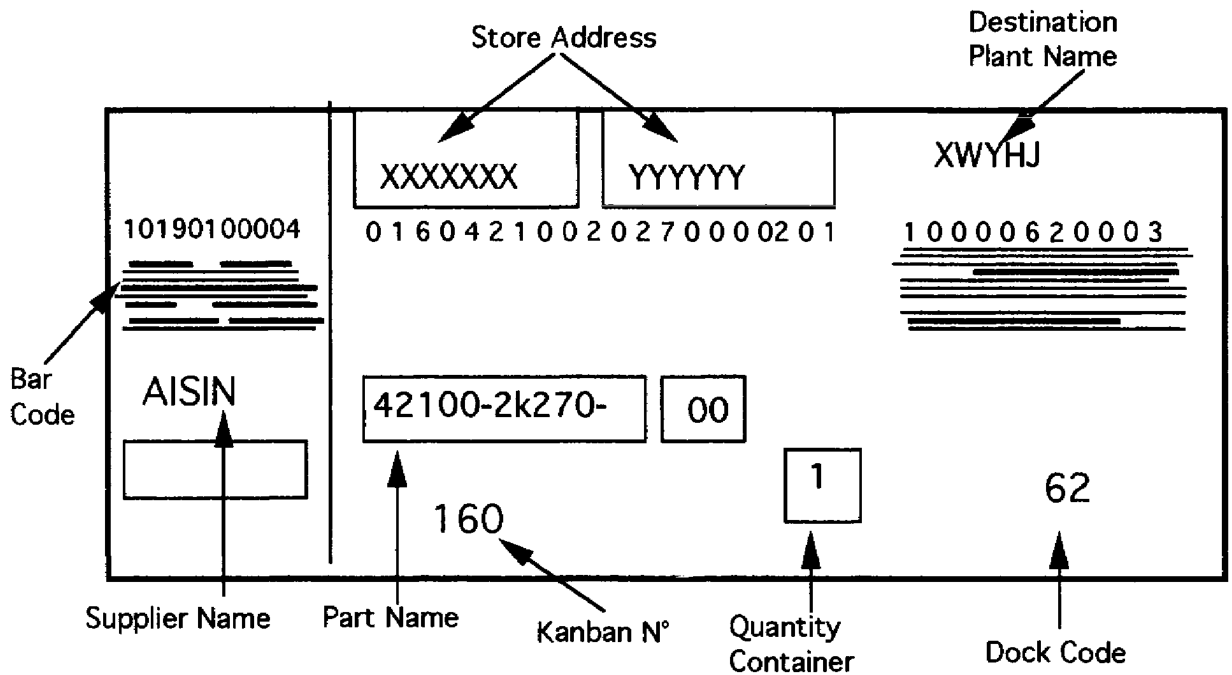


Figure 1 Material and Information Flow for Car Assembly



Appendix 1. Kanban Card

CHAPTER 5

CONCEPTUAL VIEWS FOR CIM

This Chapter studies CIM, aiming to put forward idea's of the concept. Perhaps one of the most interesting questions concerning the progress of manufacturing systems towards CIM concerns the conceptual aspects. In our opinion, conceptual views cope with a large number of problems such as the definition of CIM, its components, its scope, its relations, its borders, its steps, its consequences and even its limitations.

The experience achieved by companies in a never more open environment shows that question needs special attention in order to understand, as precisely as possible, what a particular concept is covering. In fact, when the path of technology development is faster than ever before and when this development has a universal character, it naturally causes already some misunderstandings between people coming from different countries or having different cultures.

So problems such as CIM need some kind of a priori understanding and comprehension by people in companies engaged in a CIM project. In other words, what is the concept and how to present, clearly, the same concept for everyone. It is a very good exercise to study this question in the framework of Japanese CIM technology. This teaches us many things that we want to share with others. To achieve this development we have selected some examples concerning CIM in the Toshiba Corporation and CIM in the Omron Corporation. In fact, it seems in these companies more than in others, that the CIM concept has to be a higher relevance. In addition to that, we present the CIM concept of Toyo Engineering Corporation (TEC).

But before we begin this study, let us recall one fundamental difference quoted in CIM technology compared with other uses of computers in the past (see Section 1.1). Until CIM, the computer was preferentially a tool for helping people in some activity. From there, the reserved expression was every time "Computer Aided Something". But when CIM appears, the computer is not a simple tool for helping but, essentially, for *"integrating" activities in which men intervene. This is a radical semantic difference that we need to keep in mind* whenever we are studying conceptual issues of CIM technology.

5.1. OME WORKS TOSHIBA CIM (OT-CIM)

This Section studies the case of the Toshiba Corporation's Ome Works, one of the most advanced factories in implementing new technology that we have ever seen. We give first a short descriptions of the activities of the Toshiba group and, after, about the Ome Works (OW):

The Toshiba group of companies in Japan consists of more than 500 firms active in a wide range of businesses. In principle, each subsidiary and affiliate is entrusted with full management responsibilities and operates independently of Toshiba Corporation. The relationship with the parent company is non-exclusive and very flexible. At the same time, all the member companies are encouraged to enhance cooperation to achieve the continued development and fruitful co-existence of the Toshiba Corporation. Each Toshiba company articulates its mission in clear and practical terms.

The motto of Toshiba is E&E (Electronics and Energy) and it must promote a new form of society: the communicationless society. Substantial resources are being directed to the promising fields of information/communications systems and semiconductors, a transition given concrete form in two major programmes: "Project I" and "Project W".

Project I is advancing the capabilities of the company in information processing, telecommunications systems, and control systems for industry and public utilities. Project W reinforces the semiconductor business that underpins Project I. Together, they facilitate Toshiba's identification, promising growth areas and the development and refinement of products that are winning the support and trust of users the world over.

Both projects have already achieved signal success. Toshiba is the leading developer and manufacturer of semiconductors. Among the accomplishments of Project I there are laptop and notebook computers. And among other areas, the company is very active in liquid crystal displays (LCDs) that are fuelling the demand for colour portable personal computers.

The situation of Ome Works is:

Location: Ome-shi Tokyo

Founded: January 1968

Site: Land area 120 000 m2, floor area 79 000 m2

Main products: distributed data processing computers, small business computers, micro-computers, personal computers, LAN equipment, word processors, packing switching unit, workstations, optical character readers, winchester disk drives, peripheral devices, various computer systems and communication systems.

5.1.1. General approach

The super-sophisticated CIM system at OW integrates the following three concepts:

- FA, Factory Automation
- EA, Engineering Automation
- OA, Office Automation

Most of these concepts have already been studied in the previous chapters (especially 2, 3 and 4). But in the Toshiba Corporation, these concepts are clearly distinguished and referenced as components to one or other real factory activity. Indeed, these concepts are integrated to streamline the flow of the entire factory operation.

As Toshiba (1991) says, the engineering staff and production crew use this system to develop and design both hardware and software, and manufacture, test, ship and market high quality products. It is the leading edge technology for creating advanced information systems and equipment. These three concepts are fundamental to the progress in building more and more advanced productive systems, which means, in the Japanese view, more and more "intelligent" systems. About the use of the word "intelligence", see Chapter 7.

It is not a simple question to determine which of the three FA, OA or EA, is the more important. In reality, CIM is not a simple seasonal fashion that we can easily add to the existing systems, but a quite complicated thing arising from the transformation of these systems. In every situation we must compare CIM as to the existing system, and try to understand the interrelations between all parts integrated by CIM.

From this point of view, information technologies have a key role in understanding not only the internal links but also the more general relations outside companies. Indeed, the study of Ome Works CIM is probably one of the most instructive cases for understanding the above assertions. This factory may be qualified as an "intelligent" factory, following the common approach of intelligent things existing in Japan. CIM is called here "OT-CIM" which means "Ome Toshiba CIM".

This system is an advanced one which is able to produce both advanced information systems and the corresponding equipment to process that information. Looking more attentively at OT-CIM, we have the feeling that we are facing what some Japanese scientists call "the production of technology by technology itself" in IMS (1992).

According to the nature of production delivered to satisfy consumer demands and the time needed to ensure the right delivery, Toshiba *classifies CIM into the following categories* (OT-CIM, 1991):

(1)CIM for indent systems.

This first category involves parts and products; order-based production; products for plants, heavy apparatus, aircraft and others

(2) CIM for product orders based on market prospects.

In this category are ranged parts, prospective production, system products, labour-saving devices, automobiles, etc.

(3) CIM for products off-the-shelf.

In this third category there are parts and products, consumer products, office automation equipment, small engines, etc.

(4) CIM for standard components.

In this category are ranged all products that are not included in any other category such as semiconductors or cathode-ray tubes.

As in the other cases studied (see previous chapters), the background of OT-CIM depends on several factors. These factors include:

- diversification of user's needs,
- tough competition,
- faster technological innovation,
- globalization of corporate activities,
- shortening of product life cycle,
- difficulty of getting economies of scale

From this set of factors, two have special consideration in the Toshiba view: *globalization* of corporate activities, and *faster technological innovation*, as Hidenori Ohkubo (1992) underlines.

These factors are related to each other and are not acting in isolation.To retain the leadership in technological innovation becomes a determinant factor for maintaining the performance of global activities. Reciprocally, the globalization of this corporation enables it to have an international vision and to be in a better position for innovations. To combine effectively innovation and globalization is a delicate question for management, but we do not study this point.

5.1.2. Steps and campaigns for OT-CIM

As in normal situations, we put OT-CIM in its historical perspective. Figure 1 shows this history from 1968-1977 to the present day. In total, count *five steps* of development *leading* to Computer Integrated Manufacturing.

The steps.

First step 1982-1984.

This step is characterized by the introduction of a distributed processing system. It concerns the passing from direct ordering from branch stores, at the Corporate level, and centralized processing by a host computer (On-line- OW Level), to the On-line connection for individual operations (Corporate Level), and On-line connection between production (FA) and production control (OA) (at OW Level).

The distributed processing system is the first attempt to integrate marketing, management, FA, OA and EA which were until then using a centralized processing system by host computer (Batch-processing oriented).

Second step (1983-1985) (overlapping the first step).

This is characterized by the office automation of general operations and the On-line connection between engineering (EA) and production (FA). This step is fundamental to establishing a more integrated links at the manufacturing level. The compartmentalizing of different activities concerning manufacturing is gradually disappearing.

Third step (1985-1987).

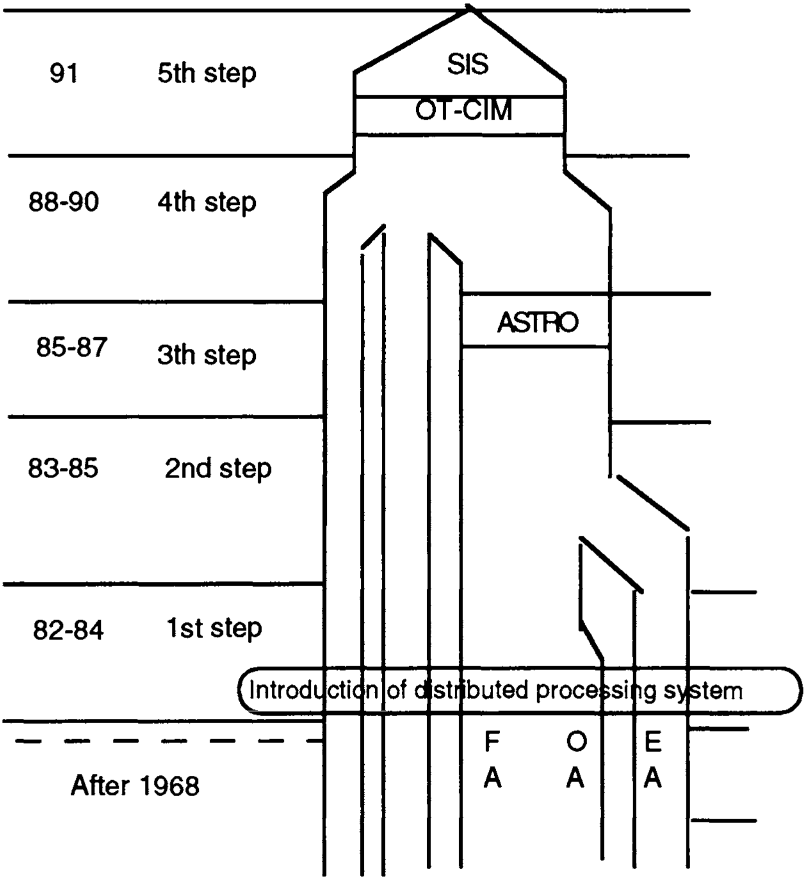


Figure 1. The development of information systems towards CIM

The main characteristic of the third step is the direct ordering from distributors and an integration of OA, EA and FA which results from the integration of links at the manufacturing level.

Fourth step (1988-1990).

The main achievement of the fourth step is the establishment of direct marketing. This integration consists essentially of the integration of marketing and management. So at this point we have two main activities both integrated:

a. the FA-EA-OA integration, and

b. the marketing-management integration.

Fifth step.

The direct marketing creates better conditions for progressing towards a higher integration characterized by the integration of all Toshiba and OW activities. That characterizes the fifth step, in which the total integration of the manufacturing (OT-CIM) and ta direct connection to corporate management becomes reality.

This last system is called **SIS** (Strategic Information System) that we have already met in the case of other companies (see Section 2.4). The principles of Toshiba SIS are **similar to those of Hitachi SIS** and, in general, similar to any other Japanese Corporate SIS. SIS is both the achievement of one important step of the computer integration development and the source of many problems for Japanese companies at the local (Japan) and the international (overseas) level. SIS is a challenge not always without problems for companies.

Another important point is the increasingly close links that appear at every step between the so-called corporate level and the OW level. The way for CIM and SIS is then a parallel one: at every time it is necessary to solve different kinds of problems in order to create and expedite *information flows in real time*, concerning vertical and horizontal views. Figure 2 shows an example of this assumption.

Campaigns for CIM.

OT-CIM and SIS are currently improved by many campaigns and the corresponding policies, as the images of OT-CIM (1991) show. The main campaigns are:

- TP (Total Processing)
- STEP (Software Technical Engineering Processing)
- ISM (Information Sales Management

The basic policy of the TP campaign is to establish a production system rationalized in order to meet the market demand. To achieve this policy, the engineering department must reduce the stock level by half, shorten the lead time and streamline the production system. In addition, it is necessary, at every time, to match supply and demand via outside sales, frequent rapid delivery by small lot and control of short life cycle products.

The *STEP campaign* deals with the software improvement campaign (ST) and high value-added product sales doubling campaign (EP) by creating competition-superior products. The basic policy of this campaign is the acceleration of new product development oriented to market demand. To achieve this, the targets of the engineering department are doubling of competition-superior products, improvement of engineering marketing ability, improvement of element and system technologies and optimization of marketing costs.

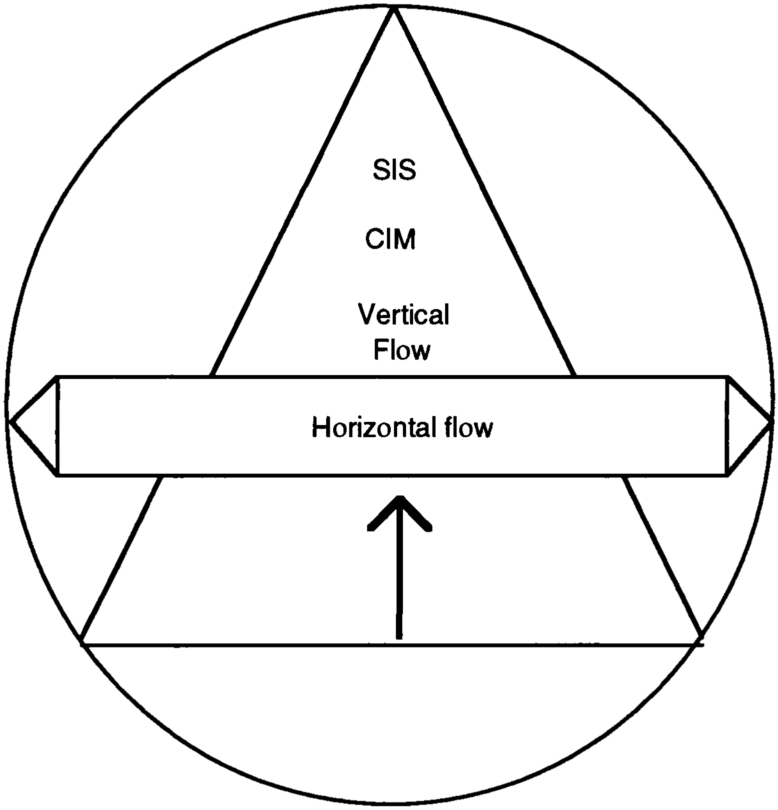


Figure 2 CIM and SIS integration flows

The target of the ISM campaign is to double the marketing strength and the sales profit rate.

These three campaigns are interrelated with each other and with "quick" Ome strategies. Ome must be the top factory in customer-oriented quality products in creating a pleasant, congenial working atmosphere, and in the office automation campaign (small group activities).

Cooperative distributed processing is now a new technology that opens up a new era of fast, cooperative data processing via adaptable networks that are accessed by computers and workstations installed at various levels of the corporate organization. The core of this system is the TP90 series, a single architecture group of machines produced by Toshiba.

TP integrates computing at all levels of the corporation and factory: personal, group, departmental and corporate. As we see in figure 3, this gives a CDGP concept (Corporate, Department, Group and Personal levels for CIM). This figure is quite equivalent to the CIM concept.

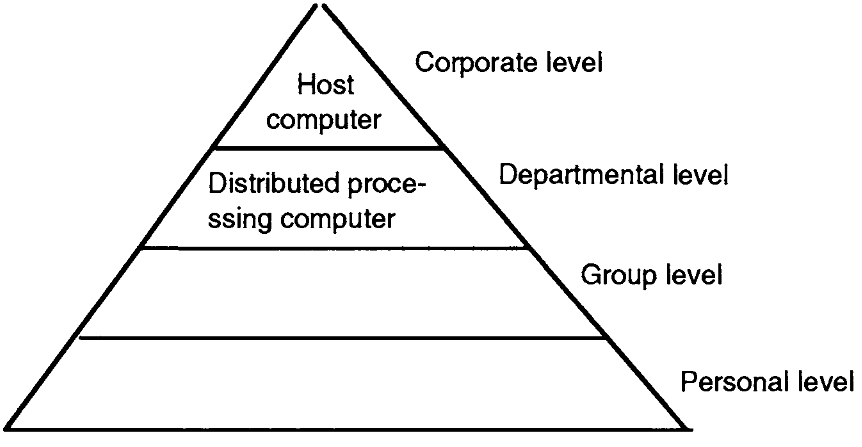


Figure 3 The CDGP philosophy

Planning is also an important dimension of the OW activity, but there are some outstanding differences from other planning systems studied before (see, for example, Sections 2.4, 3.3 and 4.1). In fact, OW (and in general, Toshiba) seems to pay more attention to the conceptual approach and in software development for the new products, and in this way retains the customer-oriented strategy. This approach is called the "project organization which actualized the concept".

The project organization has four steps:

(1) the approval of plans by the steering team (at the top level of management);

(2) the planning and directing, in which the project leader uses the general guidelines issued from the previous step in order to prepare more detailed guidelines to be used;

(3) the concept planning and maintenance. The detailed guidelines are used in this step by the system development team. This team has direct relations with the user's work group (in the concept actualization and operation guidance) and they prepare the required specifications and operational structure that is sent to the system development team.

(4) the system development in which the software development team prepares the detailed design specifications, based on the basic design specifications received from the system development team.

Figure 4 gives a general view of this planning system. As we see one decisive aspect in this kind of planning is the design work based on concepts and specifications prepared by different groups during the four planning steps.

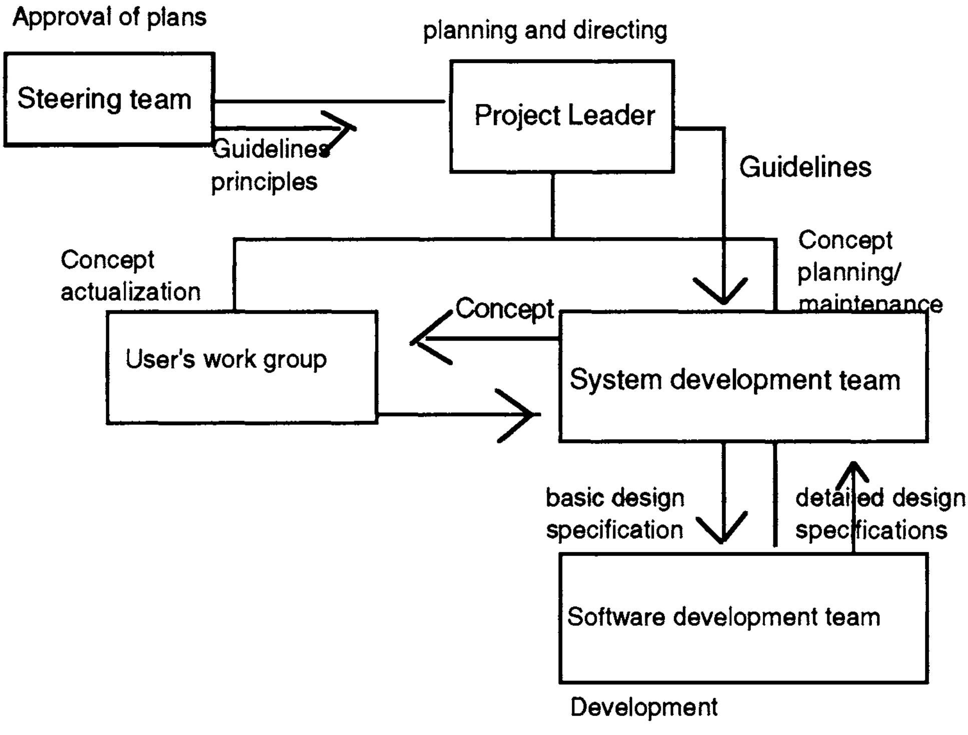


Figure 4 Actualized Concept and Project Organization

5.1.3. Database and networks for CIM

Database and networks are among the main aspects for the conceptual approach to CIM implementation. So the role of the database in CIM is very important. But this database must be, by definition, a shared database. This is true for whatever company is involved. However, one problem is to know how to share this database in the local conditions of one particular company.

An approach to the Database.

To understand this question, the T-CIM (Toshiba-CIM) can be represented as three concentric circles around the database:

(1) The *inner circle* contains at its centre the database which is principally shared by Total Processing (TP) and Software Technical Engineering Processing (STEP). Surrounding this DB we find CAD-CAM-CAT, Distributed production system, RAINBOW, brain spot MRP and other elements.

(2) The circle surrounding the inner circle is an intermediary circle containing decision making (end users computers, teleconference, filing simulation, action files), technical control (development control, technical documentation support, technical information control) and added system technology (artificial intelligence, network, concept, new media, integrated database, distributed processing, E-mail).

Crossing this circle are also *the relations* between the DB and the outer circle. For example, TP phase 1 (which concerns manufacturing Total Processing), in relations with DB, deals with production planning, the material procurement system, PCB distributed system, overseas subsidiaries and contractor support systems,outside order support system, and maintenance parts control system.

(3) The outer circle concerns: human factors (new personnel management techniques), CIM (processing and control systems group), money (new accounting), material (FA-mecha-tronics). In this last circle, one essential point is CIM handling of information, which must allow the management of the whole system. In this circle we find TP Phase 2, which concerns the supply and demand system total processing, TP phase 1 concerning manufacturing total processing and STEP.

Figure 5 shows the place of the Database (DB) in this CIM architecture.

The types of network.

From the point of view of network technology, we can distinguish two kinds of networks:

- the networks for internal purposes, and
- the networks for external purposes

The networks for internal purposes must have the highest flexibility in order to increase computer utilization. Thus the networks topology for internal purposes must be a flexible one. For example, in OW there is a *complex topology* including the LAN Ring, the LAN Bus, the Token Ring or the LAN Star configuration. So, to obtain higher flexibility, the following relations must be carried out:

- LAN Ring connects LAN Buses
- LAN Bus connects LAN Star
- every LAN Bus connects OA Link, which is a simpler network surrounding workstations.

Note that all these configurations must be organized in such a manner that they should be *optimal* at every level. This is an important problem within the network topology framework for flexible CIM systems.

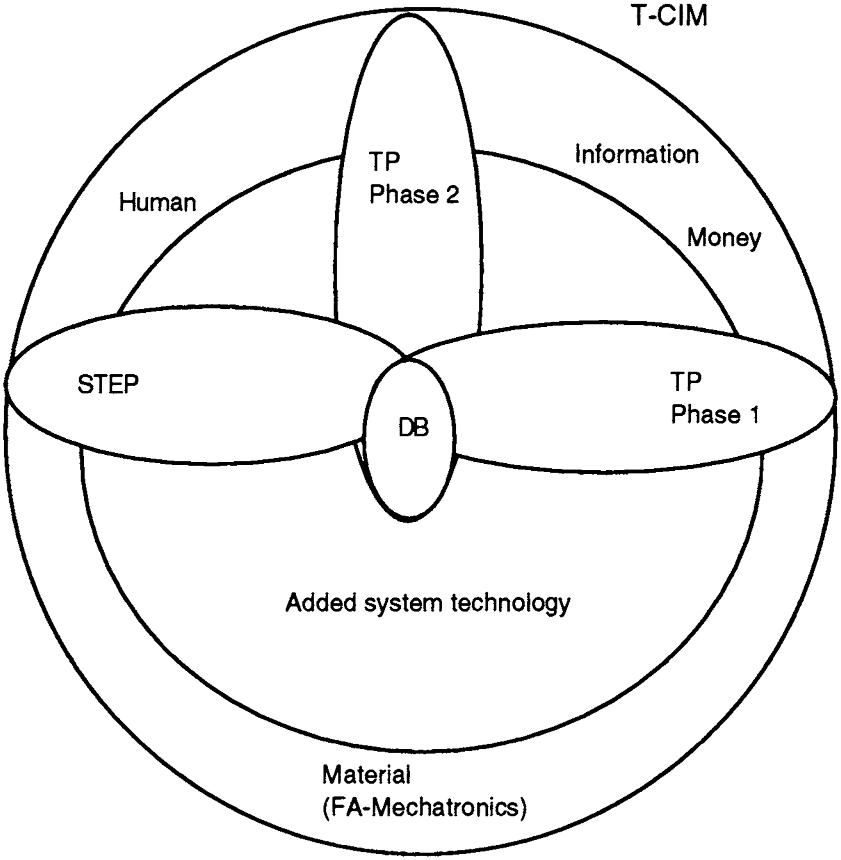
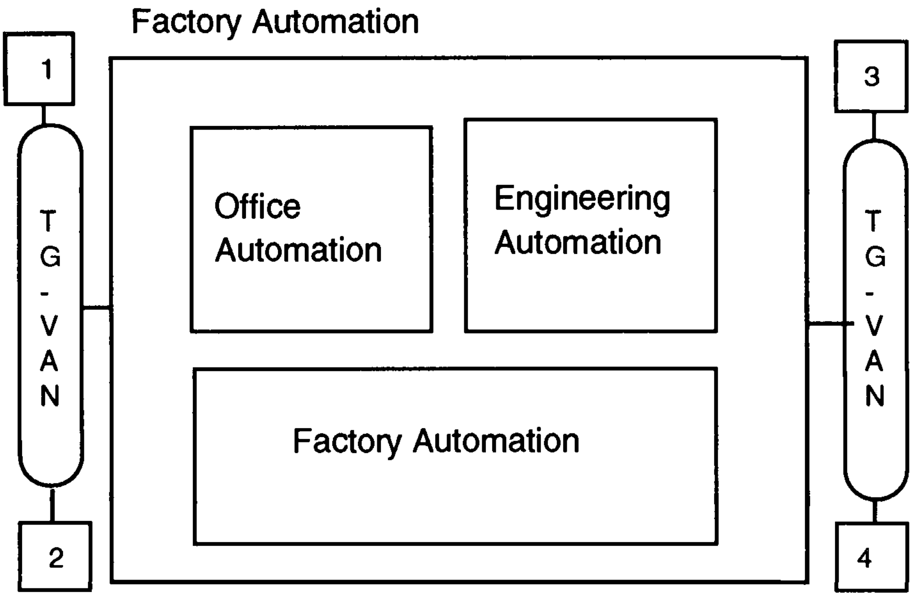


Figure 5 Database in T-CIM concept

In order to optimize this topology, software development and design (Group LAN), Hardware development and design, total OA (group LAN), Purchasing management system (group LAN), Technical staff (group LAN), Production staff and FA LAN are connected to the Optical Fibre LAN (400Mbps).

Figure 6 gives an overview of networks in OT-CIM. We can distinguish the main body containing the three main concepts: FA, OA and EA. Through the TG-VAN, all of these are connected with the headquarters, the system centre, the distributor, the maintenance corporation, the overseas localizations, the technical computer centre, the engineering corporation, other factories and vendors.

The book system has a reservation status list using information coming from customers via TG-VAN. Then the development design and production planning activate material control and purchasing systems in order to prepare the production support system. The answer must be just-in-time, as a required strategy. Normally, the book reservation system processes each night the demands to help the final next daily production plan.



1 Headquarters
2 System centre, distributor, maintenance companies
3 Overseas subsidiaries
4 Technical computer centre, Engineering Corporation, other factories, vendors

Figure 6. Overview of networks in OT-CIM

The network for external purposes is principally the TG-VAN (Toshiba General Value Added Network). As it occurs in most Japanese Companies, TG-VAN covers Japan and international areas. There are two types of external connections:

- relations with maintenance, distribution, and the system centre. The book system plays an important role in this context (see below)
- relations with overseas subdivisions, technical computing centre, engineering companies, other factories, and vendors.

RAINBOW is a system for improving the materials control system and purchasing system. RAINBOW uses MRP (Material Resource Planning) as a basic principle for operating. In a wider sense, this book system may be represented by two sections, related by sales targeting, prospect information and the book database. The two sections are the marketing section and the factory supply and demand control section.

The marketing section comprises consultation, price quotation and prospects. This prospect information aids the sales targeting and is entered as input in the production schedule (factory and control section) and in the factory support and demand control used to set the production framework.

