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Present Trends of the CIM Implementation
(A qualitative survey)

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Introduction

As the euphoria concerning CIM has worn off and as many companies have started to implement CIM it seems opportune to point out the present level of research and the trends of the development in order to learn from the experience of the pilot applicants and to be provided with new ideas for our own proceeding. Therefore we will start out describing the process of the CIM-implementation. We will then point out typical CIM-implementation paths as functions of different branches of industry and business structures, discuss the tool equipment that is currently available for implementing CIM and characterize the existing standard software from the present point of view as well as future trends that can be anticipated.

Fig. 01 shows that in comparison to the United States and Japan Europe is priviledged in the field of integrated industry automation. The concept of integration and the higher complexity of the CIM systems resulting from this concept seem to give Europe a chance in the international competition. However, the percentage of integrated automated systems is still of minor importance in Europe.

Empirical research with regard to the present state of CIM-implementation has proven to be problematic. The concept of CIM including its CA-components is ambigious and has led to problems of interpretation both for the respondents of our survey as well as the authors of empirical studies. At the same time the development within the field of CIM comes about so rapidly that empirical results are valid for a restricted period of time only. For this reason, subjective experiences and opinions of the author arising from his own CIM-implementations or various other sources of information should be taken into account when judging the state of implementation.
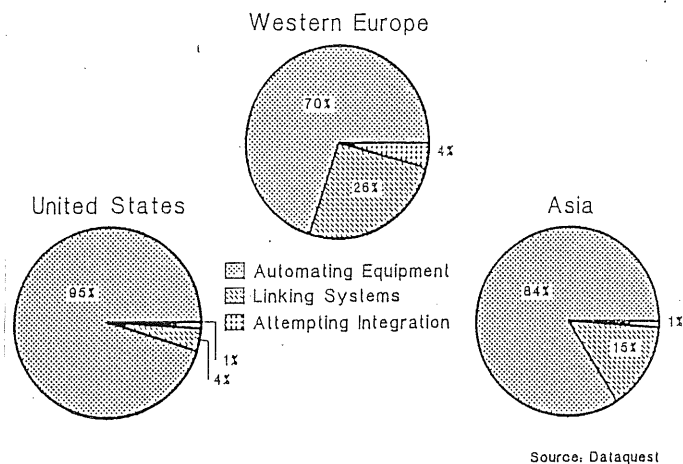
IMPLEMENTATION FORECAST

1987

Western Europe

United States

Asia

☒ Automating Equipment
☷ Linking Systems
▦ Attempting Integration

Fig. 01:   Implementation forecast

A. Phases of the CIM-implementation

The CIM-implementation process takes place in phases (cf. Fig. A.01). During
the phase of conception, the weaknesses of the current information processing
are detected by an analysis of the existing system. As a second step, the
problem description based upon the analysis is developed. In general, it is
comprised of conceptions for

- organizational processing chains
- data structure
- application architecture
- application software
- hardware architecture
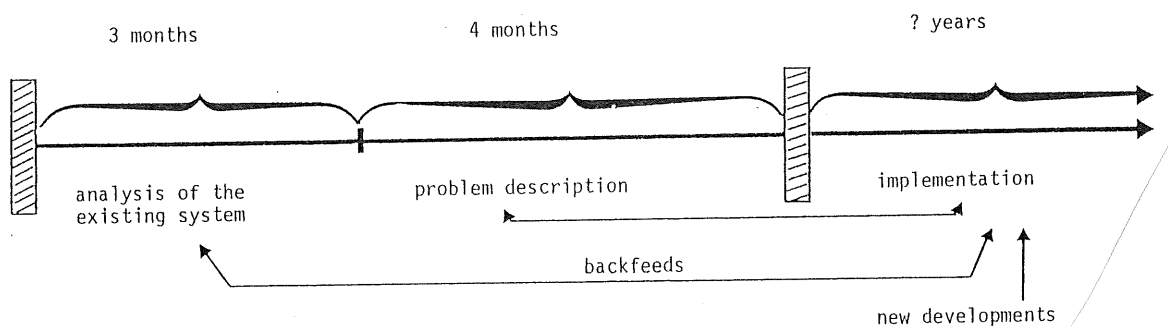- network architecture and operating systems.

Fig. A.01: Structure of a CIM system development process

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Whereas the elaboration of the conception can be handled within a restricted period of time (according to the author's experience, 7 months may serve as an approximate value if supported by external experts), the implementation process may take years. In addition to the substance of the conception, it is necessary to set up an exact project structure that accompanies the implementation process. The CIM-package must be divided into sections which help in developing a logical structure and providing for chances of success at short intervals.

However detailed a CIM-conception may be, there is always the possibility that new developments occur in the course of implementation which may lead to a correction or extension of the conception. By the means of corresponding feedbacks which may also entail the adoption of new analyses of the existing system and of new conceptions, the implementation must be constantly adjusted with respect to former conceptions and new insight.

When developing a CIM-strategy we will meet with two risk areas concerning the time aspect. First of all, many companies have difficulties in setting up a CIM-project because the responsibility remains uncertain which is due to many inter-division questions. Therefore the company management should give the necessary impulse if it does not want to lose time prior to the realization of the CIM-project. The second risk area consists in the transition from the completion of a conception in detail to its implementation. Here it must be seen to that no wordy discussions and conflicts of responsibility arise after the completion of the conception phase. At this stage, the problem description must be elaborated in an organizational form (e.g. formation of subject-overlapping working groups) such that it guarantees high acceptance and can be realized without any loss of time.

