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COMPUTER INTEGRATED MANUFACTURING

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CONTENTS

I.- INTRODUCTION

A new industrial revolution started with the development and diffusion of organizational changes and modern automation technologies. Although the first impact of this new industrial revolution is already felt it will become increasingly strong in the years to come.

After the middle of the 70's the demand for mass-produced goods started to decline and many manufacturing industries were forced to produce customized products. The new market requirements asked for medium to small batch product series, i.e. for flexibility in the production. Thus, once again the conflict between flexibility and productivity had to be overcome (the last time this conflict appeared, the solution was found in mass production).

Until now industrial automation developed in a very fast and therefore very chaotic way. But flexible automation requires a complete system idea, beginning at the single production task and reaching the global concept of the plant layout.

A lot of industries realized studies, showing that the benefits that could be obtained through technological improvements or work rationalization are reaching an asymptotical value. This means that in the future only a great technological jump or a structural reform could allow a new increase in productivity. The success of this concept called Computer Integrated Manufacturing will depend on the way in which all the separate technologies will be connected.

The key to CIM and to reaching economic benefits lies in the understanding of the rules of the game between production objectives, technical components and the organizational structure of the industry.

II.- STRUCTURE OF THE PAPER

This paper intends to give an introduction to some basic concepts involved in the CIM idea and its influence in the developing and industrialized countries. It does not pretend to give all the solutions and answers but possibly to present some of the most significant problems and questions.

The paper is organized in five parts:

Part 1: Gives a short overview of some changes which have occurred in the industrial environment along the years, and tries to evaluate the influence that will cause the introduction of organizational changes and modern automation technologies all over the world.

Part 2: Gives an overview of the basic so-called Computer Aided Techniques (CA-X Techniques), showing the actual trends and the future developments of the whole industrial environment.

Part 3: Gives an overview about the software developments related to the CA-X Techniques, beginning with the Standard CIM Software, following with the existing tools and those under development for the different areas and ending with an introduction to the future developments that will cause a new revolution in the industrial environment: AI & ES systems and Decision Support Systems.

Part 4: The first three parts show the key role that communication will have in all the applications and new developments and therefore this part is devoted to the introduction of the "Computer Esperanto" and the past, present and future standardization work.

Part 5: Gives a short overview of the impact of CIM components in the industrialized countries, and shows also the advantages and possibilities that well planned organizational changes and modern automation technologies could introduce in the developing countries. It ends with some personal ideas about this introduction.

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PART 1

1.- The industrial environment and CIM

1.1.- Historical Evolution

The real history of automation in manufacturing process began in the early 50's with the introduction of the numerical control (NC) just at the time, when a lot of rising industries in developed countries worried about the lack of working forces. Also at the same time a lot of population development studies, specially in Japan, began to advertise about the need to prepare alternative solutions to the fact that in the 90's the young workers increase will not follow the industrial requierements. They trust that the industrial automation could bring a solution to this problem.

Starting with the application of numerical control at the single machine tool level, the development continued with the integration of more than one machine and auxiliary support devices, like material handling systems, tool handling systems and so on. The development of industrial robots occurs practical simultaneously with the Computer based NC (CNC); but although the first industrial robot was developed at 1961, they began to be important for industrial processes at the end of the 70's.

With the introduction of the microprocessor the situation of dependance between the progress in computerized manufacturing and the advances in information technology hardware (storage capacity, data processing time, reliability, cost, etc.) changed considerably and most interest became focused on developments in software and communication aspects.

The logical follow-up at the manufacturing process, is the use of computer technology beginning from the moment of product conception and developing according to market information to its final delivery to the customer.

In contrast with the traditional automation in which chains of inflexible, special purpose equipment has to deal with the mass production of relative homogeneous products, the new automation technology is flexible and applicable to a wide range of machine building operations.

1.2.- Computer Integrated Manufacturing

There is no official CIM definition but the Working group on Engineering Industries and Automation, a subsidiary body of the Economic Commission for Europe selected in the report on Software for Industrial Automation the following concepts for describing CIM:

A closed-loop feedback system in which the prime inputs are product requirements (needs) and product concepts (creativity) and the prime outputs are finished products (fully assembled, inspected and ready for use). It comprises a combination of software and hardware, the elements of which include product design (for production), production planning (programming), production control (feedback, supervisory and adaptative optimizing), production equipment (including machines tools) and production processes (removal, forming and consolidation). (From the Proceedings of the UN/ECE Seminar on FMS in Sofia, Bulgaria).

It is not easy to evaluate the real influence that will cause in the world the rapid technological change introduced by the industrial automation, it is only possible to point out some of the elements that would be surely changed:

- Humanization: individuals will be replaced at insalubre works like: chemical product handle, environmental problems (noise, security, etc.), repetitive work, etc.

- Quality: not only a constant documented quality level could be reached, but also some work impossible to do manually, because of the precision, miniaturization, cleaning, etc. could be realized.

- Reduction of raw material and in process stocks.

- Reduction of production lead time.

- Improved control over the fulfillment of contracts and meeting of deadlines.

- Increased flexibility in meeting market demands.

1.3.- Flexibility and the organizational structure

The most important factor in industrial research has been an aim how to reach higher productivity. Flexibility as an industrial factor has varied cyclically over the years, accompanied by a constant increase in the productivity levels. Without an increasing flexibility almost no industry will be able to reach a new increase in productivity.

But, it will be very difficult to increase the inherent flexibility of modern industrial resources, they are already very flexible. So, the main effort must be directed to reach a better synchronization between elements and between elements and products. In this field an increase of flexibility seems to be possible (a better interrelation, could be reached by changing the physical and/or the temporal distribution of the resources).

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2.- CA-X TECHNIQUES

2.1.- INTRODUCTION

Todays enterprises are "forced" to develop new strategies for production as a result of growing competition on national and international markets parallel with changes in manufacturing conditions from mass-production to customer-specific production. The main requirements are concentrated at higher flexibility of the production process, higher productivity and better product quality.

New developments in semiconductor technology, enabling a broader application of computer systems and automation at the entire production process, were a precondition for many enterprises to approach these requirements.

The rapid development of automation control techniques within the manufacturing process as well as the integration of computers with machines, has led to the application of new manufacturing concepts and strategies, assigned with "CA-X techniques", to a wide range of industries. The main characteristics of these techniques will be outlined in the following points.

2.1.1.- CAD: Computer Aided Design

The design process can be regarded as the starting point within the production process. Several steps of this process (from alternative concepts and evaluations of solutions to the final design of single work pieces), result in the preparation of data for manufacturing analysis as the subsequent area of product development. As a rule the design process is accomplished interactive, integrating economic questions as well as technical alterations, to arrive at an optimal solution.

For the presentation of geometric objects, different models can be distinguished. Starting with two-dimensional forms of object presentation, today an increased tendency towards 3-dimensional presentation (solids) is prevailing, due to the limitations of 2-dimensional models for integrating new manufacturing methods.

At the user interface of a CAD-system the work of designers is supported by several "comfortable" instruments like tablets, light pens or mouse-techniques, combined with a high resolution screens. Already at the beginning of CAD, mainly out of technical reasons, separate workstations have been introduced. Frequently these stand-alone-systems are connected to host computers, whichs function is reduced to the management of geometric data and piece list information.

2.1.2.- CAM: Computer Aided Manufacturing

In contrast to conventional production, where machines are operated manually, according to work plans and drawings, computer controlled manufacturing works with programms, functioning as information-carriers for job instructions and control measures.

The preceding area of design determine the way of machining and assembling of work-pieces or piece parts. By means of translating instructions to a form, understandable for controllers of specific machines, robots or conveyers, a continuous flow of information, from product development to manufacturing can be established.

NC-machines can be regarded as the first components for introducing CAM-methods, starting with punched tapes for information transfer. For attaining more flexible ways of data transfer, CNC (Computerized Numerical Controlled) machines were developed, allowing the direct transfer of machine programmes and their variation or correction at the machine.

A more advanced form of machine organization, a DNC (Direct Numerical Controlled) System, has a number of advantages compared with conventional NC/CNC machines but also disproportionate requirements to control system and software. At a DNC-solution several NC/CNC machines are directly controlled by a central computer, which manages NC-programms and distributes them to single machines. Programming and corrections can be accomplished at this computer, as well as instructions and acquisition functions.