Reservations, or preliminary order acceptance by the marketing section is booked by the system. Then, in the factory and control section, adjustment of the "production seat" reservation framework (receiving the reservation and job number information) is also booked. The marketing section gives a job number and asks for a delivery date, within three days. Then a delivery notice is booked and a manufacturing order is launched.

The CIM pyramid shows association of each level with the computer networking. So, starting from the top we have:

- corporate: Mainframe computer for Headquarter and Scientific use
- department: TG-VAN linking mainframe computer of Headquarters and Factory and Affiliates Subcontractors
- group: Total-LAN linking distributed CPU for sales, production control, manufacturing control and design
- personal: Office LAN linking LAptop and MAP linking automated machinery.

The OA corner comprises the management information system, the factory control system, the supply and demand adjustment, the book system, the production schedule support and the material control system.

Finally we have the concept of a Total Corporate System which includes the following parts:

- sales and marketing (service oriented marketing activity, discover the customer's needs in advance)
- development (quick introduction of products, preserving the benefits of market opening, development of high level value-added products) and
- production (rationalize production to meet market demand).

All the components of this system are integrated in the so-called SIS which management uses to preserve a dominant market position and reflect market trends (see Section 5.1.2.).

5.2. OMRON CORPORATION

This study concerns the Mishima Office FA System which belongs to the Omron Corporation. Omron is one of the top level control system equipment manufacturers. It focuses on manufacturing and sales of electrical machines and appliances. Among the main products are relays, switches, timers, programmable controllers, FA computers, Automatic Teller Machines, Cash Dispensers,traffic control systems, low-frequency models, and engineering workstations.

The OMRON products are goods or production systems which enhance the customer's Flexible/Factory Automation and OMRON is continuously aiming to implement CIM in order to improve its production capability.

5.2.1. Improvement information function for CIM

In 1988, OMRON concentrated its company-wide approach to the development of CIM,. Nevertheless, different actions for the "Improvement of infrastructure for CIM" began about 1981, in particular in the areas of information systems and FA. Among these actions we point out:

- production concepts improvement with a proposal for "distributed controls and integrated management" (1981)
- installation of MRP (1982)
- automation of the parts warehouse (1984)
- automation of small-PC assembly (1985)
- Flexible Intelligent Manufacturing System for PCB mounting (1986)
- installation of ONPS (Omron New Production System).

Based on the production concept of "distributed controls and integrated management" (proposed by the company in 1981), a centralized main information system was developed in the main host computer at the Kyoto Computer Centre. This system consists of MRP (production control), CAD (design management), and ATTEND (sales and distribution management); this last is developed on the host computer at Kyoto Computer Centre. ATTEND means All Tateisi Telecommunication Network Data Processing (field distribution). Tateisi is the old name of Omron.

This information using the top-down/bottom-up concept is represented in figure 7. At the base is installed FIMS (Flexible Integrated Manufacturing System) linked through VAN with other parts. But the centre of the whole system contains the intersections of CAD, MRP and ATTEND. This centre is related to both sales channel and cooperating companies and suppliers.

With the completion of this system, the company hopes to obtain the estimated benefits such as:

- provide delivery date information for orders and negotiations coming from 440 special agent stores;
- daily MRP based on order information coming from special agents and distribution centres, and production schedule information;
- provide daily purchasing information to suppliers and cooperating companies through VAN;
- automatic conversion of production bills for material, based on integrated databases for engineering and material;
- company-wide integration of item (product) number.

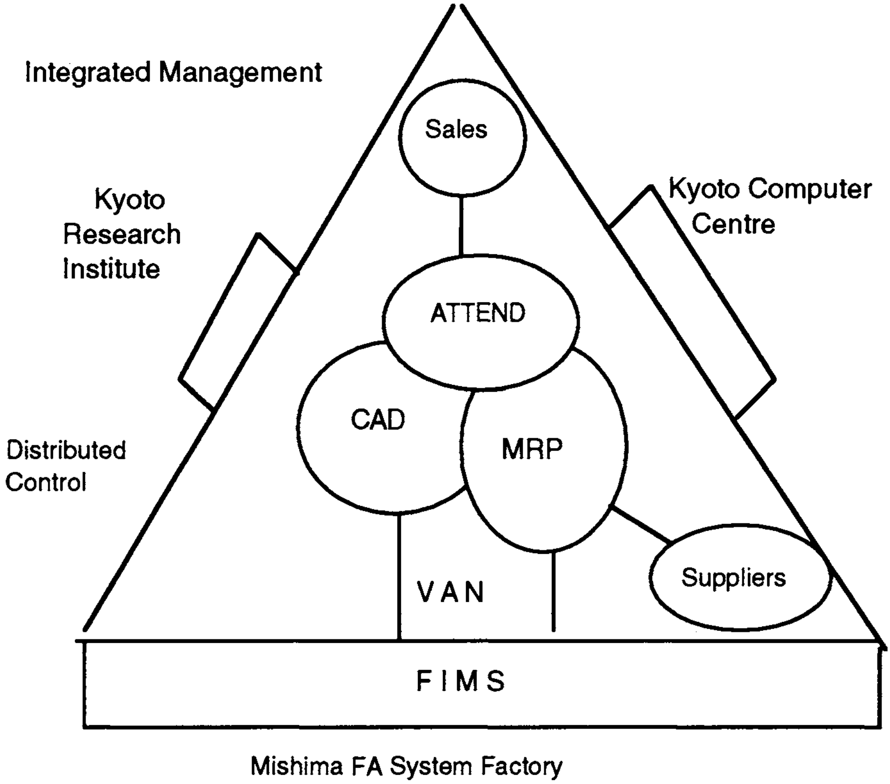


Figure 7. Main information system

Within this context, the mixed production of medium variety/medium volume items appears as an important challenge. For achieving this, it is necessary to structure its Flexible Automation for smaller order lots. Omron calls this system "System of Small Lot Production Flow". This means "to produce the necessary product in the requested quantity, when needed according to the order processing to production".

The implementation of this system takes three steps: automation of the parts warehouse, FIMS Lines for PCB Mounting, and ONPS (Omron New Production System). We comments on these steps in the following paragraphs.

a. Automation of the parts warehouse.

To produce and assemble electrical products such as PCs in small lots, the process of kit allocation, which sends the right quantity of necessary parts from the warehouse to the production line, is very important for quality maintenance. Due to the complexity of this process, it is usually done manually. In 1984, to cope with the increasing number of orders, caused by smaller lot sizing, OMRON decided to develop a parts picking instruction system, which contains an automated warehouse with turning shelves.

According to this system, after parts are inspected, they are temporarily stored in the automatic warehouse with turning shelves. This automatic warehouse system is linked with MRP, and the picking information for next day production is passed on to the PC located at the turning shelves via FA PC. Therefore, if workers enter the production order number by ID (Identification) cards, the necessary quantities of an item are placed into each order's tray, from the specified location on the turning shelves. For identification purposes, the specified location is recognized by its blinking lights.

As a result of the installation of this automatic system, the process is three times more efficient because workers need not see the picking list every time they are handling items.

b. FIMS Lines for PCB Mounting.

(Flexible Intelligent Manufacturing System)

To cope with production orders of smaller lot sizing, in 1986 OMRON developed FIMS lines for PCB mounting. Generally, in order to assemble PCBs that come in different types and sizes, it is difficult to avoid an overall decrease of efficiency in its industry-common assembly cell of straight-line-shape. This is because different PCBs have different processes and process routes.

OMRON, therefore, used a new layout with seven different insertion robots, and a rail which connects all of the robots. The seven robots work like an assembly cell, and they are placed in the shape of a comb. The rails between the robots carry PCB boxes/carts with a data carrier using an ID sensor. As a result, each box/cart skips unused robots, and is only transferred between necessary robots.

To improve the overall efficiency of FIMS, OMRON conducts dynamic scheduling by using an on-line sequence instruction expert system, called ORDERS. Based on each robot's operating condition and the progress status of each order, this system's knowledge base, which contains the experts' know-how, computes and produces the most efficient line sequence instructions.

Figure 8 represents the Omron approach to flexible manufacturing production structure.

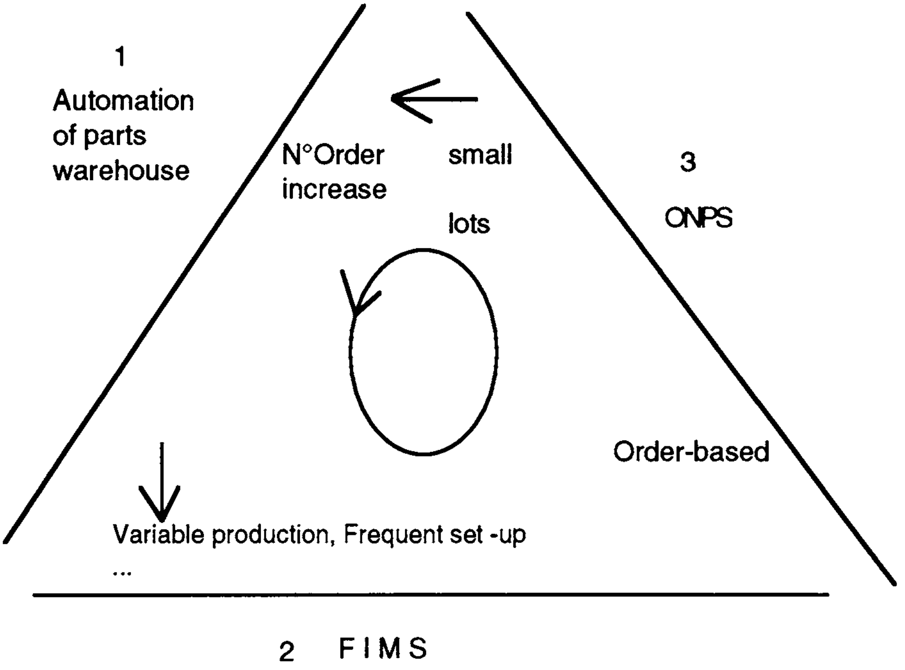


Figure 8. Approach to Flexible Production Structure

c. ONPS (Omron New Production System).

Since 1986, OMRON has been building logistics systems which aim to realize "Flexible and Flowing Logistics" in the flow of customer - special agencies - distribution centre - factory (production planning, parts supplement/shipment, manufacturing, finished goods shipment). This system is called ONPS (Omron New Production System).

By getting closer to the customer information and shortening production lead time, OMRON tries to accomplish the following two points:

- to reduce total inventory of OMRON.
- to prevent loss of sales opportunity by avoiding product shortage at the special agencies.

Generally speaking, OMRON products can be classified into two patterns by their flow from receiving an order to shipping:

Pattern 1: Production items based on orders

Pattern 2: Standard inventory items for immediate delivery.

ONPS is designed for pattern 2 items, the Standard inventory items. It well balances the quick response for actual demand change and the levelled production. The concept of levelled production is one of the pillar ideas of the Toyota production system (see Section 4.1). The implementation of ONPS has consequences such as:

i. 440 special agency stores avoid the risk of the financial loss from potential dead stock, because they do not have to holds any inventory.

ii. Recognition of total inventory reduction has been strengthened by directly watching the actual market demand from the production side.

5.2.2. Conceptual approach to CIM.

Improving the infrastructure for CIM creates better conditions to develop a more convenient approach to CIM implementation in this company. This approach to CIM implementation advances via the following main steps: establish a common concept; user requirements; and conceptual design.

a. Establish Common CIM concept.

In 1988, OMRON formulated a common concept, named "the Top-down/Bottom-up concept" of job site orientation, in order to establish a company-wide consensus because each division then had a different understanding of CIM. We find here one problem, more or less important according to the companies, but the solution of which is a strong factor for successful CIM implementation.

The first step is to develop the total integrated image of CIM including production, factory management and company management. The next step categorizes the objectives and target area in 3 steps (CIM-1, CIM-2 and CIM-3), and implements the steps, bottom-up, from CIM-1 (see figure 9). This figure recalls the idea of hierarchy already studied in the general CIM framework (see Section 1.1). But in this particular case, it is representing a classification of CIMs. In other words, the conceptual approach for CIM should think in terms of CIM figures and not in terms of real or physical hierarchies. This is a very important conceptual issue for CIM implementation.

So the three CIM figures needed the next explanations:

(1) CIM-1 corresponds to the production level. This target is to solve the issues in the flow of information of production which is appropriate for Omron's business;

(2) CIM-2 deals with information systems for efficient management and related operations: production planning, purchasing and synchronization;

(3) CIM-3 is related to the integration of sales/ production/development information to keep the competitive advantage.

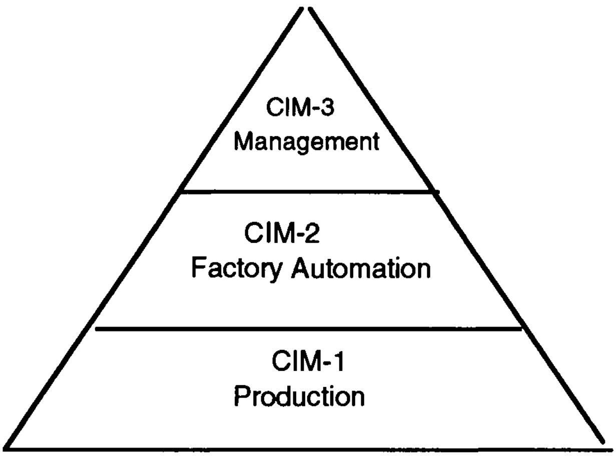


Figure 9 Approach of CIM implementation

b. User requirement (What to do).

The job site working group is established on a part-time basis, in order to make their own issues clear (CIM-1 case) (for organization purposes, see Section 1.2).

The following points came into consideration when the selection of the group members is to be made:

- to have a person who will serve as a key person when the actual operation starts, after installation;
- to have somebody from a previous operation and somebody from post operation;
- to give an opportunity for younger people to participate in a project.

Each working group proposes an ideal vision and a possible vision for the next two years. These proposals are made in a meeting with all the members of the management and discussed in order to produce a CIM image that people desire.

c. Conceptual design (How to do).

The functional user requirement is developed by the job site working group. OMRON establishes a joint project with a system engineering company because it considers it essential to have knowledge in system integration, such as network and databases, in order to satisfy the user requirements.

The report prepared by the joint project contains CIM systems specifications, hardware and software functional requirements, estimated cost, schedule, etc. The development of the CIM-1 implementation is based on this report.

CIM-1 is the activity developed from 1988 to 1990 in order to solve issues regarding the production control information. During this period the objectives were:

- An information strategy for "Control Information" at the production level.

The main issues of this objective are:

i. the major objective of CIM-1 is to establish both the production and quality (inspection) control information which has been excluded from the usual MRP support.

ii. this is because of a drastic increase in requirements for the PC's quality, cost, and delivery, along with recent improvements in the FA network;

iii. OMRON is calling this "Improve the Ability of Quick Management and Accomplish the Q.C.D. Innovation".

- A showroom for a CIM model, with OMRON's own product.

This objective consists of achieving CIM with OMRON's own products, and making the factory the showroom for the CIM model. The important issues of this objective are:

i. to prove to customers an ability to achieve CIM, as the FA equipment manufactures;

ii. to gain and accumulate the know-how for design, development, support and maintenance of CIM;

iii. to prove the possibility of the CIM development approach by adding the new information network to the existing FA production facility rather than establishing new facilities.

In CIM-1, quality Information Control improvement is also an important element to be studied. For this purpose, the company has developed a distributed database network, which is based on the workstations. The target of this database is to centralize management for all information regarding records of important parts, production process quality, market claim quality, and repair/maintenance.

Quality information on a real-time basis, and analysis at each production layer of the causes of inferior goods, have become possible due to this development. In addition, the manufacturing Information Control is managing key aspects, such as the order progress from issue of parts to shipment of products, the actual work load for different machines, active facility, and production information for goods. This also positively influences the facility utilization and on time product delivery percentage.

The POP (Point Of Production) system is introduced as an information gathering tool for this manufacturing information control system. By using this tool, the magnetic card is published for each production instruction chart which is produced by the MRP system. These magnetic cards proceed along with the parts collection box which moves through each production process. The magnetic card will be inserted into the POP terminal located at each production process site, and information such as the position of each collection box, the time required for the production process (workload), and condition of the products is transmitted to the FA computer and processed.

From the point of view of system structure, CIM-1 represents station management, cell management and area management, according to the six-level network developed by ISO (ISO, 78).

For a backbone, OMRON installed mini MAP (V3.0) (for MAP see Section 4.3) which is considered as a possible FA international standard LAN in the future. Among the reasons to install mini MAP even though full MAP could be used are:

i. shopfloor environment of one closed factory;

ii. quick response time and low cost;

iii. high priority for OMRON to develop this technology

OMRON developed distributed database application software using a Sigma workstation (SX9100) (Japanese Program Sigma for software development), see Chapter 7, as an area computer which enhances functionality and better performance. Concurrently, the gateway software which exchanges the protocol between mini MAP and SYSNET (FA-LAN) is also developed.

The POP system which is the network software for FA terminal and FA computer, FASTAR ((FX9200), is developed and installed.

Concerning Data Flow the daily production order on floppy data from MRP is distributed and downloaded through a workstation and gateway to each production line FASTAR. FASTAR issues the magnetic cards for each production order. The information, on magnetic card, goes with the production order through the production process.

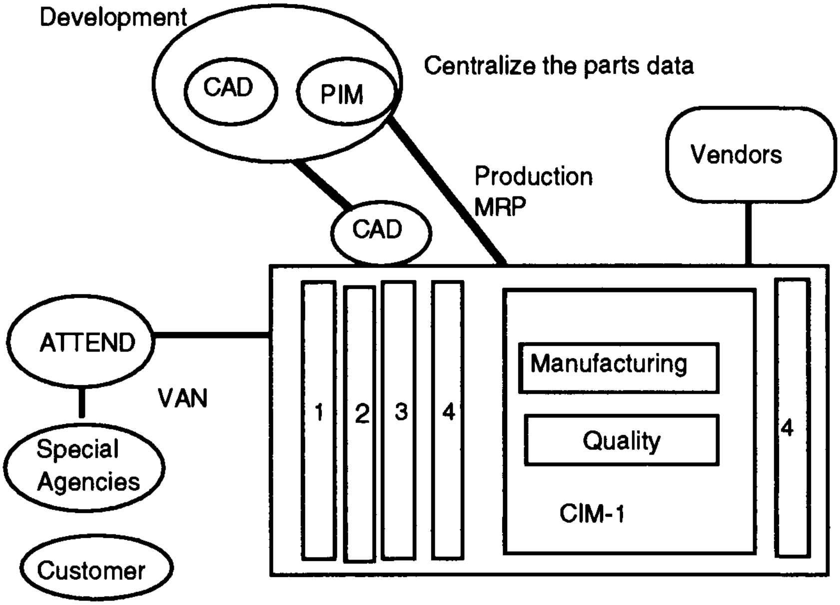
30 POP terminals are connected to FASTAR, and they collect raw production data and quality information. For example, the collected data such as malfunction information, quality defect information, actual work hours, and progress information is processed and displayed on FASTAR or workstations, sorted by purposes. The cause data and the off-line data is input from a keyboard by the operator.

Concerning CIM-2, the main goal is to enhance the functionality of ONPS, because the target area of CIM-2 is similar to that of ONPS. This target must be summarized as follows:

- management of flexible parts manufacturing by MRP and kanban, that is, to promote bar code operation and to adjust the quantity difference between MRP's planned order and the Kanban's actual order

- levelled production planning for inventory reduction, that is to automate the process of production planning.

Figure 10 shows the concept of CIM-2. As we see, CIM-2 includes CIM-1. So CIM-2 deals with the same functions as CIM-1. In addition CIM-2 deals with production planning, procurement, receiving and shipping. In the near future, CIM-3 will increase the field of CIM technology, including all the connections as indicated in figure 10.



Note: 1= Production Planning; 2= Procurement; 3= Receiving;
4= Shipping

Figure 10. The concept of CIM-2

5.3. CIM CONCEPT IN TOYO ENGINEERING CORPORATION (TEC)

It is interesting to interrogate Toyo Engineering Corporation. Toyo Engineering Corporation has extensive worldwide experience in plant engineering. According to TEC (1992) the company was established in 1961 to offer engineering services. For a quarter of a century since its founding, TEC has engaged in a wide variety of plant projects in such fields as petroleum, natural gas, nuclear energy, coal conversion, fossil fuel power, fertilizers, petrochemicals, metallurgy, food processing, pollution control, energy conservation and social development.

TEC activities.

TEC has organized a unique group of enterprises to cope flexibly with the ever-changing economic and industrial environment. The companies composing the TEC group follow their own ways in their respective fields, but are ready for effective cooperation to show their united power to provide client satisfaction. In total there are 23 associated companies in Japan and all around the world. The field of activities of TEC are:

- energy
- petrochemicals and polymers
- fertilizers-chemicals
- nuclear
- food- medical-biotechnology
- environment facilities
- factory automation
- metallurgy-ceramics
- regional development
- computer application and contract search

In the field of factory automation, TEC works in sectors such as food processing plants, pulp and paper plants, building material plants, plastic moulding facilities, ceramics plants, electrical industry, machining, assembling facilities, product distribution centre, medicine plants, cosmetic plants and laboratory automation.

It provides:

- Planning and economic viability reports.

The company conceptualizes the client's plan for SIS and CIM, provides technical and economic justification, and submits a feasibility study to the client;

- project management and implementation proficiency;
- operation support capability

So, in the CIM field, Toyo Engineering Corporation propose a *system integrator*. According to this proposed service, every company must differentiate itself from its competitors and attain increased efficiency at every level. But in this direction, companies are often limited because of the shortage of available human resources. To cope with these kinds of problems, Toyo Engineering Corporation propose to build a CIM system in close cooperation with the company client.

According to Toyo Engineering Corporation (1991), CIM today serves as the infrastructure supporting a manufacturing corporation, and demands coming from companies for improving its productive system must be met from the CIM point of view. Nevertheless, demands for CIM cannot be met by conventional problem-solving methods. So Toyo Engineering Corporation has proposed its own methodology which responds to their own conceptual view of CIM.

The starting point of this concept is the demands coming from client companies. In this respect, Toyo Engineering Corporation quotes demands as the following:

- change product configuration
- new plant construction
- establishment of physical distribution points
- increasing plant efficiency
- new production line construction
- plant automation
- large decrease in lead times

- integration of product management and sales
- application of design data production
- company information infrastructure improvement
- integration of estimate and design operations

The CIM TEC CIM paradigm.

To meet these demands successfully, Toyo Engineering Corporation creates a so-called Toyo Engineering Corporation's *CIM paradigm*. This paradigm distinguishes the following important steps:

(1) change in market needs, such as diversification of product line-up, short product life, etc.

(2) in-house change due to external environment. For example, increasing information volume, complicated management data, more information per product, etc.

(3) problems of conventional improvement methods. For example, limits for bottom-up improvement, limits of equipment improvement, inefficient transfer between sections, shortage of engineers, etc.

(4) change to be made (see below)

(5) specific measure for the change (see below)

In the Toyo Engineering Corporation *CIM concept*, the main points are the *changes to be made and the specific measures to be applied* to realize these changes. The changes proposed are summarized as follows:

- Basic idea
- systematized information
- improved product line-up
- efficient operation transfer between sections
- manpower allocation for product development.

These points require some comments. The basic idea concerns the review of production general processes (marketing, design, manufacturing, logistics) and the reconstruction of the system, and the integration of information, operation, and equipment. But in this direction the information system is a crucial point that needs special attention in the CIM approach. So, the systematized information deals with the data hierarchy necessary for production, integration, distribution and ordering of data, and efficient management, judgement, data and processing operations.

According to these basic ideas, the specific measures for the change must deal with:

- set-up of all company subjects (for example, extract subjects considering company as a one system composed by the sections)
- design of production system (for example, reconstruction for future systematization and design of CIM process)
- making of basic database
- classification and ordering of information
- pilot system construction
- standardization of operation

As we see, the main ideas that we were studying in the real situation of companies approach the Toyo Engineering Corporation CIM but from the point of view of the companies themselves and not from one outside point of view, which is now the case in Toyo Engineering Corporation. The main Toyo Engineering Corporation ideas about CIM remain integration, systematization, standardization, and design efficiency. But the main point of Toyo Engineering Corporation is, probably, the strategic view. Under this aspect, CIM must be considered as a new response to demands coming from companies, who are themselves confronted by tough competition. Toyo Engineering Corporation's answer is a concept in which methods for solving problems are entirely new and different.

Then CIM must result from closer cooperation between Toyo Engineering Corporation and companies demanding for engineering services. In short, that means the variety of supporting technologies needed for building CIM must be combined with know-how of the Toyo Engineering Corporation and the companies and, therefore, the responsibilities of participants for each procedure must be clarified. Indeed, there are client's technologies and Toyo Engineering Corporation's technologies that envelop the CIM technologies, such as hardware and software technologies.

In turn, these technologies envelop other technologies such as company diagnosis technology, CIM process design, CIM project control, computer software technology (CAD/CAM/FMS/MAP/AI), standard design technology, standard manufacturing technology, computer hardware technology (large computer, personal computer, communication), and special manufacturing technology.

CIM integration proceeds via the preliminary reports, the conceptual planning, the basic design, the detail design, the production construction and software creation and the test operation. In every step, Toyo Engineering Corporation and the company client share their specific responsibilities. In particular, client specifications are important for CIM progress. In collaboration with the client, Toyo Engineering Corporation carries out CIM engineering covering the above steps.

CHAPTER 6

STRATEGIES FOR CIM IMPLEMENTATION

INTRODUCTION

We have so far studied CIM via a general approach, the relationships between CIM and concurrent engineering, the relationships between the most advanced networking technologies at the shopfloor level, and the formation of the CIM concept. In all these situations we introduced some theoretical elements but concentrated on real cases in the activity of Japanese companies.

In general these case concerns the biggest Japanese companies, which means those having sufficient resources (human, material and financial) for research/development and implementation of CIM programmes. These companies were, in general, the most prestigious of this country, recognize around the world because their size or technology advance in many aspects.

This Chapter continues these developments. Nevertheless, the Chapter is centred around one principal question, that is, what strategy the companies are following to implement CIM. For doing so, we distinguish, in general, two phases: the technology situation of company before CIM implementation, and its technology situation once CIM is established.

To study these problems, we have selected some examples concerning companies that we have not already seen in the previous chapters. The companies are:

- Tokyo Electric Corporation
- Fanuc Corporation
- Shimizu Corporation
- Nippodenso Corporation

These companies belong to different sectors of the Japanese economy and, they are (with the exception of Shimizu) smaller than Hitachi Ltd., Mitsubishi Corporation, Toyota Motors or Toshiba Corporation, studied in previous Chapters. So the interest for studying these companies is twofold:

(1) to show that CIM implementation is incorporated in a general technology trend concerning all Japanese enterprises and not only a set of leaders;

(2) to indicate that the technology level of CIM implementation is not so different from that already known about in the biggest companies.

6.1. TOKYO ELECTRIC CORPORATION

Tokyo Electric Corporation (TEC) merged with Toshiba Jimuku in 1966. It is a leading manufacturer and supplier of POS (Point of Sales) systems. TEC manufactures:

- distribution equipment, such as POS systems, electronic cash registers, and electronic measuring machines;
- peripheral and OA equipment, such as printers, and information processing machines;
- light electrical equipment, such as home electric appliances and lighting fixtures.

The study of TEC concerns principally the Ohito Plant. This plant produces POS systems and electronic cash registers (ERC) for the domestic distribution industry, and computer peripherals (dot-matrix printers, image scanners) for overseas OEM products. POS systems are produced to client's orders and specifications. POS systems and other products are produced at a volume of approximately 100 units per month. This is considered a multi-item/small-volume production and a small-lot production.

Parts which compose the products are procured in the following ways:

- the parts with high added value, such as dot-heads and PCBs, are produced inside the Ohito Plant;
- the Ohito Plant purchases semi-assembled parts from its related companies;
- Ohito Plant purchases unassembled parts from non-related companies;
- the Ohito Plant consigns purchased parts to subcontractors for partial assembly.

The technology before CIM implementation was characterized by the MRP implementation of system, the parts and work-in -process control system using bar codes and the company-wide implementation of Total Productivity (TP) movement. We comment on these points in the following paragraphs.

6.1.1 Implementation of MRP system

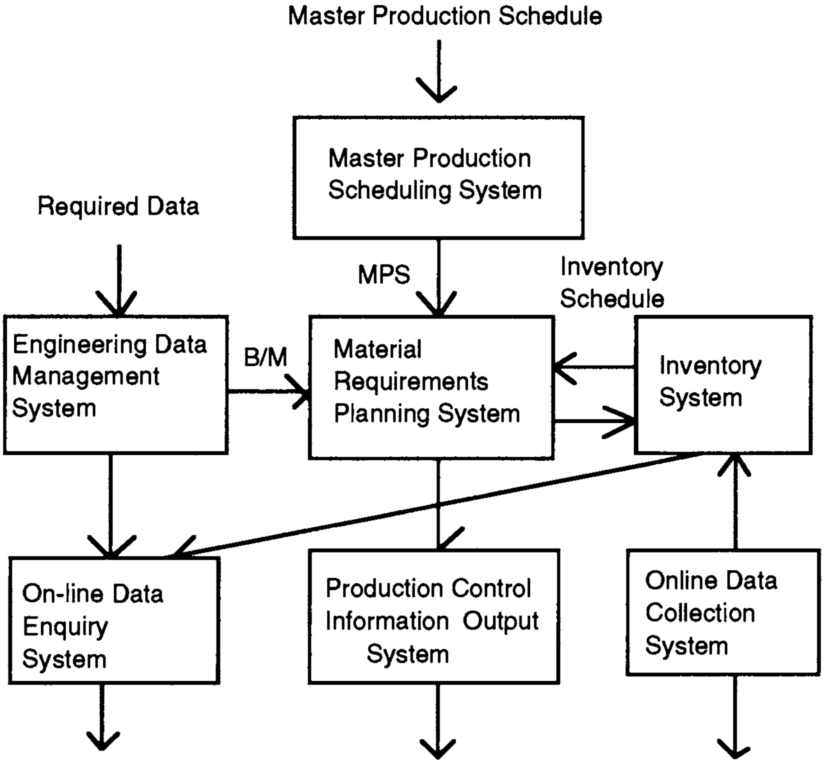
The production control system before implementation of MRP handled each transaction on a monthly basis. Nevertheless, there were problems with parts replenishment by the person in charge and with making planning changes manually.

