DESIGN RULES FOR A CIM SYSTEM

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Chapter 1

Introduction

The subject of production mechanisation is not a new one. The inventor of the first potters wheel was motivated by objectives which were not dissimilar from those of a late twentieth century Production Engineer considering the introduction of a Flexible Manufacturing System (FMS) cell - namely, how to perform more useful work with less human effort. What has changed and changed quite dramatically in recent years, is the degree or level of automation which the available technology can support. The very advanced level and sophistication of contemporary technology has led many lay people to conclude that the 'unmanned' factory is already an entirely realisable possibility - even though professional practitioners recognise that this age-old vision is, at least for many kinds of manufacturing, still a very long way off indeed. Contemporary technology does however support very advanced levels of automation for certain kinds of manufacturing.

People working in the field of advanced manufacturing technology are increasingly coming to recognise that higher levels of automation require broader levels of approach. Where the mechanisation of a given process can be realised by means of a single simple machine, the project manager can quite often restrict his principal area of interest to, say, the design and operation of just this one machine. In such cases, the mechanisation of the process is done in almost total isolation from all of the other activities which take place within the company - often even in isolation from other processes which are to be performed on the same product.

Even in the case of a single machine however, higher levels of automation demand that consideration be given to 'related' as well as to 'direct' processes and activities. For example; a company contemplating the introduction of even a single numerically controlled machine tool will be obliged to give consideration to the method for creating numerical control part programmes. This in turn may oblige the company to study the much larger subject of Computer Aided Design.

If a company introduces only a very limited number of new or modified products each week, it may be quite sufficient for that company to establish a parts programming operation which works directly from paper drawings. An operation of this kind may not however be appropriate to say a jobbing shop which needs to create many tens or even hundreds of new parts programmes each period, and which has insufficient machine capacity to devote very large amounts of machine time to the validation of each parts programme. In either event, the project manager charged with introducing the new machine will need to consider other company activities - besides the machining process itself.

Where a mechanisation project involves a number of associated machines and processes, the company will find it necessary to consider a great many related activities in order to effect a high level of automation. In the case of say a FMS cell, the company may need to introduce a large number of new systems to address such diverse activities as parts classification, capacity planning, production planning and scheduling, inventory management and control, and many other production related administrative activities, as well as many 'engineering' and 'production' activities such as product design and development, process planning, etc.

The highest levels of factory automation (which include but is by no means confined to unmanned operation) may, and almost invariably do, require a re-examination of almost every activity which takes place within the organisation concerned. The identification of this requirement led directly to the creation of the term Computer Integrated Manufacturing (CIM) as embracing almost every department and function of a manufacturing organisation. The ESPRIT (European Strategic Program for Research in Information Technology) project of the European Economic Community established a CIM Group to study this problem. The diagram opposite this page admirably illustrates the scope of CIM, as perceived by the ESPRIT-CIM group.

The comparatively low levels of automation which were introduced in the past could be, and often were, managed entirely by members of a single discipline - frequently the Production Engineering discipline. As higher levels of automation require broader levels of approach they also require the involvement of a wider range of different professional disciplines. The more advanced levels of automation which the current technology now makes possible, need to be addressed by multi-disciplinary teams - which may include not only Production Engineers but also Computer Systems Engineers; Product Design Engineers; Robotics Engineers; Production Control experts; Telecommunications experts etc.