B. CIM-Implementation Paths

CIM is a comprehensive conception for reorganizing industrial companies and comprises a great variety of company size groups, branches and production structures. For this reason, CIM cannot comprise the same complex of problems in each company. Discussing a special case of CIM therefore includes that the priority points of the company need to be carefully defined.
According to the branch and production structure of the company the emphasis that is put on the realization of the CIM-concept may vary. The five integration areas represented in Fig. B.01 form typical priority points within the

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CIM-implementation. They are briefly introduced in the following. We also state determinants for their priority of implementation (for further cf. Scheer, CIM 1988 and Scheer, Wirtschaftsinformatik 1988).
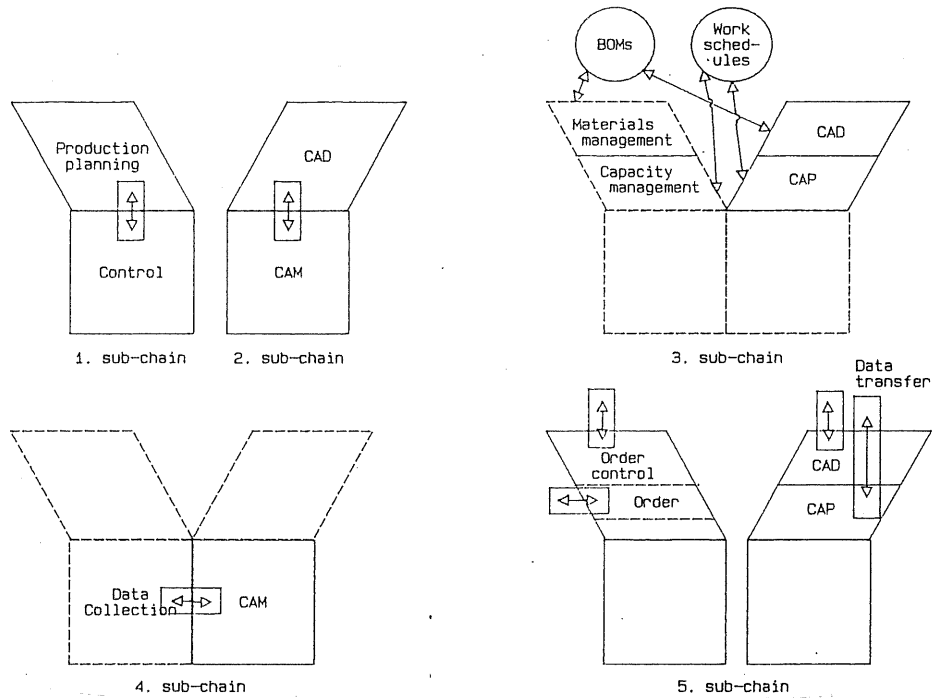

Fig. B.01: CIM sub-chains

The significance of individual CIM sub-chains within the CIM-conception depends on the production structure of the relative company. A rough order of priority is given in Fig. B.02.

	"Parts production"			Process oriented production	
○ = High ○ = Medium ● = Slight — = Zero	One-off production	Ordered small series production	Large series/ mass production	Small series orders	Large series/ mass production
1. sub-chain: Planning - control	◯	◯	○	◯	○
2. sub-chain: CAD/CAM	○	◯	●	—	—
3. sub-chain: Primary data management (BOMs, work schedules)	◯	◯	◯	○	○
4. sub-chain: CAM-provision	◯	◯	○	◯	○
5. sub-chain: Data collection control	○	○	◯	◯	◯

Fig. B.02: Weighting of CIM sub-chains

Within these two groups, further differentiation can be made, for unit produc-
tion between one-off production, order and small series production, and large
series and mass production, and for process oriented manufacturing between or-
der and small series as well as large series and mass production. One-off pro-
duction in process oriented manufacturing is not considered, since this is
atypical of this manufacturing form.

1. Sub-chain: Linking of Planning and Control

As a result of the greater importance of decentralized production units (e.g.
production islands) and hence control issues, the weighting of individual
functions within production planning and control will be shifted from planning
to control.
The differentiated stratification of the planning levels according to the de-
gree of detail and the planning timescale reduces the problem in each case to
manageable proportions. Due to the greater availability of decentralized
hardware, more suitable simultaneous planning approaches and optimization mo-
dels can be employed even in limited planning sectors, which up to now has al-
ways been impossible due to the volume of data involved.
The first sub-chain describes the specification of a CIM hierarchy. This must
be regarded as fundamentally important since the basic planning and control
functions are here distributed to a computer architecture (cf. Fig. B.02). The
importance of establishing a stronger hierarchy increases if the decentralized
units are given considerable freedom in the optimizing of the manufacturing
process, such that independent scheduling functions can occur within order
supply from a higher hierarchy level. With large series and mass production
the manufacturing process is already so strongly optimized (e.g. in the use of
production lines with strict timing) that local scheduling largely disappears.
For this reason the process of establishing the planning and control hierarchy
in this case receives middle weighting.

2. Sub-chain: Linking of CAD and CAM

The linking of CAD with CAM is a much discussed sub-chain and has often been
identified with the term of CIM. First of all, the CAD system must possess an
interface via which geometric information relevant to the CAM system can be
passed on. For example, shading information, which can be of value in a
drawing in the design area, is useless for production. Hence a processor is

required, which can translate the transferred geometric information into a NC-language (e.g.EXAPT). The result is a so-called machine neutral data format (CLDATA). Since the NC manufacturing machines (drilling tools, milling machines) are already equipped with control by their producers (Siemens, Bosch, Allen Bradley, Philips, General Electric, etc.), these control instructions must be adapted to the characteristics and formats of the specific machine control. This is accomplished out by a post-processor. These linkages must, therefore, be taken into account in the choice of CAD and NC programming systems.