2.1.3.- CAPP: Computer Aided Process Planning

CAPP can be defined as the process of determining the methods and the sequence of the manufacturing operations necessary to produce a finished part or component, according to design specifications and within the available manufacturing facility. Process planning has been usually carried out by qualified and experienced process planners or machines. The creation of a good optimal process plan is largely dependant on the individual skill of a planner and his aptitude for the planning task, his knowledge of manufacturing processes, equipment, materials and methods which are available in his production environment in particular.

NC-programms can be regarded as detailed work-plans combined with instruction functions for numerical controlled machine tools. Work plans describe the transformation of work-pieces from raw material to the final product, including specifications like manufacturing sequences, operating material and allowed times. As a starting point for the preparation of the work plan, geometrical data from the design area are supplemented with technological characteristics of the work piece. As a result, specific work plans (in the case of conventional production) or computer programms (in the case of computer controlled manufacturing) are developed, enabling a consistent linking of CAD and CAM.

2.1.4.- CAQ: Computer Aided Quality

Today, quality is a competitive factor and thus decisive for the market position of an enterprise. Quality insurance and maintaining can be seen as an integrative part of the production process, from inspection of materials via monitoring of manufacturing to final inspection of products.

Quality ensurance procedures become more and more computer controlled, allowing rational and assignable association of quality data to certain products, as well as the determination of trends of quality specifications. In many cases monitoring and analysis by means of measuring equipment like sensors or gauging machines is accomplished automatically. Parallel to hardware also the planning of monitoring processes can be optimized by means of computers, analogous to manufacturing planning.

For planning of quality ensurance functions, a number of methods have been developed in the fields of statistics and operations research. In general a tendency towards integration of quality ensurance into the manufacturing process can be observed (for example, if quality ensurance consists of checking weights and capacities). If computer aided planning of measuring and testing is supported by administrative issues, the test program represents a part of the workplan for production planning and scheduling. For the storage of test programms, separate systems can be used, or these plans can form a separate cycle within the manufacturing workplan.

2.1.5.- CAP: Computer Aided Planning

The application of production planning and scheduling systems (like materials management or calculation) started already when other C- techniques like CAD-CAM were still at the development stage. Although they can be regarded as a classical field for electronic data processing within an enterprise, there do still exist a number of obstacles during the implementation phase. The required complex structure of the systems, as a consequence of the demand to cover the entire production process, frequently necessitates company-specific solutions.

In general the concept of production planning and schedulling sytems is based on single planning stages succeeding one another, with a temporal and logical termination, supported by basic data-management tools. These tools supply materials and time management with master data, which allow the working out of the manufacturing plans as a basis for the controlling of the manufacturing process. Parts lists management and work schedule combined with (groups of) operating material form not only the basis for planning and controlling but also for the calculation of products.

2.2.- Actual Trends

Within a Computer Integrated System two fundamental types must be defined: those where a new development could be made on-line (using simulation, automatic program generation and others) and those where it could be done only off-line. A third possibility could be one where the tasks needed for new developments are planned and scheduled like any other job. This means an "on-line off-line" development. This normally decreases the flexibility of the system, because although the process is not stopped, the resource being programmed has to be disconnect. For the system it looks like a total breakdown of this resource.

2.2.1.- Control levels

Industrial systems are continuously varying and therefore the development and application of DYnamic Control Optimization mechanisms (DYCO) and not static ones will be necessary. By this systems, manufacturing sequences, paths and duration of cycles are to be controlled on-line. The previously determined sequences can be corrected while manufacturing is progressing. In addition, error detection and correction is a necessary feature of the control system.

Different levels of control of a system could be defined:

a) Electronic control: this is the level where the direct control of the electronic is realized. It has no intelligence by itself, but a high reaction velocity, so as much as possible must be controlled at this level. Normally this control is done by devices like PLCs. As an example, in a robot this level would control the motors and input/output signals.

b) Hardware control: based on a limited logic and a group of control algorithms the first decision will take place at this level. The most important feature of this level is to realize a good filtering of the variables to pass only that one useful to the upper control level. Normally this control is done by the dedicated controllers included in each machine.

As an example at a robot where the point to reach and also perhaps the way to reach it is known, the controller must resolve which movements must be done by each axis and transduce this to the necessary signal for the motor.

c) Data transfer control: this is the first level where some intelligence is needed and also the first one affected by the production planning and schedulling. At this level there is a great part of the flexibility of the system. The function of the controller here is to control the resources. This means, for example, to load and unload programs from local memories, or to follow the elements being moved and also to secure a correct transfer of information without collision problems or time problems.

For the controller the elements will no more be robots or transport systems or some specific devices, they must be only resources or objects with a determined group of characteristics. This will no more define hardware details but a set of programs that could be done, the time they need to do them, how much each costs, etc. Normally micro- or mini-computers could be found at this level. An example could be a micro-computer distributing programs from the central memory unit to all the machines with no collisions, or by requirement of the upper level showing the state of each resource and each job being done

d) General control: this is the fundamental level of the system where functions like control of a consistent functioning of the resources (each one must have what they need), resolve dynamically the fail problems that may appear, realize the alternative analysis in case of a variation on the goal schedule and control the communication of a cell with the "world". In order to secure the readiness of elements it will need to continue functioning.

Most of the parts of the cell like expert systems, simulation modules, management decision support, etc., will be located at this level. Also this is the level where all system functioning modes differing from the automatic mode, like starting mode, degraded mode, ending mode, debugging mode, etc., must be analyzed and "well done".

e) A number of studies have shown the enormous interdependence between system functioning and external world. The long time suppliers require to sell products, could annul all the efficiency of an Industry. A large stock is also not a solution because its cost would also annul the decrease achieved by the use of organizational changes and automation technologies.

Perhaps the only solution will be in the future to generate a higher level that includes relations among the industrial participants. The future could most probably require a JIT-production and management system that includes all parts and even raw material suppliers, linked together by a communication network.

2.2.1.- Robots, Transport and inventory

In a similar way as CNC/DNC machines are controlled by computers, robots or transport and inventory systems can be integrated into the production process. Today in many cases the use of robots within a CAM-system is limited to machine loading/unloading or the repetition of a certain sequence of operations (example: welding at the automotive industry). Solutions utilizing the full flexibility of a robot, combined with sensor applications, off-line programming and Artificial Intelligence methods, allowing the execution of variable/new orders, are still realized at laboratories or as prototypes at some large factories only. Especially at the assembly sector, where products with many variants and in small batches (but at the same time at high quality standard) are to be assembled automatically, sophisticated robot-systems have to be introduced.

With regard to computer aided transportation and inventory, some industrial applications have reached a high level of integration. Combinations of automated transport and inventory systems can help to improve factory logistics, aiming at a reduction of transport and buffer times. As a result, the flow time of orders can be reduced in a high degree.

2.2.3.- FMS: Flexible Manufacturing Systems

Developments in the NC-techniques sector have mainly been concentrated on the machining (cutting) sector, resulting in the introduction of Flexible Manufacturing Systems (FMS).

This could be seen in one early definition due to Kearney and Trecker is: " FMS combines the existing technology of NC manufacturing, automated material handling, and computer hardware and software to create an integrated system for the automatic random processing of palletized parts across various work stations in the system".

Today, many researchers consider that FMS is an approach to a particular set of manufacturing problems rather than a single technological configuration. The Economic Commission for Europe attempted to define it in 1986 as "an integrated computer-controlled complex of NC Machine Tools, automated material and tool-handling devices and automated measuring and testing equipment that, with a minimum of manual intervention and short change-over time, can process any product belonging to certain specified families of products within its stated capability and to a predetermined schedule". This definition includes the human element, although making clear about the tendency of the international efforts to reach an quite unmanned FMS.

Although the idea of FMS has been created almost twenty years ago, it started to be of significant interest to the research community at the early 80's. This can be measured by the number of books and papers published and the conferences helded (IFS Publishing Ltd. and North Holland Publishing Co. have annually published proceedings of the International Conference on FMSs since 1982).

FMS can not be regarded as a new technology, which can be installed and operated like traditional machine tools, aiming at a reduction of labour costs. FMS is rather a new philosophy, utilizing data processing methods to "transfer" the advantages of industrial scale production also to small-lot or job-production. The decisive factor "flexibility", characterizes the ability of the system, to be automatically adaptable to different manufacturing conditions (products) at minimal set-up times.

Assembly systems and Machining Systems have many common problems, such as control and scheaulling of material flow or the importance of distributed storage of Work-in-Process or the difficulties in predicting performance. Altough, they must be analyze separately and whith different theories and mechanism, because they utilize different time unit for the system analysis.