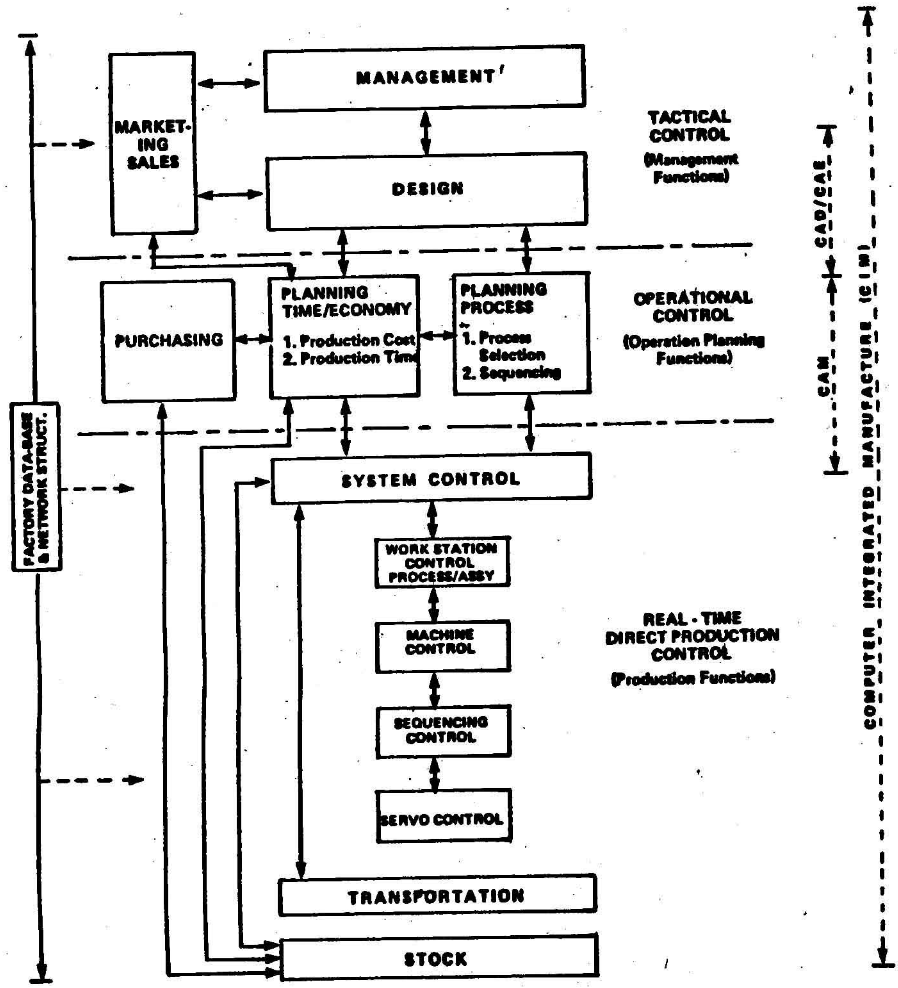
This presents many different problems of both technical and organisational nature. Many particularly difficult problems arise as a direct result of the fact that no single vendor (no single industry even), could possibly supply all of the many different products and services which would be required for even a modestly high level automation project.

In short, a number, possibly a quite large number, of different individuals and suppliers are normally involved in the introduction of high level automation, and a wide variety of dissimilar subjects and activities need to be addressed and provided for. The administrative and organisational difficulties which these two problems occasion, are very seriously compounded by the fact that no agreed structures and definitions for CIM currently exist.

The situation in many ways resembles that of the Tower of Babel. CIM; MRP; CAD; AMT; CAM; JIT; FMS - everyone knows the terms, no-one understands what the terms mean. More precisely, many if not most attach different and often conflicting meanings to such terms. As a result, a large number of individuals, from widely different cultural backgrounds and disciplines, who are mutually dependent upon each other for very advanced and complex undertakings, are greatly handicapped by the total absence of any formal structure or even an agreed vocabulary for the undertakings they are charged with. The problem is made even worse by the lack of agreement, the lack of willingness to co-operate even, within the IT industry itself.

Whilst everyone involved in CIM recognises that CIM comprises many separate modules or sub-systems, there is no generally agreed sub-system structure, not even a generally accepted list of sub-systems. There is not indeed any accepted understanding of the range of company activities which any one sub-system should address. Do Computer Aided Draughting and Finite Element Model Generation constitute separate sub-systems ?, or are they simply two functional elements of a single sub-system ?. Different vendors group or 'package' support for different company activities in dissimilar ways. Some will provide support for a very large number of activities within a single product, whilst others will sub-divide the same range of activities to produce a range of different products. Furthermore, the groupings adopted by any-one vendor will normally differ from the way in which other vendors package these to produce competitive products.

REFERENCE MODEL OF MANUFACTURING CONTROL SYSTEM



Manufacturing companies therefore invariably experience great difficulty in incorporating products from different vendors into a single composite integrated manufacturing operation. In many instances, product incompatibility is not due to accident but to design - shortsighted and damaging though this may be. Vendors who deliberately make it artificially difficult for clients to interface products from other vendors, to those which they themselves supply, damage both themselves and European manufacturing industry.