In order to solve such problems, an MRP system with the following characteristics was implemented:

- handling production plan changes for the system
- standardization of production control

- simplification of data management (e.g. bills for materials)
- central management of production control data
- providing valuable management information
- efficient utilization of indirect employees
- reduction in inventory through proper management
- prevention of the under-utilization of assets

Figure 1 shows the main components of the MRP System at Ohito Plant. We comments some on of them.



(Abreviation B/M means Bill of Material)

Figure 1 The MRP System at Ohito Plant

(1) Master production scheduling system.

Under this subsystem, the master production schedule is based on the three months' production estimate made by the management department, the production control department, and the manufacturing department, after considering order requests from the sales department at headquarters.

This schedule is made on a weekly basis. Even after it is completed, it is reviewed every week in order to deal with change requests coming from the sales department.

(2) Engineering data management system.

This system manages data such as bills of material requirements and information of order placements and lead times. Bills of materials (B/M in figure 1) can be referenced and utilized by the engineering production, accounting, and service departments whenever necessary.

Note that the master production schedule cannot be transformed, adequately, to the material requirements planning system when a bill of materials is not registered properly in this system.

(3) Material requirements planning system.

The material requirements volume is calculated weekly, based on the master production schedule (MPS in figure 1, which is the output of the master production scheduling system), bill of materials, and inventory information. If any of this data is modified, the plan is reviewed on a weekly basis, however, it is impossible to change it on a daily basis, in principle.

(4) Inventory control system.

This system updates inventory files on an on-line basis. The inventory control system thus aids the reduction in lead time between parts issuing and products completion. As figure 1 shows, there is a current data flow between the inventory control system and the material requirements planning system.

(5) Production control information output system.

Order placement, assembly instructions, issuing instructions, and manufacturing instructions based on MRP, are output and arranged according to the user specifications at the end of every week. This information becomes the manufacturing instructions given to employees at the beginning of the following week (on Monday). Thus it gives the assembly manufacturing instructions, the orders and the issuing instructions.

The above systems are completed by the on-line data collection system and on-line data enquiring system.This on-line data collection system collects actual results of receipts and issues instantly, and updates the data while maintaining coordination between related files. The on-line data collection system deals with the following problems:

- accounting: in this case the data concern, for example, ML (Material List) enquiry, cost enquiry, item list enquiry, cost estimate enquiry
- production: data are confirmations of ordered parts, items list enquiry, enquiry/correction of ML, service unit price enquiry

- production engineering: data concern ML enquiry, cost enquiry, item list enquiry
- manufacturing: data are enquiry/ correction of ML, item list confirmation, cost confirmation, order release confirmation
- purchasing: data purchasing master list, unit price enquiry, suppliers enquiry.

6.1.2 Parts and work-in-process control system using bar code

The bar code is a particular point concerning this company. In general, a bar code is used as part of an identification system. It is perhaps the cheaper system to identify physically a mobile item during its shipping. Furthermore, it is simple: a collection of bars representing numbers, inside the determined areas, which correspond to the name of the company, the name of parts, the quality of parts, etc. To-day, practically, everybody has seen a bar code on boxes!

Nevertheless, its use is strongly enhanced when the new identification technologies, using micro-computers, scanners and telecommunications networks are implemented everywhere. In that situation, a bar code is becoming a precious tool for capturing information in real time and in this way to localize the movement of any mobile wherever it is. However, matching bar codes and new technologies brings new problems that need solutions. This guarantees making the system using bar codes a really effective one.

In this new framework, one of the main applications of the bar code is the *tracking* and *traceability* of information. It is increasingly accepted that "tracking" information means accessing it punctually at a precise moment and at a fixed point of space. Conversely, "tracing" information is not a punctually action but rather a permanent contact with all information about an object.

In normal circumstances, companies (not all companies, perhaps) are even more interested in the tracking or traceability of information. Manufacturing companies are among the first to have such an interest. It is important both during the production process and during the shipping process. Furthermore, when companies are working according to the just-in-time philosophy, tracking and traceability of information enables them to be sure that mobile items (in the present case, products) are moving correctly, at the right time and place.

Computers, networks, identification and bar codes plays all contribute to this. In the present case, the situation before the implementation of the bar code control system was characterized by problems such as:

- because an entire package of one part was issued to the assembly line, the unused quantity had to be stored somewhere temporarily, or the other parts necessary for the assembly had to be prepared at the assembly line;

- it was difficult to figure out which were the specified parts and/or to prepare these parts;

- overall work progress control covering related companies and subcontractors was lacking, and response to problems was comparatively slow.

So the bar code system was implemented to gather *accurate and timely* information on the status of parts receipt, parts inventory, production progress, and products inventory. Beside this objective, there is another point which is very important for TEC. In fact, TEC itself is a bar code machine manufacturer. The question is then to *acquire know-how* on using bar code machines at an actual production site which should enable TEC to improve the production it sells to customers.

The parts and work-in-process are controlled using the bar code to follow the different steps in the production process. In general, the Ohito Plant distinguishes the following steps:

- the parts warehouse. Here the system using bar codes controls the parts arrival, their acceptance inspection, receiving, storage, and issue, and the kit creation (see below for this kit);

- the PCB automated mounting. Here the system using bar codes controls the start of automated mounting, the automated mounting process and the issue to subcontractors

- the subcontractors, the system controls PCB/Assembly/Adjustment;

- the final assembly. At this stage, the system using bar codes controls PCB acceptance inspection, and the product assembly line;

- the product warehouse. During this stage, the system controls the finished product reception and product shipping.

In more details, the parts and work-in-process control system using bar codes runs as follows:

- a bar code label is issued for parts delivered from outside dealers after the receiving transaction; this bar code is read for updating inventory data after the parts acceptance inspection;

- two types of bar code labels for issues (one for kit, the other for parts) and a kit list output by serial printers are utilized to prepare kits. Workers collect the necessary parts according to the kit list description and attach the appropriate part-issue labels to the parts. When the whole kit is prepared, the kit-issue bar code label is read, and part inventory volume data is updated;

- bar codes are read at the beginning and end of each work process on the PCB automated mounting and product assembly line. When finished products are stored in the warehouse and product shipping instructions are given by the sales department at headquarters, product labels are read for updating inventory volume data.

Currently, all the shipping transactions for domestic sales are issued in a batch by the sales department.

6.1.3. Development of total productivity (TP) movement

As in the previous subsection analysis, the TP movement is also rather a particular point before CIM implementation in this company compared with developments made concerning others in the previous chapters. In 1988, TEC began the TP movement, based at the production headquarters, in order to cope with the diversification of user demands and the escalation of competition in the company's markets.

The movement is concerned with:

- lead time reduction
- inventory reduction
- productivity improvement

The TP movement has been implemented in each plant and office since this date. However, as CIM technology is arriving, the TP movement is being promoted under the form of CIM.

6.2. APPROACH TO CIM DEVELOPMENT

6.2.1. The need for CIM

As we know a general objective of CIM is to achieve better productivity, but there is no standard strategy for implementing CIM. TEC is no exception to this rule. So in the Ohito plant case, CIM implementation starts from MRP problems needing a solution for improving the productivity.

In fact, the Ohito Plant has implemented MRP techniques in order to deal with multi-item/small-volume production. Nevertheless, it was not easy to monitor the work process status accurately. This was because the production *control time frame was shortened from weekly to daily,* while MRP manages production on a weekly basis. So it was necessary to revise the MRP production control method in order to make it more flexible and to adapt to the new basis.

In addition to that, dealing with the diversification of user demands complicated the works flow, increased the number of indirect employees, and slowed the flow of information. The solution of these problems must be a condition for successful TP implementation. Thus, by integrating existing systems, benefits localized in a single department were extended to many other departments in the plant.

In order to achieve management's goal of total productivity improvement, the Ohito Plant, especially the production headquarters' engineering management department and the plant's production technology department, has been going forward with CIM conceptual planning since 1990. Currently, the Production Control Improvement team, which is one of the TP programme improvement teams, is leading this effort and has been pursuing the integration of production and sales.

According to the above development, the objectives for CIM are:

(1) implementation of the demand and supply balancing system.

This means creating mechanism which connects the sales department at headquarters with the plant in order to promote the integration of production and sales.

(2) review of MRP method and planning unit.

Two aspects are involved in this question: first, to try to synchronize MRP with the production system and at the same time to review the scope of MRP operation, and second, to change the planning time frame to daily and automate the daily plan and schedule

(3) integration of the engineering information system and the production system

The question is to provide an automated link between the engineering information system and the production system, in order to improve the product development system and reduce lead time for research/development

(4) review and integration of plant's existing systems.

Re-examine the relationship between each system in the plant and work to improve productivity and reform indirect operations

(5) active expansion of the bar code system.

Implement a bar code system for work-in-progress management, manufacturing instructions, and collection of actual results; try to monitor information instantly and simplify information input.

6.2.2 CIM at the TEC Ohito Plant

In the strategy for CIM implementation, it is possible to distinguish two main elements: the function system, and the structure system.The function design depends on the control system ideas. The structure is closer to the network development. We study these two systems.

a. Function system.

The production control system consists of the following subsystems:

(1) Factory management
(2) Production control
(3) Manufacturing control
(4) Engineering management
(5) Shipping

These subsystems are connected to headquarters, other plants, related companies, and clients with TEC-NET network. Figure 2 depicts these subsystems. Below, we comment briefly on each of these subsystems.

Factory management system.

This system establishes and manages key business performance indicators and a business forecast for the whole Ohito Plant, and promotes office automation for indirect operations.

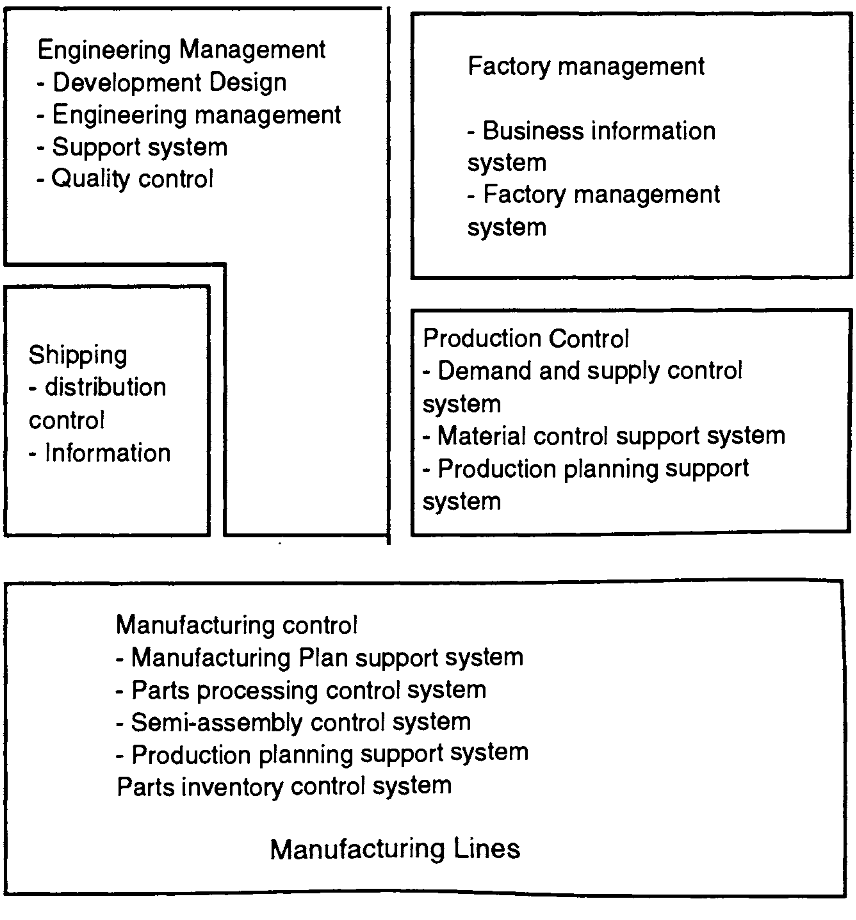


Figure 2 Overview of subsystems

Production control system

This system limits existing MRP system operation to the material procurement area and also reduces procurement lead time and inventory by shortening the production plan time frame from weekly to daily and linking it to just-in-time operations

The sales department of the head office and the plant can share the information and communicate with each other on terminals used by the demand and supply balancing system, which is part of the production control system. As a consequence of this, the sales department can cope appropriately with user requests, such as those concerning delivery.

The demand/supply balancing system operates production load status, delivery time response status and production status. It uses inputs coming from the production plan/adjustment.

Manufacturing control system.

As we saw in the previous Section, *MRP* used to be planned on a *weekly basis,* so daily planning and scheduling were made manually. This situation made it difficult to change plans which had already been prepared. Indeed, by automating this work, it is possible both to synchronize operations among departments and to reduce defective products and work-in-process.

When the bar code system is implemented (see Section 6.1.2) for the assembly process control and receipt/shipping control systems, the efficiency in information gathering is, normally, improved. In fact, the *bar code facilitates the identification of parts circulating* all along the components of the production process. This, coupled with micro-computers and networks, considerably improves the identification of parts and the use of this identification for real-time purposes. So the work process information is utilized by related systems as actual results data.

Engineering management system.

Implementation of a CAD system, which anticipates CIM implementation, achieves an increased efficiency in development and design work and a reduction in work time. However, this improvement remains limited because the linkage between the production and manufacturing systems remains insufficient.

In detail, the CIM technology can contribute to solving this kind of problem. Indeed, after CIM implementation, information is stored in the comprehensive engineering information database and could be referred to by the production and manufacturing systems whenever it is necessary.

Shipping system.

After shipping instructions are received from the sales department of head office, products are shipped from the automated warehouse.

All the other subsystems are under the control of the Ohito Plant, but the shipping system is controlled by the headquarters sales department. The plant has the responsibility until products are stored in a warehouse, and the headquarters sales department takes responsibility after that.

Figure 3 depicts the relations between these subsystems, the headquarters of TEC, and all other partners involved in their activity. At the bottom, there are connections with other factories, subcontractors, related companies, customers and cooperative companies through the TE-NET network. At the top are the connections with the headquarters through the TEC-NET network. Finally, the central square contains the main subsystems of the factory: engineering management, factory management, shipping, production control and manufacturing control.

b. System structure

As we know, one important tool in CIM implementation strategy is that of an infrastructure for information flow circulation. The collecting and transmission of highly accurate information, quickly, is the most important prerequisite of a CIM implementation.

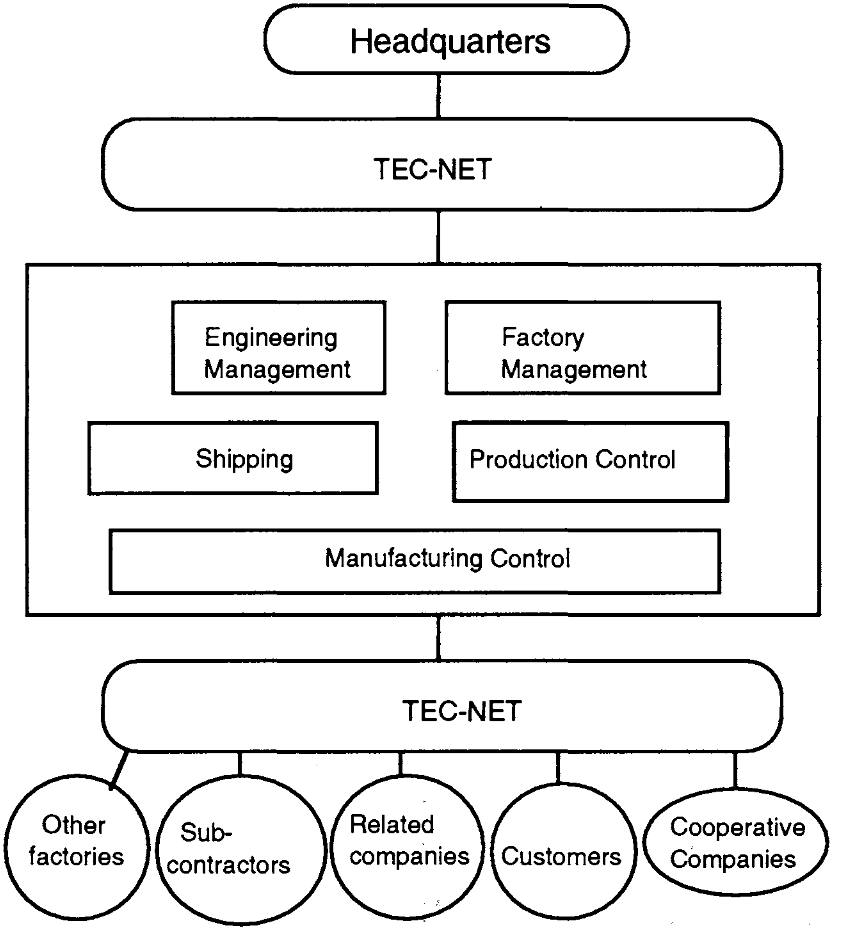


Figure 3 System function connected by TEC-NET

TEC installed the TEC-NET networks, which include a high-speed digital network between the Ohito Plant, headquarters and other plants, and an LAN between the buildings of the Ohito plant (100m optical cable, inter-building: 10M bus). TEC also joined TG-VAN (Toshiba VAN) (for TG-VAN explanation see Section 5.1) and receives information as a member of that group.

The data are divided into the following three levels

- the headquarters host (NEC ACOS1000) is in charge of sales and MRP
- the factory distributed host computers (TEC V7/60, V7/70, Toshiba 90) execute the production control (except MRP), factory management, manufacturing control, and engineering management systems. These host computers issue orders at the work unit level;
- process control terminals are installed on each production line; the total number of the terminals is around 150. These terminals collect production results data, which is uploaded to the factory distributed hosts.

Table 1
Before and after CIM in Tokyo Electric Corporation

Before CIM	After CIM
(1) Implementation of MRP system - master production scheduling - engineering data management - material requirement planning - inventory control - production control (2) Parts work-in-process control system using bar code - parts warehouse - PCB automated mounting - sub-contractor system control - final assembly - product warehouse (3) Development of Total Productivity movement	(1) Function system - factory management - production control - manufacturing management - engineering management - shipping (2) System structure - local area networks - wide area networks - optical fibre

What are the results of this CIM experience? The main results can be summarized as follows:

- reduction of lead time
- reduction in inventory by 40%
- decrease in the number of employees and indirect labour through the efficient usage of information

Comment: at present, TEC is spreading the concept of total productivity improvement beyond the Ohito Plant, to the related companies, subcontractors, etc.. so that the overall level of TEC group management is increased, and quality of the products of the whole group is improved. Table 1 gives a resume of information about Tokyo Electric Corporation, studied above, before and after CIM.

6.3. FANUC LTD.

We now present Fanuc Ltd. This company is a leading world manufacturer of NC equipment for machine tools, and its main strength lies in the in-house production of servomotors. To enter into CIM business operation, Fanuc started from the machine processing field and works on in cooperation with the Fujitsu corporation. CNC equipment sales have had an important increase recently.

Within the framework of the Fanuc strategy for CIM implementation, we follow the case of the Tsukuba factory. This factory is mainly a manufacturer of CNC wirecut electric discharge machines and CNC drilling machines. The principal goal for implementing CIM is an ambitious one: the factory plans to become an example of the next generation factory, that is, this factory is thinking according to FGMS (Future Generation of Manufacturing System) which is the continuation of the IMS (Intelligent Manufacturing System) programmes running at present in Japan (see Chapter 7 for this question).

6.3.1 The situation before CIM

The Fanuc strategy for implementing CIM is a special situation because it is an FA equipment manufacturer. From this viewpoint, Fanuc needs to develop, produce, and sell its FA products at a good rate while maintaining high quality. As we saw before, FA equipment is one of the most important components in CIM strategy. It is the first step on the way to CIM. The FA manufacturer then has a challenge to overcome behind its customers and competitors.

But for facing this challenge, it is very important to recruit, train, and keep top quality personnel with good communication skills. So, one of the purposes of CIM implementation is to reduce the number of additional employees that will be needed to expand the production scale and utilize the multi-item production. In addition to that, it is also critical for Fanuc to establish a pilot factory as a CIM showroom for its CIM promotion effort.

The technical Fanuc goal is to implement CIM which integrates the following areas:

(1) FA: factory automation of production facilities

(2) OA: office automation to rationalize headquarters' administrative department

(3) LA: laboratory automation of the design and research development using CAD/CAM

Figure 4 depicts these three areas to be integrated as a result of CIM implementation.

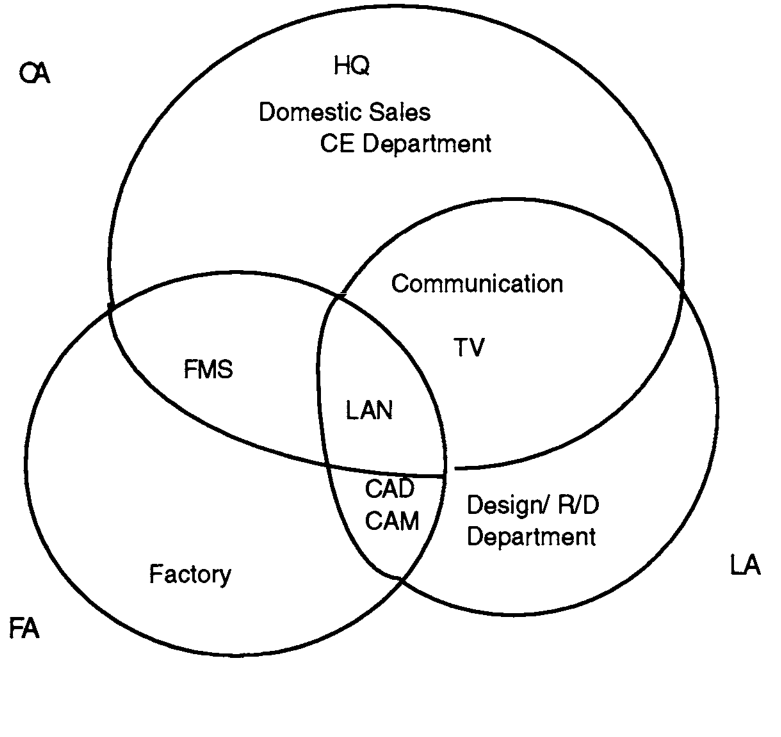


Figure 4 System concept

A company should use CIM as part of its effort to integrate business functions through systems implementation. This integration has the following meanings:

- to get a close relationship between the production control system and the FA-system which uses FMS (Flexible Manufacturing Systems)
- to get a linkage of LA and FAA systems using CAD/CAM

- to obtain a close relationship of all systems with the expanding OA system, which includes key business systems such as business information management and sales management system

The TV conference system was implemented at an early stage, and is used for the extensive and timely examination of the products which are developed by the design department. It therefore has an important role in the close communication among teams.

In the next paragraphs we study the three areas to be integrated, as they were before the implementation of CIM.

a. FA system.

In Fanuc's FA system, the basic unit is "a cell" which is the compositional unit of processing and assembly based on NC machine tools and robots. AGVs (Automated Guided Vehicles) and conveyers connect cells with the automated warehouse. Cell controllers and mini-computers control all production lines.Factory management and the management of information for the entire company are done together.

As we see, Fanuc's goal is *CIM-oriented FA*. It is quite different from other CIM systems studied in the previous chapters. For example, that of Hitachi or MELCO is a *customer-oriented CIM*. Perhaps one explanation is the particular position of this company relative to customers. However, the most important point is to consider the reality of the production process in the Fanuc Corporation, that indicates the FA level as the first approach to the research for CIM.

The FA objectives are:

- implementation of a common CAD/CAM system for the design and production departments
- connection of the production departments with the administrative and sales departments using a LAN
- control and management of the flow of materials information from order receipt through shipping using computers

Whenever these objectives are accomplished, high quality and low price products will be possible.

b. LA system

The reader should understand the importance of *LA* in the Fanuc position. This is maybe one of the reasons for which LA appears clearly as a vital component in the strategy for CIM implementation. We recall that in the MELCO CIM *concurrent engineering* was the prevailing approach. The Toshiba CIM has *EA* as a vital part to be integrated in CIM strategy.

An overview of the engineering information system LA, in addition to the various experimental analysis systems, shows that is a critical area in the transfer engineering information rapidly and smoothly to other departments.

The engineering information system consists of a drawing management system, a materials control system, and a technical document control system.

b.(a) the drawing management system

The role of this system is the management of the designs made by CAD (CADAM Tm and ICAD). Thus the primary functions of this system are:

- registration of drawing ID number
- control of drawing versions
- lending of drawings
- check of drawing formats
- approval control
- print-out and automatic distribution of drawings which were formally registered or changed.

Then, the necessary drawing copies for each related department are automatically printed out and distributed, based on drawing ID. In addition, it is possible to search and display drawings not only on CAD equipment but also on general on-line terminals of the purchasing and operation departments. The necessary drawing copies, after reconfirmation of content, are sent for NPL printing immediately.

b.(b) Bill of materials control system.

This system controls the bill (inventory) of materials, which is a key data item for the design department, and also provides for CAD linkage with the production control system. After the implementation of this system, it becomes possible to retrieve this information from the CAD design data and send it directly to the production control system.

As the result, it is unnecessary to input both the codes from on-line terminals and the design data from the CAD display oscilloscope.

b. (c) The technical document management system.

This is a control system for technical documents, product manuals, and chart-style documents prepared by the design and research departments. Documents are generated first on OASYS word processors in each department, and then, after the off-line or on-line file transfer of these documents, they are stored and managed on the host computer.

With document storage in a library, it is possible to monitor work progress and expand the re-use of documents. Product manuals are retrieved by the engineering management department and used, without changes in format, by a computerized phototypesetting system of the printing company, so that it is possible to create new versions or to print manuals quickly.

Remark.

The chart-style documents (for example, of a production system or an order list for selecting options) have been translated into English by machine translation for overseas experimental use. This is done because product names, technical terms, and the short sentences in comments are appropriate for machine translation. This system improve product quality, shortening the time period for creation of English documents, and reducing subcontractor costs (less work of English translation and rewriting, less work involved in chart layout and printing).

One other problem related to LA is the linkage of the CAD/CAM/CAE system and the engineering information system. The CAD system for machines has implemented CADAM tm and all former drawing-board work is now done using displays. This system is also linked with CAE systems for structure analysis and simulation through an integrated database.

It is possible to transfer information rapidly and accurately to other departments by extracting NC data, because of the linkage of the CAM system and of the engineering information management, including drawing management and bills of materials management.

The CAD system for printed circuit board design uses mainly ICAD/PCB. All design and production work, including circuit design, pattern design, foundation board preparation (by outside order), and mounting of parts with an inserter, are executed by transferring ICAD data.

The CAD system for electrical products, such as the system machines, is linked to drawing management and bills of materials management. As a result, the technical information management system operates without regard to CAD system type.

c. OA system

This system's goal is to reduce indirect labour in the administrative departments of the head office. In other words, it tries to create an office where there is no unnecessary walking about and to promote the efficient use of database information. In the offices, each person has a booth with a terminal installed so that they can retrieve the necessary information without leaving their desks.

The OA tasks which can be accessed from each terminal include 123 types of business tasks, within which there are 600 programmes, including common OA tasks and section OA tasks in addition to key business processing. The EDP management department selects these OA tasks after through discussion with operational departments. The OA tasks are retrieved by analyzing actual terminal use for each section and individual.

6.3.2 Status of implementation of CIM

In the last subsection we presented an overview about the situation before CIM. Now, we develop some aspects concerning the path towards CIM. The first question is that of the objectives assigned to CIM. These objectives can be summarized as follows:

(1) better productivity.

In order to enhance productivity, it is necessary to:
- rationalize design work using CAD/CAM
- automate production facilities
- rationalize the administrative departments

(2) reduction of lead time.

Timely monitoring and adjustment of the series of steps from product estimates to shipping, in order to reduce total lead time

(3) unification of materials flow and information flow from order receipt through to shipping.

To achieve accurate and effective product development and production methods, it is necessary to institute procedures whereby feedback concerning automation promotion and automation status is provided to the management department, the sales department, and the research development department.

The CIM implementation must take into consideration many kind of problems. Among these problems there are:
- the system hierarchy
- the LAN network
- the factory management system
- the warehouse and delivery system
- the cell control system.

(1) System hierarchy.

This problem was studied in Chapter 1. In the present case, it is necessary to clarify and develop a hierarchy for the functions and management cycle of the system which make up CIM, such as the research and development system, the production system, the sales system, and the work process management system, so that these systems can be linked and integrated.

Based on the CIM concepts defined by an ad-hoc team, the following six levels for the system are to be considered important:
- enterprise
- factory
- shop
- cell
- control station
- facilities

Starting from this hierarchy, the next step is to provide a system to achieve efficient usage and data integration with the appropriate computer and network resources assigned to each level. Figure 5 shows a CIM computer system associating an operation to each level.

Hierarchical level	System Composition	Functionality
Company Factory Shop	Headquarters Host	business, production, sales, design
	Factory Host	shopfloor control, inventory control
	CAD system	micro CADAM
Cell	Cell control system	automation of inspection process
Control Station Equipment	Warehouse and delivery system	AGVs and automated warehouse control
		multi-purpose terminals

Figure 5 CIM Computer : hierarchy, composition, functionality

(2) LAN network.

As in other similar cases, the enterprise network is connected to related companies abroad, domestic sales departments, and customers. One of the first tasks is the implementation of real-time order processing. But, at the network level, generally two levels of connections must be distinguished: the connection between factory and headquarters, and the connection at the Tsukuba factory level. Figure 6 depicts this situation.

All networks near headquarters are LANs. These LANs enable a rapid information exchange among systems, an essential prerequisite for enabling a company to make serious advances in CIM implementation.