The CAD/CAM link is especially important in unit production structures with flexible and small series manufacturing. With large series and mass production forms, however, the relationship is not so important, since here design adjustments can be planned more in advance and are less dependent on a strict data flow. In process oriented manufacturing (e.g. the chemical industry) this chain is even unimportant.

3. Sub-chain: Linking of Primary Data Management

The selection of a CAD system must take into account whether the automatic generation of bills of material is possible and in what form these data structures can be passed on to the PPC system. These kinds of links are currently available from many systems, e.g. between CADAM and COPICS (IBM), CADIS and IS (Siemens) or PROREN and PS (for diverse hardware). Equally significant is the link between work scheduling and NC-programming.

The primary data management chain for bills of material and work schedule information is of considerable importance throughout unit production. In process oriented manufacturing this applies to control instructions which are administered by development as well as production control, and also to the associated work schedules. The provision of decentralized CAM entities, such as produc-tion islands, is particularly important in one-off production and small series order production, since these kinds of systems are more widespread here than in large series and mass production.

4. Sub-chain: Linking of Data Collection and CAM

The intensity of the relationship between production data collection and intelligent control systems increases. Intelligent controls collect machine status and performance data, from which production data about equipment and or-

ders can be derived. For this reason it makes sense to transfer these data directly from the control to the production data collection system. Here, hardware interfaces of data collection terminals can be used.

The links from production data collection and process control to the control of computerized manufacturing installations are of primary importance in large series and mass production within unit production, as well as in the entire range of process oriented manufacturing. In one-off production procedures, order and small series manufacturing, on the other hand, automatic data transfer is not easily achievable, since the automatic transfer of order related information (e.g. quantity and quality) depends on a high degree of standardization of the manufacturing process.

5.Sub-chain: Inter-Company Process Chains

Given that data and functionally integrated computer systems have been developed for the functional areas of the enterprise, and that the CIM concept has given rise to process chains between financial and technical functions within the industrial company, information technology then logically allows the integration of process chains accross company boundaries to customers and suppliers. For simple data transfer functions, the electronic mail service of commercial network systems, the videotext system of the German Bundespost, manufacturer network systems (e.g. SNA from IBM, DECNET from DEC, TRANSDATA from Siemens) and individually developed networks are available. This data transfer allows data from one computer system to be moved to the database of another computer system.

The inter-company data transfer is already realized between car manufacturers and their suppliers. By transmitting the callings of the car manufacturers directly to the mailbox files of the supplier industry, the inter-company data transfer relates to the transfer of planning data. In a similar way CAD-data is transmitted from the car manufacturer to the supplier industry, particularly for the production of tools.
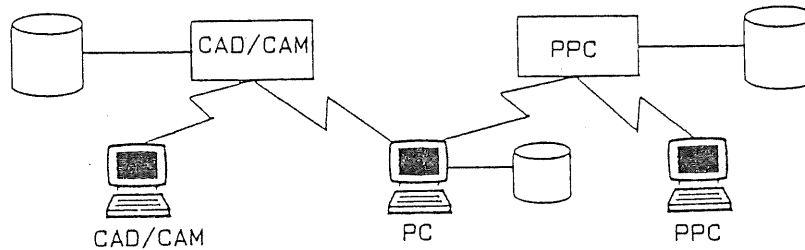
C. Integration Tools

For the technical implementation of CIM we have various tools at our disposal which permit a more or less close data and functional integration. In Fig.

C.01 some tools are represented using a level-by-level approach, where only the fifth level makes a real inter-application integration of different CIM-subsystems possible.

1. Level: Organizational integration of independent data
          processing systems

2 devices
at the workplace
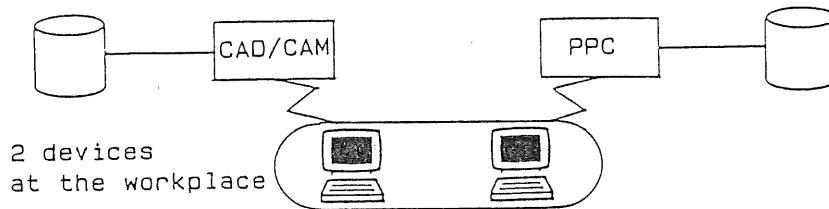
2. Level: Integration of independent systems by way of tools
          (PCs, Query, Networks)

CAD/CAM   PC   PPC

3. Level: Data transfer between systems

CAD/CAM   Mail box   PPC
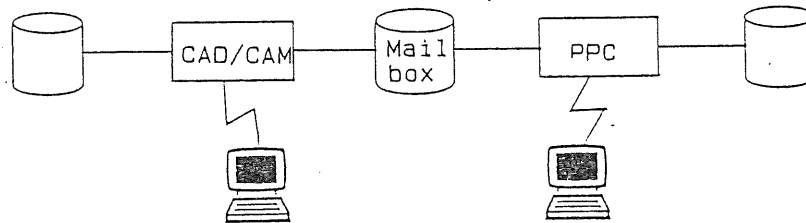
4. Level: Systems sharing common database