As previously stated, no single vendor, no single industry even, could possibly provide all of the different products and sub-systems which make up a total CIM operation. Such an operation may comprise computers, machine tools, robots, telecommunications equipment, automated warehousing and transportation facilities etc., along with a truly tremendous range of different software products, including facility management, control systems and production administration systems of many different kinds. Where a particular vendor designs a product in such a manner as to make it costly and difficult for a client company to interface other products from different vendors to it, it has the corollary effect of making it equally difficult for the client to add the same product to an existing composite network of systems.

Furthermore, by making it unnecessarily costly or technically difficult for client companies to implement higher levels of factory automation, vendors discourage large numbers of otherwise highly motivated organisations from doing so. This not only depresses the overall market upon which the vendors depend, but also greatly hinders the European manufacturing industry in charting a course away from labour intensive manufacturing, towards automated manufacturing, This is an essential pre-requisite to the survival of the European manufacturing industry in a competition with countries where labour costs are substantially lower.

The principal objective of this study, as an ESPRIT Pilot Project (No. 5.1/34) titled 'Design Rules for Computer Integrated Manufacturing Systems', was to propose a European CIM Systems Structure. In particular, it was proposed to address three separate but related goals:

1 To modularise the total CIM into functionally discrete sub-systems.

2 To describe the minimum functional specifications of each sub-system.

3 To identify the interrelationships that exist between any one CIM sub-system and all the other sub-systems.

The CIM-Structure presented here, is not, and could not be, either definitive or final for two reasons. Firstly, no structure for CIM can be made definitive except by general consensus; secondly, technology is dynamic and innovative and no attempt should be made to halt progress and invention at a particular point in time. Even structures which are proposed in reference to scientific subjects (such as that proposed by Carolus Linnaeus for biological classification) have to be updated in line with advances in scientific knowledge. The subject of manufacturing, even at this time, includes almost as much art as it does science - and new methods, new disciplines even, are being evolved at an ever increasing rate. As a consequence, no manufacturing structure may be considered to be scientifically 'correct' - it can only be considered to be pragmatically useful at a given point in time. It is nevertheless hoped that the proposed structure will constitute an initial European framework, which can be regularly refined and updated - in accordance with consensus wishes, and in line with evolving needs. The proposed structure is therefore intended to provide both a base and a focus for the European industry.

An undertaking to provide CIM structures which would comprehensively address all of the needs, of every branch, of every form of manufacturing industry, would be too ambitious for an initial study. It was, for this reason, necessary to limit the scope of the undertaking in three particular respects. These were:

1 the sector of industry

2 the range of company activities

3 the levels of mechanisation supported.

Each of these three constraints therefore need to be considered.

Sector of industry

In this study we decided to address only the 'machining' sector of the mechanical engineering industry. There were a number of reasons for taking this decision, as discussed below;

- There are more manufacturing organisations in Europe involved in machining than in any other single type of manufacturing operation. Machining therefore represents the single largest market for CIM system products, and would accordingly be of more immediate interest to a greater number of potential CIM system vendors, than would any other sector of manufacturing industry.
- Machining presently offers greater and more immediate scope for automation than most other types of manufacture. Machine tools, mechanised conveyancing systems, robots for material handling, automated stores for the control of tools, work-pieces, etc., of the kinds needed by the machining industry, are all readily available in the form required to support high level automation.
- Machining organisations afford greater and more immediate scope for vertical integration than most other kinds of organisation. Linking of the sub-systems used to design and evaluate products (CAD) to the sub-system used to generate numerical control programmes (CAM programming) for machining operations (eg. millings; drilling; wire spark erosion; flame cutting; turning; grinding; punching; nibbling, etc.) can be achieved more directly and easily than in, say, component assembly operations, sheet metal forming operations, etc. The linking of other sub-systems (process planning; CAM-scheduling; CAM-machining; CAM-inspection, etc.) is similarly more direct than it is in connection with other types of operation.
- Many of the sub-systems required by the machining industry will, with relatively minor modification, be appropriate to other branches of manufacturing industry. The group of sub-systems needed to support the machining industry, as presented here should therefore be viewed as a set of 'primitive generic' modules from which more complex models can be constructed.