Until now, practically all the FMS models were developed for machining systems, the reason being probably, the high costs of such systems that enable financial support by the industries. This holds for most of the investigated problems, like machine balancing, aggregate planning, resource grouping, etc. all of them applied to large industries only. It is important to make a differentiation between FMS's, because the development of new machining centers have progressed so far that all the cell work is done inside the machining centers. This transforms the cell problems into internal machine problems.

The main components of a FMS are:

- CNC/DNC machine tools or machining centers,

- automatic transport and handling devices for tools and workpieces,

- measuring/monitoring systems (integrated or as separate machines)

- central computer for automatic control of all FMS-components (CAM), linked with preceding areas CAD, CAP via Local Area Networks (LAN).

2.2.3.1.- Types of FMS

Some of the most important FMS types are:

a) Flexible Manufacturing Cells: Several machine tools ar interlinked and operated according to a fixed process sequence. As a simple version a single machine tool is linked with an industrial robot for loading and unloading workpieces from a transport pallet to the machine tool.

b) Flexible Manufacturing Systems: these systems consist also of several machine tools or machining centers, but beyond that, of software capacities which allow a variable and optimized feeding of workpieces. Equipped with a central computer and algorithms for parts identification, automatic set-up etc., a high degree of flexibility can be attained, enabling the economic production of small lots.

c) Flexible Transfer Line: Similar to conventional transfer lines operations are accomplished at a "rigid" street, according to a fixed sequence, and applying special machines at different working places. Different to conventional solutions, at Flexible Transfer Lines machines are numerically controlled and linked with a central computer.

2.2.3.2.- FAS: Flexible Assembly Systems

Assembly as a part of the production process obtains a central position in production if short processing times and at the same time low in-process supplies are to be realized.

Technical conditions for obtaining these aims can be provided by means of flexible assembly that can be regarded as one ot the main bottlenecks in the manufacturing process. By integrating flexible assembly into this process, linking areas like computer aided design, production planning, parts manufacturing and quality control with the assembly area, organizational conditions are provided.

The main requirement to assembly, including transport of parts to and from the system, feeding, inspection etc. can be outlined as follows: Flexibility has to be increased in those assembly areas which apply specific methods and techniques for manufacturing of different products, not being regarded at the planning stage of the plant. Otherwise an assembly cell has only limited flexibility and can be used for a certain amount of variants of a certain product only.

The configuration of assembly components has a direct consequence for the realization of this principle. The Technology Oriented Stations concept, that could be found in %%%%, represent one possible configuration of the assembly components in a FAS.

2.2.4.- CAP Methods

In the middle of the 70's a lot of Japanese companies began to experiment and adopt a whole range of new manufacture management approaches (developed in the 60's at the Toyota company in Japan), for improving overall productivity and eliminating waste. This new approach was first called "Ohno System" (in honor to Taiichi Ohno, mastermind of the system by Toyota), or simply "Toyota Manufacturing System". Trying to find a "better" name, the idea was mostly incorrect named. Some examples are "Kanban System" (referring to one of the main elements of the system that was a pull schedulling technique using kanbans, container in Japanese), "Zero Inventories" or "Stockless Production" (referring to the stock reduction, but a misnomer since no process can run without stock), "World Class Manufacturing" and "Continuous Flow Manufacturing". Actually, the most correct term that has become most widely used is Just-in-Time/Total Quality Control (terminology from R.J. Schonberger).

2.2.4.1.- Total Quality Control

During the first half of the 20th century customers expected to pay extra for quality. However in the competitive business climate of the late 80's, quality is no longer an option; it is a positive requirement without which an organization cannot survive. Companies deciding to embark upon the "Total Quality Road" will reap great rewards like improved productivity, committed customers or improved certainty in operations. However, one of the decisive factors to achieve results like these, is through commitment by management, starting with the chairman. Total Quality must be management-led, company-wide in implementation, dedicated to continuous improvement and the responsibility of every employee.

The new style which has emerged has three basic features. First, "customer-oriented", everything is driven by customer needs. Next, it concentrates on managing the "process" in the business, which deliver to these customer needs (like products, services etc.). Third, it focuses on the "people" who work the process, inspiring and empowering them to produce even-better results for their customers. Thus, Total Quality depends on total organization. It relies on every individual passing on quality parts, quality services and quality information to the next individual.

Following these statements, Computer Integrated Quality - CAQ, as already outlined, can serve as the technical presupposition for meeting the requirements of Total Quality. The integration of these two ways of approaching higher quality, from the technical side and from the management side can be regarded as the key to a CIM-oriented quality strategy.

2.2.4.2.- Just In Time

The key philosophies of JIT are simplification and continual improvement. It is an approach for the cost-effective production and delivery of only the necessary quantity of parts, at the right time and place, at the right quality, while using a minimum amount of facilities, equipment, materials and human resources.

JIT is dependent on the balance between the supplier's flexibility and the user's flexibility. It is accomplished through the application of elements which require total employee involvement and teamwork.

Prof. C.A. Voss in the preface of Just-in-Time Manufacture, ranked the main benefits of JIT in the UK as: Work In Process reduction, increased flexibility, raw materials/part reduction, increased quality, increased productivity, reduced space requirements and lower overheads.

He also grouped the most important techniques and approaches associated with JIT, in three main areas: Manufacturing techniques, Production/Material control and Inter-company JIT. The following points gives a short description of these main areas.

2.2.4.2.1.- Manufacturing techniques

a) Set-up time reduction: like Shingeo Shingo's SMED system (Single-Minute Exchange of Die) that introduces the concept of external (off-line) set-up times in order to reduce the internal (on-line) setup times.

b) KANBAN or Pull Schedulling: by the Kanban system the preceding production stages generate new manufacturing orders, just when its stock of finished products has come down to a safety stock quantity. In practice, by means of special transport KANBAN-containers the supply of material is organized for a predetermined amount of piece parts. Thereby each container carries his order-card, showing a specific parts quantity. By handing over this card, the planning process can be realized. In this way the last production stage determines the further "suction" of products into manufacturing. The successful introduction of KANBAN is closely connected with two requirements to production: high stability of production quantities and high quality standards.

Other principles also associated with pull schedulling include the principle of the use of the smallest possible machine, the "preventive maintenance", the "Poka-Yoke" (Japanese for Proof-Mistake, consisting of foolproof devices, like checklist, to prevent unadvertised mistakes and defects), the automatic stopping of the production equipment when abnormal conditions are sensed or occur, etc.

c) Cellular manufacturing: including group technology.

2.2.4.2.2.- Production/material control

a) JIT-MRP: MRP (Materials Requirements Planning) and JIT can, with some changes, mutually support each other.

b) OPT (Op imized Production Technology): a scheduling technique developed in Israel to allow JIT production in an environment characterized by complexity and known bottlenecks.

c) Schedule balance and smoothing: using techniques like "Under Capacity Scheduling", "Visible Production Control" or "Load-oriented Release of Orders" (based on the principle that only a certain amount of those orders are released, which can be manufactured within a certain period. As a result a more "anticipating" release of orders can be attained, preventing an overload of manufacturing with subsequent high inventory and processing/machining times).

d) Simultaneous material and time management: at traditional production planning and schedulling system, material and time management are not connected sufficiently. As a characteristic of the simultaneous method, critical orders are released first by forward-termination, getting a higher priority in relation to other orders. Afterwards non-critical orders are adjusted to fixed terms by means of backward termination. As a result, the entire order system can be reduced to manufacturing orders, probably increasing already existing bottlenecks and orders to be allocated to non critical capacities.

2.2.4.2.3.- Inter-company JIT

a) JIT-purchasing: application of the JIT principle on an inter-company basis, requiring that goods are supplied in small quantities, exact amounts, at frequent intervals and at 100% quality. The techniques utilized include single sourcing, use of standardized containers, supplier quality certification, point-of-use delivery, family of part sourcing, purchasing Kanban and above all mutual trust.

2.2.5.- Layout planning and simulation

The layout planning process has to be supported by Computer Aided Methods for ga ing high productivity with capital intensive manufacturing uipment like FMS. Which kind of manufacturing organization would yield optimal results for which part program has to be analyzed. Not only isolated manufacturing units but "cooperating" cells and systems are to be investigated by means of a simultaneous planning of all components and operations involved. Different variants of layouts and capacities have to be analyzed, aiming at the optimal solution.