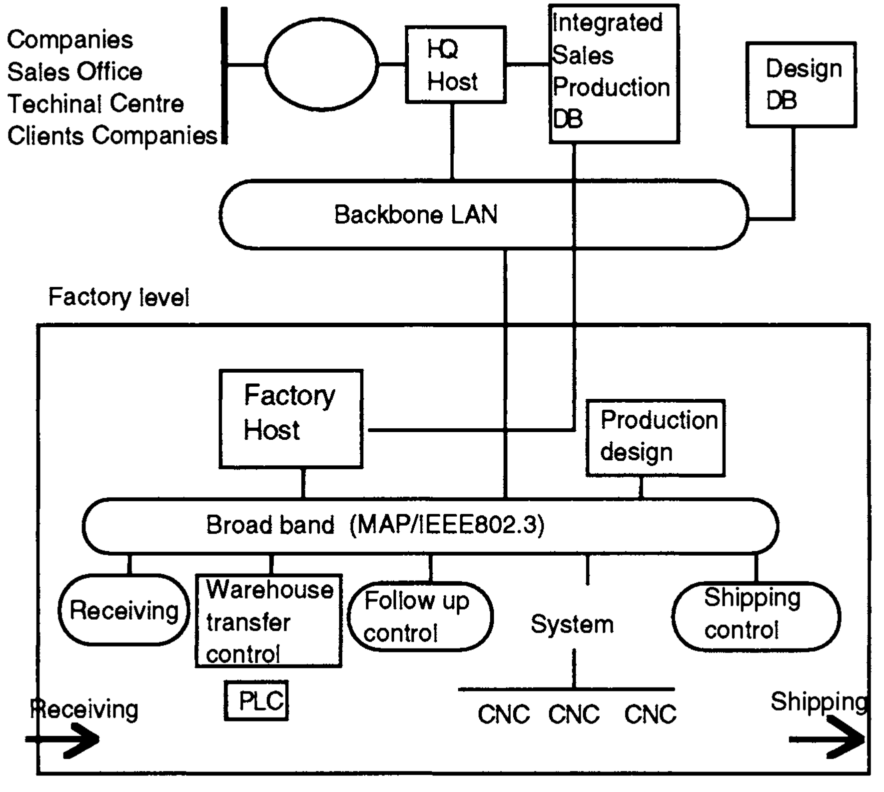


Figure 6 Network system from factory to Headquarters

At the Tsukuba factory a broad band network is installed, and a protocol compatible with IEEE802.3 for the management information LAN and MAP V3.0 for the control information LAN implemented. Simultaneously, transmission of management information and control information using the same line is also taking place. This should be able to handle future factory expansion as well as an increase in future information volume.

The two LANs (near headquarters and at the Tsukuba factory) are connected by a high-speed digital network (64kbps), and the interface between them is integrated. This enables information sharing between headquarters and the Tsukuba factory, despite their distance, at the same level as that between existing locations in the proximity of headquarters.

(3) Factory management system.

The Tsukuba factory management system, which has the factory host as its core, handles many functions in cooperation with headquarters host, the warehouse and delivery system, and cell control system. The system includes shopfloor control, inventory control, shipping control, and delivery instructions. This system uses, principally, a LAN for information exchange among computers. It is now possible for the headquarters to do real-time monitoring of the Tsukuba factory's inventory status, assembly status, and ordered parts receipts.

The factory host computer is the heart of the factory management system which handles the parts warehouse control and shopfloor control. Information exchange between the headquarters host computer, the warehouse and delivery system, the cell control system, and the LAN are the factors increasing the efficiency of the whole factory operation.

The order information managed by the headquarters host is sent to the factory host after it is adjusted in the production planning and control process. The factory host identifies the processes required to carry out the production instruction, and determines the optimum production schedule. Then it issues instructions for the planned assembly work and issues parts based on the schedule. How the production status is progressing is then available an enquiry from the sales department or production control department for each order. Under these conditions, it is possible to respond rapidly to clients about due dates.

Information from the design department of headquarters can be provided to the production department in a timely fashion and parts can be supplied under a just-in-time methodology to the assembly line using the automated warehouse and AGVs. AGVs carry workstations, and picking work instructions can be viewed or input en route without unloading the palettes, by watching the standard screen output package from the factory's terminals

(4) Warehouse and delivery system.

The full automation of storage and delivery operations seeks to reduce the parts transfer and associated administration workloads that are increasing as lot sizes decrease, by means of storage and delivery system connected to the factory host. Thus the objectives of this system are:

- to supply necessary parts to each assembly factory as required with progress checks according to the production schedule
- to improve the man-machine interface for easy operation (for example, the use of an operational panel)
- to implement 24-hours operation of AGVs without human intervention, including battery change.

From the point of view of its structure, this system embraces of warehouse components, delivery components, and the distribution control system.

The warehouse and delivery control system runs as follows:

(a) The warehouse and delivery control system and factory host comprise a hierarchical system, which receives palette instruction data (for example, the starting point, the destination, and the palette number) which is extracted from the inventory control system managed by the host computer

(b) This data is converted to instructions for the material handling instruments system, including conveyers, automated warehouses, and AGVs and instructions for individual delivery machines

(c) The system gives instructions to the control units (programmable controllers) of individual pieces of equipment.

(d) For each palette, the system also controls tracking of AGV delivery routes, such as from a receiving conveyer to the indicated shelf of the warehouse, from the shelf to an issuing conveyer, from the issuing conveyer to the receiving station of an assembly line or shipping floor.

Table 2
Main aspects before and after CIM
(Fanuc Corporation)

Before CIM	After CIM
(1) FA system	(1) Established system hierarchy
(2) LA system - drawing management - bill of materials - technical documentation management	(2) LAN networks
	(3) Factory management system
(3) OA system	(4) Warehouse and delivery control

(e) Each palette has a bar code label which indicates the palette number: the system reads this bar code at each important position to maintain accurate tracking, and it controls the route at junction points.

(5) Cell control system.

The cell control system seeks to achieve automation of the inspection process using automatic inspection data and quality control data. In the process, assembled machines go through running tests under the self-controller. This self-controller controls the NC data for running, the NC optional parameters for a shipping machine, and accuracy inspection for data collection through a sub-network, based on HDLC which is installed inside the assembled machines.

Table 2 shows a summarized view of the Fanuc factory situation before and after CIM.

6.4. SHIMIZU CORPORATION

The Shimizu Corporation has expanded to become a global engineering and construction company. Shimizu has developed for the future a world-wide image, building in overseas activities that span three decades. The company global network now boasts 91 offices and subsidiaries in 33 countries, allowing a complete and comprehensive response to the globalization of its operations. As the 21st century draws near, the company is still challenging new frontiers in space, underground, ocean, and desert regions.

Approaches and activities.

The Shimizu approach can be divided into five major steps:

- the plan prepared by the customer is studied and proposals made concerning planning directions and implementation
- traffic conditions, site access, land use conditions, and other issues affecting the area of the proposed project are studied and analyzed
- type, scale, and methods of the business proposed are considered
- land use plans, long-term profitability plans, and development schedules are proposed
- finally, building design, tenant arrangements, medium term profitability planning, manpower planning, ideas for use in negotiating, and ideas for attracting tenants are provided
- through this approach, Shimizu is able to meet all the needs of its clients, from initial planning to management of the completed project.

Among the activities of this company are:

- contracting for building, civil engineering and other construction works
- research planning, soil investigation, surveying, design, supervision, management and consulting in connection with construction works
- research, planning, design, supervision, management and consulting in connection with regional development, urban development, ocean development, space development, resource and energy development and environment improvement, and the like
- purchase, sale, letting, brokerage, management and appraisal of real estate
- construction, sale, lease and taking charge of residential houses, and other kinds of building and development and sale of land

- design, manufacture, sale and lease of construction machinery, concrete products for construction, furniture and interior fittings, and sale and lease of construction materials

- acquisition, licensing and sale of industrial property, know-how and computer software

- design, engineering, sale, lease and consultation of and in relation to communications systems and automated building management systems, and the like

- management and consulting of and in relation to athletic clubs, tennis clubs, golf courses and other sports facilities

- management and consulting of and in relation to hotels, restaurants, resort facilities and condominiums with nursing services for senior citizen

- sale of medical machinery and equipment, educational materials and equipment, and sporting goods and the like

- planning, production and sale of advertisements, publications, printing, motion pictures and other information media

These and other activities need a major research and technology development effort that the company is ready to undergo. The Institute of Technology has charged this task. Basic research is the main function of the Institute. The staff carries out initial research and investigates promising areas.

The Institute covers subjects such as the following:

- construction engineering (construction methods, architectural performance, material properties, concrete, construction management),

- structural engineering (steel structures, earthquake engineering, building structural engineering, civil structural engineering),

- underground engineering (rock mechanics, groundwater hydrology, soil dynamics and seismic engineering, foundation engineering, soil engineering),

- environmental engineering (acoustics, air technology, fluid dynamics, ocean environment engineering, water environment,human science, social science),

-facility engineering (facility systems, HVAC, electronic facilities, information facilities),

- planning engineering (fire safety, information systems, architectural design methods),

- advanced technology (advanced materials, applied biology, applied physics and radiation) and

- technology development engineering (applied technology, large-scale testing room, vibration testing, material testing).

So the Shimizu Corporation is one of the most important construction companies in the world and one of the most important producers of advanced technology in this field of activity. Shimizu has one of the leading roles in CIM implementation in Japan, but it is not a traditional manufacturing company. So, what is the strategy of such a company for taking up CIM?

The "Computer Integrated Construction" (CIC).

To begin, we consider the concept of CIM. In Shimizu terminology it is simply *"Computer Integrated Construction"* (or CIC) as writes Y. Yamazaki (1992). In fact, one important challenge in the field of construction is the integration of design and construction processes (there is not one, but many different processes). Building construction involves cooperation among engineers, designers, and project managers, so comprehensive organizational planning and management tools are required. This is the starting point for a strategy for CIM implementation.

To advance in the right direction, the first question is to establish a framework for research and development of an integrated construction system, as the company wants to do. Three majors problems are identified in this way:

(1) basic information procedures and knowledge about construction technologies is *not shared* between designers and constructors

(2) *interactive procedures* at the early design stages, to apply building systems and construction methods, have *not yet been developed*

(3) there is usually no systematic evaluation and feedback of relevant data and information from the construction site.

To solve these problems, Computer Integrated Construction should first be addressed to improvement of designing, planning and management productivity applying information and knowledge engineering methodology. Indeed, Computer Integrated Construction is composed of a design and engineering system, construction planning and management system, and construction system, including building system construction, and facilities (machinery and robots), which are adopted for construction automation.

This system needs a consistent and flexible database for storing design and engineering information, construction planning and management information, manufacturing information, transportation information (this last, for example, is under many constraints). As a result a common data and knowledge representation scheme for product modelling (building space model, elements ...) and process modelling (design, planning, ...) should be established to allow an efficient exchange of information between the different functions.

According to Y. Yamazaki (1992) a major interface between design and construction is an interactive investigation process between building system planning and construction system planning, which also produces construction activities and construction site layout, reviewing conditions and constraints. Figure 7 depicts this interactive system.

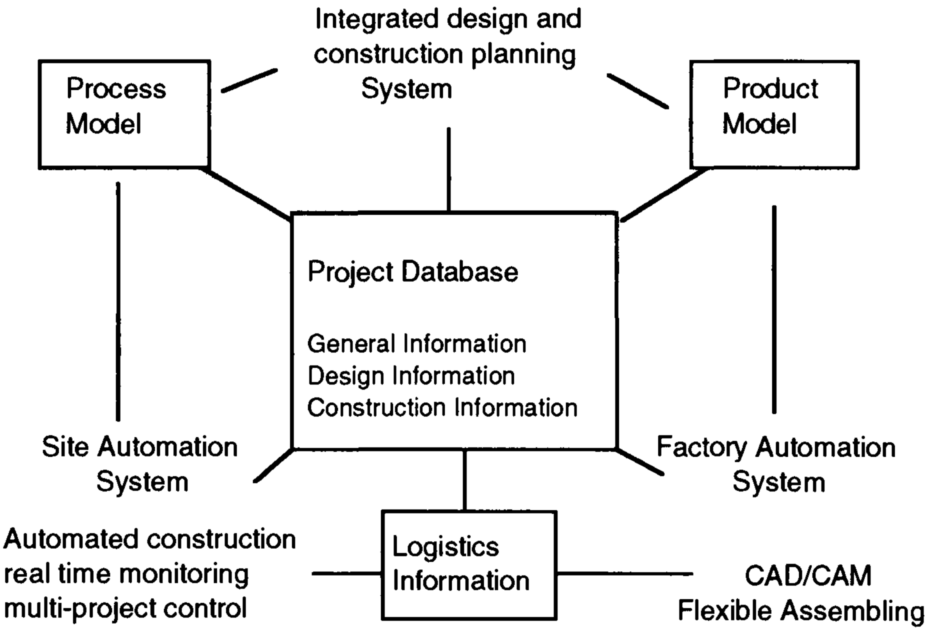


Figure 7 A conceptual view of Computer Integrated Construction

The knowledge and the object-model.

As in other cases already studied, one good way for designing an optimal system is to call for the participation of all people involved with the activities covered by Computer Integrated Construction (engineers, designers, project managers) at the early stages. This integrated research by designers, engineers and project managers improves productivity at the construction stage and saves time through the better utilization of all resources. This cooperative planning defines an integrated design and construction planning. As we see, the strategy is quite similar to that applying the principles of concurrent engineering that we studied in Chapter 3.

In this way an object model for integrated design and construction planning is produced which is as close as possible to user needs and also optimal resource consumption. But for the realization of this planning as a computer system using *knowledge*, it is necessary to represent the following functionalities:

- negotiating knowledge module for schemes produced by different planning modules at the simultaneous phase
- planning expansion of knowledge module for producing an eliminating planning object, as required at each step of planning
- constraints management module (adds, modify or eliminate constraints)
- working memory for investigating objects by subsystems in knowledge modules

- relational database (store hierarchically objects models, project information and planning process)
- production database and integrated construction system database (present reference information and store technical information).

From the point of view of knowledge representation, two *types of knowledge* are required and implemented:

(1) surface knowledge depending on the purpose and acquired through analysis such as the classification of characteristics between buildings and construction methods, technology available or strategic knowledge

(2) more advanced knowledge, depending on the domain and structured, for example, as a hierarchical network of object models (representing building models), user-defined relations (representing, for example, connections between elements and components), and methods or procedures for controlling information.

So, by this means an *object model* to be applied to an integrated construction planning system is built In general, the applications of this object model need the implementation of two major stages (Y. Yamazaki (1992)):

(1) the conceptual scheduling.

Conceptual scheduling must be rather uncertain, and therefore many assumptions (e.g., building system or construction methods) need to be set up efficiently

(2) Construction system planning.

Construction system planning must be designed to be an activity producing the best mix of building systems, construction methods and major temporary equipment. So it requires a hierarchical modelling which permits the best selection.

As an example of implementation of the Computer Integrated Construction notion, Y. Miyatake (1992) presents the automated construction system for a high-rise building.

In this example there is an application of the so-called A/E/C (Architecture /Engineering /Construction). There are three of these systems: integrated design and construction planning system, site automation system, and factory automation system. As an example of A/E/C, Shimizu developed an automated high-rise building construction system called SMART (Shimizu Manufacturing system by Advanced Robotics Technology).

The SMART system is a part of the Shimizu strategy for developing construction systems which integrate the high-rise construction process from foundation to site management, including structuring, finishing and installation works. With the introduction of the SMART system, both the labour and the construction period are greatly reduced.

The SMART system automates a wide range of construction procedures, including the erection and welding of steel frames; the placement of pre-cast concrete floor planks, and exterior and interior walls panels; and installation of various units. The system uses prefabricated components including columns, beams, floorings and walls, and the assembling of these components is simplified by the use of specially designed joints.

Furthermore, the assembling process is organized by a real-time computer control, resulting in construction site operation in a highly automated way. Information management at the site level is efficient because et the SMART system, so it is reducing the quantity of waste, and improving the overall site management and scheduling.

The kernel of the SMART system is constituted by lifting mechanisms and automatic conveying equipment installed on the operating platform, which is finally the top room of the building.

Steel-frame columns, beams, floorings and walls are automatically conveyed to designated locations, where they are effectively assembled and mounted with specially made joints. The steel-frame welding process is also automated, with the intervention of an automatic welding machine. So, when one of the floors of the building is completed, the entire automated system is lifted vertically and the work for the next floor begins at this moment. Indeed, construction work proceeds systematically, floor by floor, until the whole building is finished.

In addition, the SMART system provides complete all-weather enclosure for the site, accommodating satisfactory working conditions and safety, and leading to higher quality and durability for the product. There are plans to reduce labour and construction period to half of the present norms.

6.5. NIPPONDENSO CORPORATION

According to M. Sakakibara and K. Matsumoto (1991) Nippodenso has always based its activity on the concept that in-house manufactured equipments are essential to optimize the products in quality, quantity and cost. As a consequence of this policy, the company tries to develop as far as possible their own production system. This concept also governs the strategy followed by this company in CIM implementation.

The same M. Sakakibara and K. Matsumoto (1991) define CIM as a self-activated and integrated production system, which connects the material flows with the information flow, achieving in this way the ideal conditions of quality, delivery, cost and humanity. These authors imagine the way to CIM as a geometric shape, as follows:

- a *spot* which represents an automated equipment (for special purposes)
- a *line* which represents the automation lines (for example, transfer lines)
- an *area* representing the automation systems (for example, a production process from fabrication to assembly)
- finally, a *cube* representing CIM (an integrated automation system)

Figure 8 shows this evolution. One comment about this representation: in our view, it is an extreme simplification because in fact, when man intervenes, especially in technology development, there is linear progress of things. Sometimes there are many feedback developments. The progress is rather a spiral trend than a linear one.

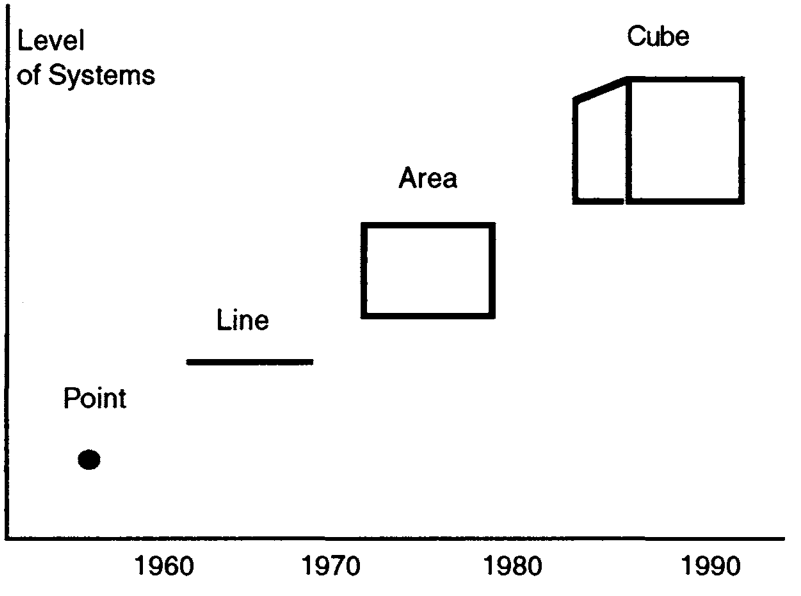


Figure 8 Evolution of automation in Nippodenso

The UTOPIA Project.

As we see, this route leads to an intelligent factory activated with self-control and becoming almost human. For achieving this ambitious idea, Nippodenso created a project for an ideal factory named UTOPIA (Useful and Totally Organized Plant Information Systems for Action). How will UTOPIA achieve CIM?

UTOPIA must combine two approaches: the conventional approach, and the micro-electronics application.

(1) From the traditional approach, it must learn:
- the oriented work flow
- the mass production, with few kinds of products
- the oriented hardware
- direct labour, etc...

The problem is not to refuse or accept one or other of these elements. The problem is to study how they can enter, or must be modified to enter, the new era. Under this condition, they must be added to the micro-electronics application in order to give CIM.

(2) From the micro-electronics application, it is interesting to keep:

- integrated work and information flow
- speedy information and feedback
- integrated hardware and software
- intelligent equipment
- indirect/overhead operation
- autonomous function, etc.

The same above reasoning is applicable to the elements constituting this approach. As a result there is the next addition:

(1) + (2) = CIM, where CIM comprises the integrated production system (factory autonomous), hardware, software, etc. This system is assumed to permit a total flexibility. Then in the ideal factory, we find humanity (worthwhile working, sense of achievement), quality (new technology, zero defect, quality assurance), delivery (frequent delivery, minimum lead time, zero inventory) and cost (minimum cost).

Starting from this concept of CIM, the next step of the strategy was to build a CIM system in practice. Nippodenso has decided to do it in the Kota factory. Then the project took a different name: UTOPIA Kota CIM.

According to M. Sakakibara and K. Matsumoto (1991), the main objectives of this system are to:

(a) obtain an ideal just-in-time system

(b) make the most of the information network: cooperation with sales, engineering and production departments, and speedy information flow

(c) build up know-how by developing, and making active use of, in-house products (example: bar code)

(d) make an easy-to-use system with sufficient reflection and feedback from the shopfloor

(e) establish a production system of higher productivity and better quality.

One interesting point must be underlined in the strategy for CIM in Nippodenso. It is the establishment of an organization for CIM. At the top level of this organization there is a Kota plant engineer committee, headed by the Senior Executive Vice-President in charge of cooperation-wide production. There are also several subcommittees (CIM, Automation, Electronic Production, IC Production, Facilities) developing point implementation planning in their area and receiving global approval.

The effort is concentrated on cooperation between many existing systems at the Kota factory. It leads to much smoother communication with related departments, intensive operation training, and designs for counter-measures against system interference, while adjustment of system operation and maintenance are promoted.

Several systems (OA, CAD/CAM) make up UTOPIA Kota CIM, but they are centred on the production control system. All these systems are connected by an information network. The production control system has two delivery patterns: a kanban delivery (accept a firm order with kanban only a few hours before shipping) and Push delivery (accept a firm order two or five days before shipping).

These delivery systems are compatible with the production system but for producing just-in-time (produce only when the order is accepted - kanban receipt), engineers create a hybrid production system. This makes a production plan within a certain lead time from order acceptance to final shipment and manufactures products in time for shipping at once or, for the ones not in time for shipping, by supplemental production. As in general CIM goals, by this means Nippodenso intend to meet customers requirements while reducing parts inventory and production lead-times.

But perhaps one of the most interesting things in the strategy for CIM implementation at Nippodenso is the integration of material and information flows. We have already studied this problem in the Toyota case. In order to enable quick, accurate and low-cost input and to be easily automated, the factory has adopted the bar code. But for the internal needs of the project, the company developed new bar code units including radio bar code scanners, high-speed bar-code eyes and high-speed kanban printers.This system realizes an easy-to-use system reflecting user opinions and aid future CIM development (M. Sakakibara and K. Matsumoto (1991)). So the bar code integrates material and information flows.

From the viewpoint of its communications network, the Kota factory CIM design uses a broad-band LAN in order to meet the following requirements:

- idea of information outlets
- inter-linking between computers of different manufacturers
- high reliability and low wiring cost
- compatibility with MAP
- transmission of sufficient information

CHAPTER 7

CIM, IMS AND FGMS

INTRODUCTION

This Chapter puts the study of CIM in its historical perspective, formed by the present situation of manufacturing systems and corporate organizations, and what is called the next generation of manufacturing systems. At present, the next generation of manufacturing systems is an object of research and development, and there are many studies underway in this direction. In our approach to manufacturing technology development, CIM results from the improvement of productive technology of the manufacturing system. In turn, CIM must integrate, as one whole, the future development of these systems.

Indeed, the important questions appear at this point. For example, How will these systems come about? Are we able to predict their main features? Are we able to design such kinds of systems?

From our point of view, humans are now reaching a stage where the conditions permit the creation, if not of the entire design of future systems, at least of the main features. Furthermore, one of the principal factors enabling humans to make it possible are advances in the information technologies field. Within this framework, new questions are appearing. For example, For how long can humans design the future systems? How many features of these systems can we see clearly at the present time?

The answers to these questions depends on the research institutions, company prospects or governmental institutions involved. In practice, the most advanced countries have created special teams that are preparing answers to the above questions. For example, the MANTECH programme (DoD programme) has organized a group to study the question of future manufacturing systems. The result of this study is the report "Agile Manufacturing".

In Europe, CEC in particular through the intermediary DG XIII, promotes many programmes of research and development such as the CIM-OSA (CIM-Open System Architecture) model or CNMA (Computer Network for Manufacturing Automation) network. These programmes search not only for a configuration but also for technology components of the future systems.

In the same order of ideas, Japan has developed different kinds of research and development programmes. In particular, during the last decade, this country has launched important programmes in the field of new information technologies. Assuming the great importance of these research programmes for the design of future systems, we comment on some of them in this Chapter.

These programmes are connected directly with improving the efficiency of the manufacturing systems. For this presentation we choose three programmes: Sigma, FAIS (and FNET) and IMS. But to begin this Chapter we present the position of CIM following the historical trend. This is one of the main aspects to take into account in the Japanese approach to CIM, and, we think, in any other approach.

7.1. HISTORICAL TREND AND FUTURE FRAMEWORK FOR CIM

As we saw in the Chapter 1, CIM is appeared in the historical trend of improvement of manufacturing technology. So all Japanese companies consider CIM as some inevitable stage that manufacturing system development must reach one day during its development. We studied in previous Chapters how automation, computerization and networking contribute to define and implement CIM at this stage. In turn, CIM is entering in the definition, characterization and implementation of the future generation of manufacturing systems.

Following this approach, the conditions for establishing CIM are not easy to fulfil. In reality, companies must have complete automation of the factory, which means automation at every level of the manufacturing system: machine, cell, production process and department. In addition, companies must have complete automation of engineering production, from design itself (for product, process and scheduling), and finally, complete automation of the office, this last involving all kinds of administrative tasks.

A good example of the above assumptions is the trend towards CIM in the Hitachi vision of this problem. In this trend, Hitachi identifies the next three steps:

- FA (Factory Automation)
- CIM (Computer Integrated Manufacturing), and
- IMS (Intelligent Manufacturing System).

As we know from Section 2.2, Factory Automation deals with flexibility (variety of products, alternative scheduling...) and automation (standardized products, stable production schedule...). The background for automation comprises standard products, stable planning and large-size lots. This is linked to the needs for flexibility, with its larger variety, flexible planning, shorter lead time and smaller lot size.

In turn, CIM deals with integration and information-circulation. CIM asks for integration because of the inefficiency of isolated subsystems: requiring information and control in particular, a coherent view of what is going on, coherent control, timely information access and timely business action. Finally, IMS deals with a future factory prototype. The main features of the IMS are the manufacturing office, the separation of personnel from equipment, and the user-friendly.

Figure 1 depicts this situation. As we see, FA is included in CIM and CIM will be, normally, included in IMS.

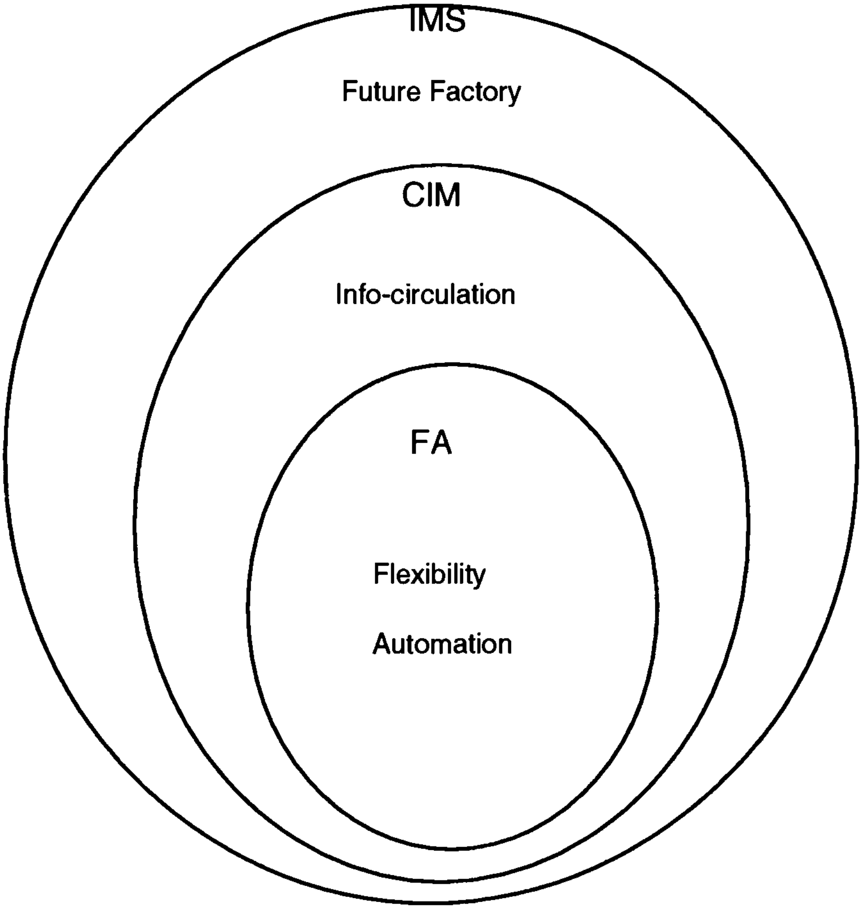


Figure 1 The trend towards CIM and IMS

Looking at the wider perspective, CIM represents a turning point in the evolution of the so called production paradigm (see below, Section 7.4), in the Japanese view. It is the technology achieving computer communication which is fundamental for a transition from the present production paradigm characterized by the replacement of human labour to the future production paradigm characterized by the replacement of human intelligence.

Table 1 shows the main steps of this evolution. A summary by Y. Furukawa (1992) quotes in total five principal eras. These eras correspond, principally, to the crucial transformation in human and material forces that have taken place within the productive system. So there are five important tools modifications and four human changes (because the authors seem to assume that the first change corresponds to the birth of mankind).

Table 1
Main steps of production paradigm

Eras	Workforce	Material forces
Ancient Era	Human dependent production paradigm	Pyramids
Midle Era	Human independent production paradigm Labour intensive	Hand tools and other mechanisms
Modern Era	Human independent production paradigm Human skill dependent	Power machines tools
Present Era	Eco-harmonic production paradigm Substitution for human labour Human brain dependent	Computer communication
Future Era	Substitution for human intelligence	Artificial intelligence

To sum up, CIM is representing a key issue, for characterizing an entire era in human history, and must integrate the more advanced systems such as IMS. But before we study IMS, we propose to study some research programmes directly addressed to the creation of the more favourable environment for the future generation of manufacturing systems.