Range of company activities

This study was designed to provide support for all of the activities that are **directly** related to the design and manufacture of machined products This project was therefore not designed to address such 'indirect' activities as Market Research; Financial and Management Accounting; Sales and Distribution; Purchasing, etc. - but was instead focussed towards those functions and activities which are normally described as the 'Engineering' activities of a company - including both Design and Production Engineering.

These activities were grouped under five principal headings or 'topics', namely;

- Computer Aided Design (CAD)
- Computer Aided Production Engineering (CAPE)
- Computer Aided Manufacturing (CAM)
- Computer Aided Storage and Transportation (CAST)
- Computer Aided Production Planning (CAPP)

Although certain of the above topic titles are already commonly used within the manufacturing industry, there is no generally accepted definition of the scope or range of company activities which are addressed within each title. Also, certain of the above titles have been expressly created for this project. A definition or description of each of these five topics is included as the introduction to each topic.

Levels of mechanisation supported

Levels of mechanisation supported in the machining sector span the entire range from an 'unlinked NC machine' to a 'Flexible Manufacturing System which can be defined as follows;

Unlinked NC machine operation relates to the use of numerically controlled machine tools, which are not served by mechanised work-piece conveyancing or work-piece loading/unloading facilities. This type of operation is normally managed and supervised by human operators, supported by computer generated outputs. These outputs typically include punched NC paper tapes, printed job set-up instructions, printed production schedules, printed job cards, etc. Production Schedules for this level of operation would normally be determined in accordance with 'planned operational sequences' as these are established by a Process Planning Engineer - alternative NC programmes are not normally provided to permit operations on any one part to be carried out in any sequence other than the one devised by the process planning engineer.

Flexible Manufacturing System (FMS) refers to an environment in which DNC (Direct Numerical Control) Machine Tools are used to carry out the machining processes - and where these Machine Tools are served by automated work-piece conveyancing, and work-piece loading/unloading facilities. Notionally, this type of operation is managed and supervised directly by intelligent and semi-intelligent devices. Production in this environment is 'sequenced' rather than scheduled and decision making related to 'the next task to be performed' is carried out only when an already initiated machining task is nearing completion. This type of operation may involve the use of complex automated support facilities such as automated warehouses, automated tool management and delivery facilities, etc.

Many of the sub-systems which are needed to support a specified level of operation could be applicable to even lower levels of operation. For example, a Computer Aided Design sub-system would be applicable to an organisation which employs lower level machines than NC - as would the production scheduling sub-system, and the systems used to create printed job cards, printed job set-up instructions, etc. Although this might be an important consideration for gradual automation of existing facilities, it was not intended that this pilot project should make **comprehensive** provision for levels of operation lower than an unlinked NC machine. The objective of the pilot project was to consider all levels of operations between an unlinked NC machine and FMS.

The ordering and structuring of CIM requires the creation of two quite different types of rules -rules that apply to particular sub-systems and interfaces, and rules that are generally applicable to all the sub-systems of CIM. To differentiate these two separate issues, the term 'Design Rules' is chosen to imply rules which relate to a particular sub-system and interface. Rules that posses universal applicability across all sub-systems and interfaces, are termed 'Maxims'. The project therefore requires the creation of both design rules and maxims.

Design rules are principally concerned with defining the functional scope of each sub-system. This document accordingly identifies every significant CIM activity, and describes which of

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these are to be provided for in a specific sub-system. Rules relating to particular interfaces will be principally concerned with the nature, scope and form of the data which each specified sub-system is to make available to each related sub-system. Although the authors recognised the need for rules relating to interfacing data, these could only be provided for at a high level within the scope of the project.

Vendors wishing to claim that their CIM products confirm to the EEC Design Rules would be obliged to combine functions in the groupings defined within the established design rules. In order to avoid confusion which is frequently caused by vendors questionably claiming that their particular products comply with recognised standards (as for example happened in respect to the CODASYL data base proposal), the project team recommended the creation of EEC Certification Centres. These would evaluate CIM products and authorise the use of EEC approved CIM symbol on certified products and within sales literature used to advertise these products. It is however not certain at this time if this proposal will be adopted.