CAD/CAM   PPC

Common
data
base
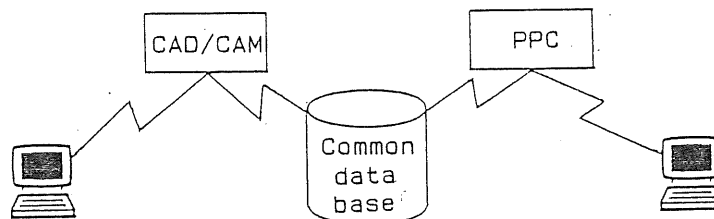
5. Level: Inter-application contacts via program integration

CAD/CAM
PPC

Common
data
base

Fig. C.01: Possible Integration Tools

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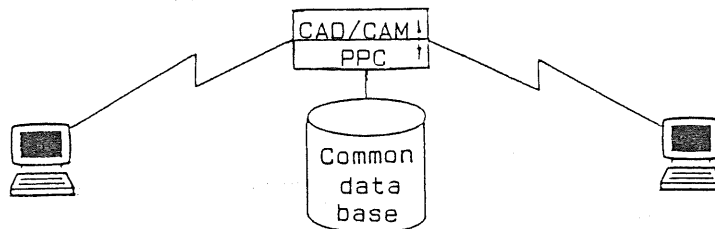The first level merely represents an organizational integration which is important for those companies which have established isolated solutions within CIM-subsystems and which therefore only have the possibility of organizationally linking these isolated solutions in a rough-and-ready way. Separate CAD and PPC systems which at the workplace of the constructor or of the process planner are put to the desk officer's disposal using a switch-selectable terminal or fittings of seperate terminals may serve as an example.

The second level represents typical CIM-integration tools, such as the micro computer, in-house networks, etc. for linking originally unlinked application systems. Particularly the open system architecture of micro computers is often applied in CIM prototypes for linking heterogeneous hardware systems with the network. The advance of MAP-interfaces accelerates the design of homogeneous systems.

The third level includes the file transfer connection which is frequently applied nowadays and which for instance passes bills of material information from a CAD system to a PPC system. This implies the development of individual solutions for concrete CAD and PPC systems or the use of so-called neutral data formats (e.g. in the sphere of CAD: IGES). The data transfer may be a desirable form of data linking for many users, but it is not sufficient for consistent CIM-systems. The transfer is problematic in view of data consistency and cannot be regarded as equivalent to an inter-application relation.

The fourth level supposes a common database for CIM. This does not necessarily imply a physical unit but should be considered in view of logical consistence. This means that updates are automatically forwarded from one domain to another. As the development concentrates more and more on relational database systems, the common database of different CIM-components approaches its realization. However, there are still considerable conceptual problems to be solved which arise from the different requirements on application (planning data, geometric data, real time processing).

Only the fifth level guarantees the unlimited combination of the applications. This can be observed in the development of new architectures for CIM-software.

D. CIM Standard Software

1. Present situation

Among the five levels represented in Fig. C.01 only the first three levels are realized by the current standard software. The third level, namely the data transfer among different CA-systems, constitutes the latest stage of development. This means that different suppliers agree to forward data from one domain to another by linking the software.

These possibilities are enlarged by the adoption of inter-chain status monitorings into which data transfer functions are embedded. One possibility of realization is given by the conception of a CIM-handler which has been developed at the Institut für Wirtschaftsinformatik of Saarbrücken (cf. Scheer, CIM 1988, p.113). It starts out from the fact that software is available for different CIM-components in the form of separate architecture levels that are divided into hardware and software. The CIM-handler now takes control of the inter-domain process chains by providing the chain with a status monitoring, thus being able to trigger off or give preference to functions at previous and later stages (cf. Fig. D.01). For example, such conceptions are put into practice with the implementation of IBM CIM-package solutions in the computer world /36, where the linking system COMPASS assumes the functions of linking PPC- and CAD-systems and other CA-components (cf. Scheer: CIM-Paketlösung für den Mittelstand, lecture on the occasion of the '87 IBM-user congress "Industrie und Technik" at Garmisch, 21.-23.10.1987).

In extending the software of the company SAP from the PPC-domain to other CA-components, it has been planned to implement the functions of the developing process of time consuming redesign via a project monitoring system (cf. Scheer: Die CIM-Konzeption im Rahmen der SAP-Logistik-Software, lecture on the occasion of the international software congress at Karlsruhe, 7./8.9.1987). Here the results of an operation are kept in the database, and the next processing step points to the results of previous processings. This operation chain covers the domains bills of material processing, construction and work scheduling.

By exploiting the possibilities of the idea of a CIM handler, i.e. the linking of existing components, many CIM-processes can already be designed in an integrated way. Today, there are developments in sight which, on the basis of new ideas, try to set up an EDP-based architecture for the design of CIM-systems.
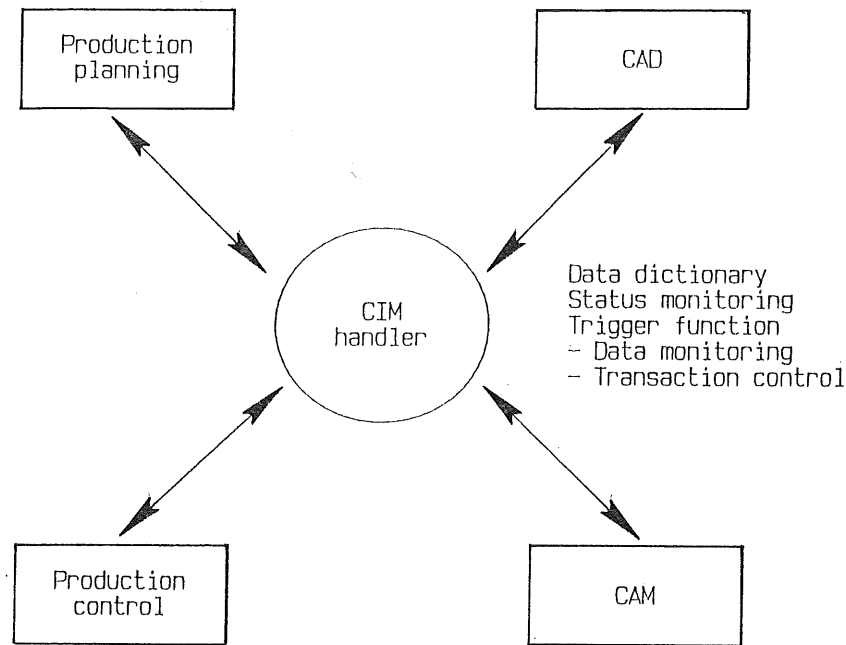
Fig. D.01: CIM Handler Concept