Computer simulation can be regarded as a rational way of optimizing the planning and in a more advanced form also the operation of complex production plants. It is an appropriate tool for investigating component lccations, inventory sizes, transport ways or buffer-capacities. Simulation allows the quantitative determination of different objectives, dependent of the structure of the plant and the system-parameters. Different variants can be contrasted and valuated. Subsequent to the definition of the system structure, simulation supports also the location of maximum operation levels and the optimal layout of the plant control-system.

Simulation methods are mostly used as a means of layout planning only, but they will have to be integrated more intensively into the entire production planning process, as an addition to production planning and schedulling systems. As an example, the simulation of different orders, could show at an early stage, when and where bottlenecks could occur, and an optimal solution could be found without interrupting the real production process, by computer-supported investigating of different variants of orders and machines.

2.2.5.1.- Analytical and evaluative models

Traditional batch manufacturing systems were criticized because of the elevated levels of Work-In-Process (WIP) and because the jobs spent most of the time "waiting for something to happen to them" (WFS-Time). These two elements depend strongly on logistics and planning and scheduling (P&S) and also on the hardware and its layout.

Some very interesting advances were made in order to reduce the WFS-time, for example in the machining area, a better understanding of the internal and external setup times (see SMED or POKA-YOKE) or the CAD/CAM coupling.

In the same way techniques like JIT, or the new possibilities opened by simulation programs, give ways to reduce the WIP levels.

These new techniques provoked developments of Flexible Manufacturing Systems (FMS) models, using operational research theories for performance evaluation and programming, and control theory for the development of scheduling and operating procedures.

Simulation models are of great value for evaluating specific systems designs, but analytical models are superior in terms of the amount of insight which they give. They enable the key parameters and their influence to be clearly identified and suggest directions for system improvement. The extent of abstraction from the real system which must be made in order to solve them, generate normally slow developments, although they can lead to significant improvement in our understanding of how complex systems function.

The analytical models that have been developed enable the establishing of basic design problems and provide insight into a number of key design issues, such as central versus distributed storage or machine grouping. They have been use to address some wider issues such as the meaning of flexibility or the value of dynamic routing and schedulling.

The analytical models can be used also to determine how the overall production capacity of the system is affected by the product-mix, the number and capability of the resources, the lot-sizes, the number of pallets, machine breakdowns, etc. This makes the models very useful at the preliminary design stage when it is desirable to determine the main features of the system.

Some of the main models used to evaluate FMS performance are:

- Static allocation models for feasibility and sizing studies.

- Queueing network models for interactive preliminary decision values for design and operation problems.

- Computer based discrete event-simulation for a more detailed decision values for design and operation problems.

- Perturbation analysis for fine-tuning, efficient and real time values for design and operation.

- Extended Petri nets for design, operation, modelization and real time control of the system.

2.3.- Future Developments

2.3.1.- Machining sector

The machining sector is the most advanced area within enterprises. But it is limited on the one hand to a few manufacturing technologies (like turning, milling, grinding) and on the other hand, in many cases, to a mere NC-programming. CAD/CAM has not truly fulfilled its promise and the underlying reason is a lack of communication among CAD-systems, CNC-machine tools and coordinate measuring machines. While there is certainly communication between CAD-systems and CNC-machine tools, this communication is limited and there is virtually no communication anywhere else.

Future developments at the machining sector will not focus on machine tools only, but also on the communication side, fixturing and tool monitoring, the integration of measuring tools and the application of knowledge-based systems. The communication side will be discussed in an other chapter.

2.3.1.1.- Fixturing

Numerical control of machining paths do not account for the position of the part on the machine tool. That means, the part must be "locked" in a specific position by the fixture, a specialized fixture unique to the part must be created. To meet these requirements, product-specific fixtures are to be designed and manufactured parallel with the products to be clamped and organized like specific tools of the machine. Fixturing has to be integrated with tool-management, with similar monitoring and identification devices. The development of "fixturing- standards" for workpiece-families could help to reduce the high expense combined with "CIM-oriented fixturing".

2.3.1.2.- Machine tool managment

Critical to unmanned machining is tool management. Unmanned machine tools require a considerable number of monitoring systems in order to operate effectively. This is the case in areas like tool wear monitoring, identification of tools, setting tool offsets, error correction caused by thermal drift etc. Some form of sensor has to be included in the system whatever the monitored function requirements will be.

As one answer to some of these requirements, a so called "intelligent" tooling approach was introduced, applying microchips memories (as a read/write facility) embedded into the tool holder. The organisational integration as well as the full utilization of the advantages of this approach for an optimal tool management has not been realized to a high degree yet.

2.3.1.3.- Monitoring, sensing and controling

Adaptive control is another field of interest, related to unmanned machine tool systems. It describes the in-process adjustments of operating parameters, such as spindle speed or more usually feed rate based upon the actual process characteristics. Two main adaptive control systems can be distinguished: adaptive control optimisation and adaptive control constraint. There exist some advantages of the second, so called "tongue controlled" system. This makes up a feed-back loop in which continuous monitoring by sensors and updating of the CNC using adaptive control, produces optimal cutting conditions for the combination of the tool and the workpiece.

For any unmanned machining operation it will be essential to provide an in-process tool-breakage sensing system. Tool breakage detection using the acoustic emission principle is now emerging as a reliable method, applying the direct piezoelectric effect.

It is all very well having a sophisticated cutting tool monitoring system, but some care has to be taken over workpiece identification, set-up and gauging. During the machining time there are a number of ways in which the parts quality can be assessed: In process gauging (mainly used in grinding applications) or in-cycle gauging (on turning and machining centers within FMS). One method used to overcome the errors in the machine tool by form of a compensation, is to use the so called "footprint" method of part inspection. Another method, which can be denoted as a still controversial one, is the "deterministic metrology technique", which predicts and corrects for errors, based upon trying to anticipate any machining errors in real-time situation and therby correcting them. This technique is still as yet confined to the laboratory, but it will have a considerable impact on work measurement and its control.

Apart from all the diagnostic sensing devices used to monitor the machine tool, there is a variety of other sensors to maintain a "status quo" of consistent part quality. For example, thermal sensing is used to compensate "machine growth" caused by heat in motors and bearings. It is possible to close-the-loop by feeding these errors into the machine tool, allowing for more consistent part quality.

Monitoring systems like those outlined, cost a considerable amount of money and are an indirect production cost. But such systems are necessary as a result of the lack of human involvement in the machining cycle, to achieve high quality products, as a step in the direction of "zero defect quality".

2.3.2.- IR, assembly and sensor technology

2.3.2.1.- Industrial Robots

The International Organization for Standardisation proposed the following definition: the Industrial Robot (IR) is an automatic position-controlled, reprogrammable, multi-functional manipulator having several degrees of freedom, capable of handling materials. parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks. It often has the appearance of one or several arms ending in a wrist. Its control unit uses a memorizing device and sometimes it can use sensing and adaptation appliances that take account of environment and circumstances. These multi-purpose machines are generally designed to carry out repetitive functions and can be adapted to other functions without permanent alteration of the equipment.

Industrial robots were originally developed for handling and process application. The control principles used were pure positional or path control from taught or preprogrammed action pattern and this concept has dominated until today.

2.3.2.2.- Assembly process

The final result of an assembly process depends on the quality of the parts to be assembled and of the correct performance of all operations. Every part must be gripped, transported, fed, inserted and joined so that the final result fulfills a given function within its tolerances. It is of great importance that the parts are positioned in the gripper within given permissible tolerances to permit the consecutive suboperations to be correctly performed. Even if parts to be assembled have the correct quality, an unfavorable turn-out of the dimensions may make the fitting impossible or give a faulty result.

2.3.2.3.- The IR in the assembly process

A robot work station with magazines,fixtures tools and workpieces is not allowed to vary outside given tolerances. These are given by for example: fixtures, implies magazines designed to each specific workpiece, or tools and workpieces which have to be manufactured with close tolerances to avoid uncertainty of part positions. Unexpected states during program execution are not allowed at all.

Robots have a limited positional repeatability and could be affected by wear resulting in drift. The same thing holds as well for other system components. Thus there is a need for supervision of the different stages of the process by means of sensor technologies.

2.3.2.4.- Tactile Sensing

Optimum sensor compliance is a severe problem in factory floor applications of tactile sensor arrays. The human skin has the ability to adapt its compliance to the grasp of an egg as well as to that of a brick. To mimic this remarkable property in a tactile sensor implies high complexity as well as high cost. In industrial applications, different tactile sensor arrays have to be used, with different degrees of compliance, for different tasks: one type for the egg, another type for the brick.