To develop the maxims, which are valid across all sub-systems, it is noted that Processing, Data and Communication are universal concepts applicable to all CIM Sub-systems and accordingly maxims for these have been developed. Maxims for one of these are collectively termed as a Strategy. Three strategies are therefore necessary in reference to any CIM undertaking:

- A Processing Strategy
- A Data Strategy
- A Communications Strategy

The method chosen to formulate a strategy was to develop maxims which could help a designer of CIM sub-systems to more easily find a lasting solution. Maxims have a number of characteristics: they are generally applicable throughout CIM (hence they represent strategic maxims), they address important aspects of CIM (such as complexity of local processing), they recognise the state of the art (capacity trade-offs) and they emphasise tendencies and ways towards further interpretation in CIM (distribution of processing).

The Processing Strategy concerns the manner in which processing is to be distributed between a large number of different processing devices. These will almost certainly include one or more 'centralised' mainframe computers, a large number of mini and micro-computers of greatly varying size and type, programmable logic control units, and a very large number of 'intelligent' and non-intelligent devices -from robots to relays. The Processing Strategy must be designed to take account of differing, and sometimes conflicting objectives encountered in such systems.

The Data Strategy concerns the design and distribution of the total data such that all processors and procedures may have access to consistent and authoritative data values - particularly in reference to items of data that are of common interest to many different manufacturing functions and activities. Due to substantial differences in the way in which many sub-systems need to process basic data, certain data will have to be replicated in several different files, of many different kinds. The maxims therefore should ensure that all copies of each data item are consistently maintained to correspond with the 'master' occurrence - eg. 'latest' modification level, 'current' stock level and price, etc. It should however be noted that it is a Data strategy which is being proposed, not a Data Base Strategy. The authors believe that it would be entirely impractical to attempt to propose physical arrangements for the storage of all the data needed to support every CIM activity. It is considered to be entirely infeasible that any single cohesive data base management system, of either a centralised or a distributed nature could be developed within the foreseeable future. This is not to be taken to imply that certain activities may not share certain common files (eg. Computer Aided Design and Parts Programming using a common Product Data Base) - the authors would indeed entirely subscribe to this practice.

The communications network for a computerised manufacturing system needs to be built in such a way that all transmissions can take place within the required time frame. Between each two communicating processes using the network a protocol must be chosen. For an integrated manufacturing system, all processes communicate, at least conceptually over the same net. A communications protocol has two aspects, the general format which may exist on each level, and the particular format that two processes have agreed upon. Integrated manufacturing needs both. In addition, tools are needed to map a particular format onto a general format, so that designers only need to be concerned with application formats. Standards in this area which can be mapped onto general formats such as OSI layer protocols, are vital parts of any manufacturing system. Many of the communication strategy maxims have to do with the fast evolving state of the art in communication techniques and consequently the lack of standardised methods. It is therefore important that the maxims emphasise the special requirements of communication in CIM, so as to be able to decide where forthcoming general solutions can be adopted and where more expensive but specific solutions are necessary.

Chapter 2

Development of CIM Design Rules

Everyone involved in Computer Integrated Manufacturing recognises that CIM comprises many separate modules or sub-systems, however, the problem is that no agreed structures and definitions for CIM currently exist. There is, as stated, no generally agreed sub-system structure - not even any generally accepted list of sub-systems. The scope of any system can only be defined in terms of function - or more precisely, in terms of the particular company activities which are expressly catered for by the system. Terms such as Product Design or Process Planning, whilst useful as generic titles for general disciplines, are not sufficiently precise for the purpose of defining the scope of particular systems. The reason for this is that such terms are portmanteau expressions for large numbers of discrete and quite different activities. It would invariably be inappropriate, and almost always impractical, to attempt to provide support for say each and every different Product Design activity, within a single computer system - even if Europe-wide agreement could be reached on the total list of detailed activities which together make up the generic term Product Design.

Attempts to label particular systems by use of such terms (eg. a Computer Aided Design System, a Production Control system, etc.) have contributed greatly to the confusion and scepticism which presently exists in reference to IT(Information Technology) products developed for manufacturing industry. The scope of any CIM sub-system needs to be defined in terms of detailed company activities, which, unlike generic 'roles' are essentially non-contentious. This is not to be taken to imply that every company will or should carry out every identified activity - nor that say the Product Design department of each and every company will have organisational responsibility for an identical sub-set of these activities. What is intended, and required, is that the various activities associated with CIM can be defined in such a manner that they can be universally understood and related to.