7.2. THE SIGMA PROJECT

This project was developed in Japan during the 1980s to achieve an important improvement in the software production in this country. The issues associated with this project can serve as an important input for a more advanced technology project dealing with information technology, especially data processing.

In this Section we describe the main characteristics of the Sigma project in order to give additional information which, we hope, will allow readers a better understanding of a heavy research/development project such as IMS or others.

In the past, every software-related company has been trying to solve various software-production difficulties by itself. However, many companies have now claimed they cannot solve these difficulties by themselves. There is a growing recognition of the need for an infrastructure or some kind of common platform on which effective development of high quality software can be carried out.

The Sigma (Software Industrialized Generator and Maintenance Aids) project was thus an initiative for a cooperative effort to construct the infrastructure and related software system for a better software development environment.

We study successively the objectives, strategies and activities of this project as well as a Sigma system overview.

7.2.1 Objectives, strategies and activities

Sigma defines, first of all, a set of objectives to be fulfilled. But to implement these objectives it is necessary to follow some strategies that, in turn, must be translated into specific activities. These points are developed in this subsection.

The project objectives

The main objective of this project is to improve software development productivity. To achieve this objective, the project proposes to carry out the following activities:

- to develop a computerized software development system

- to promote computer network usage for technology transfer, as well as for providing mechanisms for resource sharing
- to promote and expand the software tool market
- to establish a platform for software development environment.

Indeed, the Sigma project must be qualified as a generic name for all these activities. Because these activities and approaches are too difficult to be achieved by a single company, this project is the result of cooperative efforts of many companies and engineers. The foundations of this project start from some estimations concerning the evolution of software human resources made by MITI.

Table 2
Demand and supply of software manpower

Year		1985	1990	1995	2000
Demand	SE	182	327	536	828
	Programmer	289	520	852	1317
	Total	471	847	1388	2145
Supply	SE	165	220	296	406
	Programmer	263	376	580	774
	Total	428	596	876	1180
Gap	SE	17	107	240	422
	Programmer	26	144	272	543
	Total	43	251	512	965

Source MITI's "Software Human Resources in 2000"
Unit 1000 persons SE means Software Engineer

Table 2 describes this situation for programmers and software engineers (SE). As we see, the gap between demand and supply for both kinds of specialists will be increasing dramatically at the horizon 2000. So a double effort must be undertaken without delay: to prepare more SE and programmers, and to find a solution allowing a steady increase in productivity of the software industry in Japan. The Sigma project tries to answer the second challenge, the first point being a matter of the education system and governmental decision-making.

The project was designed as a 5-year project, running from 1985 to 1989. The target was to have a widespread commercial use in April 1990. The project had 189 members. However, a two stage approach was made:

- in the first stage (October 1985-September 1987), the prototype Sigma system was developed to evaluate the prospective users' reactions
- the second stage (October 1987-March 1990) focused on enhancing and improving the prototype system.

Thanks to this two stage approach, MITI, and the companies and Research Laboratories can make an intermediate report which is useful for guiding more accurately the next steps of this project, according to the changes and deviations observed, in order towards the primary goals.

The strategies of the Sigma project.

In order to achieve the goals of this project, four strategies were designed: infrastructure for software development, promotion of software tool-market, collective will and power, and promotion of the electronic community. In the next paragraphs, we give some details concerning the four strategies.

(1) Infrastructure for software.

The Sigma project's goal is to construct a software development environment which functions as an infrastructure or platform for development of software. The common platform provided by the Sigma project consists of a hardware system, an operating system, software tools and a nationwide communication network. It will b specialized development environment for use by software developers. This specialization results in a major enhancement of software productivity and reliability.

(2) Promotion of software tool market.

To make the Sigma system operational and effective, the following are promoted:

- sound growth of software tool market

Users will be able to choose good software tools, and the market success will further promote good tools (enlarging the market)

- encouragement of information providers

In the highly sophisticated computerized society, providing information on software related issues will be a good business, and will be useful for users, primarily software developers.

(3) Collective will and power.

The objective of the Sigma project can be attained only through the collective will and power of participants in the software development process.

For this reason, the Greek letter Sigma is used for naming this project. That means "to sum up" the forces being: all human resources, knowledge, and effort focused on information processing.

(4) promotion of electronic community.

This is a well known challenge for the electronic community, where production, processing and distribution of information will be done more rapidly and effectively than in the non-electronic community.

The above strategies progress via many activities. Among them, the followings need particular attention for understanding the issues of the Sigma Project:

(1) Infrastructure for software.

The activities in this field, among others are:

- define Sigma OS (Operating System) Interface Specification as a common OS interface for the software development environment
- present hardware guidelines for the Sigma workstation as a personal software engineering workstation
- allow the manufacturers/vendors to develop their Sigma workstation/OS and market them on an open and equal opportunity basis
- provide the manufacturer/vendors with the Sigma OS verification service (test)

(2) Promotion of electronic community and software tool market.

The main activities are:

- promote the business protocols based on protection of intellectual property rights as well as providing users with adequate services at reasonable prices
- define data architecture (for example, interface between tools) and Sigma ICE (In-Circuit Emulator) Interface Specification for third party vendors
- construct and operate a Sigma Centre for network and database services
- promote joint business with the participating companies, such as consulting business on the software development environment, etc.

(3) Collective will and power.

- utilize existing software development tools and technologies as a basis for Sigma tools
- promote technology transfer in the industries, using as a vehicle the Sigma software development environment
- provide users with specific software tools to bridge Sigma workstations and target systems, in collaboration with the target system manufacturers

Figure 2 shows the sequencing of the Sigma project for software productivity. So the Sigma Project offers Sigma OS, Sigma Network, Sigma Center, Sigma Tools, Sigma Data Architecture and Sigma ICE. The anticipated effects assumed for this project are sound growth of the software tool market, consolidated and improved software development technology, computerization of the software development process and effective training of software people. All these elements act as a sequence giving, finally, improved software productivity and quality (the final goal).

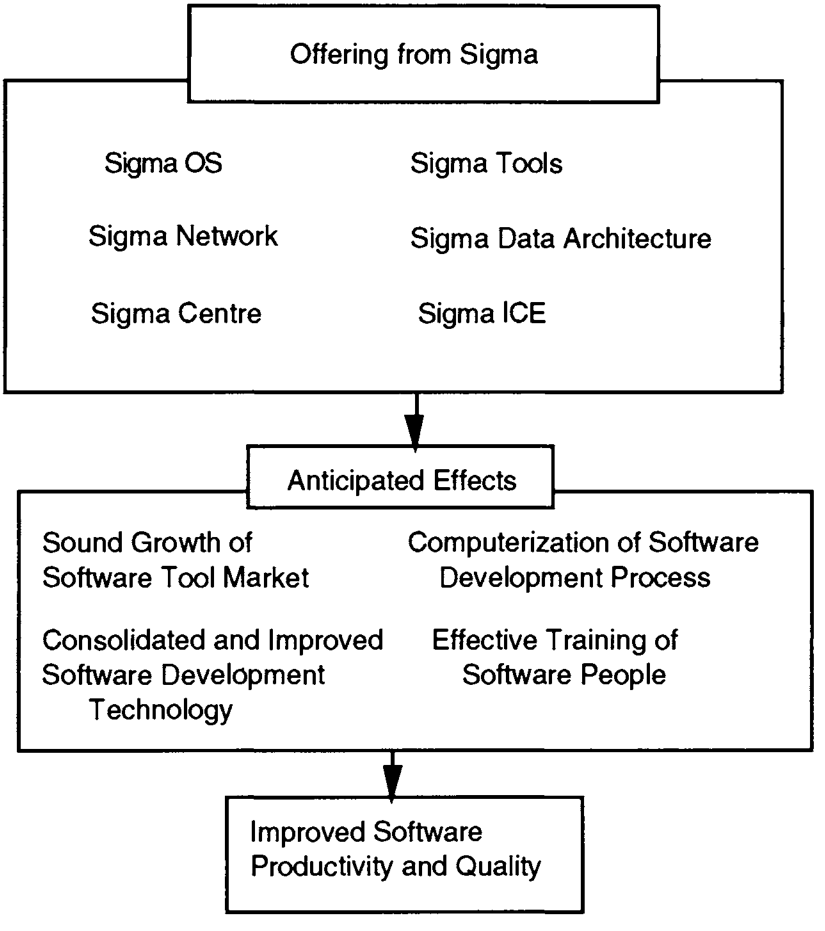


Figure 2 Sigma Project for software productivity

The prototype Sigma system began experimental test use in 1989. This test, called the monitoring test, use of outside parties that did not participate directly in the design and implementation of the system. The results of this test were fed back to the project in order to improve the prototype Sigma system. Work is being done on tools together with workstations, the operating system and the Sigma Centre. Forty companies are testing the Sigma system engineering application tools, and fifty companies are testing the business-application tools.

In the realization of the Sigma programme, 189 companies and government participate.

The companies are as follows:

computer companies 6
equipment companies 9
software companies 109
foreign based companies 11
other companies 54

7.2.2 Sigma system overview

Most of the software development environments used in Japan are time-share systems. These systems are also used as target computers on which application programmes are executed. As a result, the current development environments are completely dependent on target computers. This prevents software companies from investing in their software development technologies, and environments vary widely and are subject to the manufacturers' policy. The Sigma project seeks a better software development environment independent of the various target computer systems.

The following elements give an overview of the Sigma system:

- standardized distributed software development environment independent of the various target systems environments
- nationwide Sigma network for effective collection, accumulation, exchange and processing of various information

In this overview, an important point to be discussed is the Sigma configuration. The Sigma system configuration consists of the Sigma Centre, Sigma network and Sigma users sites, as depicted in figure 3.

We describe each of these Sigma components in the next paragraphs.

The Sigma Centre.

The Sigma Centre helps users who are constructing software development environments and subsequent development of programmes using those environments. The centre provides database services, demonstration services, and a part of the network services (it does not provide time-sharing or remote job-entry services). Experimental database, network and demonstration services are available.

This centre promotes the construction of a nationwide infrastructure. Because these services are dedicated to software developers and the industry, they allow construction of distributed software development environments in the wider sense of the term.

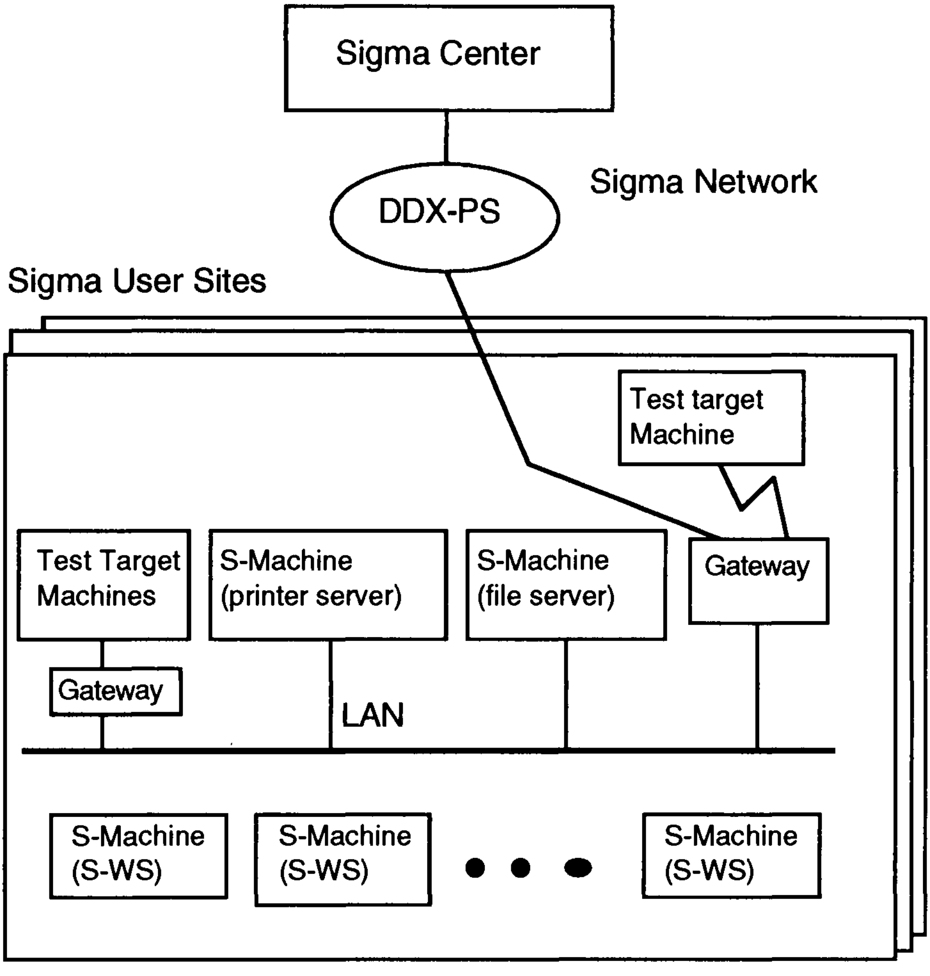


Figure 3 Sigma system configuration

The services of the Sigma Centre include the following:

- message-communication services. Among these services there are electronic bulletin boards, public bulletin boards, private bulletin boards, electronic conferencing, administration and distribution of sites' network addresses, and gateways to external networks and commercial database
- information providing services. The database services can provide six types of data: software information, services and company information, Sigma system information, hardware system information, and reference information

- demonstration services:
demonstration of the Sigma system functions
- consulting service to potential users

Sigma network

The Sigma network is a UNIX-based network that connects the Sigma Centre to the Sigma user sites, and the individual user sites to each other. Indeed, the network is a part of a Sigma system's infrastructure. The electronic community of the networked software engineers is able to share the benefits of the industrialized software development.

The Sigma system provides three kinds of services:

(1) message-communication functions allow communication among Sigma users through electronic mail, electronic newsletters, electronic conferencing, electronic bulletin boards and electronic chatting. This system handles Japanese language characters.

(2) file transmission functions let users rapidly and reliably transmit and distribute data, programmes and documents

(3) target-machine access functions let users of Sigma workstations access the resources of the target systems. For example, users are able to test their programmes in the equivalent environment of a target computer by remotely logging in to computers connected to the Sigma network. In addition, these functions include file transmission and remote job entry.

Because of its high speed, high reliability, and relatively low transmission cost, the project uses the high-speed Digital Data Exchange-Packet Switching network as the main connection of the Sigma network.

Sigma user sites.

A typical Sigma user site includes Sigma workstations running Sigma OS (Operating System), a local area network, and a Sigma Gateway. Figure 4 represents three examples of Sigma user site configurations:
- a single-machine Sigma system
- a distributed system (vertical type)
- a distributed system (horizontal type)

Sigma workstations hardware.

The basic hardware facilities are Sigma workstations. Although there are many models and brands, all can operate alike: all run software tools with the same functions and use the same communication protocols. This allows the Sigma system's users to install and handle freely their own selection of Sigma workstations, and to construct their sites in a range of sizes, from simple single-machine sites to much more complex sites with hundreds of workstations, according to their requirements.

The development environment advocated by the Sigma project calls for each software engineer to have his own Sigma workstation.

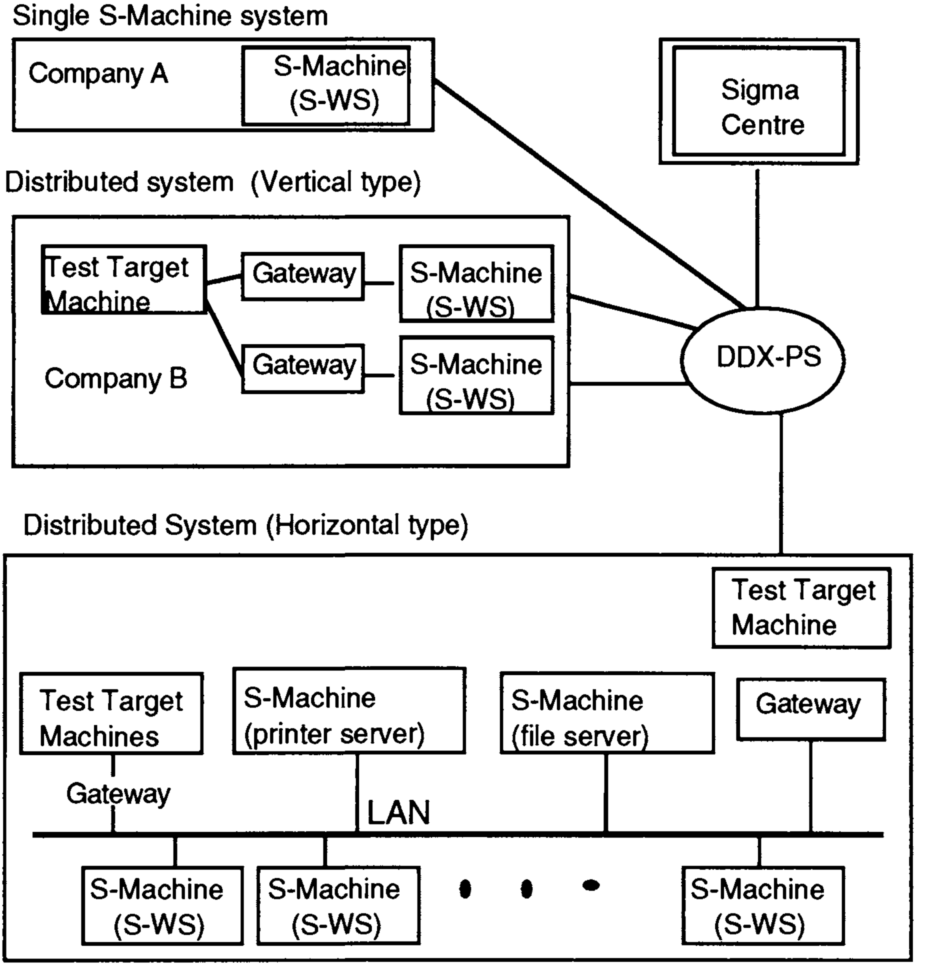


Figure 4 Sigma User Sites

The specifications for the prototype Sigma workstations require that they fulfil the following functions:

- be dedicated, 32-bit workstations so that each engineer can enjoy powerful computing
- have powerful network functions in a distributed environment
- have an advanced user interface (high-resolution display, mouse, and graphics support), and
- have at least the minimum hardware resources needed to run Sigma OS and Sigma tools

The development of the Sigma workstations and their provision to Sigma system users are entrusted to a number of computer manufacturers. Prototype Sigma workstations are available from hardware manufacturers that are preparing new products in order to satisfy market requirements.

Sigma operating system.

One of the most important activities of the Sigma project is to set a de facto standard OS to assure the portability of Sigma tools. As with the hardware, the Sigma project office does not develop the OS but instead has defined its external specification and is allowing manufacturers to develop their own implementations. When they furnish the Sigma OS to their workstations, manufacturers can change the OS's hardware -dependent part and upgrade its performance. Nevertheless, they should not make changes that affect the external specifications. Manufacturers are provided with a verification service for Sigma OS.

Different studies has confirmed that the Sigma OS should not be developed from scratch but rather should be a revised version of the UNIX system. The UNIX system was selected because it fulfilled most of the requirements for Sigma OS:

- the functions of Sigma OS are derived from both ATT UNIX system V and 4.2 BSD. Sigma OS includes all System V functions but only those 4.2 BSD functions considered beneficial to software development
- because UNIX does not satisfy all requirements for Sigma OS, some functions had to be added and strengthened: Japanese language processing, graphics, multiple windows, and database
- new functions developed for future versions of UNIX are considered for incorporation in later versions of Sigma OS.

Sigma tools.

The Sigma project provides many development tools for the Sigma workstations. Functionally, these tools can be categorized into two major groups: basic tools and application-oriented tools. Basic tools can be used during software development and are independent of the variety of applications and of the development phase. The application oriented tools fulfil different requirements of the development phases and application type.

The Sigma project office has developed three major design principles for Sigma tools:

- they should let the users create an optimal integrated development environment for their needs
- they should promote technology transfer
- they should encourage the development of future third-party tools.

The next paragraphs comments on the two types of Sigma tools.

(1) Basic tools.

The basic tools provided with the prototype Sigma system are documentation, network, and project-management tools. For example, the documentation tool allows the user to write and update documents easily. Documents may include Kanji, Kana, Roman alphanumeric, and symbol characters, plus diagrams that consist of combinations of lines and circles, tables, and formulae. Another example is network tools which allow the user to communicate with other users, send files, enter jobs remotely, and provide virtual-terminal functions required to use remote systems.

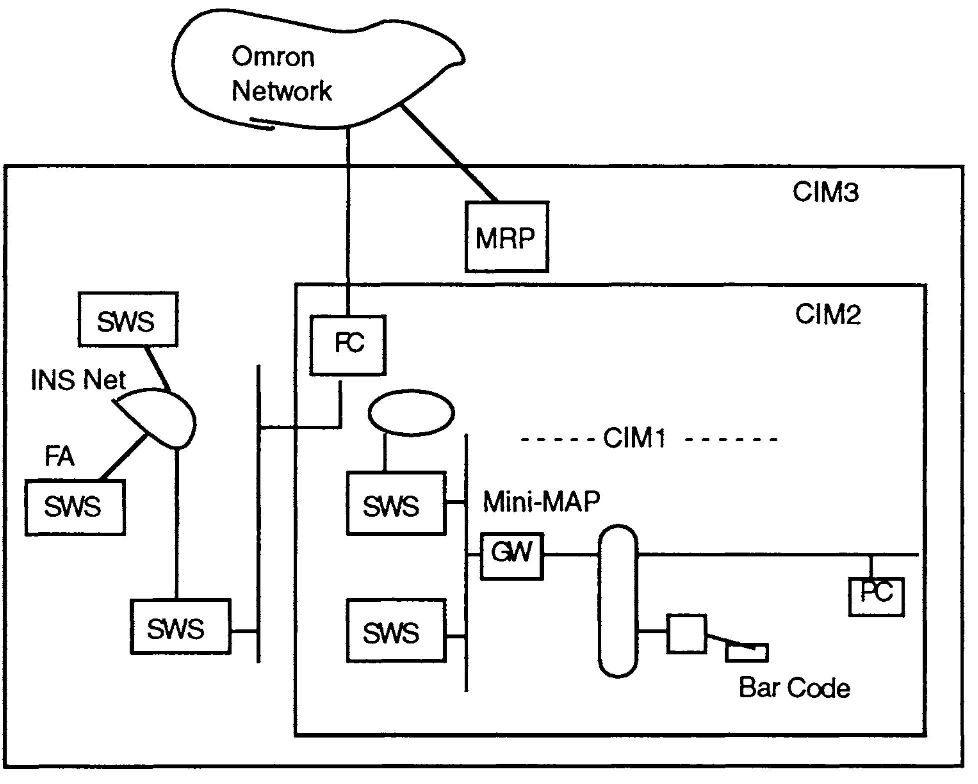


Figure 5 Types of CIM using Sigma Workstations

(2) Application-oriented tools.

The prototype Sigma system's application-oriented tools handle languages, application fields, and development phases. For example, they support languages such as Cobol, Fortran, C and a few micro-processor assembly languages, or application types such as business, scientific and engineering calculation, process control, and embedded microcomputers.

As examples of current tools, we indicate:

- business application tools: requirements analysis tools, system design tools, programme design tools, data design tools, programme chart tools, programme composition tools, syntax editor tools, static analyzer tools, tool manager, target link tools, etc
- engineering application tools: requirement analysis tools, system design tools, detailed design editor, programme consistency checker, C static analyzer tools, etc.

As an application of one result of the Sigma project, we can quote the case of Omron CIM (for more details about this see Section 5.2). Figure 5 depicts the configuration of CIM1, CIM2 and CIM3. Here we can see the Sigma workstation in the case of CIM1, and CIM3. In the case of CIM1, these workstations are linked to the Mini-MAP network and in the case of CIM3, the workstations are linked to the INS network. Both networks are related by the factory control (FC), and through the FC they are linked with the Omron Network.

7.3. FAIS (FACTORY AUTOMATION INTERCONNECTION SYSTEM)

FAIS is another important research programme aiming to provide to Japanese companies with an appropriate infrastructure for communications. During three years from 1987 IROFA was engaged in a research programme assigned by MITI in order to contribute to the advancement of factory automation systems by achieving interconnection between different makes of equipment at the manufacturing site.

7.3.1 The FAIS goals and FNE requirements.

According to the FNE'92 (1992) document, the research/development has been carried out in the following fields:

(1) the development of FAIS implementation specification
(2) the development of tools for conformance tests
(3) performance of conformance tests for demonstration equipment, and
(4) interconnection tests for demonstration equipment.

FAIS has been promoted through a very large number of companies supported by MITI, following the worldwide trend towards open systems in the information processing area. In fact, FAIS has been developed with the aim of realization of a truly open network which will form the infrastructure for the next generation CIM towards the 21st century. During 1993, it was decided to seek official approval of the FAIS installation regulation developed during this project as a Mini-MAP and as adopted in their version MAP.TOP 3.0 (1993 Supplement version). We note that FAIS appears as a contribution to the international standardization. For more details about MAP and Mini-MAP, see Sections 4.3 and 4.4.

When conformance tests are at an advanced stage, FAIS reaches a new step of its development. This is the FNE (FAIS Networking Event) step which is, actually, running. FNET is a demonstration event whose first edition was in 1992. The purpose of this event was to demonstrate the effectiveness of FAIS through an open exhibit demonstration of inter operability between different models simulating an actual manufacturing plant, using various types of actual scale FA machines implemented with FAIS, and to promote the use of FAIS in both domestic and overseas markets, while contributing to the worldwide standardization of the protocol in the field of Mini-Map.

The goals of FAIS and its characteristics are as follows:

- building of a system for a cell-level multi-vendor environment
- high-speed cell-level data communication with excellent real-time capabilities
- Mini-MAP subset based on Mini-MAP specification: connection with full MAP
- support of carrier band system and optical fibre system as a medium

FAIS conformance testing is performed at the MAP Test Centre (MTC) of the Japanese Society for the Promotion of Machine Industry, Technical Research Institute. The test items are the following:

- physical layer
- data link layer: LLC, MAC
- application layer: MMS, MM, OD

Application.

In a demonstration real situation, the FNE plant manufactures cassette tapes and commemorative plaques. It also produces the plastic used as a raw material for such products, and supplies it to production plants. The production system must operate within a very short lead time to produce customized products, typically represented by name-engraved products, in addition to standard products.

7.3.2 The FNE Plant system.

To meet these requirements, the production system at the FNE Plant is established as in figure 6. The cassette tapes are fabricated and assembled in the FA1 plant, the plaques in the FA2 and FA3 plants. Plastic is produced in the process plant. The Plant utility section provides centralized monitoring of energy consumption and facility operation of these plants, supporting the maintenance of optimal operation in the FNE plant as a whole.

PLCs, robots, machining equipment, inspection devices, and other intelligent devices in these plants are implemented with FAIS/MMS (Manufacturing Message Standard). These devices exchange operation instructions, performance reports, trouble notifications and other information through communications with the cell controllers via the FAIS network, to achieve automation at the level of unmanned operation.

The production instructions for the three manufacturing plants are sent daily to the cell controller at each plant, in on-line batches based on standard orders. Nevertheless, rush orders can also be received, given priority over standard orders, manufactured to optional specifications given by a visitor to an FNE plant and distributed to the visitor at the designated delivery time.

In addition to this process from order processing to shipping, the Production Management Section is capable of monitoring the production progress, facility utilization and manufacturing costs for the whole plant, on a real-time basis. The Section's goal is to achieve accurate management while responding to the dynamic change in the manufacturing process.

This production system is possible through the MAP network, which enables real-time information exchange between local applications at individual plants and global applications centred around the production management function.

Production management section.

Production management.

A production management system with a "guaranteed delivery time" is required at the Production Management Section of the FNE Plant to fill the rush orders for customized products from the marketing Section, in addition to the orders for standards cassette tape and plaque products.

The strict schedule control system for meeting market needs can maintain its accuracy only when the real-time information on production status of the plant is obtained and is incorporated into the manufacturing plant. Strict schedule control is achieved through the production management system.

Order entry.

FNE plants accept rush orders as well as standard orders. For a rush order, optional features are entered; these include colour, name and delivery requested by the customer who won the lottery among the visitors. When a rush order is received, the Manufacturing Planning Section is notified and the lottery winner is given an exchange ticket with a bar code printed on it.

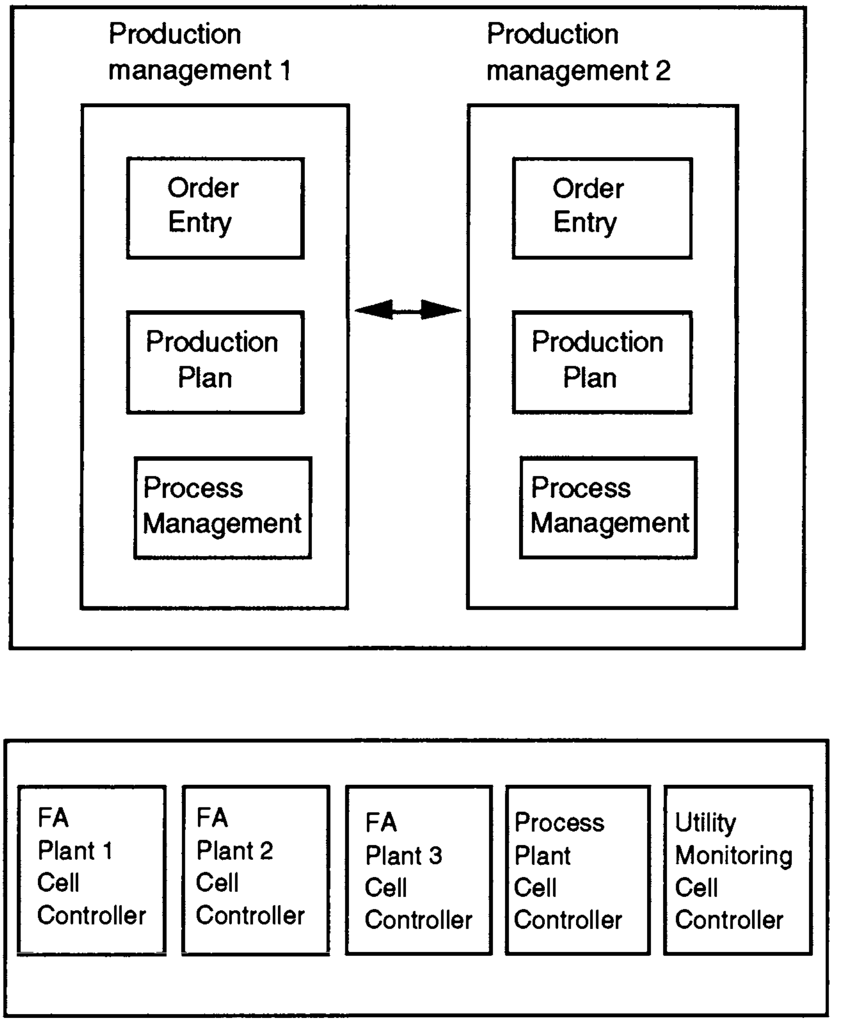


Figure 6 FAIS : production management section

Manufacturing Plan.