For a future extension of the range of application, tactile sensing should be combined with other senses, vision but also proximity sensing, if the function of sensor-controlled adaptive robot is to be optimized. The sensor units must be easily and rapidly inter-changeable. The combination of several senses (sensors), results in synergetic effects when compared the use of a single sense, even if the latter is of outmoust sophistication (e.g. 3D-vision).

Today, many laboratories working in the field of assembly automation are engaged in the development and application of sensor technology. In spite of this engagement only few sensor-based solutions (single sensing) like vision-systems are applied for practical use in industry. As a main obstacle to a broader application of sensor-technologies, the lack of communication support as well as suitable/standardized sensor interfaces to robot controllers and users should be mentioned.

Future developments in this area should be concentrated on:

- the improvement of robot control systems concerning sensor signal processing.

- the improvement of integration capabilities of sensors and robots,

- the development of task-oriented strategies for evaluating sensor signals for systems programming and process-guidance.

The integration of sensor-guided assembly with industrial robots into a CIM-environment is very far from realisation today yet. It will take a couple of years to reach standard solutions, allowing to introduce structures at the assembly area, at a similar level as already attained in the machining sector.

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3.- SOFTWARE DEVELOPMENTS: PAST, PRESENT AND FUTURE

The optimal selection of the Software elements for an Industry is a technical prerequisite for successful implementation of integrated automation, sometimes even more important then the installation of powerful hardware.

Like most of the CIM related technologies and tools, a software solution require a prior complex analysis of the Industry. The omission of this step will result in the incorporation of existing organizational deficiencies into the software solution to be elaborated. Expensive trials on the shop floor can be minimized by taking full advantage of the opportunities of modelling.

The selected software must be capable of operating under both regular manufacturing conditions and adapting to emergencies. the success of integrated automation depends on the clearly defined hierarchical classification of responsibilities and tasks in the management process. The tasks should not be adjusted to the existing management structure, but vice versa, the management structure should be adapted to the tasks.

3.1.- Flexibility and Software

In the last years, it was easy to see a reduction in lot-sizes, an increase in the complexity of the required manufacturing techniques and at the same time in the number of product variants, and also the need of a fast reaction to market changes. All these changes could be resumed in the saying that the production began to be more and more flexible.

The concept of flexibility is usually associated with the capacity of a production system to adapt "correctly and quickly" to alternative constellations. Two types of flexibility can be distinguished: Dynamic flexibility, which determines principally the term "quickly", and static flexibility, mainly responsible for the term "correctly". A production system can adapt itself to several product variants by means of the control system. The greater the number of different variants, the greater will be the chance for the system to achieve economic solutions for new products. Thus, flexibility can be regarded as a dimension of different variants, co-existing in a production system.

According to the tenets of control theory, the complexity of a system and thus the time necessary for the computation of a new solution increases exponentially with the number of alternatives. This means that the complexity of a software structure, used for achieving the dynamic optimal solution, increases exponentially with flexibility. Although most of the systems could actually be guided to a dynamic optimal solution with traditional methods (as system flexibility increases), software control structures become more and more the key to the optimal functioning of the system.

3.2.- The "STANDARD CIM SOFTWARE"

There does not exist a static problem in the production system. When increasing the productivity by solving a problem, at the same time the structure of the factory changes and so a new system has to be analyzed. This means that there is no solution that allows you to reach a higher productivity level, without at the same time, confronting you with a new problem that needs to be resolved.

A static industry is a dead industry, thus the only solution is a continuous looking for new solutions. There is no such thing like an "off-the-shelf" software package unless there is a standard factory. But there does not exist something like a Standard Factory.

There is no sense by trying to find a standard software package for CIM. With enough money a special development adapted for a factory could be made and it will be an optimal solution until it is installed, because at this moment the structure will change and so also the software package will need to be changed.

The problem will be always the same: to operate a flexible production system that reacts dynamically to the market requirements, a flexible software package and not a static one would be necessary. But, what does it mean to have a dynamic, flexible software system?. It means that the system will be only a decisions support, only a tool that will allow, to reach an answer to the questions in a faster way or to increase the working speed in some special areas of the industry. These two possibilities are given by: decision support systems for the first one and specially developed software tools for the second one.

3.3.- Software tools

It is not in the scope of this paper to make a survey of software developments for industrial automation. Only a survey about the areas where software tool could be applicable will be given (mostly based on the document of the Economic Commission for Europe, about Software for Industrial Automation).

3.3.1.- NC Tools

The Numerical Control (NC) programs prepared manually in production planning are very rarely used nowadays. Considerable importance, especially with respect to unattended manufacture, is being given to the computer-aided NC-program generation.

The main areas of software for Computerized-NC (CNC) are:

- Function databases that allows a geometric information processing, for a easy use of complex work processes (e.g. given only two points and the ratio, generating the corresponding circle sector).

- User interface software that could guide the operator in conversational mode using windows and menuing techniques or symbolic programming,and also a graphic support as a help for understanding the work.

- The service software, for support of diagnosis and maintenance of data input/output control.

- The adaptative control software for controlling the influence of continuously varying process parameters (e.g. temperature, forces) and also for tasks like prediction of tool failure.

The development of Direct NC (DNC) was initiated to make possible the control of machine tools from a central computer, using the time sharing capacity of the digital computers. The most important element by the DNC software is the data transfer. This transfer could occur between the computer, the NC-machine, the programming device and other different functional complexes of the system.

Future developments in this field will allow a better utilization of the CAD/CAM systems for NC-machines. a better interrelation between the NC-machine and the hole production by on-line communication, and also the integration of process-accompanying monitoring systems.

The next step in this development is to have groups of NC machines, acting as one optimized flexible machine, controlled as a single unit.

3.3.2.- IR Tools

From the given definition one of the most important areas for software application by the IR is the programming of the device. Programming could be done manually with the help of mechanical stops or hard-wired control, or it could be done with the help of microprocessor based systems.

Using microprocessor based controllers, programming could be done in form of a teach-in programming where the user moves the IR to the successive wanted positions and the system memorize them, or it could be done by a classical programming method similar to those used by general-purpose computers. For this classical programming several languages have been developed (almost each robot manufacturer has one), some adaptation of existing languages have been done (e.g. Pascal or C) and some of the existing are also beeing used (e.g. assembler languages).

The actual trends in IR-Application software are basically:

- rational programm generation through the utilization of high-capacity computer techniques,

- reduction of the unproductive idle time of the IR,

- integratior into CAD/CAM systems,

- automatic programm generation,

- self-optimizing IR with the help of sensors (e.g. vision systems).

Special problem oriented programming languages are designed to minimize the demands of programming, using high-level commands or macros, similar to those normally used by a man during assembly, and at the same time to retain all the powerful properties of high-level languages. Different approaches are based on operator/system dialogue with a special operator panel and it can be supplemented by a camera and a screen for object identification. This kind of languages requires further developments in fields like environment-description modelling or decision making methods.

The current highest level on robot programming is represented by the off-line programming languages. They may be seen as a task of technological planners using techniques for the description of manufacturing systems. The aim of these developments is to transfer the programming activities to the technological planner and to ensure that the programmes thus developed can run in the production process with minimal changes. Graphic simulation when used with a mathematical description of the robot environment and the kinematic of the involved elements, is a tool which can be applied effectively for preventing collisions.

3.3.3.- Material handling and transportation tools

This field includes Automatic Guided Vehicles (AGV), automated storage systems and integrated storage and inventory control. The main concept of this kinds of tools are:

- to collect and maintain the information about the material flow

- to answer questions about the location, the quantity or the status of the materials in the factory

- to calculate and optimize the material routing.

The objective of such systems is maininly to perform a service to other software packages, transforming planned material movements at the model level into material movements at the real world.

3.3.4.- CAD Tools

Two dimensional CAD systems permit the creation of drawings of both primitive and parametric objects, using broken lines, points, circles and ellipses and provision can be made to include special attributes related to the objects. With these systems it is possible to solve plane geometric tasks, work with text, work with libraries, to do archiving and also to do transformations such as shift, rotation and affinity.

The world trend goes towards systems using UNIX as a base, because it permits simultaneous interactive execution of extensive tasks; and also towards three-dimensional systems which permit, by means of the volume-elements method, the execution of calculation and plotting tasks as well as automation of plane and special geometric tasks.

An important component of CAD software is to handle data-base management. In this regard, many complex software systems are being developed on the basis of the users own CAD software. Such systems tend to be specialized for certain product areas. The systems have the advantage of being compact, but the disadvantage of incompatibility and narrow specialization.

Actually the main efforts are being done in making three-dimensional systems faster and cheaper with special regards to the required hardware.