The development of design rules for CIM systems has been approached from a simple but fundamental hypothesis that the basic or fundamental activities which need to go on within any manufacturing operation do not change - it is only the methods and technologies which are used to carry out these activities that change. The prehistoric designer of a megalithic monument such as Stonehenge may have used a stick and sand to construct a geometric representation of the product he wished to create; a mid-20th-century designer instead used a pen and drawing board, and a designer in 1985 might use a computer terminal for the same identical purpose. The essential or fundamental task has not changed during this time - only the methods and technologies which are used to carry out such tasks have changed.

New insights into basic activities also permit greater levels of sophistication and scientific precision within each activity, but do not change the fundamental list of activities which have been evolved over many decades of manufacturing experience. An early decision was therefore taken to base the required CIM systems structure upon these elemental manufacturing industry activities - rather than upon currently available products and offerings. There were several reasons for not allowing current IT offerings to dictate the required systems structure.

The first and most obvious reason is that different authorities and vendors have, to date, pursued dissimilar and often conflicting approaches to CIM. The second major difficulty is that many of even the most basic CIM related activities have yet to be addressed by the IT industry. Whilst manufacturing clients can frequently choose from a plethora of offerings to support certain of their activities, there are often no IT products of any kind to support other equally perplexed, equally costly, and equally time consuming activities - which need to be supported if CIM is to be effectively achieved.

Another very important reason for adopting this approach, was to identify a number of opportunity areas for new IT products. It is believed that this will be of benefit to both the IT industry, and to European manufacturing industry.

Before considering the detailed approach which is followed here it would perhaps be helpful to reiterate the essential aims and objectives of the project.

- Initially the principal, indeed the only, objective was to **identify** the sub-systems and interfaces which form essential parts of Computer Integrated Manufacturing. The development of Design Rules and Maxims followed as extensions to this undertaking.

Each sub-system has therefore been identified in terms of 'function', i. e. in terms of the business activities which are to be addressed and supported by each system. Design rules for sub-system functionality have been evolved to address two separate but very closely associated subjects:

1 The basic business activity which is to be addressed by the sub-system.

2 The minimum list of factors which must be used to condition or determine each business activity.

One example might serve to illustrate these two separate aspects of functionality. The first sub-system within Computer Aided Production Engineering(CAPE) concerns the evaluation of different proposed manufacturing technologies. A product, such as say a motor vehicle crankshaft, could be produced as a forging, as a spheroidal graphite casting, or possibly by some other manufacturing technology. The principal business function of the first CAPE sub-system is to decide (or to 'aid' a Production Engineer in deciding) which of all the available technologies should be chosen for the manufacture of a proposed new product. The minimum list of factors which must be used within this sub-system to condition or determine this decision would include

- Projected sales or manufacturing volumes.
- Details of all possible alternative technologies.
- Details of existing plant and equipment within each technology.
- Details of projected work load capacities on existing plant and equipment.
- Cost of procuring additional plant and equipment capacity.
- Rough processes, times and costs under each possible technology.

(Note: It will be appreciated that the above example has been greatly simplified in order to illustrate the difference between basic functions and conditioning functions. No inference should be made concerning the sub-system in question without a detailed study of the sub-system titled Evaluation of Design for Manufacturing Requirements of the CAPE section.)

CIM Design Rules do not instruct IT vendors on how systems have to be designed, or which technical standards have to be adopted. The above example of the first CAPE sub-system could, at the discretion of the vendor, be developed in any one of several different ways,

eg 1:
It could be developed as a conventional 'algorithmic' system, using traditional imperative computer programme coding techniques, against say a CODASYL type data base.

eg 2:
It could be developed by the use of knowledge representation and inferencing, by means of declarative type computer programming (ie. as an 'expert' system) against a Knowledge Base. Different vendors will be free to choose different technologies, and it is foreseen that alternative products will eventually become available to manufacturing clients.

For the development of Design Rules the following three steps were adopted.

Step 1 Flowcharts

The total CIM area was initially analysed into the five fundamental topics previously identified, and flowcharts were produced for each topic - detailing, in chronological sequence, the various activities and procedures which need to take place in order to take a product from the conceptual design stage, through to final manufacture.

Step 2 Sub-system tables

The next step was to group the very detailed 'tasks' shown on each chart into CIM 'activities' - or sub-systems. In grouping tasks together to form sub-systems it is necessary to take account of two quite separate factors - Functionality and Processability.