For a mixed product manufacturing line, a manufacturing plan is developed for each plant, and a manufacturing sequence plan is established daily for standard orders. Production is rescheduled each time a rush order is received. A rush order is squeezed into the standard order schedule to meet the delivery time desired. The rescheduled rush order is sent to the appropriate manufacturing plant as manufacturing instructions, via Process Management.

Process Management.

Process Management for the FNE plant is responsible for issuing manufacturing instructions, tracking work and monitoring facility operations on a real-time basis for the four manufacturing plants. Process Management communicates with cell controllers at FA1 and FA2 plants in Production Management 1, and at FA3 and Process Plants in Production Management 2.

Inventory Management.

The manufacturing performance reports on the FA1 and FA3 plants are immediately sent to the inventory management function, in the form of inventory entry notifications. For a rush order with delivery time, the products are shipped in exchange for the exchange ticket issued by order entry. Inventory status is also updated at that time.

Cost Management.

This is an essential point in every automated Japanese system. Manufacturing cost management is based on power consumption, boiler consumption, facility utilization factor, material consumption, and product shipment. Regular communication is maintained with the Utility Monitoring Section.

NM/OD.

NM (Network Management) and OD(Object Directory) have been packaged for flexible management and operation of the FNE factory. The reliability and convenience of the network have been greatly improved. For more details about NM and OD see below.

Utility.

Managing the Plant Utility (Power demand, Resources, Monitoring Environment), comprising each cell from FA plant 1 process

Process Plant

The processing plant manufactures g materials for production commemorative shields for the FA factory. The plan is drawn up from the production planning computer, and in line with the plan, a cell computer sends manufacturing instructions to the respective control equipment to carry out manufacture.

FA plant 1

FA factory 1 is a cassette case manufacturing plant. The markings are engraved on the cassette cases using NC' machine tools, and the cassette tape is inserted by an assembly robot. After an inspection robot has checked the colour of the cassette tape, a carrier robot sets it on the delivery slope.

FA plant 2

FA factory 2 is linked with factory 3 to manufacture 'FNE commemorative shields. When FA factory 2 has inspected the bevelling of the commemorative shield and the depth of the mounting holes for the stand, it prints the destination and delivers it to factory 3

FA plant 3

FA factory 3 is the assembly plant for commemorative shields, the colour and the shape of stand for the shield are inspected, and the stand is fitted onto the plate sent from FA factory 2. After inspecting the assembled product, it is forwarded to the despatch depot.

7.3.3 FAIS and MAP.

The Specification of FAIS 2.0 complies with the Mini-MAP system conformance requirements prescribed in MAP 3.0 Chapter 2, Section 6: Manufacturing Automation Protocol Specification Version 3.0

FAIS architecture.

The outline of the architecture of FAIS 2.0 is based on a comparison with OSI standards. FAIS 2.0 specifications are based on the following international standards:

- MMS ISO 9506 Manufacturing Message Specification
- NM ISO 9595 Information processing-Open System Interconnection - Management Information Service Definition

ISO 9596 Information processing-Open System Interconnection - Management Information Protocol Specification

ISO 9072 Information Processing-Text Communication-Remote Operations

OD MAP 3.0 Chapter 13, Section 3 Mini-MAP Object Dictionary Service

LLC ISO 8802-2 Information Processing Systems- Local Area Networks Part 2: Local Link Control

MAC ISO 8802-4 Information Processing Systems -Local Area Networks Part 4: Token -Passing Bus Access Methods and Physical Layer Specifications

CB ISO 8802-4

Table 3 gives an overview of the FAIS architecture and the OSI standards used by it.

MMS is an international communications standard (ISO9506) designed for computer monitoring and control of LPCs, NC equipment, robots and other FA equipment. MMS defines several services and parameters, for application to communications with various types of equipment. So when MMS is installed in

FA equipment for specific use, required services and parameters are selected. In the case of FAIS, the MMS range of available services and parameters are defined, and called a subset of MMS. As in MMS a unit service is called Service CBB, and the unit for defining the range of parameter values is called Parameter CBB.

Table 3
Architecture of FAIS compared with OSI standards

<table>
<tr><td>OSI</td><td colspan="3">Mini-MAP/FAIS</td><td colspan="4">Full MAP specification</td></tr>
<tr><td rowspan="2">7
Layer</td><td rowspan="2">CD</td><td rowspan="2">MMS
9506</td><td rowspan="2">NM
9595
9596</td><td>MMS
9506</td><td>NM
9595
9596</td><td>FTAM
8571</td><td>DS
9594</td></tr>
<tr><td colspan="4">ACSE 8649/8650</td></tr>
<tr><td>6
Layer</td><td colspan="3" rowspan="4"></td><td colspan="4">Connection oriented
ANS.1 8824/8825</td></tr>
<tr><td>5
Layer</td><td colspan="4">Connection oriented
Session protocol 8326/8327</td></tr>
<tr><td>4
Layer</td><td colspan="4">Connectionless 8073 Class 4</td></tr>
<tr><td>3
Layer</td><td colspan="4">Connectionless 8348/8473
ES-IS routing 9542
Internal organization of
Network layer 8648</td></tr>
<tr><td rowspan="2">2
Layer</td><td colspan="3">LLC 8802-2
Type 1/3</td><td colspan="4">LLC 8802-2 Type 1</td></tr>
<tr><td colspan="7">Token-Bus 8802-4</td></tr>
<tr><td rowspan="2">1
Layer</td><td colspan="7">Token-Bus 8802-4</td></tr>
<tr><td colspan="2">Fibre
Optics</td><td colspan="2">Carrier
band</td><td colspan="3">Broad
band</td></tr>
</table>

The numbers indicates ISO Standard Number

The MMS subset in FAIS 2.0 defines:

- services CBB: Environment Management Service, VDM Support Service, Domain Management Service, Variable access Service, Operator Communication Service, Programme Invocation Service and File Access Service, and
- parameter services: STR1, NEST, VNAM, VADR.

NM is a communications protocol by which the NM node acquires and controls remotely the information held by the object being managed by the NM agent node; this provides efficient operation and maintenance of the network. NM defines a common management information service (CMIS) and a remote operation service (ROSE) for accessing the information held for management objects by the management information database (MIB) through the system management application process (SMAP). CMIS in F>AIS 2.0 handles the common management information, such as confirmed service and unconfirmed service.

OD is a communications protocol matching the MAC, LSAP address and application identification of the destination of the communication or access with the logical name, and for management address change, so that the destination of a communication can be specified by a logical name in the MMS application programme regardless of the address change. This protocol is characteristic of Mini-MAP 3.0, but its functions are the same of OSI Directory Service (DS). OD defines the OD services used for access to the Mini-MAP dictionary information service agent (mDSA) and the Mini-MAP dictionary information base (mDIB) managed by the mDSA; the Mini-MAP user agent (mDUA) and the local dictionary information base (mDIB) managed by mDUA; and the mDIB managed by the mDSA. The OD in FAIS defines the information managed by mDIB and the services and protocols for access.

Finally, some examples concerning FAIS and CIM. The first concerns Shimizu Corporation. For realizing real CIM system, Shimizu offers a system integration service which covers the Information Network System for factory building. In this case the Information Network System is an essential tool for CIM for many years. Kawasaki Heavy Industries creates a Js-10 model common to many other robots models, which comes equipped with the ability to interface with various sensing devices, cell control equipment, and LAN. This allows the robot to be easily incorporated into sophisticated CIM processes as an integral system component.

7.4. THE IMS PROGRAMME

The IMS programme was launched by Japan at the end of the 1980s as an internal research and development programme aiming to design, as far as possible, an image of the future generation of manufacturing systems. In addition, IMS has been launched as an international research and development programme at the beginning of this decade.

The beginning of this kind of research needs the active participation of most developed countries as principal partners. But this is not a simple question of adding forces in the international field, because of the existing differences, interpretations and interests of potential partners. So the first task to be undertaken by the international IMS deals with a feasibility study of current projects under investigation.

But IMS present many interesting aspects for everyone who is looking at the design of future manufacturing systems and, principally, for manufacturing companies that need to know of what the future will be made. Meanwhile, we do not discuss all the problems concerning IMS but only some relevant aspects for understanding the main ideas and for positioning it with respect to CIM, which is our main study subject.

Beginning this study, we present an approach to the concept of CIM systems and the next generation. After this, we study a more specific presentation of IMS, including some discussions about the main ideas which are determining its content, such as, for example, the significance of "intelligence".

7.4.1 The concept of the CIM system in relation to the next generation

This Section presents some problems concerning the future trends of the next generation, taking CIM as the main point for comparisons.

Trying to look at the future generation of manufacturing systems, Y. Hasegawa (1992) made a comparison between what he called conventional CIM and next generation CIM. So the comparison presents the Future Generation as a construction founded on the actual CIM system, but a renovated and more advanced CIM. This author illustrates characteristics of the future CIM from the standpoint of 15 items. These items are:

internationalization, response to market, environment for product development, processing for engineering jobs, production system, production lead time, production planning, machinery facilities, communications, response to system renewal, human interface, amenity, contribution to region, response to international standardization and response to earthly resources environment.

We comments on some of these points.

(1) Internationalization. In conventional CIM there is a regionalization, while in the next CIM generation there will be a globalization

(2) Response to market. In conventional CIM there is a flexible product output, while in the next generation there will be a market input (we will find this expression below, but having a quite different application)

(3) Environment for product development. In conventional CIM there is a job-supporting systemising CAD and other electronic means, while in the next generation there will be a display of originality and response to customer need by use of artificial intelligence techniques

(4) Processing for engineering jobs. In conventional CIM there is a discrete partially parallel processing, there while in the next generation will be global concurrent engineering processing

(5) Production system. In conventional CIM there are various kinds, and variable quantities, of production, while in the next generation there will be job-order mass production

(6) Production lead time. In conventional CIM there is a short lead time(a few days), while in the next generation there will be a very short lead time (a few hours)

(7) Production planning. In conventional CIM there is a stock or order production system, while in the next generation there will be a complete job-order production

(8) machinery facilities. In conventional CIM there are a conventional machinery facilities, while in the next generation will be an autonomous module facilities

(9) Communication. In conventional CIM there is conventional communication system, while in the next generation there will be an ISDN or satellite communications

(10) Contribution to region. In traditional CIM the main contribution is economic, but in the future there will be a positive contribution to regional industry and culture at the same time

(11) Ecology. In conventional CIM the preference is for productivity deals, while in future CIM will push preference for resolution and reduction

To sum up, by the time the next CIM systems materialize, full production of the overall systems may exceed user demands. Therefore, manufacturing industry in future will manufacture and supply products as soon as possible, responding to the concurrence of user demands. After satisfying these demands, the manufacturers will run their facilities at normal operational level considering about break-even profits, until the further generation of demands, even if the operation ratio of the facilities is decreased.

From this assertion, according to Y. Hasegawa (1992), the future manufacturing industry should be seen as follows:

(1) production lead-time is very much shortened

(2) most products are manufactured by order-led production, and

(3) mass production corresponding with the received needs is implemented

One important question then appears. This is the question of dealing with research assignments for CIM technologies facing the next generation of manufacturing systems. To study this question, it is useful to start from one model, and in this case an appropriate model is that of ISO/ TC184/SG5/WG1. According to ISO/ TC184/SG5/WG1, the hierarchy of manufacturing systems is divided into six levels (in reality, manufacturing systems are hierarchical, see Section 1.1 and Chapter 4). These levels are equipment, station, cell, section/area, factory/department and corporation. Figure 7 depicts this ISO/ TC184/SG5/WG1 model.

The research assignments of the future CIM technologies are considered from three levels: the first is the corporation level, the second is the department and the factory level, and the third is the level of shopfloor control. The problem to investigate now is what assignments are required for the successful implementation of the next CIM generation. For answering this question, we comment below on the principal assignments of the future CIM technologies, following the three above-mentioned levels according to the Y. Hasegawa (1992) approach.

<table>
<tr><td colspan="3">Hierarchy</td></tr>
<tr><td colspan="2">Corporation</td><td>1</td></tr>
<tr><td colspan="2">Factory Department</td><td>2</td></tr>
<tr><td rowspan="4">Shopfloor Production</td><td>Section/Area</td><td>3</td></tr>
<tr><td>Cell</td><td>4</td></tr>
<tr><td>Station</td><td>5</td></tr>
<tr><td>Equipment</td><td>6</td></tr>
</table>

Figure 7 Hierarchical Model of Production System (ISO/TC184/SG5/WG1)

(a) Assignments at corporation management level.

For the construction of the next generation CIM, the following assignments should be required from the standpoint of the corporation management level:

(1) Development of evaluation techniques for user satisfaction.

The future problem here is to evaluate the adaptability of final products in response to customer needs (marketing production)

(2) Development of economic evaluation techniques for investment.

In this direction, the development of a method for the proper evaluation of investment, including characteristics of a strategically unique system, is required

(3) Development of management techniques for intelligent assets which permit better relations between "public technology" and "private technology"

(4) Promotion of public research and development projects

(5) development of systematizing technology

This question will be developed later, in Sections 7.4.2 and 7.4.3

(b) Assignments of department and factory level.

Among the assignments for CIM technologies at this point, the following are important:

(1) Development of a capability evaluation technique for resource recycling.

At the phase of product design, this technique suggests capability of resource recycle to designers in view of the product life cycle

(2) Development of concurrent engineering techniques.

As we know from Section 3.1, this technique systematically and concurrently designs the total manufacturing system, through product design, process design, production preparation, and manufacturing activities

(3) Development of system architecture and reference model.

A standard system model has to be developed to construct the fundamental system architecture and check its performance

(4) Development of visualizing technology for the production system.

This technology visualizes a concept plan of system design by using computer graphics or 3-D reduction model

(5) Development of holistic production system.

The holistic production system harmonizes individual system elements in a total production system, and it is fundamental question to improved performance of the overall system

(6) Development of factory composed of module production subsystems.

Flexible plants consisting of intelligent module subsystems easily respond to transformation of product types and quantities by rearrangement of these individual module subsystems

(7) Development of information network technology.

As we have already seen in every case studied in the previous chapters, this network is essential to communication within the CIM system, and between the inside and outside of the system

(c) Assignments for the production system at the shopfloor level

These assignments concern four components of the CIM system: hardware, software, organization ware (orgware), and human ware. We gives some examples of assignments dealing with each of these components.

(1) For hardware, there are as examples:

(a) Development of processing machines with self-control and high functions

(b) Development of autonomous robot technology

Such intelligent autonomous robots will be main agents in the future CIM systems

(c) Development of autonomous transportation technology.

This is an important development because the field is continuously changing, so an intelligent AGV or flexible 3-D transportation system must be used as transportation hardware between the facilities

(d) Development of high-function automatic warehousing for workpieces, tools, and jigs

(2) For software technology, some assignments are the following:

(a) Development of design techniques for knowledge database and management

(b) Systematization of computer software technologies required for the next CIM system

(c) MAP development

That means to develop MAP between communication instruments in the new CIM systems.

(3) Organization ware, some assignments are the following:

(a) Response to the multiple vendors, using interface technology which integrates manufacturing systems by combining various facilities and peripheral machines provided from multiple vendors

(b) Development of manufacturing technology for self-control distribution

(c) development of production management and control technology by using neuro-networks or fuzzy concepts

(4) Human ware

(a) Consideration of human roles in the next CIM system.

From the viewpoint of constructing the next generation, CIM must reconsider the roles of human operators, engineers, and managers in order to improve their working conditions

(b) Development of artificial reality technology, which means an artificial reality technology which informs the actual feelings of real-world operators

(c) Development of sensual measuring technologies according to the five human sensory organs and, creating tools by analogy to those

(d) Development of education systems for human resources to establish the next CIM generation

This point is crucial because the efficiency of whatever system, even more when this system is an advanced one, is dependent on skilled people to perform work in the new technological conditions.

7.4.2 An overview of IMS

IMS asks many questions. Some perhaps have not, unfortunately, an adequate answer at the present time. On the contrary, some other questions must be studied without more delay. But in general, IMS is not a simple acronym to be used without discrimination. IMS has recently provoked passionate discussions in Japan itself between people, especially academic people. In general, researchers and managers can be ranged into two fields: those liking IMS as a good and feasible idea; and those criticizing IMS as an impossible challenge, because of not only the financial constraints but also the technical ones.

Nevertheless, these open discussions, research and development on the IMS programme are going ahead and we must take them into account. From a wider point of view, we consider IMS as a very good principle containing many ideas. Some of these ideas must be qualified as generous ones for which human have striven during thousands of years. And this is an important question in our day.

Outside the discussions or feelings about IMS, we think that is interesting for readers to know some particular details about IMS itself. So we study now some primary questions concerning the origin of this programme, the reasons why Japan is stimulating such a kind of research, the nature of this research, and the return for companies involved in, or investing money in research laboratories.

IMS and the new production paradigm.

As we discussed in previous sections, IMS is placed in its historical perspective. So for a better understanding of IMS it is more fruitful to see it according to this perspective. For doing so, Y. Furukawa (1992) uses the paradigm approach. According to Furukawa (1992) the word "paradigm" (a word coming from T.S. Koon 1962) is interpreted in Japanese as a generally accepted set of concepts (precepts, deeds or facts) during a given period of time, which serves as a standard for people, specially for scientists, to interpret natural or other phenomena.

Looking back at human history, it seems that there have been only a few changes in the social consensus, that is a paradigm matter, on manufacturing: the first was the move from individual handcrafts into labour-intensive manufacturing, which occurred in the oldest era, and then the substitution of machine-tools for human labour which took place through out mediaeval times to the modern era. But today we are coming to another paradigm, with the replacement of human intelligence by the artificial counterpart in our time.

In this way the Japanese establish the main paradigm of human history. The first paradigm is the "primary manufacturing paradigm" characterized by the intensive human labour employed, as it was the only available production means (see Section 7.1). When mechanical means was substituted for part of human labour, we have the so-called "secondary manufacturing paradigm". This is still the principal factor of prosperity of industrial nations around the world. The main characteristic here is the replacement of manual labour by mechanical means. But the idea we have already advanced in the last Sections is at present the crucial one to know what is the future production paradigm.

It seems that man may have begun replacing his own brain, a complex thinking apparatus, by artificial means, judging from the fact that computers have been rapidly invading factories as well as management and sales departments as data storage and processing devices, integrating in this way the all production activities into CIM with interconnecting information network systems. But the problem now is that computers are only replacing the most simple brain functions such as memory but not its more complex functions such as knowledge, reasoning and judgement, although some of them are realized at the rudimentary level using expert systems. So, this is a part of the "third manufacturing paradigm".

But, unlike previous ones, this last paradigm is facing the new problems that it is necessary to study in order to advance some solutions as soon as possible. Among these problems, we find the environmental issues (see items proposed by Y. Hasegawa in Section 7.4.1). The Japanese call this paradigm "eco-harmonic type manufacturing paradigm". In reality, the human-intensive manufacturing, the mechanized manufacturing paradigm and the eco-harmonic manufacturing paradigms must coexist, at least at the beginning of the 21st century.

From this situation, Japan is arguing two ideas for promoting a new kind of research about the future generation of manufacturing systems:

- the first is that Japan alone among industrialized nations keeps accumulating wealth by improving production efficiency using the mechanized manufacturing paradigm (for example, replacement of human paradigm)
- the second is that a simple transfer of existing technologies from advanced countries to less developed nations will not help enough for narrowing the technical gap which exists between both sets of countries

The objectives of the manufacturing systems in the future.

Starting from the reality that nations are developing trading relations and that this reality must be advantageous for every nation trading, N.P. Su (1992) considers that one of the major goals of IMS must be the diffusion of manufacturing technologies to maintain parity among trading nations for long-term growth of the world economy. At this time no nation has complete dominance in manufacturing. The IMS programme should further diffuse manufacturing technologies to increase the demands for each other's goods and thus increase the wealth of the world and improve the quality of life for all people on this planet.

One of the key issues for the IMS programme is the future selection of R/D projects and their long term objectives. Technologies can obviously be developed in many different directions, ranging from the development of intelligent machines, intelligent materials, and intelligent manufacturing systems to intelligent processes.

The IMS programme must also emphasize the more extended use of computers to simulate entire manufacturing operations through the creation of "virtual factories", as well as the scientific and technological basis for unmanned factories to spare human beings from undesirable and dangerous jobs. The future limit of such a programme is naturally our lack of sufficient imagination and willingness to try out unorthodox and even presently unthinkable ideas.

Under these conditions, the future manufacturing system must pursue the following objectives:

- to help reduce the technical and economic gap between advanced nations and less developed countries by accelerating technology transfer through organization and standardization of manufacturing technologies that are sources of wealth
- actively to promote standardization of manufacturing technologies that are likely to be dominant during the next decade so as to improve world-wide productivity by securing interchangeability among relevant technologies used in advanced nations as well as less developed countries
- to create a new manufacturing paradigm, taking into account factors such as human creativeness, pleasure, and harmony with the eco-system including social and natural environments, far beyond present industrial concepts based upon the market-oriented economy in which the sole purpose of developing and manufacturing products is to make profits.

So it is clear that such a programme cannot be implemented without the anticipation of most advanced nations in a cooperative manner. This cooperation must be realized, first of all, by Japan, Europe and America, the three richest regions in the world. But this cooperation must be realized also by partners involved in future research and development programmes, that is administrations, companies and research institutions as well as universities. These are the most relevant and distinctive characteristics that the research must assumed by the future generation of manufacturing systems.

Starting from the actual problems encountered by all nations, a new philosophy is emerging; the techno-globalism concept, as proposed at the OECD/TEP Symposium (1990). The techno-globalism concept is quite different from the techno-economic philosophy which dominated the last step of the market economy. In fact, techno-globalism advocates a free market of technological knowledge, including product development, design and manufacturing know-how and aims at "making technological knowledge a common asset to all mankind".

It is understandable that this new approach of the development paradigm has many consequences, among which are:

- to make technical knowledge available to all nations, companies or individuals of the world so that they can make use of them at their will and be provided with the same starting line from which to compete with each other;
- to eliminate or reduce the technological and economic gap between North and South and East and West;
- to develop new technologies using non-fossil energy resources to preserve the natural environment.

The launching of IMS.

This programme is called Intelligent Manufacturing Systems (IMS) and it was launched by Japan as an invitation to most developed countries to do something together for the future of manufacturing systems since 1991.

The programme begins with feasibility studies involving partners coming from overseas countries. After this stage, the programme enters a more advanced step with the development of one particular set of feasibility research programmes in which are now participating Japan, EC, EFTA, Australia, Canada and US.

Nevertheless, some questions need more explanation. Three of them are of special relevance: the organization of manufacturing knowledge, the standardization of manufacturing knowledge and, as a corollary, the research and development of next-generation manufacturing technology. We make some comments about each point.

The first point concerns the organization of manufacturing knowledge. An accurate study on the technological knowledge of traditional industry permits us to divide it into products design knowledge and the related manufacturing knowledge. So manufacturing knowledge will be improved in proportion to products design knowledge and, conversely, manufacturing knowledge is reflected into products designing knowledge. As this last is intended for a tangible product, it is easy to describe details which normally are incorporated in invention rights, so becoming public knowledge. On the contrary, manufacturing knowledge includes many intangible works (for example unspecified variables). This knowledge remains under the form of "know-how".

Thus one question is how to gather the manufacturing knowledge. One possible solution is to collect and to systematize it. This solution must permit one to accelerate the activation of the firm holding such knowledge and facilitate the technology transfer from advanced to less developed countries, and to diffuse those technologies to small and medium scale firms.

More precisely, manufacturing knowledge can be separated into confidential information and non-confidential information. From this separation, Y. Furukawa proposes to collect, organize and systematize non-confidential information during the first step of the research. And the Japanese propose to do it in one of the IMS research programme.

Nevertheless, the systematization of manufacturing knowledge is not a simple codification of this knowledge. In reality, if countries truly want a transfer of knowledge, it is necessary to simplify and reorganize the manufacturing knowledge in such a manner that it can be easily understood by technical personnel in developing countries. In addition, it will be appropriate to develop machines and equipment to be easily adapted, and offer them, to these countries.

The second point is the standardization of manufacturing knowledge. This point must be attacked in parallel with the progress of the organization and systematization of manufacturing knowledge. It is assumed that the development of the future production system, to be realized within the 5 or 10 years represented by CIM, is now being undertaken by individual countries as well as companies. But this approach cannot continue because of the high risk of leading to a chaotic situation in the near future.

Some progress has been made, such as the CIM protocol standard by MAP/TOP, but for the moment this is not enough. In addition, a standardization of relevant technology and knowledge aimed towards CIM (the major production system for the future) can avoid duplication of investments.

The third point deals with the development of next-generation manufacturing technology. It becomes more and more clear that firms (especially the bigger firms) cannot continue to compete for development in all enormous and sophisticated industries without risking some negative consequences. So cooperation must be envisaged by firms, but not from basic technology to production. Rather they would jointly study and develop basic and pre-competitive technology common to each firm.

Japan is looking, attentively, at the European research and development programmes. The Japanese consider that programmes, such as ESPRIT, are giving fruitful results. So IMS must be proposed as a joint international programme to handle information and results, available for all people as a common asset to the whole of mankind.

7.4.3 The significance of the word "intelligence"

Intelligence has many interpretations according to the point of view followed by the people and sciences involved. Perhaps the more common interpretations are those give by social scientists biologists and medical specialists. However, the increasing use of new information technologies makes more and more researchers and scientists aware of the reality of recognizing that intelligence also incorporates material things: computers, software, machine tools, robots, production processes, etc. So a new interpretation arises. Concerning Intelligent Manufacturing Systems in a wider sense, we quote two interpretations given in the same framework for similar purposes: the foundations of the IMS programme.

N.P. Suh (1992) explains that term intelligence is often used to imply the possession by a machine of the decision-making capability that is equivalent to that of human operators and engineers. This definition, nevertheless, is very limiting, in that we are now capable of creating machines and systems that are able to perform tasks that human beings cannot handle. One example of this is that machines can be made to sense a minute variation in chemical composition in a manufacturing system and to make corrective decisions based on the input of sensors and decision making algorithms.

Another example is the development of a scientific knowledge base and an intelligent system that has the ability to design an intelligent manufacturing system or intelligent machines. In this sense an IMS should be defined as the autonomous or near-autonomous system that can acquire all relevant information through sensing, render decisions for its optimum operation, and implement control functions to achieve the objectives of its manufacturing tasks, including the overhead functions.

So N.P. Su distinguishes three kinds of intelligence levels: design and optimization of large complex systems, intelligent machines and intelligent processes. Developing as an example, we add some comments about the first two levels.

(1) Design and optimization of large complex systems.

There is no fundamental basis for designing a large manufacturing system anticipating decisions during the stage of designing. For such kinds of design it is useful to consider the Thinking Design Machine (TDM) to show how the axiomatic design concept can be used in designing a large, complex system that is highly flexible, at least on a conceptual level.

(2)Intelligent machines.

If we attach enough sensors and develop algorithms that can follow the "If ..then" type of logic that controls the machines, people think they may make intelligent any machine in this way. But this is an unproductive way of creating intelligent machines. N.P. Su says that a better solution must be either uncoupled or decoupled machines to be intelligent in performing a given set of tasks to satisfy their functional requirements.

From his side, Y. Furukawa (1992) considers intelligence within the framework of CIM. So he says that "intelligent CIM" can be defined as a system which can substitute for, or support humans in the aspects of their intelligent activities including sensing, memorizing, thinking, recognizing and judging. From this viewpoint, the structure of intelligent CIM consists of three hierarchical levels: management, design and factory level.

The first level (management) should see all the activities of firm and factory in a reduced form, thus helping the Decision-Making Process. The essence of this intelligent system is the Database linking activities such as the current and future market needs, the manufacturing, and research and development. Actually, Business Requirement Planning (BRP) (an extension of MRP) and SIS are typical elements of this CIM trend.

Design comprises product design, process design and production scheduling, which are not yet connected directly to each other today. Thus intelligent design is not so much developed, but progress must be made rapidly. Based upon and linked to product models, the process and scheduling will be simultaneously processed.

At the factory level, the first important aspect is to link CAM to CAD. But this realization needs to be in connection with the Product Model and the Activity Model. To explains this, Y. Furukawa says it should be called "intellectualization", instead of referring to "intelligentialization" of the shopfloor components such as robots, machine tools and others. Expert Systems, Artificial Neural Networks, Fuzzy Theory and Sensor Fusion are the main technologies of today's "intellectualization", and they will move to objects of more autonomous nature.

We thus reach a synthesis in which there is a paradigm associated with the technical features and the corresponding effects (see Y. Furukawa, 1992, IEEE).

In the FA paradigm (substitution for human labour), the technical features are the integration of non-autonomous mechatronic devices (in the sense of substitution for human manipulation) into production systems at the shopfloor level, resulting in automated factories. The effects of the FA paradigm are further reduction of direct labour, high production rate and product diversification.

The CIM paradigm (incorporation of information processing into production systems) has as technical features the integration of all components of manufacturing activities, including product development and design, manufacturing and management, as well as non-autonomous hardware therein, into a single system at the corporate level, through the use of computers and interconnecting networks. The effects of this paradigm are a reduction of indirect labour, market-led production and a faster business.

In the IMS paradigm (substitution of human intelligence), the technical features are characterized by the incorporation of human skills and knowledge into production systems using autonomous hardware and computer technologies, and their integration into a human-oriented, flexible intelligent manufacturing system on a global scale. The effects of this system are human-oriented production and the improvement of factory amenity, regionally adaptable production systems, the preservation of global environments and global localized production.