3.3.5.- CAM Tools

The CAM sytems uses construction and technological data to produce order-independent manufacturing documents. Also production organization data are elaborated on the basis of construction and technological requirements to provide order forms at the due date, specifications on material and manufacturing equipment at the proper time, as well as other documents required for planning and disposition of parts.

The current development efforts are directed towards improving:

- the adaptability of CAM software to various computer and user environments,

- the capacity of software for the handling of operating data, and

- the structure and generation of centralized and distributed database systems.

In the last years, the interaction between CAD and CAM software received a lot of attention and there exist a lot of products in the market that allow the direct generation of machine programs using design data. This kind of traducer is normally called post-processor and it allows also the use of mechanical simulation modules on the CAD specific hardware.

3.3.6.- CAPP Tools

There are two main approaches to the automation of process planning, the variant and the generative approach. The variant approach can be defined as the preparation of the process plan through the manipulation of a standard plan or of the plan of a similar part. From the other hand, the generative approach is the logical creation of a process plan from information (rules), available in a manufacturing database with little or no intervention by a planner. They require the use of a set of inferential and/or heuristic rules which, applied on a factual database, allows to solve problems (Expert Knowledge Systems). A combination of the generative and the variant approach could also be found.

The application of CAPP software can be divided into three principal areas:

- Production-process design, working either on the basis of type or group technology or on the principle of multilevel synthesis from elementary standard elements of technological processes.

- Programming of NC-machines using special languages for the technological rationalization of the production process and graphics to speed up the work and for simulation purposes.

- Automated design and technological preparation of the production of special manufacturing facilities, where practically all types of tools are designed by computer.

3.3.7.- Database managing Tools

CIM is a concept that relies on a common manufacturing data base for production planners and schedulers, shop-floor workers, accountants, etc. and a clearly structured information system that effectively links all main functions of the factory: engineering design, manufacturing planning and control and factory automation.

The database is a central element within a CIM system. Different types of data (geometric, technological,organizational, etc.) used by different modules to solve given problems must be systematically classified and controlled.

The database software, controls the long-term recording, management and handling (local and remote) of all data. Data transfer between the functional modules of the system is performed via the system interfaces. The result is the logic interlinking of communication modules and the data files. These system interfaces are of particular importance for integration measures.

The actual trends are concentrated into the relational and the object oriented approach to database management.

3.3.8.- CAP Tools

The traditional CAP method is to calculate always a goal schedule. This goal schedule is normally of high complexity and quite always arrives at suboptimal solutions that require an enormous computational effort. This kind of method produces an inherent limitation in industry that is: the goal schedule will only be recalculated if the variation is very great.

So the traditional system works normally at an "Adapted" (inferior) level of a suboptimal solution; this shows the necessity of new P&S structures.

Two types of scheduling could be defined: Long Time Scheduling (LTS) and Short Time Scheduling (STS).

LONG TIME SCHEDULING: This kind of Scheduling is usually based on the required work, the industry knows with a great time anticipation. This comes from the batch style systems, where the producer fixes the minimum time before an order must be solicitated or he works on stock.

There are a lot of different production planning systems, that more or less allow a LTS. But, one of the changes CIM must introduce is to reduce drastically the involved time periods. The unit of LTS must be reduced from years and months to weeks and days.

SHORT TIME SCHEDULING: This is the level where a fast reaction is needed when the internal or external variables change or even the model parameters change. The only way to reach the solution by a fast reaction, is not using all the existing information in a centralized way, the reason being that computational efforts will surely not be enough. In most of the cases the information that could be treated locally is very limited because it is not easy to know the way it affects other areas. A possible solution to this could be the use of expert systems. They allow to find rapidly an information structure and this permits to distinguish between fundamental variables that must be sent for a central analysis and those whose influence could be analyzed using local heuristic knowledge in order to send a kind of resumed variable only to the central control. Also the expert systems allows the early detection of failure causes (for example to find a degraded function of a robot, based on the power consumption of a motor), which enables a reduction in the number of errors tending to the ideal Zero Quality Control.

An introductory idea to a STS System could be found in %%%.

3.4.- Artificial Intelligence

Artificial Intelligence could be defined as: The study of computer techniques to supplements the intellectual capabilities of humans in order to realize a more effective use of digital computers through improved programming methods. Related to the use of AI we could define it as: The ability of any machine or routine to learn and improve its performance as a result of the repetitive execution of a given activity or search for solutions to a given set of problems.

Conventional data processing techniques and AI techniques are complementary in the manufacturing field and they address different classes of problems. Nowadays it is known the fact that any actual or future manufacturing facility would collapse without a high level of support from conventional data processing and possibly in some years the same will be valid for the AI techniques.

The initial intention of developing universal mechanism and theories of intelligence for problem solving has been postponed, at least temporarily, in favour of systems that function in narrowly defined domains with very restricted task specific knowledge.

As knowledge processing develops, Artificial Intelligence might be of help to overcome some of the difficulties of the organizational area by building Managerial Decision Support Systems (DSS). Therefore, the basic processes have to be understood and capabilities and conceptions have to be evaluated.

Many consultants are used already today as an excuse for not taking up the responsability of decision making. There is the danger that automated systems could serve in the same way if the role of Support of the DSS is not well understood. Taking the part of an expert in automation-aided consultations, they would only assist and advise the user in problem solving.

3.5.- Expert Systems

Professor E. Feigenbaum a pioneer in the AI field defines an Expert systems as: an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. A ES consists basically of:

- A knowledge base or knowledge source of domain facts and heuristics associated with the problem

- An inference procedure or control structure for utilizing the knowledge base in the solution of the problem and

- A working memory or global database for keeping track of the problem status, the input data for the particular problem, and the relevant history of what has been done.

Expert systems are designed for automated problem solving in special applications, where the applied knowledge of experts of a specific field is transferred to computing systems. Also expert systems in form of DSS, would assist human experts to free them from their routine jobs and let them concentrate on the more difficult ones, at the same time expanding their expertise. They might give also the possibility to preserve the Know How of a human expert and make it available at all times.

Based on the fact that knowledge acquisition is very difficult, time consuming and expensive, the main efforts are directed to study and develop various methods for knowledge acquisition, including induction by observation or analogy, discovery by construction, and the reading of text from highly specialized sources of knowledge.

In the industrial sector, ES for diagnosis have emerged as the most common area of application. Process control, CAD and CAM comprise a significant percentage of industrial applications.

While some commercial ES offers real time capabilities, the AI community, in general, lacks experience with sensor interfacing, data interpretation, real time control and other manufacturing specific areas. For real time ES with a large number of rules, current processing speeds may also be too slow. An approach of reducing the model complexity and the computational time could be found in %%%%.

3.6.- Desicion support systems

The sequencing/scheduling problem must be solved by searching the space of possible solutions in the factory and when the search space is large, a decision support system becomes important.

An automatic control is not always the optimal control. The automatic control has always boundary conditions that give a rigid context to it. As an example, let us suppose that an industry receives an express order which exceeds the disposable resources. It is possible that the system is working JIT and so has no possibility to include this new order in a new schedule. But it is also possible that some factor (for example economic or strategic) makes it convenient for the industry to pay the recharges of finishing later other works in order to schedule the new, more profitable express order. In conjunction with the management, the "frontiers of automatic decision" must be determined. This means which boundary conditions could be changed in an automatic way and which must be asked for. The definition of priority levels for the characteristics of the jobs could be very helpfull.

An user-friendly environment, is necesary to allow the management an easy comparison of alternative possibilities and also an easy change of all the parameters that can be changed by him. This allowance, established by the system manager allows a hierarchical structure of the decisions.

In order to allow a correct analysis of the distinct possibilities of the system, a simulation module will be helpfull, enabling the analysis of not only the utilization of resources possibilities but also the economic side of each of them.

Interdisciplinary work trying to combine existing techniques in a new way, and, if needed to develop new ones is a necessary prerequisite for a good DSS.

An introduction to this principle could be found in %%%%.

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4.- Communication

Each time a digital control for a mashine or process is installed, a so called "Automation Island" is created. At the normal operation, the control systems of an industry has to receive a lot of digitized information (starting at the level of sensors and going up to the level of complete data sheets). This data flow must be multidirectional, providing the hole company (beginning at the senior management and going through the departments of sales and distribution, handling, warehousing, material purchasing, product design and development, and so on down to the machine operator at the shop floor level), with the necessary information and all needed parts, tools and materials, at the appropiate place and at the appropiate time.