Functionality

In grouping a particular sub-set of tasks together to form an activity, cognisance has to be taken of 'logical procedural breaks'. Thus, the design of a product is seen to be a different procedural activity than say the development of an NC parts programme to manufacture that part. Several different factors may condition a logical procedural break. One reason might be that a person possessing a different kind of skill might be required to progress a procedure from a certain point. A procedural break may also be necessary if some time delay is unavoidable within a procedure - such as where a procedure generates a proposal which has to be approved before it is further acted upon.

Processability

Grouping of tasks to form activities also has to take cognisance of extreme differences in processing requirements. Thus computer aided draughting might be supportable by a relatively low-performance computer such as a micro-computer - whereas finite element analysis(FEA) would require much more powerful equipment. Many micro-computer vendors might therefore wish to develop a systems product to support draughting - but would be excluded from being able to do so if they were also required to provide support for FEA within the same product, in order to claim that their product complies with the Design Rules

It should be noted at this point that whilst technology was not allowed to influence the determination of the basic manufacturing tasks depicted on the Flowcharts, it has been allowed to influence the manner in which the basic tasks shown on the chart have been grouped together to form CIM sub-systems. However, as it is intended that the eventual rules will permit vendors to merge support for two or more sub-systems into a single product (subject to certain quite stringent conditions), changes in technology should not invalidate the structures which are proposed.

Step 3 Sub system interfaces

The third and final preparatory step to the creation of design rules or maxims, was to identify the way in which each sub-system relates to all other sub-systems. Essentially, this involved identifying the data inputs and outputs of each sub-system - and determining which sub-system has 'prime authorship' responsibility for each kind of data.

Following the above procedure, the various CIM sub-systems and their interconnections have been identified. A convenient way of representing such a comprehensive view of CIM is in the form of the 'round-table' chart which appears on the front cover. The applicability of CIM design rules to small firms was also investigated by the Department of Industrial Management, University of Dublin, Ireland. The results of this investigation are reported in an Appendix on 'CIM in the small firm'.

Chapter 3

Computer Aided Design

Introduction

The scope of Computer Aided Design (CAD) includes the use of a computer based system to assist all those tasks involved in the process of developing a concept for a product into a fully engineered design, described in sufficient detail to enable it to be manufactured.

The process starts with a Product Functional Specification, i.e. a statement of the parameters relating to the time, cost, size, weight, appearance, performance, durability etc. within which the design must be constrained. The process ends with the release from Engineering to Manufacturing of information describing the shapes of the constituent parts of the product, the materials from which they are to be made and the manufacturing processes and assembly instructions which may be mandatory to ensure the integrity of the design. The technical activities of engineering embraced by CAD can be divided into three broad categories :-

a Design

b Design Analysis

c Engineering Test

Computer Aided Design is generally understood to embrace only the technical activities of engineering and does not usually include such things as manpower resource allocation systems, project control systems, parts usage and parts procurement systems, systems for accessing competitor and supplier information, administrative and accounting systems and other information systems necessary for the efficient running of an engineering department. While CAD does not embrace these non-technical activities, it should be borne in mind that as much as 75% of the time of technical staff is absorbed on non-technical work. However, since the use of CAD as part of a CIM environment requires both the management of large quantities of data and strict control of change, two particular administrative functions are regarded to be of sufficient fundamental importance to warrant inclusion within the scope of CAD for ESPRIT purposes. These two functions have been categorised as follows:-

d CAD Administration

e Design Modification and Engineering Change

Design

- Design is primarily concerned with establishing the geometrical shape of the parts which will make up the product, the materials from which they will be made and certain aspects of the manufacturing and assembly processes mandatory to ensure the integrity of the design.

Design can be divided broadly into three areas: Concept Design, Engineering Design and Detailed Design.

- Concept Design is concerned primarily with establishing the basic shape and appearance of the product resulting in a Design Proposal upon which a business decision to proceed can be based. It is also concerned with the broad evaluation of different ways in which the requirements of the Product Functional Specification could be satisfied. Establishing the basic shape of the product can potentially make much use of graphics systems capable of creating complex geometrical shapes; of displaying them in any view or of dynamic rotation of them; of displaying them in various colours, or combinations of colour, shading and surface texture to enable the designer to visualise already what the final appearance of the product will be. The database of geometric data established at

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