2. New Approaches towards a CIM-Architecture

The suppliers of EDP-backed systems for the implementation of CIM pursue a double strategy. On one hand, they try to apply the existing systems to CIM as described for the CIM data handler. At the same time, they make new approaches towards CIM. This applies not only to existing hardware and software systems but also to the provision of the required organizational know-how. Thus, many producers assume the so-called general contractor functions in order to share the responsibility of introducing CIM. This means that they have to cooperate with various hardware partners. Hence, they are forced to disclose the system links and at the same time to standardize hardware and system software more efficiently. Even though every hard- and software producer has its own CIM-philosophy for new systems, some developments are observed which can be summarized by the following headings :

a) application independent data design
b) application conceptions to solve newly emerging problems
c) wide acceptance of open standards
d) development of new flexible application software
e) embedding of CIM into the information pyramid

a) Application independent Data Design

In the development of database systems it has become possible to design data structures independent of their restricted range of application. Beyond the design of logical data structures it becomes apparent that the data can be administered independently of special applications, i.e. updated and backed up. This is particularly important for CIM since essential integration relations of CIM can indeed be achieved by means of shared exploitation of data. A neutral form of the data structures is a prerequisite for application independent data administration. To achieve this, appropriate of design tools have to be employed. The entity relationship model is a widely accepted procedure for constructing data structures. In Fig. D.02 the data structure of the CAM-domain has been developed using the entity relationship model (for further details cf. Scheer, Wirtschaftsinformatik 1988,pp.331). The so-called entity types are represented by rectangles, and the logical connections between entity types are characterized by diamonds.
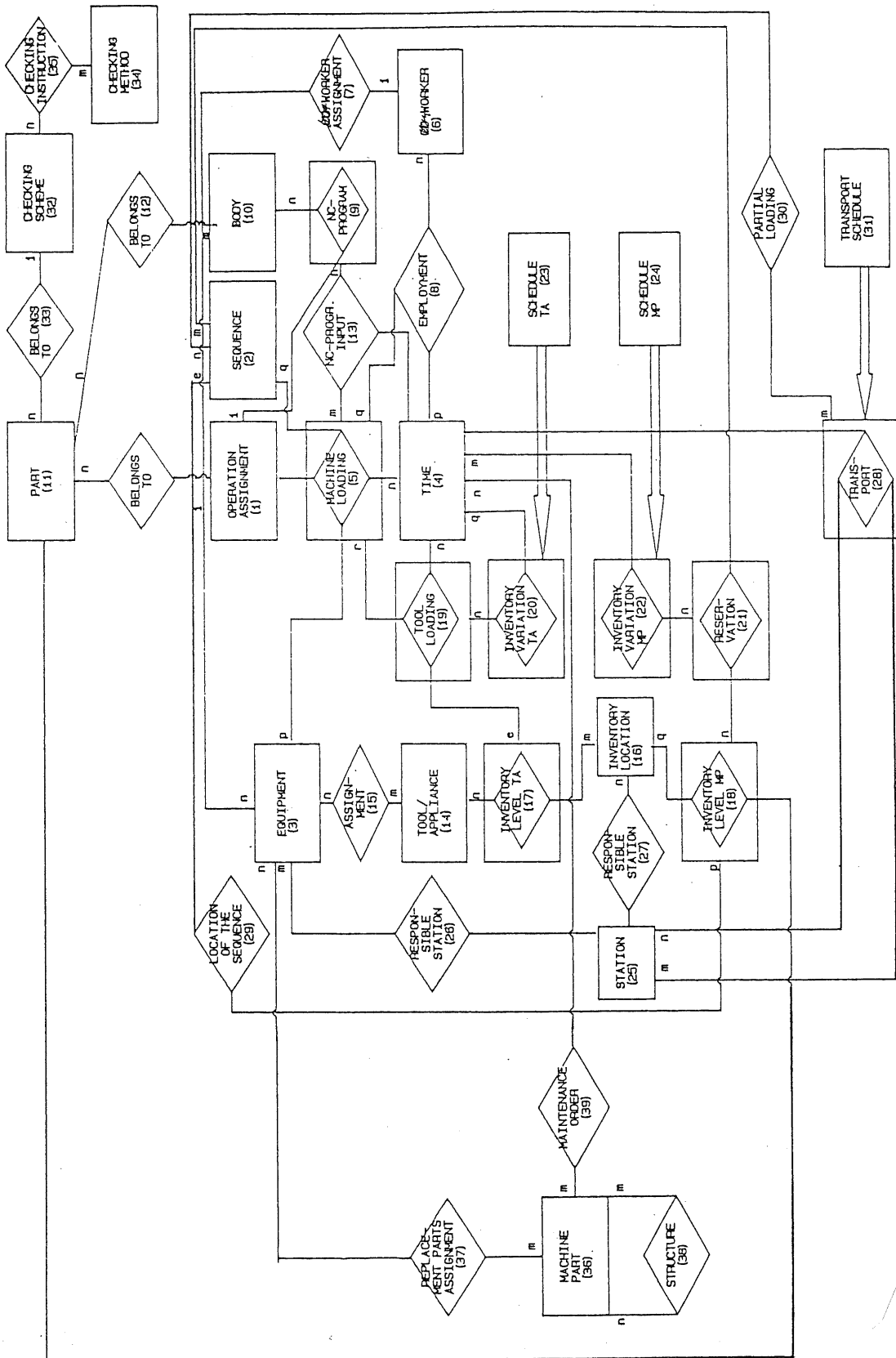
Fig. D.02: Data structure of the CAM-domain