Following this interpretation, the borders between CIM and IMS are not clearly defined. Nevertheless, the above interpretation of "intelligence" embraces a double assumption:

- CIM is not only different, according to the companies or processes involved, but it is also evolving during time, becoming more and more "intelligent"
- CIM must be considered as an input in the creation of the future generation of manufacturing systems (FGMS).

So from the previous discussion, we can summarize some points on the significance of IMS: two need to be quoted here. The significance of IMS is not clear for many people and produces some confusion in discussing the IMS programme, but according to the latest developments, IMS may have the following significance:

- to systematize manufacturing know-how into "knowledges"
- to organize "standards" by finding out common rules among these knowledges
- to undertake, based upon these manufacturing knowledges and standards, research into "intelligent manufacturing systems" in which machines and systems are capable of thinking, judging and acting for themselves.

But it is also possible to add another interpretation to this previous one. This interpretation can be:

- to develop next-generation technologies and their standards by scrutinizing past manufacturing experience that has been accumulated by mankind, and organizing and systematizing it
- to organize standards and knowledges for future (within 5 or 10 years) manufacturing technologies in advance
- to undertake research and development on manufacturing technologies expected to be used at the beginning of the 21st century.

Why the IMS programme?

Whatever the interpretation of IMS, it must be a research programme involving many different partners (companies, Universities, administrations) and countries. IMS may be viewed as research about the transition from the actual to the future production system. The following elements are interesting for understanding this: the transition of the manufacturing paradigm; the techno-globalism (the technology is now without country borders); the needs for systematizing technological knowledge and the significance of IMS (interpretation of intelligent).

As we see, CIM is in the limelight as the manufacturing system capable of instantly responding to the present day's market demands. But the IMS proposal cannot abruptly change the actual market structure. The problem involved in the next generation manufacturing systems can be regarded as being consistent with those concerning today's CIM. In our opinion CIM is a necessary layer around the kernel, which is the robotic.

So the following issues are proposed as concepts of IMS:

1- diversified market structure.

(a) increasing flexibility of manufacturing systems
(b) innovation of basic technologies
(c) development of basic information technologies

2- implementation and diffusion of novel technologies.

(a) standardization in advance of marketing
(b) publication of post-competitive technologies
(c) organization of mechanisms for technology transfer

3- human factors.
(a) improving working environment
(b) enabling technologies for unskilled workers
(c) integration of human skills and automation
(d) cultural and ethical factors

4- globalization of manufacturing.
(a) collaborative R/D
(b) standardization
(c) development of integrated information systems

5- preservation of natural environment.
(a) to save natural resources and energy
(b) to recycle resources by developing closed-loop systems
() effective use of waste products
(d) systematization of environment monitoring and assessment

The requirements for IMS.

IMS aims at establishing next generation manufacturing systems that can achieve five objectives as mentioned above, and that can be adopted by people and societies with different cultural and social backgrounds as well as different labour-market conditions. For these reasons, the direction for IMS to take can then be identified by five following characteristics:

- market adaptability
- human-oriented
- openness and universality
- adaptability to natural and social environment
- cost-effective

The technical scope of IMS.

In particular, the keywords of technologies in which Japan is interested are the relations with concept, characteristics and technical areas that the IMS programme embraces. The technical areas to be considered in the IMS programme roughly coincide with those suggested by five preliminary studies. These studies lay particular emphasis on certain specific areas, as follows:

- intelligent devices
- autonomous control and system integration
- system design
- system architecture
- information integration

The proposed topics are then classified into the four following categories, assuming that production systems comprise management, design and manufacturing:

- topics concerning organization of knowledge from existing excellent technologies
- topics aiming at the standardization of production activities comprising management, design, and manufacturing, as well as information
- topics aiming at development of future manufacturing systems commensurate with the concept of next-generation production systems
- topics dealing with the relationship between production systems and such factors as man, society, and natural environment

7.4.4 Some actual research programmes in IMS

The actual research programmes starting from the CIM basis comprise, in general the following themes:

- global manufacturing,
- enterprise integration,
- systems components technologies, and
- clean manufacturing (recycling).

As examples we have:

a. To develop models of total production activity, considering product functions, productivity, maintainability and disposability, establish a methodology for preliminary assessing of the models in a variety of industries; test and observe various technologies and development techniques utilized in transferring the software system into real-world installations in a variety of industries. The IMS study should not only be theoretical, but also aim at development of technology which can be utilized for practical fields of production. A virtual production environment will be verified, to extract problems which would not be discovered through theoretical study only.

b. Systems components of autonomous physical modules and their distributed control system for next generation Intelligent Manufacturing System. Machining modules assembly, modules for control systems

c. Architecture for biologically-oriented manufacturing systems: modelling DNA, enzymatic model for biologically-oriented manufacturing BN (brain and neuron) type information processing technology, concurrent localized system technology human-oriented information processing technology.

d. Design methodologies of intelligent information processing in manufacturing system by distributed knowledge system based on an object-oriented model in global manufacturing, a key concept for 21st Century. To realize this concept of the new manufacturing system, three categories are considered as follows:

- concurrent engineering
- organization and economic aspects

- supplier and distribution management

The purposes of these categories are attained by autonomous distributed manufacturing sub-systems and developing the design methodology of intelligent information processing at all levels of the manufacturing system, from management level to shopfloor level. In order to develop the autonomous distributed manufacturing system, the following items must be developed:

- information processing and control methods of each autonomous module which is of a self-organization nature
- simulation methods
- scheduling methods
- architecture and communication network to integrate each module

e. Cognitive human interface for complex manufacturing system. Next generation man-machine interface, with cognitive ability to study. Present a more efficient tool to assist optimum decision-making in manufacturing system operation, at the same time intend to make operators free from obsession, hallucination and fatigue. The Core is a neural network system which combines with multi-sensor perception system, extracts and recognizes key features, or tendencies in the object system performance and suggests the best action to be taken This methodology will be extensively used for system diagnosis in a prediction fashion

As IMS is now becoming an international research and development programme, we comment on two IMS programmes that are actually running at the feasibility study stage. One of them is Gnosis, which is an international IMS research programme. The other is Evaluative Methods of the Manufacturing System, which is a Japanese-only IMS research programme. The intention is to give examples rather than fully explain this programme, because it is quite outside our present purposes. For this reason the presentation remains only at the general level but, we hope, is enough, for understanding what we call the"take-off" of IMS.

A two-year feasibility study of IMS started in February 1992 and aims to solve four critical issues: methods of cooperation, intellectual property rights, funding, and technical project areas. This study includes six test cases, every one involving at least three of six international regions managing international IMS.

Manufacturing Engineering publishes the list of six IMS test cases and region coordinators. These cases are:

- Case 1: process industry clean manufacturing.

Participants: ICI (EC), Finish Forces Industry Federation (EFTA), Abitibi-Price (Canada), Toyo Engineering Corporation (Japan) and DuPont (US)

- Case 2: Global concurrent engineering.

Participants are Technology Transfer (EC), Northern Telecom (Canada), North Carolina State University (US)

- Case 3: Globeman 21 (Enterprise Integration).

Participants are British Aerospace Defence (EC), Alsthom Machinery (EFTA), CRSRQ (Australia), Toronto University (Canada), NewportNews Shipbuilding (US)

- Case 4: Holistic control system

Participants are Softing Gmbn (EC), Softing (EFTA), Broken Hill Proprietary and Co (Australia), Queens University (Canada), Hitachi Ltd. (Japan) and Allen Brodley (US)

- Case 5: Rapid product development.

Participants are Daimler-Benz (EC), Moldflow Pty Ltd. (Australia), Pratt&Whitney (Canada) and United Technology Corporation (US)

- Case 6: Gnosis.

Participants are Adepa (EC), Asea Brown Broveri (EFTA), Alberta Research Council (Canada), Mitsubishi Electric Corporation (Japan) and Deneb (US).

Gnosis.

Gnosis is an international IMS research programme led by Mitsubishi Electric Corporation from Japan, with the Agence de la Productique coordinating for EC countries, the Alberta Research Council acting for Canada, and Finland's ABB Research Centre coordinating for EFTA countries. Deneb Robotics is the US coordinator. Other participants include Nissan Motors Ltd., Fuji Xerox Ltd., IBM France, Telemecanique, Germany's Fraunhofer Institute and IPA, Cambridge University (UK) and Finland's VTT (Technical Research Centre) and Tehdasmallit Oy.

Gnosis is a long-term goal project to develop an approach to a post-mass production paradigm. To support this goal, the test case aims to develop systematization of knowledge for design and manufacturing and the concept of virtual factory. So work will proceed within the following research streams:

- systematization of knowledge and supporting information for design and manufacturing: this includes the identification, classification, and formalization of the functional and other knowledge of artifacts required to permit the verification, sharing and re-use of the knowledge and the associated manufacturing environment
- configuration management systems: research will be carried out on an integrated configuration management system which permits the formalization of manufacturing problems and constraints in a distributed environment. This stream will focus on the manufactured product
- configurable production systems: research will investigate configurable production systems, production control and factory design principles. This stream will focus on the production process
- soft machinery: in order to advance the long term goal mentioned above, research into soft machinery will utilize the results of the other streams to propose and to develop conceptual prototypes of next-generation artifacts

According to Automotive Industries (August 1993) the Gnosis project is a step towards the virtual factory. Quoting Dornan, an automation consultant with Deneb Robotics, the project will address the need for the more powerful manufacturing software required to drive, change tooling and diagnose problems on the intelligent machines employed in tomorrow's "virtual" factories. The project will also work on the many complex issues still needing to be resolved in data communication. The final project phase will unify and integrate the work packages into a new model mass production. This virtual factory will permit rapid validation of new approaches that incorporate the complexity of the real world.

For example, the factory model which immerses operators in the simulation environment, providing real-time feedback and control between the 3-d graphics model and factory floor, will enable immediate responses to machines breakdowns, product variations, or changes in scheduling priorities. After determining the optimum production methodology, it is possible to initiate and observe it through the virtual factory scene, writes Manufacturing Engineering (April 1993).

Planning and Evaluation Methods of Manufacturing Systems.

This is a Japanese only research project on IMS. The prime contractor is Shimizu corporation and it is running from December 1992 to April 1994. As members, there are seven company and four university laboratories: Fuji Xerox Co. Ltd., Nippodenso co. ltd., Makino Milling Machine Co. Ltd., Mitsui Engineering and Shipbuilding Co. Ltd;, Sanyo Electric Co. Ltd., Taisei Corporation, Japan Society for Promotion of Machine Industry, Kobe University, Sizuoka University, Tokyo Metropolitan University.The aims of this project are:

- systematization of evaluation methods for manufacturing system
- development of simulation environment for overall evaluation

These aims correspond to the discrete manufacturing system on the domain of factory to cell. To achieve this, the following steps are defined:

- clarifying evaluation criteria for the manufacturing systems
- determining evaluation points for the manufacturing systems
- preparing simulation requirements for the evaluation
- proposing the new concept of simulation environment

The problem here is to start from real factory modelling and simulate operations using operational parameters and corrections. The results are evaluated and if they are not good, analyzed and used as inputs for the corrections that are entered as input both for operational parameters correction and for a new modelling iteration. This real process is evaluated at every step. The main input for evaluating are the data, after they are evaluated by a different method creating an evaluation index, which permits the comparisons.

In all situations, the user request side must be respected. This request needs to emphasize the easy modelling, the easy operation, the integration of individual simulation and the user-friendly MMI (Man-Machine Interface). So among the primary activities developed are the verification of a useful simulator for the people planning and evaluating the manufacturing system, the standardization of the interface of each simulator and the adjustment of each database used in the simulator.

These activities must permit for the first time, the creation of a platform for the evaluation of the manufacturing system. Then the simulators are designed. In fact there are many simulators integrating this configuration. For example, we find a manufacturing system simulator, the simulation of the machining assembly and inspection cell, the transportation system simulation, the assembly process simulator, and the transportation process simulator.

Each of these simulators gives an output. For example, the manufacturing system simulator has in its output the manufacturing system model. With these outputs the models and evaluation system are constructed. Among these models there are the manufacturing system model base, the system model base of machines, the assembly process model base, the machining process model base, and the transportation model base. Finally, there are the simulators, the simulation model and the model base.

CHAPTER 8

FINAL COMMENTS, AND PROSPECTS FOR CIM IN JAPAN

INTRODUCTION

In this Chapter we sum up some issues about Japanese CIM. As the reader knows, there are many different aspects involved in the reality of CIM in Japan, it is quite difficult to select one point as more important than another. In addition, the points of view adopted by readers (engineers, researchers or managers) may differ according to their experience of dealing with CIM matters in their own companies. Nevertheless, the need for surveying and organizing or exploiting the information given in this book has a special importance at this stage of our study.

In order to reveal the main characteristics of CIM in Japan, the following aspects assume a particular interest:

- technology assumptions about CIM and the Japanese experience
- definitions, factors and objectives for CIM
- strategies for implementing CIM
- types of CIM, in the country and inside companies
- planning and CIM reality
- networks for CIM
- problems and results of CIM implementation
- incorporation of CIM in the future generation of manufacturing systems

So this Chapter recalls some of the main aspects developed in this book. To do so, we presents a short survey of results and problems, as well as putting CIM in the wider historical framework, which is the prospect of future Intelligent Manufacturing Systems (IMS).

8.1. THE REALITY OF TECHNOLOGY AND CIM IN JAPAN

In Chapter 1 we quoted some assumptions concerning CIM that we consider among the most suitable for our countries. These assumptions were made by the IIASA (International Institute for Applied Systems Analysis, Luxenburg, Austria). Following this approach (see Section 1.2), CIM is prompted by four linked assumptions:

(a) new manufacturing possibilities created by rapid technological progress in electronics and telecommunications (supply side of the economics equation)

(b) the complexity of manufacturing increases the chance of human errors, because people cannot work at repetitive tasks (dramatically increasing) without making errors; this leads to an increasing utilization of computers and the adoption of robotics and CIM

(c) the rapid introduction of new products (or new models) and increased product variety, the greater flexibility in manufacturing technology and on the part of the manufacturer, and the more rapid production changes cry out for CIM implementation

(d) the trade-off between economies of scale and economies of scope that result from flexible automation.

What about CIM in Japan?

We can observe two characteristics. On the one hand, Japanese CIM is not in total contradiction with these assumptions, but on the other, not all these assumptions are equally relevant for CIM in Japan. For example, assumption (a) is considered and used in practice in all company situations. So this assumption must qualify as a universal one, but the other assumptions seem to have less impact. Although assumption (c) has not the same attraction as assumption (a), it has some consideration, especially when the analysis is from the point of view of flexible manufacturing and technology.

However, assumptions (b) and (d) do not have the attraction of the others. In fact, we conclude from the case studies we conclude that the increase of human errors is not taken into account as a key factor in computerization or robot processes. Perhaps in another technology framework this assumption should have its importance, but not just in CIM implementation. Concerning assumption (d), it seems to have no importance at all in the current CIM explanations, either in documentation concerning it or in manager's speeches and seminar discussions. The Japanese seem not willing to spend time in detailed explanations about, for example, scope economies as a concurrent hypothesis behind the classical scale economies, or whether one is more important than the other. In conclusion, the quoted assumptions have only a modest value regarding the CIM experience that we know. Table 1 gives an overview of this situation.

Table 1
IIASA Assumptions and CIM in Japan

IIASA Assumptions	CIM in Japan
(a) new manufacturing possibilities because of progress in electronics and telecommunications	It is kept in mind and used in practice : universal one
(b) Human errors induce use of CIM implementation	It seems not relevant
(c) new products, flexibility of company manufacturing technology, rapid product change	Important, especially flexibility
(d) scale and scope economies	Not invoked as important

The Japanese trend is to thinking of technology as a subject wider than a simple classification and in continuous movement towards the future. The word kaisen is sometimes used in references of this kind of trend. So it is not simple to distinguish what are enabling technologies or transition or central technologies for CIM.

In practice, for example, technologies, such as NC machine tools, programmable controllers and robots must be considered as technologies central for CIM and not just as transition technologies, because of the fundamental character given to the supply side for responding to the demands. These technologies are inserted in a sequence supply and it is rather difficult to isolate them. In other words, Japan seems to have a set of technologies central for CIM and wider than expected in Western Europe or in America. Table 2 gives an example of this comparison.

We also studied in Chapter 1, the *technology background* of CIM following R.U. Ayres (1992) who distinguishes three categories of technologies: enabling technologies, transition technologies and technologies central to CIM (see Table 1 in Chapter 1 and Section 1.2). We recall that the first category concerns telecommunications, micro-electronics and computers, technologies applicable far beyond the domain of manufacturing. In the second category we find technologies such as NC machine tools, programmable controllers and robots as examples. The third category consists of technologies directly related to computer integration, such as computer-aided design and manufacturing design, computerized manufacturing resource planning, local-area networks and flexible manufacturing systems.

Table 2
Technology classification and CIM in Japan

Technologies for CIM	CIM in Japan
Enabling technologies	Set of technologies
Transition technologies	Rather central technologies
Central technologies	Sequence of set of technologies

Another aspect needs some additional comments. It is the distinction between two kinds of flows: material flows and information flows in productive processes. This distinction is very clear in most companies, and has many important consequences on the different domains of analysis. Perhaps one of the most important consequences appears, in the theoretical field, because this distinction induces a change in the nature of relations taking place in the productive sphere and in the relations between companies and the environment.

If information is more relevant, some people think that systems are now piloted by information. In other words, all production must be managed, controlled, exploited, performed and improved by information tools.

Under these conditions, the collecting and transmission of highly accurate information quickly is the most important prerequisite of CIM implementation.

8.2. DEFINITION, OBJECTIVES AND FACTORS FOR CIM

In this Section we study definitions and objectives of CIM, and factors for CIM, because we think all these problems are related. Definitions are important in the technology field because they can clarify the scope of its application. We have also had the opportunity to underline the significance of every word composing the acronym CIM, but this is not a definition in itself. Japanese companies sometimes give a definition at the beginning of their CIM involvement. This means that managers have clearly in mind what the target is, and has a great influence on people in charge of developing CIM and who are, normally, from different departments of companies. So the people are now working on some similar lines.

A conceptual definition.

Definition is also important for the conceptual approach to CIM. But in Chapter 1, it was indicated how difficult it is to set out a standard concept for CIM which is available everywhere (see Section 1.1). In fact, CIM depends on many factors, and some authors do not hesitate to consider that it is more practical to build up a specific CIM concept by company, rather a general one.

Among the factors affecting a single CIM definition, the following were underlined:

- market demands (products, quality, delays..);
- technical and economic objectives of company (reduction of manufacturing costs, improvement of material flow, information flow..)
- degree of computerization and networking (type of hardware and software, network implementation, size of network, distributed architectures...)
- factors specifics to the manufacturing conditions (formation, personnel, type of machines, type of technologies, production structure, size of company...).

Concerning the Japanese CIM, a general definition for CIM exists at least at the overall company level (a company here means one company and many other partners trading with it). One example quoted in Chapter 2 concerns Hitachi Corporation. This company tries to define as accurately as possible what it understands by this or that technology, not only in CIM matters but, in general, in technology research, development and application. Indeed, in the case of our study, Hitachi considers CIM as an integrated information strategy system that connects all business activities, such as acceptance of an order, design, manufacture, inspection and delivery, into one employing computers which use an integrated database and communicate with one another through an information network, thus achieving high efficiency and flexibility.

Another example of the definition was quoted in Chapter 6. It concerns the Shimizu Corporation (see Section 6.3). We already indicated that this company is not a "classical" manufacturing company because construction must be considered a different process, with very specific characteristics (particular work localization, variety of inputs, time differences for input requirements, difficulty of automating some manual operations, etc.). So one question is "What definition for CIM to use in that case?". In the present company case, the solution found is expressed by an acronym, which is created from the substitution for "manufacturing" of "construction". This is not a simple letter play because it contains an essential point, that there exists a "Computer Integrated Construction" (or CIC), just as there exists a Computer Integrated Manufacturing. It has, probably, a double consequence:

(a) a first consequence, an essential one, is that a computer is integrating a construction process as well as a manufacturing process, and

(b) a second consequence is that if construction can be integrated by computer, we can assume without inconvenient an extension of the CIM principle (the integration by computer) to any human productive activity. In other words, and this should be true at least from the point of view of definition, CIM should be a universal step or, in the Japanese view, "a productive paradigm" which is in correspondence with an era (see Sections 7.4 and 7.5)

Why is CIM needed in the construction industry? According to the explanations of Shimizu researchers themselves, CIM is a necessity because one of the most important challenges in this industry is the integration of design and construction processes (in reality there is not one, but many different processes). So, building construction must involve cooperation among engineers, designers, and project managers. Indeed, comprehensive organizational planning and management tools are required. The concept of integrating the design and construction process is the starting point for n strategy for CIM implementation in the building industry.

A more subtle general presentation of CIM at the whole company level is that of Toyota. As we see in Chapter 4, providing outstanding products swiftly and at low cost - is the most important question of production at Toyota. In order to respond to the increasingly sophisticated and diversified needs of customers, Toyota strive for state-of- the-art production technologies and to establish a flexible production system. By constant efforts to automate the production system, the company intends to transform the production process into one that offers a creative challenge for the human labour force.

But in this case there appears very clearly the closest link between production technology and a flexible production system, both, in turn, related to the planning system. This is, perhaps, a more distinctive vision of CIM. However, if Toyota's CIM approach has some similar aspects to other Japanese CIM models, there are other points in which Toyota has an even more clear definition. For example, the whole Toyota system is highly dependent on planning system performance. When this company is designing this planning system it distinguishes, more clearly than others, two main flows: material flow, and information flow. The Toyota CIM model is then closely related to this distinction.

Another example (in the conceptual vision) is the approach made by Nippodenso in UTOPIA project. According to this project (see Section 6.4) it is necessary to combine two approaches, a conventional approach and a micro-electronics application. From the traditional approach, the company must learn:

- the oriented work flow
- the mass production of few kinds of products
- oriented hardware
- direct labour, etc...

From micro-electronics application, the company must keep:

- integrated work and information flow

- speedy information and feedback
- integrated hardware and software
- intelligent equipment
- indirect/overhead operation
- autonomous function, etc.

The problem is to find a more appropriate mixing of traditional approach and electronics application for building a good CIM definition. Concerning the traditional approach, one important question is not to refuse or accept one or other of these elements, but to study how they can enter, or must be modified to enter, the new era. In other words, one condition for creating a CIM definition and concept is to take into account the elements belonging to the traditional approach and add these to the micro-electronics application. Under these conditions, CIM is constituted by the addition of all these elements as indicated in following equation:

(1) + (2) = CIM, where CIM comprises an integrated production system (autonomous factory), hardware, software, humanware, etc. This system is assumed to permit a total flexibility. Then in the ideal factory, we find humanity (worthwhile working, sense of achievement), quality (new technology, zero defect, quality assurance), delivery (frequent delivery, minimum lead time, zero inventory) and cost (minimum cost).

Table 3

Example of classification of objectives for CIM
A. General : improvement of product quality shorten lead time
B. Specific review of MRP system expand bar code
C. Techniques unify information and material flows establish links between FA and LA unify CAD/CAM systems and integrate within company relationship control and FA using flexible manufacturing
D. Economic improve added value increase productivity establish a demand/supply balancing system

The objectives.

Another question concerns the objectives of CIM determined by every company according to their own reality, interest and perspectives of development. Objectives must be of different kinds such as general, techniques, specifics, commercial, economic, social, human or management. Table 3 gives some examples of objectives following a classification of these into general, specific, techniques, and economic.

In general, a common list of objectives for CIM, specified by companies, is as follows:

- improvement of high value added products quickly,
- improvement of product quality,
- accelerate business speed,
- establish customer/market oriented organization,
- establish a flexible production system,
- shorten working hours, and work environment improvement.
- shorten lead time,
- improve productivity,
- speed up management of order-to-production information,
- improve/maintain product quality,
- integrate OA/FA equipment,
- integrate FA and SIS, and
- improve production flexibility for customer responsiveness.

Now we make comments about some particular companies. Tokyo Electric Corporation is an example of a company specifying general, specific and technical objectives. A more detailed explanation about the objective of this company is given in Section 6.1. For example:

(1) the implementation of a demand and supply balancing system is a general objective in the sense that it is also specified in other companies. We recall that it means to create a tool which connects the sales department at headquarters with the plant in order to promote the integration of production and sales.

(2) review of MRP method and planning unit is a specific objective, and we cannot find it easily specified in the cases of other companies. The use of bar codes, which is quoted in table 3, is a similar matter. We recall that the MRP question involves two aspects in the Tokyo Electric Corporation CIM implementation:

- first, try to synchronize MRP with the production system and at the same time review the scope of MRP operation, and

- second, to change the planning time frame to daily and automate the daily plan and schedule

(3) integration of the engineering information system and the production system is rather a technical objective, clearly specified at the beginning of the project. In this case the question is to provide an automated link between the engineering information system and the production system, in order to improve

the product development system and reduce the lead time for research/development

(4) review and integration of a plant's existing systems must be considered as a general objective, underlined in some cases as being more important than others. This means to re-examine the relationship between each system in the plant and work to improve productivity and reform indirect operations

(5) active expansion of bar code system. As indicated in table 3, this is a specific objective for this particular company. In the present case it means two things:

- to implement a bar code system for work progress management, manufacturing instructions, and collection of actual results, and
- to try to monitor information instantly and simplify information input.

Study of the Fanuc Corporation (see Section 6.2) furnishes a clearer example of separation between general and technical objectives.

Thus the first approach to this question permits us to present the objectives assigned to CIM. These objectives are summarized as follows:

(1) better productivity, which means to rationalize design work using CAD/CAM, automate production facilities, and rationalize the administrative departments;

(2) reduction of lead time, in relation to timely monitoring and adjustment of the series of steps from product estimates to shipping in order to reduce total lead time;

(3) unification of materials flow and information flow, from order receipt through to shipping.

But in the second approach, the Fanuc study specifies Fanuc's technical goal. This technical goal is summarized as an implementation of CIM which must integrate the following areas:

(1) FA: factory automation of production facilities

(2) OA: office automation to rationalize headquarters' administrative department

(3) LA: laboratory automation of the design and research development using CAD/CAM

This integration has the following meanings:

- to get a close relationship between the production control system and the FA system which uses FMS (Flexible Manufacturing Systems)
- to link LA and FA systems using CAD/CAM
- to obtain a close relationship of all systems with the expanding OA system which includes key business systems such as business information management and sales management systems.

Some factors.

Finally, we comment on the factors leading to CIM implementation. There are many factors acting for this achievement and they can be ranged from general factors to technical factors. These factors are more or less present, according to the company strategy in implementation of CIM. For summarizing this point, we give two examples:

(1) Hitachi.

Here the main factors declared by the company are:

- changes in expenditure (selection by wiser consumers, society longevity/ increase of careered housewives, labour shortages and foreign workers)
- international changes (free trade and capital circulation, Yen appreciation, trade conflicts, rushing of NIES especially in South Asia)
- changes in values (power of new generation, improvement of quality of human life, reconsideration of Japanese style of management)

(2) Ome Works Toshiba CIM.

In this case, we find the following factors for implementing CIM:

- diversification of user's needs,
- tough competition,
- faster technological innovation,
- globalization of corporate activities,
- shortening of product life cycle,
- difficulty of getting economies of scale

8.3. STRATEGY AND STAGES OF IMPLEMENTATION

We first look at some preliminary steps, components, and historical perspectives and phases of CIM implementation, and comment on each of them in the context of Table 4.

Table 4
Some steps and strategy for CIM implementation

Hitachi	OT-CIM	MELCO
Trend plans	FA, EA, OA	FA
FA	ASTRO	OA
CIM	TP	MPS
IMS	STEP	OE
Phase1	ISM	CIM
Phase2	CIM	
	SIS	

In Chapter 1, we give a short presentation of the strategy for CIM implementation. The strategy is linked to the technology concept, and designed according to various factors. This strategy is essentially a managerial strategy. First is a decision that it is absolutely necessary to begin a CIM project. This project must be closely related to the CIM concept (we study the CIM concept in Section 1.4).

An important aspect of this strategy is its topdown character. According to the top-down strategy (for management business), there are five going-down steps, every one linking internal users to the external users and to the CIM partners. These steps are:

- structuring of objectives
- top level company decision in favour of CIM implementation
- creation (at the top level) of a special CIM team
- set up application planning for CIM
- translating the project step-by-step into reality.

But strategy is not only a matter of following different steps during which a company must be able to reach the CIM implementation as planned. The strategy is also based on the organization structure, the participation of partners, and the concept of CIM, which is fundamental, as we have already explained. We underline now that organization must be adapted to CIM implementation strategy, and collaboration with partners must be really effective. All this impacts on the success of the overall operation.

Another point we have already discussed is the historical trend of technology. This trend has some characteristics to be taken into account. There are elements of this trend that derived from the environment and thus open to every company, but also some elements belong to each individual company, and they must managed correctly.

A classical example is the Hitachi company. In this case CIM is inserted in a wider framework characterized by a continuous improvement of productive systems as presented in document CIM 21. This trend is characterized by the following elements, clearly identified by order of appearance:

- FA (or factory automation)
- CIM
- IMS (Intelligent Manufacturing System)

So CIM appears in an intermediate position between FA and IMS. Furthermore, Hitachi distinguishes the next two phases of CIM development:

- phase 1, from 1987 to 1988. This phase corresponds to policy decision and the creation of model manufacturing lines (for example, in Hitachi Works, Totsuka Works or Kanagawa Works).
- phase 2, from 1988 to 1992. During this phase, the proceedings in the corporation and the working group activities differentiated by product fields.

Finally, Hitachi follows the top-down/bottom-up approach to CIM system construction. This approach concerns, principally, the preparation for system construction. The top-down approach concerns:

- decision on objectives,

- the breakdown of objectives and measures by using the so-called "objectives tree", and
- the design of overview criteria in order to obtain a total optimization view of the system.

In turn, the bottom-up approach deals with:
- the evaluation technique for plant activities,
- revelation of the problem by hearing suggestions formulated by plant operators and
- revelation of the problem found by industrial engineering methods.

The second example concerns Ome Works (Toshiba Corporation). As we have already seen (Section 5.1), OT-CIM is put in its historical perspective. From 1968-1977 to the present day, five steps of development leading to Computer Integrated Manufacturing are accounted. Nevertheless, unlike the Hitachi Company, here CIM is in an intermediary position between FA, OA, EA, and the next step, represented by SIS.