4.1.- The Computer Esperanto

The first approach to a CIM oriented communication systems intended to normalize factory data communications so that information can be networked rapidly and reliably within a shop floor environment. It tries to compatibilyze all the languages and protocols at the industry, using bridges, gates and converters, traducing all them to something like "computer Esperanto".

As a result of this approaches, a lot of new "computer Esperanto" systems were developed, but as there did not exist an official protocol, non of them could communicate with the other. Before going on with the idea, trying to combine all these system to an "universal normalized computer Esperanto", it is important to point out that such a solution would introduce a lot of overhead, making the system more or less a batch system inappropiate for real time communication.

4.2.- Standardization

4.2.1.- The ISO/OSI model

The idea of establishing the universal communication protocol began to be a reality with the publishing of the Open System Interconnecting (OSI) model by the International Standard Organization (ISO) at 1978.

This ISO-OSI model has been almost universally accepted as a pattern for local area network (LAN) developments in both factory and office, and so the first steps in the direction of the standardization of the communication language were done.

4.2.2.- MAP and TOP

The second step was done at 1980, when from one side the Institute of Electrical and Electronic Engineers of the USA (IEEE), created the project 802 committee to start work on LAN standards; and from the other side the General Motors Technical Center established an internal task force with representatives from seven divisions for the aim of developing a communications standard to permit communication between devices from different manufacturers. The objectives of this task force were to develop a communications standard from existing standards and procedures, for diverse, intelligent devices and to encourage vendors to adopt the standard. The first results were the development of a specification based on the existing ISO-OSI seven layer model as a framework for many established and emerging networking standards, this development was called Manufacturing Automation Protocol (MAP). Also in this early stages GM recognized the need for other companies to support the MAP specification.

In 1982 General Motors formally adopted MAP as a communication standard for all its plants and requested that equipment suppliers should follow the MAP standards for interconnecting. In 1985 General Motors implemented the first pilot MAP installation at the Detroit-Hamtranck plant, and with Boeing and their Technical Office Protocol (TOP) they co-sponsored a major demonstration at the Autofact show in Detroit. The resulting MAP/TOP network demonstrated the feasibility of a multivendor, computer integrated manufacturing facility. But a problem appears at this stage and it was that the Version 2.0 of MAP was not compatible with the version 1.0 and so a lot of developed products were no more usable. When the new version 2.1 appeared and for a second time the upwards compatibility was not guaranteed, some of the participating companies live the project and some specialized magazines wrote titles like "MAP is DEAD".

This problem did not stop the efforts of the MAP/TOP users Group, and they prepared the actual version of 3.0 and gave a new impulse to the standard. At the same time in Europe a working group began to develope the CNMA protocol that differs only in a few points from the MAP/TOP ideas.

A possible conceptual description of MAP is to say that it is an enabling technology that only specifies standard protocols to facilitate the connection on a network, between equipment from many different vendors and without the need for customer developed communications hardware and software. This situation allows the manufacturers to select the most appropriate manufacturing equipment vendors, without having to be concerned about compatibility.

4.2.2.1.- MAP-EPA and MINIMAP

For time-critical communication tasks, two additional standards were defined: MiniMAP and Enhanced Performance Architecture MAP-EPA. These two standards bypass some of the layers and therefore some important limitations, not only from the compatibility side but also from the technical features (e.g. message size, guaranteed message delivery), are introduced. The idea is to reduce overheads and give faster performance in situations where speed is critical and not full MAP features are required (e.g. situation where operations do not need to communicate with a wide variety of other devices).

The MiniMAP standard is not a MAP node because it is not ISO-OSI compatible and could only communicate outside his own segment with a gateway. The intent of this standard is to allow non-compatible equipment to coexist in a MAP environment at the early stages, but it is expected that it will phase out in the future.

4.2.3.- The actual situation

The actual situation shows that the MAP/TOP standart proposed by General Motors and Boeing is beeing accepted by leading United States firms and some west European firms such as Siemens. So although not all the function of the protocol are allready defined, it is developing to a de-facto standard for all manufacturing industries. In 1988 IBM gave a new impulse to this standardisation, announcing a PC-Card and also an PS2-Card that allows the PC to communicate at the MAP protocol.

The MAP/TOP Task group standardisation work allows a multivendor communication between different hardware elements, but it does not represent a complete solution because a lot of work has to be done at the higher levels, where the application communicates one with the other. It is very important to have a normalized communication so that one application software can communicate with the other and exchange information at the programm level and not only through a "file transfer management system". Using the idea of the computer Esperanto, the actual state is that the needed words have been allready determine and also how they will be transmitted, but the information about how to construct a sentence and to transmit an idea is not yet defined.

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5.- CIM and the world

After the middle of this century, the demand for mass-produced manufacturing goods started to decline and many manufacturing industries were obliged to produce customized products. The new market requirements asked for medium to small batch series of products, this means for flexibility in the production.

With the introduction of the microprocessor, the situation changes considerably and most interest was focused on developments in software and communication aspects. The logical follow-up at the manufacturing process, will be the use of computer technology tools from the moment of production conception according to market information to its final delivery to the customer. In contrast with the traditional automation, the new automation technologies are flexible and applicable to a wide range of machine building operations.

Until now the development of industrial automation have been done in a considerably fast and therefore very chaotical way. But the automation requires a system idea, beginning at the single production task and reaching the global concept of the plant layout.

The key to a successful implementation of CIM is to understand relationships between production objectives, technical components and the organisatory structure of the factory.

The introduction of CIM issues, like most of the new developments, has been done mostly in such a way that none of the expected results has been reached and new problems have arisen.

The fast explosion of the area and also a lot of general information articles presenting CIM as "The Panacea", or "The solution to all your problems", or "The factory of the future", and also the marketing statements of the industries that always involve the only main idea of selling its own products, have developed at the industrial word a lot of "wrong concepts".

Some of them are:

- The concept is CIM and not CIAM (Computer Integrated Automated Manufacturing).

- It would be better and more realistic to refer to CHIM (Computer and Human Integrated Manufacturing) and not about CIM.

- CIM is a concept, its applications is different in each enterprise.

- The first effect in introducing CIM is always an increase in the production cost for a short time.

- Two steps must be taken into account at the introduction of CIM technologies:

    1.- The first step must be allways a deep study of the structure of the industry and the enterprises. This study must be made in a top down way, beginning at the management level and ending at the shop floor.

    2.- The second step should be the acquisition of a decision support software at the management and intermediate levels, which will be responsible for the information flow inside the industry, and for a support for the medium and long-time production planning.

Unfortunately in most of the cases the first step has been the introduction of automation elements at the lover level, vithout thinking about the future development and the need of a communication vith a central system, or in the cases vhere this communication exist, about the compatibility of the different elements. This always leads into very expensive special developed solution like protocol adapters, post-processors, etc.

5.1.- CIM and Industrialized Countries

Manufacturing as a technology and as an industry, is undergoing substantial and significant changes in industrialized countries. These changes must be viewed as both a logical extension of the trends and innovations in manufacturing since the industrial revolution and in a revolutionary discontinuity. This will result in a new style of manufacturing operations and a new role for manufacturing as a competitive weapon (especially against developing countries) and an integral component of the business strategy. Today, there are far-reaching changes, happening in the global marketplace, that will result in a requirement for CIM-based flexibility for many enterprises.

5.1.1.- CIM-components in industry

The basic CIM-concept of an enterprise is determined by its organizational structure, the product-mix, manufacturing organization and technical presuppositions. Thus no standardized CIM-solution can be developed or analyzed. Its degree of realization at an enterprise will be determined by the number of couplings between different CIM-levels. Accordingly, two development stages of CIM-systems can be classified:

a) Implementation of CIM-components: concerning the realization of main components like CAD, CAM, NC-programming or CAQ, most of the investigated small and medium seized enterprises could be allocated to a first stage of CIM. At their plants, CAD, NC-programming and machining centers are realized, production planning and schedulling systems and CAP only to some extent. As points of main effort, the areas of calculation, scheduling, planning of machine-capacities and the definition of machining sequences can be determined. DNC-systems with direct connections between NC-programming and machine tools are not realized to a degree worth mentioning.