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Concerning the functions :
- process scheduling / NC-programming
- inventory
- transport
- quality assurance
- maintenance

an integrated CAM-data structure is developed. The production control is con-
nected with it.

An organizational CAM-unit ("factory within the factory") which disposes of
auto-control functions and has been characterized by the terms automated pro-
duction island or flexible production system may serve as guideline for the
efforts.

A superordinated order supply system accepts the open OPERATION ASSIGNMENTS
(1) which are roughly scheduled. This leads to new lots (SEQUENCE) which re-
late to an operation and which are due to optimizations respecting re-tooling
costs or waste of material (2).
EQUIPMENT of the organizational unit is to be administered as primary data
(3). The connection of these three entity types with TIME (4) generates the
relationship type MACHINE LOADING (5).
CO-WORKERS (6) who are employed with the organizational unit are connected to
EQUIPMENT via the relation CO-WORKER ASSIGNMENT (7). The scheduling of co-
workers with respect to special machines is achieved by the connection of the
entity types CO-WORKERS and TIME with the relationship type MACHINE LOADING
(5), transformed into an entity type. According to the statements on produc-
tion control, EMPLOYMENT (8) may cover for several machine loadings, however,
several employments may be assigned to one machine loading, too.
NC-programs which are administered within the organizational unit form an in-
dependent library (9). This is expressed as a relationship type (11) of BODY
(DESIGN) (10) and OPERATION ASSIGNMENT (1) which is later transformed into an
entity type. The entity type BODY expresses that, within the organizational
unit, designs can be administered for the parts produced within the unit.
The parts/materials produced and administered within the island form the
entity type PART (11). It is connected to the designs (BODY) via the relation
BELONGS TO (12).

The use of NC-programs (13) creates the relation NC-PROGRAM INPUT to MACHINE
LOADING and to TIME, where one NC-program can cover several machine loadings.
Tools and appliances administered in the organizational unit constitute the

independent entity type TOOL/APPLIANCE (14). The tools and appliances used for equipment are defined by the ASSIGNMENT (15).

In the case of highly automated systems special inventory systems for tools and appliances can be installed. The entity type INVENTORY LOCATION (16) is used for the storage of parts (in particular on the intermediate inventory level of started operations), materials as well as for tools and appliances. Of course, one may also introduce a differentiated inventory hierarchy. The inventory level of tools and appliances in one inventory location (e.g. on a palette or on a special shelf) is defined by the relation INVENTORY LEVEL TA (17).

The inventory level of materials and parts forms the relation INVENTORY LEVEL MP (18) of the entity type PART (11) and INVENTORY LOCATION (16). The TOOL LOADING (19) is regarded as a relationship type of the transformed entity types INVENTORY LEVEL, MACHINE LOADING and TIME (analogous to MACHINE LOADING, EMPLOYMENT and NC-PROGRAMMING).

The connection to the entity type TIME guarantees that the TOOL LOADING (19) is still valid beyond several machine loadings. The storage and out-of-storage operations (inventory variations) are handled separately concerning tools/appliances and materials/parts (20, 22). The inventory variation for tools/appliances, which is a storage or out-of-storage operation, constitutes a n:m relation to TIME and the transformed entity type TOOL LOADING, thus forming the relationship type INVENTORY VARIATION TA (20). The time characteristic is established by the starting of the storage or out-of-storage process.

The INVENTORY VARIATION MP for materials/parts is defined accordingly. The materials and pre-products which are necessary for one sequence are first recorded by the relationship type RESERVATION, which forms an n:m relation to INVENTORY LEVEL and SEQUENCE. The exclusion of the reserved components is characterized as the relation of the transformed entity type RESERVATION and TIME via INVENTORY VARIATION MP (22). The inventory variations are arranged as SCHEDULES (23, 24).

As to the transport system, the entity type STATION (25) is introduced. It is connected with EQUIPMENT (26) and INVENTORY LOCATION (27) via assignment relations. A special transport operation is a relation between two stations. Here, the "from" and "to"-transports of a station must be distinguished. This leads to the n:m-relation TRANSPORT (28).

Since a sequence can be stored in the inventory system after being completed, the LOCATION OF THE SEQUENCE is denoted by a n:m-relation between INVENTORY

LEVEL and SEQUENCE (29). The n:m relation makes it possible to store parts of a sequence and to identify them for later processing.

Sequences can also be transported in partial loadings. The partial loading of a sequence which is transported as an entire item is defined as the relationship type PARTIAL LOADING between TRANSPORT and SEQUENCE (30).

The transport operations within a certain period are hierarchically arranged in the SCHEDULE (31).