Furthermore, OT-CIM and SIS are currently improved by many campaigns and the corresponding policies. The main campaigns are:
- TP (Total Processing)
- STEP (Software Technical Engineering Processing)
- ISM (Information Sales Management.

The strategy depends also on the components of CIM involved. One good example is that of the Nakatsugawa Works from MELCO. In this case the manufacturing strategy of NW seeks increasing quality, reduction of delivery time and lowering of cost by the CIM concept, FA strategy, MPS strategy and OA strategy. So the FA, OA and MPS strategy aims are as below:

(a) FA strategy aims:
- the construction of a continuous flow FA line,
- the automatic production system that balances the man-machine combination,
- the expansion of a Network between systems (MAP), and
- the practical use of products in the FA production line.

(b) OA strategy aims are:
- increasing the administration benefit by the total information system,
- real-time processing in order to unify the production, and
- information flow and the construction of the corporate network (see MIND and MELNET Networks).

(c) MPS targets the establishment of a CIM base.

In the case of the Tokyo Electric Corporation, the strategy for CIM implementation is linked to some particular aspects, such as MRP system and Total Productivity development. For the first problem, the company reorganized the relation between the parts and work-in-process control system, using a bar code. The second problem is more general, it is a matter of whole policy, and it must be solved continuously.

This strategy approach drives a company to put the emphasis on other problems. For example, in the case of its Ohito Plant, the strategy for CIM implementation distinguishes the function system and the structure system.The function design depends on the control system ideas. The structure is closer to the networks development.

The Shimizu corporation is another interesting case to consider when we study the strategy for CIM implementation. Shimizu starts from its reality as a construction company. The construction process has some particular characteristics that must be considered in every technology implementation, and also in CIM. So, in order to advance in the right direction, the first question is to establish a framework for research and development of an integrated construction system as the company wants to do. This strategy permits the identification of three major existing problems:

(1) basic information procedures and knowledge about construction technologies are not shared between designers and constructors

(2) interactive procedures at the early design stages, to apply to building systems and construction methods, have not yet been developed

(3) unsystematic evaluation and feedback of relevant data and information from the construction site is prevalent

The second important question is then what solutions are needed, and how and where to find these solutions. One way is to produce an object-model for integrated design and construction planning which is as close as possible to user needs and also optimal resource consumption. But for the realization of this planning by a computer system using knowledge, it is necessary to represent the following functionalities:

- negotiating knowledge module for schemes produced by different planning modules at the simultaneous phase
- planning expansion knowledge module, producing and eliminating planning objectives required at each step of planning
- constraints management module (add, modify or eliminate constraints)
- working memory for investigating objects by subsystems in knowledge modules
- relational database (store hierarchically objects-models, project information and planning process)
- production database and integrated construction system database (present reference information and store technical information).

Finally, we present some details about the problems and difficulties of CIM implementation. For more about this question, the reader can see Section 8.7. The details concern here problems related to practical implementation. One thing is clear at this time: CIM implementation must take into consideration many possible problems that can appear during the process. Among these problems are:

- the system hierarchy

- the LAN network
- the factory management system
- the warehouse and delivery system
- the cell control system.

8.4. TYPES OF CIM

As we saw in the previous chapters, Japanese companies distinguish different types of CIM even if they have a general definition or concept for particular applications. Table 5 depicts some examples of CIM type according to the hierarchy approach and to the products involved in the company concerned. In the next paragraphs we comment on the types of CIM, following the cases of MELCO, Toshiba and Fanuc. Finally, we comment on FCIM, one of the last CIM figures created in US.

Table 5
Example of main types of CIM

A. According to the hierarchy Line CIM Department CIM Factory CIM
B. According to products involved CIM for indent systems Job-order production CIM Variant-mass production CIM CIM for standard components

Concerning MELCO, the first comment deals with the Concurrent Engineering approach because this is a distinctive characteristic related to CIM in general, and to different specific types of CIM. Remember that manufacturing companies are currently under strong pressure to supply goods, related services and information that more faithfully respond to their customers. From this reality is emerging the idea of incorporating sooner many aspects of products at the design stage.

Indeed, in the MELCO approach, concurrent engineering creates a design linking two main elements: on the one hand sales, and on the other hand, the manufacturing process. Following this principle, concurrent engineering is producing inputs for both innovative products and CIM innovative production systems. CIM and concurrent engineering links allow improved performance of computerized operations. In this way MELCO think to reach the border of human creativity interacting with complex machines via computers and networks linking computers.

As one of the consequences of the above approach to CIM-Concurrent Engineering, we have the most common view of CIM in MELCO as a MELCO customer-oriented CIM. The case of this type of CIM studied is that of moulded-case breakers. Three ideas are at the centre of this approach:

- the customer as the main orientation for every production activity
- Concurrent Engineering as a facilitating process taking into consideration all customer needs from the stage of design itself, and also taking into consideration the major aspects to be incorporated in product development
- CIM as an integrating process

In parallel to the CIM-Concurrent Engineering approach, MELCO starts from conceptual views for determining various types of CIM. In this way the company distinguishes the following concepts:

(a) CIM concept for computer-aided integration concerning only one process or manufacturing conveyor

(b) CIM concept for manufacturing-oriented systems

(c) CIM concept for large applications

And from these CIM concepts, the company deduces three types of CIM:

(1) production-to-stock

(2) variant mass-production

(3) job-order production

In a similar manner, Toshiba in the case of its super-sophisticated CIM system at Ome Works starts from a conceptual approach for CIM. In the Ome Works, the following three concepts are integrated:

- FA, Factory Automation
- EA, Engineering Automation
- OA, Office Automation

According to the nature of production delivered to satisfy a consumer's demand and the time needed to ensure the right delivery, Toshiba classifies CIM into the categories below:

(1) CIM for indent systems.

This first category involves parts and products; order-based production; products for plants, heavy apparatus, aircraft and others

(2) CIM for product orders based on market prospects.

In this category are ranged parts, prospective production, system products, labour-saving devices, automobiles....

(3) CIM for off-shelf products.

In this third category there are parts and products, consumer products, office automation equipment, small engines...

(4) CIM for standard components.

In this category are ranged all products that are not included in any other category, such as semiconductors or cathode-ray tubes.

A special comment is needed concerning the database. One characteristic put forward by OT-CIM is the place of the database in CIM. In reality, database and networks are among the main aspects for a conceptual approach to CIM implementation. So the role of the database in CIM is very important. Nevertheless, this is not a simple database but a very big one which is, by definition, a shared database. In the OT-CIM case, all users (FA, OA, EA, CIM, SIS...) can access this database. However, one problem is to know how to share this database in the local conditions of one particular company.

In the case of the Fanuc Corporation, the first step is to develop a total integrated image of CIM including production, factory management and company management. The next step categorizes the objectives and target area in 3 steps (CIM-1, CIM-2 and CIM-3), and implements the steps bottom-up from CIM-1. In this particular case, a classification of CIMs is represented under the form of figures encapsulated. This means that the conceptual approach for CIM should think in terms of CIM figures and not in terms of real or physical hierarchies. This is a very important conceptual issue for CIM implementation.

The three CIM figures need the following explanations:

(1) CIM-1 corresponds to the production level. The target is to solve the issues in the flow of information of production which is appropriate for Omron's business

(2) CIM-2 deals with information systems for efficient management and related operations: production planning, purchasing and synchronization

(3) CIM-3 is related to the integration of sales/ production/development information to keep the competitive advantage.

Finally, we make a short comment concerning FCIM. As we know, FCIM is the integration of equipment, software, communication, human resources, and business practices within an enterprise for the rapid manufacture, repair, and delivery of items on demand with continuous improvements in the process.

So, FCIM is a standard process for acquiring, scheduling, allocating resources, manufacturing, packaging, and distributing, and repairing parts. The FCIM process, which capitalizes on modern software and hardware in an effort to produce a variety of similar products smoothly and rapidly, is designed to reduce lead times, increase turnaround, and decrease cost. The main characteristics of FCIM are modularity, cultural changes and risk involved.

This characterization of FCIM is quite near to Japanese CIM, according to the case studied in the previous chapters. Nevertheless, some important differences exist. FCIM seems to insist on more flexibility of character than Japanese CIM; the later does not insists because it is probably understood as one of its characteristics. On the other hand, Japanese CIM is customer oriented, information is arriving from customer via the planning system, and is incorporated into the CIM activities. This a capital point because it means a fundamental change in all the economic logic that has dominated in developed countries during more than a century. Economics systems are now pulling by demand and not pushing by supply.Companies must understand this change and adapt their strategies to it. CIM technology is, perhaps, one of the most useful examples for creating new business in these new conditions.

8.5. PLANNING AND CIM REALITY

Table 6 gives example of steps of planning systems used by Japanese companies for CIM. Three companies are presented here: Hitachi, MELCO and Toyota. Table 6 shows some similarities and some differences in the planning steps, according to the individual companies, but we give more details below.

Table 6
Steps of planning systems : examples

Hitachi	MELCO	Toyota
strategic system vision master plan action programe	annual plan aggregate production plan monthly production plan daily plan	long-term production plan annual production plan monthly production plan 10-days production plan daily plan

Hitachi.

This company distinguishes the so called "tools for planning" in place of steps. These tools include the integrated planning methods for strategic information systems, the diagnosis and evaluation methods, and several kinds of simulations..

(a) Strategic system vision

In the first stage, the management strategy is clarified and the information system strategy that supports the management strategy is worked out. The corporation's forecast should be defined, from which the corresponding strategic conception should be drawn. The idea is to close the gap between concept and reality as much as possible at this time.

(b) Master plan

The second stage involves implementation of the strategy throughout the organization and preparation of the master plan for SIS. In the master plan, the framework of the total business operation and that of the total information system should be worked out. And the strategy should be broken down along the framework, thus creating the objective or goal for each business operation and system.

(c) Action programme

In the final stage, the procedure of business operations for achieving the goal is sought and system requirements are determined. The action programme is applied to each system defined in the master plan for finalization of the system requirements, which are the primary input to the system design process

Another point for the present company is the importance accorded to the methods for planning. The best example is the AEM method, already commented on in Section 2.5. As we know, AEM is related to another method, the Producibility Evaluation Method (PEM) presented in the document Hitachi Producibility. The application range of PEM covers the products such as VCRs, CD players, washing machines, vacuum cleaners, circuit breakers, rotary compressors, automobiles, and automotive parts.

PEM prepares drawings or samples, proposes assembly sequences and methods, proposes machining methods, and calculates evaluation indices. The PEM evaluation and AEM method are carried out in several steps.

MELCO.

In the MELCO ventilator CIM system, production planning consists of four steps that determine progressively finer details. These four steps are:

(1) annual plan
(2) aggregate production plan
(3) semi-monthly production plan, and
(4) daily plan.

Toyota.

Like other Japanese manufacturers, Toyota distinguishes several kinds of plans. In general, these plans are organized as follows:

(a) long-term production plan.
(b) annual production plan.
(c) monthly production plan.
(d) 10-days production plan
(e) daily plan.

Finally, one additional comment concerning the conceptual CIM approach and planning. This example corresponds to the Ohito Plant. In order to achieve management's goal of total productivity improvement the Ohito Plant, especially the production headquarter engineering management department and the plant's production technology department, has been going forward with CIM conceptual planning since 1990. Currently, the Production Control Improvement team, which is one of the TP programme improvement teams, is leading this effort, and has been pursuing the integration of production and sales.

8.6. NETWORKS FOR CIM

Networks are vital for CIM in Japan. Every company has faced this problem in the recent past. But the networks are currently improved by standardization protocols and procedures and companies participate actively in activities organized in this direction, as we see in the case of the Sigma project or FAIS network (see Sections 7.2 and 7.3). In the present Section we present some elements to summarize the network situation as a part of CIM. We comment on the networks of Hitachi, MELCO, Toshiba, Tokyo Electric Corporation and Toyota.

The Hitachi Information Telecommunications Network is HITNET (see Section 2.3). Assuming now that factories are forming divisions, this last level is connected with the corporate level by the intermediary HITNET network. Through HITNET, the different Hitachi divisions are connected to the Headquarters. At the corporate level, HITNET is completed by HIT-VAN (Hitachi Value Added Network). Through HIT-VAN all Hitachi parts are connected, for example, with the component suppliers. At the factory level we find the classical LAN, Optical Fibre,etc...

In the case of MELCO, there are three main telecommunications networks (see section 3.7):

- MIND (Mitsubishi Information Network by Digital Technology), and
- MELNET (Mitsubishi Electric Local Area Network).
- VAN network

A production planning system, positioned as a core system, is being integrated with a CAD/CAM system, production control and plant operation system. FA networks link FA- computers at the area level and FA controllers in cell-level controllers. It plays an important role in CIM implementation. Nevertheless, MAP installations are not increasing in Japan, and MELCO has decided to develop their own FA/MAP system. Many LAN networks operate at the factory level.

In the Toshiba Corporation, the CIM pyramid permits us to associate each level to the computer networking and conceptualize it (see Section 5.1.3). So, starting from the top we have as networks:

- corporate: Mainframe computer for Headquarters and Scientific use
- department: TG-VAN linking mainframe computer of Headquarters and Factory and Affiliates Subcontractors
- group: Total-LAN linking distributed CPU of sales, production control, manufacturing control and design
- personnel: Office LAN linking LAptop and MAP linking automated machinery.

In the particular case of the Ome Works, there is a complex topology including the LAN Ring, the LAN Bus, the Token Ring or the LAN Star configuration. So, to obtain a higher flexibility, the following relations must exist:

- LAN Ring connects LAN Buses
- LAN Bus connects LAN Star
- every LAN Bus connects OA Link which is a simpler network surrounding workstations.

The Tokyo Electric Corporation has installed TEC-NET networks, which include a high speed digital network between the Ohito Plant, headquarters and other plants, and a LAN between the buildings (100m optical cable, inter-building: 10M bus) of the Ohito plant. TEC is also joined to TG-VAN (Toshiba VAN) (for TG-VAN explanation, see Section 5.1.3) and receives information as a member of that group.

The situation of TG-VAN for Tokyo Electric Corporation is an instructive one. In fact, in Japan, companies have their own network, computer and database systems but they can be open for punctual business or for businesses that they are realizing together during some period. It is important to understand the role played by networks in actual or potential partnerships. Networks are designed to support the openness in all these situations.

In the case of Home Appliances, three levels forming its configuration are represented:

- the Factory level, in which we find the Host Computer with its corresponding data base,
- the interdepartmental level. The link between the top level and this level passes across the backbone LAN. Each department has its own Central Processing Unit on-line with its corresponding database.
- the department level, having its own LAN and running the purchasing, processing, assembling, testing and delivery operations.

Concerning Toyota, we recall and comment on some aspects of the networks. The first concerns the name Mechatronics (Mechanics and electronics) which was coined by the Japanese in the mid-1970s to describe a new technology fusion. The word has rapidly spread all over the world within the last few years. Mechatronic technology forms the basis not only for consumer products (such as recorders or compact disks) but also manufacturing systems.

The "mechatronic" definition uses two concepts, as below:

(a) A system concept.

The system concept is organized around four internal functions. The main function of one system is the operation function. This is a function to perform the purpose of the system, that means, a function to convert material, energy and information. The power function handles energy, lubrication, cooling and so on, which are required for normal operation of the system. The next function is the control information function which controls the entire system, playing by this means the functions of the brain and senses of humans.

(b) The interface concept.

The interfaces are very important in mechatronics. In fact, dealing with a compound system, various technologies and elements having different properties such as mechanisms, electronic devices, software, etc. are combined with each other. In this situation, most of the design of the system is the design of interfaces. "The thinking method of the system in view of the interfaces is called the interface concept".

The above presentation is interesting for understanding the character of ME-NET that we studied in Section 4.3 and subsequently. As we know, ME-NET is, principally, linked to factory automation of the Toyota plants. But this factory automation is one of the main components for improving CIM. Since 1992, Toyota is implementing ME-NET in all their factories. ME-NET is enhancing the whole Toyota production system.

ME-NET must also be compared with MAP created by GM (General Motors) during the early 1980s. MAP is designed for different applications including the CIM technology, and has a similar architecture of that of the OSI Model. The ME-NET position in the CIM environment of Toyota is inside the MAP structure. We can see six levels, beginning with the actuator sensor at the bottom level and followed up by equipment, line cell, shop, factory and finally company (or Corporate) at the top level. This figure represents also the levels of MAP and MINI-MAP architectures. As we see, the position of ME-NET is covering only one part of the three first levels or the so called "physical levels", of MAP.

Table 7 summarized the above developments for main companies.

Table 7
Network levels for some companies

Hitachi	MELCO	Toyota
HIT_VAN HITNET FA-LAN MAP MINI-MAP	MIND MELNET VAN-Net FA-MAP	* * * * * * MAP MINI-MAP ME-NET

*** Toyota-wide area networks

8.7. PROBLEMS AND DIFFICULTIES

CIM implementation has not, in general, had a linear progress. In practice, its implementation encounters many difficulties that need to be overcome in order to assure the assigned goals. These difficulties may be classified into several categories. Table 8 summarizes the main difficulties. One example is the following:

- difficulties due to the FA system installation. Examples of these difficulties are the need for an integrated supervision and control system to manage several kinds of process, the different capabilities of machines on the shopfloor, the coordination of different lines (painting, assembly, internal and external assembly parts...).

Table 8
Main difficulties for CIM implementation : some examples

A. from FA installation : * integrated supervision &control for managing different processes *different capabilities of machines * coordination of lines
B. from computer and network : * need for an easy upgrade of computer system * coordination of data following a system fault condition * lack of robustness of tracking methods
C. from automation itself : * steady flexibility of growing systems * coordination for optimize line operations * figuring out how to control many robots * determination of best way to automate quality assurance line
D. from humans : *understanding CIM scope

- difficulties arising from computer and network implementation. Among these difficulties are the need for an easy upgrade of the computer system, so that it can track the gradual improvements made to the equipment: the coordination of data following a CPU system fault condition is difficult, because the tracking method may not be robust enough to ensure consistency between the data and the disposition of the actual materials.

- difficulties due to automation itself. Examples of this category are the need for flexibility of the system despite the changes which go hand-in-hand with a steadily growing system; the coordinating of lines in order to maximize the operating efficiency, given the different objective functions governing the design of each line; figuring out now to control a large number of robots; and determining how best to automate the quality assurance line, given the large number of items requiring direct human intervention.

- difficulties concerning people in understanding the scope of CIM.

One important problem is to identify these difficulties and to try to organize them into categories. The next point is to act on them in order to try to find out better solutions. The solutions normally depend on the nature of the difficulty concerned. This process is one of the tasks of the CIM team in a company. In this area an important problem is the relation between man and machine and the new quality that this relation should assume. An example of this is the ergonomics and user-friendly man-machine relations: the new positions of hands and eyes in contact with matters displayed on computer screens at every level of the company activity.

Even if CIM has encountered many difficulties, its benefits are widely important. according to all the Japanese companies that we met or enquired of directly or indirectly, through the literature. Nevertheless, an additional comment is necessary. It concerns the care of CIM. CIM in Japan is more human-centred than technology-centred as, for example, it is in the USA approach. The consequence is this: If USA CIM is more advanced in use of design technology, in Japan fewer functions and a simpler hierarchy structure facilitate an easier implementation of mandatory changes, once decided at different levels concerned in CIM implementation. This gives a greater managerial flexibility.

More precisely, the main benefits of CIM implementation must be summarized as follows

- The total FA system becomes a total management and information system, in terms of on-line connection of host computer (administration). The production control system (from raw materials to packaging) and physical distribution control system (from reception of products to shipping) become a reality.

- The common CIM guidelines in a corporation such as Hitachi, for example, are:

CIM policy reduces lead times by half, from orders to deliveries, lifts productivity by 30%, and cuts indirect costs by 30% and stock-in-process by 30%.

- *In the MELCO case we have the following figures:*

(a) a reduced time index because of the servomechanisms, double head units, and programme of concurrent motions

(b) shortening of set-up times because of automatic set-up or set-up within the index time

(c) fewer stops and shorter stop times because of the production maintenance of machines and dies or warning systems

(d) synchronization and directly linked lines employing JIT, automation of Machine/Human relations and of parts supply.

- *The Omron Corporation case shows*

(a) number of market claims 7 % decrease; number of defects in manufacturing process 9 % decrease; quality cost 21 % decrease (this includes costs such as market complaints, evaluation costs such as the labour cost for production inspection, spare costs such as costs for design review meetings)

(b) reduction of finished product inventory

(c) reduction of actual hours and various costs through implementing on-line and bar code systems for the indirect operations such as car transportation receipt checks and purchasing information transfers, labour costs and expenses.

(d) raising of productivity because of the reduction of labour, increase of the line operation rate, increase in the delivery area due to the improved delivery function, increase in product quality, efficient energy use

(e) information exchange through the network enables closer communications with other departments and other factories, facilitates work planning between them and ensures smooth operation and parts supply.

In general, we establish that the use of IT mixing computer technology, Database Technology and Network technology, searching for a higher coherence with OSI model principles is a crucial point in the success of CIM. But maybe the most important factor for success is a good application of bottom-up and top-down strategy, in which the creation of a CIM team and the CIM implications for all people concerned, internal and external users (partners), are the main points.

Finally, in every case the CIM strategy is set by a clear CIM concept which is built step-by-step according to the general and local conditions and the environment of every individual company. Nevertheless, some information (crucial for some people) is lacking about CIM. One example of this is the lack of information dealing with investment and in consequence, the return on this investment, according to the companies.

What is the future?

We cannot answer this question without recalling the developments made in Chapter 7 concerning the next generation of manufacturing systems. But the future systems have two characteristics. On the one hand there are some aspects, call them public aspects, that we are able to pick up but, on the other hand, some aspects remain under secrecy within companies. These last correspond, in general, to research and development programmes having a competitive distinction.

Nevertheless, some aspects can be discussed. The first concerns the future of CIM. It is now clear that this future depends on the design of a future generation of manufacturing systems. This design takes into account the actual CIM implementation, starting from the actual functionalities of CIM and perfect it. For instance, CIM continues evolving to more and more automated systems but it is not so clear that the new systems including even more knowledge inputs will be a continuation of the actual CIM, and where there will be a disruption point beyond which CIM should be totally incorporated in a new FGMS and by this reason become like another historical step.

But one thing evident to us is that Japan has a perfect CIM, implemented in all economic sectors and not only something reserved to the most advanced companies. This is a capital point: Japan has, perhaps, the highest ability in handling CIM systems and, therefore, a fundamental human and material capital accumulated in CIM technology. The country is in this way in a more comfortable position for future progress and for use of this potential in its favour. But this conclusion seems to be quite pessimistic concerning the possibilities for other countries. If the other countries, including America itself, cannot appreciate the real situation of CIM in Japan and so define an adequate policy for research and development in this field, they will probably be in a tricky situation in the near future.

However, they are also able to define a policy such as Japan seems to make. At this stage one question is to know whether the research for future manufacturing systems must be a matter for isolated countries or a partnership, in which many countries undertake together the realization of research programmes. There is not only the financial considerations but first of all the technology considerations. For example, CIM in Japan is today turning towards an "open CIM", that is approaching the notion of the American FCIM or European CIM. The notion of openness in technology is developed first in Western countries, but actually it is a universal one.

BIBLIOGRAPHY

R.U. Ayres (1992) CIM : a challenge to technology management, R.U. Ayres, International Journal of Technology Management (Vol 7, N° 1, 2, 3, 1992)

H. Baumgartner, K. Knischewski, H. Wieding (1991) CIM, mise en oeuvre de la productique, H. Baumgartner, K. Knischewski, H. Wieding, Siemens aktiengesellschaft, Berlin, Toulouse, 1991

CALS Europe Expo (1992) European CALS Conference, Paris September, Editions HERMES, Paris, 1992

CALS Expo (1992) CALS Expo San Diego, US Department of Defense, San Diego, California, 1992

CIM Technology (1992) CIM Technology of Hitachi, Systems Engineering Division, Hitachi Ltd., Tokyo, 1992

CIM 21 (1992) CIM 21, Hitachi Technical Center, Hitachi Ltd. Tokyo, 1992

P. Drucker (1990) The emerging theory of manufacturing, P. Drucker, Harward Business Review , May-June, 1990.

FNE (1992) FAIS Networking Event, INTAP, Tokyo, 1992

I. Fukuda (1992) Customer-oriented CIM of Ventilator Business, I. Fukuda, in Human Aspects in Computer Integrated Manufacturing, G. Olling and F. Kimura Eds. Elsevier Science Publishing, North Holland, 1992 IFIP

Y. Furukawa (1992) Paradigm shift in manufacturing systems, Y. Furukawa, IEEE International Conference on Robotics and Automation, Nice, France, 1992

Y. Furukawa (1992) Joint research programe into international manufacturing system from preliminary study, Y. Furukawa in Proceedings of First International Symposium on Intelligent Manufacturing System, Tokyo, March 1992

Y. Hasegawa (1992) Strategies issues for developing Next Generation CIM Systems, Y. Hasegawa in Proceedings of First International Symposium on Intelligent Manufacturing System, Tokyo, March 1992

A. Inamoto (1990) Conceptual and Architectural Description of a class of CIM models, A. Inamoto, Proceedings of Japan-USA Symposium of Flexible Manufacturing, July 1990

M. Kajitani (1992) What has brougth Mechatronics into existence in Japan?, M. Kajitani, in Proceedings First French-Japanese Congress of Mechatronics, Besançon, France, October 1992

D. Carter et (1992) CE Concurrent Engineering, D. Carter and B. Stilwell, Addison Wesley Publishing Company, Massuchussets, 1992

K. Kojima, T. Okasaki (1992) Customer-oriented CIM of Molded-case circuit breakers business, T. Osuka, K. Kojima, T. Oksaki, MELCO, IEEE, Proceedings EFTA 1992

N. Nakano, A. Inamoto, Ch. Okumura (1992) Configuration of FA/MAP Model System, N.Nakano, MELCO, Nagoya Works, A. Inamoto, Ch. Okumura Information and Communication System Engineering Center-B, Tokyo. 1992
T. Ohashi, M. Iwata, S. Miyakawa (1991) The Hitachi New Assemblability Evaluation Method, T. Ohashi, M. Iwata, S. Miyakawa, Production Engineering Research Laboratory and Personnel and Education department, Hitachi Ltd. Tokyo, 1991
T. Ohashi, S. Miyakawa, S. Inoshita, T. Shigemura (1988) The Hitachi Assemblability Evaluation Method, T.Ohashi, S.Miyakawa, S. Inoshita, T. Shigemura, Journées de Microtechnique, Ecole Politechnique de Laussanne, 1988
H. Okhubo (1993) Activities for Development and Use of UN/EDIFACT in EIAJ, Hidenori Okhubo, EDI-Europe Journal, Vol 3, N° 1, PARIS, 1993
H. Onari, Y. Matsumoto (1992) A Computer Intergrated Manufacturing System For Electrical Appliance Production, H. Onari, Y. Matsumooto, Production Engineering Research Laboratory (internal document), Hitachi Ltd, Tokyo
OSI (1978) Open Interconnexion Systems. ISO 7498, 1978
ISO (1980) ISO 8802.4, 1980
PEM (1992) Hitachi Producibility Evaluation Method, European Business Division Department, Hitachi Ltd. Tokyo, April 1992
D. Roos et al. (1990) The Machine that changed the world, D. Roos, J.P. Womack and D. Jones, Macmillan Publishing Company, 1990
(SAN, 92) The First International Symposium of IMS, V. Sandoval, EDI-Europe, Vol 2, n°2 1992
Y. Sakakibara and Y. Matsumoto (1991) Approach to CIM in NIPPONDENSO Kota plant, Y. Sakakibara and Y. Matsumoto, International Journal on Computer Integrated Manufacturing, vol 4 n° 5, 1991
Satir (1991) Just-in-Time Management Systems, D. Durmugoglu, in Proceeding of the Just in Time Management Systems Conference, Montreal, October, 1991, Ed. by A. Satir, Elsevier Sciences Publishers, 1991.
S. Shingo (1989) A study of the Toyota production system, Shigeo Shingo, Productivity Press, Mssachussets, 1989
J. Smit (1990) CALS Strategy, Joan Smit, Technology Appraisals, London, 1990
N. Suh (1992) Intelligent Manufacturing Systemsn: a step closer towards borderless manufacturing, N. Suh, in Proceeding of First International on Intelligent Manufacturing Systems, Tokyo, March, 1992
T. Suzue (1992) Concurrent Engineering (in Japanese), Toshio Suzue, JAMAM, Tokyo, 1992
H. Takano and Y. Kawabata (1992) ME-NET proposed by Toyota, H. Takano and Y. Kawabata, Internal Document TMC, Nagoya, 1992
Teiho Plant (1992) Teiho Plant (brochure in Japanese), TMC, Nagoya, 1992
Toshiba (1991) Intelligent Works Ome (brochure), Toshiba, Tokyo, 1991

Toshiba (1991) OT-CIM, Toshiba Cor. Tokyo, 1991

I. Toshio (1992) The Roles of Man and Computer in CIM Systems, Ito Toshio, Headquarters and Manufacturing of MELCO, Tokyo, 1992

TEC (Toyo Engineering Corporation) (1992) Capabilities of TEC as a system integrator, Document, July 1992, Tokyo

Toyota (1991) Toyota (brochure), TMC, Tokyo

Toshijiro Ohashi, Takeshi Yano (1991) VTR Mechanism, Production Eng Dep Lab Hitachi Ltd)

J.B. Walder (1990) CIM, Nouvelle perspective de la production, J.B. Waldner, Dunod, Paris, 1990

M. Watanabe (1991) Intelligent Manufacturing Planning System, M. Watanabe, Y. Matsumoto, H. Onhari, H. Matoka, K. Matsuzaki, 1st Department, Production Engineering Research Laboratory, Hitachi Ltd. Tokyo, and in Proceedings IECON 1991

A. Wilson (1993) FCIM: Continuous Process Improvement, A. Wilson, in FCIM Focus Journal, Vol. 1 n° 3, Jan/Feb 1993

Y. Yamazaki (1992) Integrated design and construction planning system for Computer Integrated Construction, Y. Yamazaki in Automation in Construction 1, Elsevier, 1992