A second CIM-stage differs from the first one by the employment of FMC's, automated stores and automated transport systems and also by the extension of planning systems. This planning comprises areas like job accounting, material management, calculation and work load planning. The couppling of measuring systems with CAD is a future aim yet.

b) Interrelation of CIM-components: referring to table one, some aspects of data relation between CIM-components are to be outlined. As far as isolated solutions are concerned, most enterprises have only realized the integration of CAD-NC systems. Data transmission from CAD to production planning and schedulling systems is done manually, that means data from piece lists, orders or work plans are transmitted to the planning systems by the production engineer. At some enterprises, technology data bases are used, mainly concerning machining data (turning, milling etc.). By means of the installation of DNC-systems, operational data (machine data, order data or personnel data) can be collected economically. In many cases the integration of these systems is realized via order release, work-load-planning and scheduling.

		Degree
CAD-NC	geometry-data for NC-programming	xxx
CAD-CAPP	geometry data for work plan generation	xx
CAD-CAQ	geometry data for measuring system	x
CAD-CAP	piece list	x
CAPP-NC	tools and technology data	xx
CAPP-CAQ	workplan for integrated test cycles	x
CAPP-CAP	workplan management	xx
CAP-CAM	order-release, availability, capacity	xxx
CAP-CAQ	control data of in-process measuring	x
CAM-NC	DNC: program release and transfer	xx
CAQ-NC	NC-testprogramm for CNC-gauging machine	x

Table 1
Degree of CIM-realizations, based on coupling between CIM components (F. Liu and A. Mootz, 1988, West-Germany).

5.1.2.- CIM-Centers

Contrary to the situation in industry, there do exist some CIM-realizations with a high degree of integration. But these realizations are in most of the cases confined to prototypes as installed at so called CIM-centers. As an example for such an installation, a CIM-center in Sweden is to be outlined:

At this CIM-project, a number of Swedish companies cooperate. Its aim is to provide the means of how to tie together information and production systems to create efficient factories. A unique contact network of companies has been developed through cooperation in the project (called CIMFUTURA). New software has been produced that can handle the difficult interfaces between the various systems. And, the software is entirely application-oriented and independent of equipment performing the machining, transporting and so on. Testing procedures that bring CIM-installations into service by stages have also been developed. CIMFUTURA's first reference installation has been set up at the IBM plant in Järfalla, Sweden.

It has been integrated into the factory flow and manufactures parts for IBM printer feeders. Currently four different parts are being manufactured, and information flow has been integrated between orders, planning, design, preparation, manufacturing and delivery.

At the start of the system, material is manually loaded onto pallets which are identified by bar codes. Information from the planning system directs an industrial robot, mounted on an 11 meter track, to load the correct billet into the fixture of a machining center. After debarring and washing at another station the finished part is transferred to the magazine store. Parts are called-on from the store as required and loaded into an assembly station which incorporates a SCARA-robot (it is also possible for parts to pass directly from machining to assembly, by-passing the store). The sub-assembly is than marked and forwarded to another factory for final assembly.

In this project, design and manufacture are integrated by means of a MRP-type system, based on a relational database for flexible data access with a simplified adaption for new information needs. It works with finite capacity loading and order/operation network scheduling. But, an operator can interject into the system with an express order. The system would than be rapidly emptied to make way for the new on-demand schedule.

The CAD-system can produce NC programming functions and simulate robot motions as well as generate a part list (parametric designs are easily created). The CAM-system of the project is a so called FME type (Flexibility, Modularity and Economy), which is claimed to be a major advance on normal CAM. It undertakes information processing on the shopfloor and is said to be a new engineering philosophy, which can electronically describe manufacturing processes such as operator instructions, NC-machining or automated materials handling. It is a toolkit of PC-based program modules for communicating between cell computer and manufacturing engineer, design and planning. CIMFUTURA has already created functions, interfaces and communication protocols for a variety of devices, including robots, automated stores and machining centers.

The Swedish CIM-project can be regarded as one of the most integrative approach in this field. Its most important achievement has been, to give other (Swedish) companies the knowledge and motivation to carry through their own projects.

5.2.- CIM and Developing countries

Considerable gains in efficiency could be obtained by the adoption of contemporary methods for factory organization, planning and schedulling and production control, as well as appropriate subcontracting policy.

In the last years, the developed countries have been involved in the correction of mistakes already done in the introduction of automation in a chaotic manner. Actually, most of the industries in developing countries are still involved in this correction. This is the reason why it is now the best moment to try with a guiding consulting activity, to learn about those errors and not only avoid the increase of the technological gap, but if maked intelligently also to reduce it.

The key will be to (change) optimize the organizational structure of the industry, trying to, from one side estimulate the introduction of cooperative systems, avoiding hierarchical structures; and from the other side to understand the industry as a whole complex model, where the bottlenecks and possible deadlocks have to be determined.

5.2.1.- Some ideas about the introduction of Organizational Changes and Automation Technologies in the Developing Countries:

With this concepts in mind, some important elements that must be avoided at the preparation face, some necessary previous studies and also some of the project steps are listed below (the points outlined here should represent only a general direction, every country has to fill these actions with specific contents, based on its own socio-culturall context):

Avoid:

a) Do not simplify the problem to a "machine purchase", this will never be a solution but only a bigger problem. If one introduces a computer in a chaotic system, one obtains a "computerized chaos". If one automate the production of a bad product, one obtain a fast production of a bad product.

b) Do not believe that all the increases in productivity are caused by automation, most of them are originated at a change in the organizational structure required for the introduction of a flexible automation.

c) Avoid the confrontation between capital and labor, by creating awareness programmes with trade-union leaders, progressive entrepreneurs and the governmental politicians group.

d) Avoid bad reactions caused by the utilization of wrong terms. Most of the correct expression like CIM, automation, structure change are charged with a negative concept.

e) Avoid short-term programmes that will bring an "espureos" competitiveness based on temporal factors like low loans, tax benefits and so on. The programme must be based on technological changes and better working conditions through a better distribution of the resources.

Study:

Analyze the production market in order to select specific areas, trying to:

a) Assure a "cascade" effect in the production.

b) Introduce advances in industries that could act as pull-up or motor for the industrial system.

c) Maximize the direct and indirect benefits in the local society.

d) Promote a local technological development through selected imports.

Do:

a) Impulse the bilateral transfer and communication between industry and university.

b) Generate industry clubs that will support local technology transfer centers, implemented as external institutes in the universities.

c) Develop training programmes at all levels.

d) Use practical demonstration of new technologies (video, PC).

e) Impulse inter-disciplinary teams.

f) Create a regional information system to allow a better contact between the already existing institutions and projects.

Industry club:

Some of the characteristics of such an "Industry club" must be:

a) Independence of the product: The system must be capable of adapting itself with very small modifications to the manufacture of different types of products.

b) Independence of the used hardware and software: The system must be independent from software and hardware elements with which it interacts. This means that at the system level only resources with determined economic and temporal characteristics and not determined elements will exist. This requires to define clear interfaces, so simple as to be able to communicate without too much extra effort with elements of different suppliers.

c) Practically demonstrable: The system must be in a position to manufacture some types of product. After a study of specific needs of the market, a product that allow easily to define different types as well as different variations for each type, must be selected.

d) Flexible software: The software must be easily expandable to allow a step by step introduction in the Industry. Therefore, its design must be modular.

e) Flexible hardware: The system to be controlled must be easily expandable.

III.- Conclusion

There do exist a number of potential fields of conflict, mainly socio-cultural ones, in connection with the introduction of modern information technologies. The adoption of CIM could be a major hindrance for building up an economy, if it is not based on the special needs and peculiarities of a country. But CIM must not be regarded as the "ingenious solution for production", this is still a slogan originated in massive interests of suppliers of CIM-components, to establish new markets for their products.

Much has been said and written about the "workplace killing" effect of organizational changes and modern automation technologies in the industry. In my opinion the main problem must not only be in how to protect the working places, much more important is how to increase the "quality of live".

I like to use a model of the human future showing a man going on a road scattered with stones he had to evade. Referring to this model, I understand the "scientific spirit" in this way: our responsibility lies in supporting all the activities that could help to smooth the road, so that the man could walk without problems and rise his head.

Especially the developing countries have to be active in this process, then this "smoothing procedure" will appear sooner or later all over the world, with or without their help. But if this occurs to fast, without allowing the man to adapt himself to the new environment by making a gradual step by step development, he possibly will not be able to walk. Moreover, not prepared for such a smoothness, the "developing country man" will only walk in a very troublesome way or even fall down.

Similar to the industrial system, the human system is a dynamic one and so it is impossible to have a unique, always valid description of what this "head rising" means. But this is not really so important, because in the "dynamic human systems" the only solution is the continuous looking for new Solutions for increasing the "Productivity of Life" for every single person in the world and not of every single person in the world.

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