The checking schemes administered within the organizational unit are stored in the entity type CHECKING SCHEME (32) and connected with the parts (33). The checking methods applied form the entity type CHECKING METHOD (34) which combined with the checking scheme constitutes the entity type CHECKING INSTRUCTION (35).

The data structure for the maintenance is related to the equipment. The replacement parts (MACHINE PART) are assigned to the equipment (36, 37). The "bill of material structure" of complex replacement parts is represented by the relation STRUCTURE (38). The MAINTENANCE ORDER forms a n:m-relation with MACHINE PART and TIME (39).

The developed data structure includes many data relations that exist in reality. The central integration of the entity type TIME stresses its importance in the domain of short-term control. At the same time, the close relation to real time processes including their consequences on hardware and software is emphasized. The importance of some entities and relations is limited; they can be deleted after processing. This especially applies to transport and inventory operations.

During the construction, the degrees of relation have sometimes been neglected. The individual degrees (1:m, n:m, ...) represented by the figure can be easily derived from the context. In order to provide for a general and far-reaching interpretation, we have mostly dealt with n:m-relations. In practice they may be reduced to 1:n-relations.

b) Application Software for new Problems

CIM also generates new application philosophies. For instance, the stricter hierarchization of production planning and control leads to a new orientation of the production control. Furthermore, new forms of organization such as production islands, processing centers etc. also create new problems. Along with the development of CIM-systems, new application conceptions are developed which are supported by corresponding EDP-based systems. The control station conceptions which are represented in Fig. D.03 in form of an electronic plan-

ning panel may serve as examples. In this domain, the suppliers of standard software prove to be capable of solving practical problems in an innovative way.
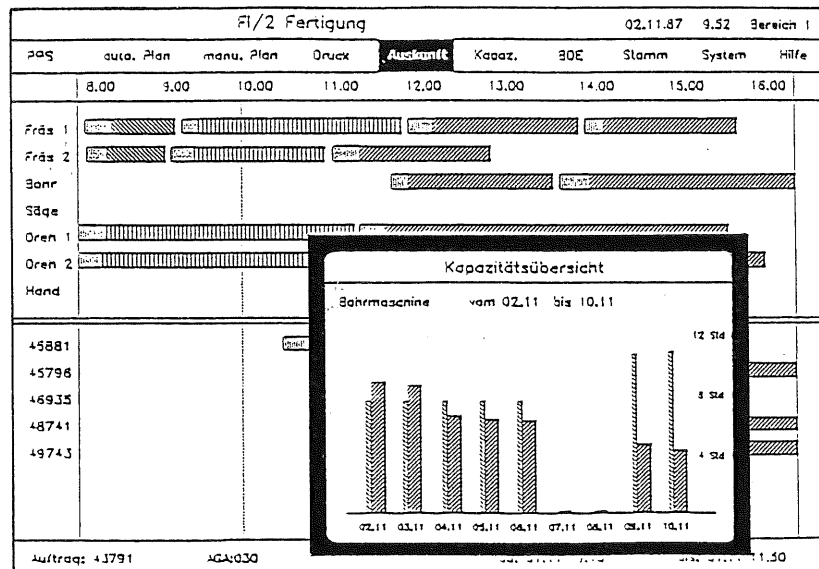

Fig. D.03: Electronic planning panel with capacity chart

c) Broad Selection of Standards

The general contractorship mentioned above which many suppliers of information systems in the CIM-domain adopt, presses for a wider acceptance of so-called open standards. This effort is also supported by big application projects of crosslinking (e.g. MAP). Though the leading firms IBM and DEC offer their own system architecture, many suppliers rely more and more on the operating system standard UNIX. Similar standards can be observed in the domain of hardware network (MAP, TOP) and in the graphic data processing (IGES, VDAFS, GKN etc.).

d) New Software

The enormous heterogeneity of the CIM-approaches requires flexible application software. Thus it can be seen that the classic form of application software is out of place, at least concerning certain domains. This applies, for instance to the domain of production control because in this domain the different demands of the production systems (capacity oriented, material oriented, production sequence oriented, etc.) must be taken into consideration. Therefore the

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system of so-called "enablers" which is currently being produced by IBM creates new possibilities for the development of application software, by providing just a tool kit in form of a macro-language for CAM-applications which software firms or users can use for the design of special systems. This tool kit can be combined with other standards of data processing and crosslinking (cf. Fig. D.04).

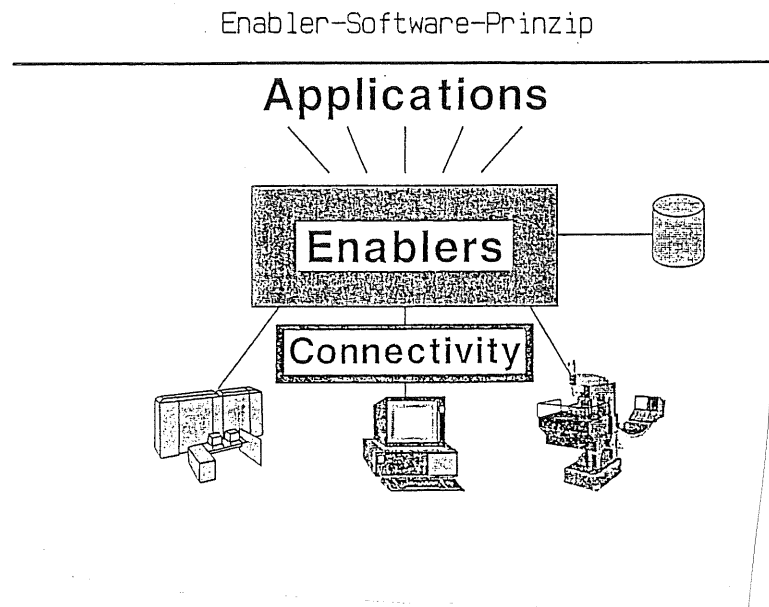Enabler-Software-Prinzip

Applications

Enablers

Connectivity

Fig. D.04: Enabler software principle

Apart from the "enabler" conception, the development of knowledge-based software systems for CIM is very important. They make sure that the various fields of knowledge required for CIM can be conveyed to the users in a form which satisfies their needs and, furthermore, that status monitorings and advice can be given in complicated situations within the application and decision process. Many producers have started to develop prototypes in the expert system domain, which proves once again the turning away from classical software architecture.

e) Embedding of CIM into the Information Pyramid

CIM is a typical example of integrated data processing which is mainly oriented towards the linking of operative levels. However, it becomes apparent that the quantity-oriented operative systems must be embedded into the entire information pyramid of the company. This is the only way to guarantee a homoge-

neous management which relies on the same data quality and processing form. The integration of CIM into today's management information system conceptions therefore is a challenge which hardware and software producers have to meet just like the challenge of providing for system links on the operative level (cf. Fig. D.05). Fig. D.05 represents both the horizontal and the vertical integration of the information processing. The connection to the data structures emphasizes the fundamental importance of this design stage for the implementation of company-wide information systems.
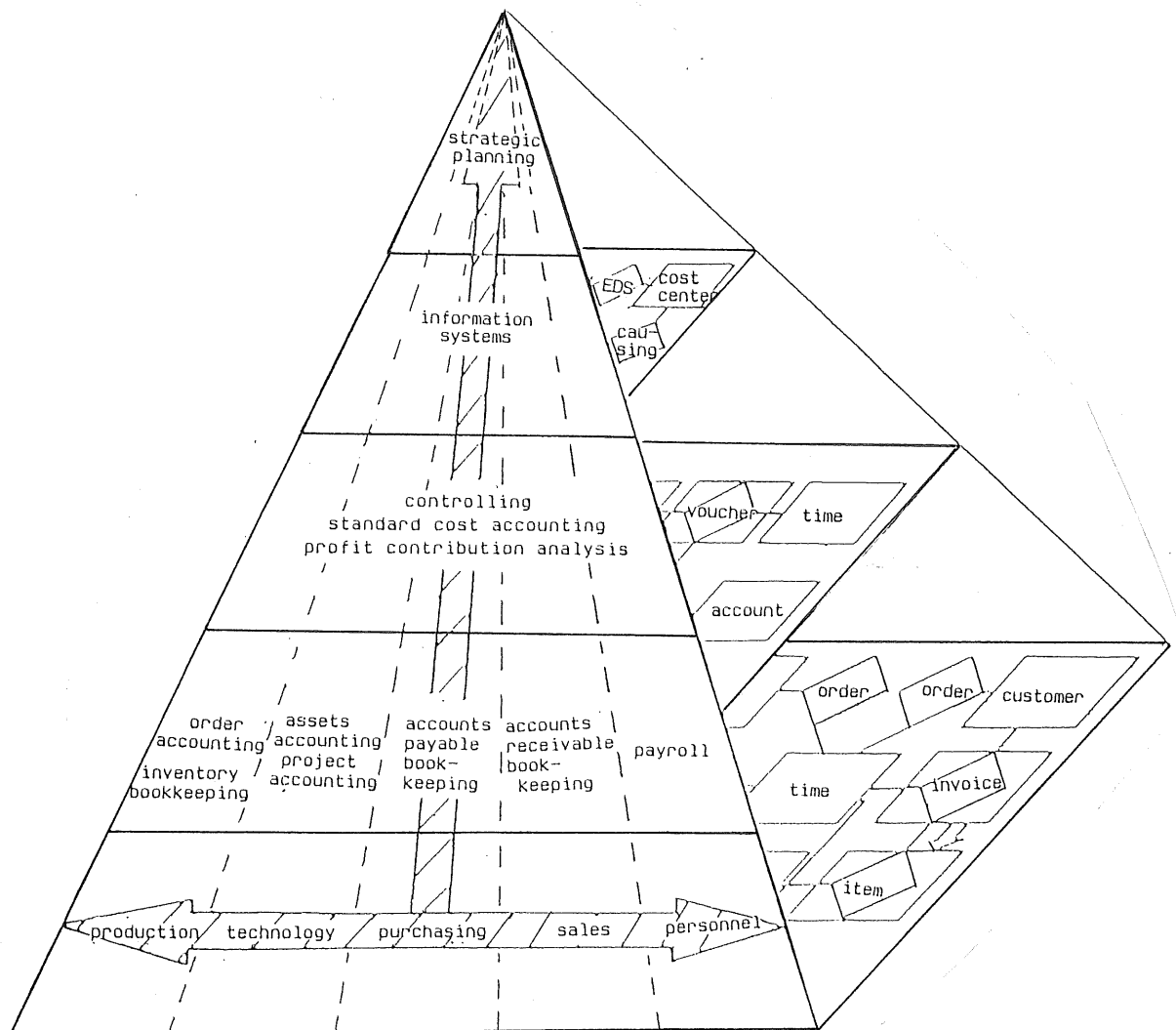
Fig. D.05:   Information pyramid

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Die Veröffentlichungen des Instituts für Wirtschaftsinformatik (IWi) im Institut für empirische Wirtschaftsforschung an der Universität des Saarlandes erscheinen in unregelmäßiger Folge.

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