Standards & Communication Systems in Construction Planning

Amadeo Sarbach
Chair for Architecture and Computer Aided Architectural Design
Prof. Dr. Ing. Gerhard Schmitt
Swiss Federal Institute of Technology
CH- 8093 Zürich, Switzerland
sarbach@arch.ethz.ch
http://caad.arch.ethz.ch/~sarbach/

Table of Contents

1. Abstract

A planning team today has to cope with new boundary conditions. On the one hand, these are the economic situation and structural changes in the building trade, and, on the other hand, the new technical possibilities in the planning process and in the area of communications.

The standards and communication systems compiled as part of our project support both aspects. Through a uniform document management, a legal basis and the standardization of the drawings time is saved avoiding a multiple processing of the same plan documents. The standards are take into account the use of modern and direct communications and tools. The data occurring is structured and organized during the planning period, so that it can be further used in the operating phase of a building.

The Engineering Data Management System manages the organizational standards and controls the different communication systems used. Thus both components are united in a single method. An essential part of our project is the development of this program. My article describes firstly the Standards, then the different communication systems and finally the developed Engineering Data Management System.

1. Introduction

For the practical realization of an integrated planning system common standards and fast, user-friendly communication systems are an urgent requirement.

My main task on the ZIPBau (Centre for Integrated Planning in Construction) project was to develop a communication concept, within the networks of the project partners and to supervise the implementation of the different standards, which I will discuss more fully in the lecture. It deals, therefore, with the practical part of the project, which could be tested on a case study. For this reason the emphasis of the lecture will be more on the practical part.

An important maxim for the acquisition and management of data / information arising during the planning phase is the desire to extend the time frame over all cycles of a building, i.e. planning, construction, operation and demolition. This attempt necessitates that subsequent information requirements need to be considered already from the beginning, even if, from the planner's viewpoint, this is often difficult to achieve. Actually, the planning stage only accounts for about 10% of the total cycle of a building. For this reason, however, it appears to us imperative for integrated planning to take the total time of a building as a basis.

In the first part of the standards the legal requirements are explained, enabling the partners to be able to share data. A model agreement, which should serve as the basis for a contract, attempts to assign responsibility with its limits to the individual project partners. In this way the planning phase and above all possible disturbances are regulated and the legal basis is provided.

Document classification is an important instrument to maintain order. Without the direct structuring of new data at the acquisition stage it is practically useless later.

The layer structure is the method for classifying data in most CAD systems. As long as this structure represents the main structure in the CAD programs and at data interchange with today's popular exchange formats and it forms the most important structure attribute, the definition and introduction of a common layer structure is vital.

A uniform classification of the building into individual elements will supersede the use of a layer structure in the medium-term.

The application of the defined standards is achieved by means of a program for Engineering Data Management, which controls the management of the data and supervises communications. As soon as the physical network is in place, the network activity can be controlled by the Engineering Data Management system. Thus management and communication are bound together and form a comprehensive data management. The physical networks of the project partners have to duly consider the different existing network types and must not be allowed to restrict an existing network.

3. Standards

A system of planners, who use the same database, demands organizational preparatory work.

The legal basis of the cooperation must be adapted to the networked partners. A contract regulates data exchange, the obligations and the responsibilities of the individual partners.

A uniform nomenclature classifies the documents that are produced. The document arrangement replaces the hierarchical filing of the documents. In this way the individual registered documents are specified and retrieved.

CAD plans in the civil engineering field are usually structured by means of a unified layer system.

3.1 Legal basis

Before a planning team works via networks on a building project those aspects have to be regulated which arise from the communication and sharing of electronic data. Within our project a contract was developed, which regulates legally the electronic data interchange (EDI).

The sources for the development of this contract are:

- ICC: UNCID Uniform Rules of Conduct for Interchange of Trade Databy teletransmission, ICC Publ. Nor. 452, January 1988
- American Bar Association: Model Electronic Data Interchange Trading Partner Agreement and Commentary, 1990
- UNCITRAL Report on Electronic Data Interchange, May 15, 1991, A/ CN.9/ 350
- EDI Association: Model Agreement for Electronic Data Interchange Agreement
- Commission of the European Communities-TEDIS programs
- European Model EDI Agreementt
- Contract Models for Suppliers and Users of Information Technology

This agreement aims to establish the methods and conditions for the interchange of electronic data (EDI) between the partners involved, the determination of the legal effect of EDI and the regulation of the remaining conditions for handling EDI between the partners. In particular, in this way disturbances are regulated as well as the division of responsibilities for the costs involved among the project partners.

The contract defines the individual legal transactions. Much importance is attached to data protection and security considerations in the contract, because the electronic data has to be dealt with separately in relation to the data protection.

The individual aspects the contract are:

Responsibilities with respect to EDI
Interruptions and disturbances
Legal effect of the delivery of EDI

Registration and storage
Data protection and data security
Costs
Responsibilities, insurances
Duration and termination of the agreement

3.2 Document classification

The significance of document classification lies in the fact that it provides the means for the identification of documents. Since the data is not, as in the file system of a computer, hierarchically stored, but listed according to the database entries, the classification of the individual documents in this system takes on a central role in the data management. If an individual document is recognized and retrieved by the document management of the computer's operating system by only using its name, the possibility exists in a data management system to find arbitrary values in addition to its name. The operating system uses as a means of classification a hierarchical allocation in lists. The document management system , on the other hand, can reproduce a detailed document classification and also utilize it for the structuring of the individual documents and is not for this reason dependent on the classification system for the files.

The document classification allows a clear allocation of each individual document. In addition, however, it is also possible to classify the document according to its contents. In most cases (above all in the processing of plans and visualisation) the allocation of the entire document suffices to retrieve it uniquely. For some documents, however, an assignment according to contents can be of far greater significance. The minutes of a meeting, for instance, must be input to the document management according to the individual items, since it contains statements over several areas of the document classification. Otherwise, the assignment is hardly better than a simple nomenclature.

The document classification divides into 8 different categories:

Environment/ location
Project description
Visualisation
Costs
Finances
Deadlines
Organization
Administration

Attributes are assigned to each category, which may or may not require a value. The individual values are also contained in the document classification. Although technically possible, when the values are assigned they should not be redefined, but selected from the predefined document classification. In EDL, the data management tool we use, which I will explain later, these values are each obtained from lists.

3.3 Layer classification

At the moment great efforts are underway in Switzerland to correlate the layer classifications produced by different organizations. Since the beginning of this year ZIPBau along with the AfB (Office for Federal Buildings), the SIA (Swiss Association of Engineers and Architects), the CRB (Central Office for Rationalizing Construction Work) and the SSUC (Speedikon User Club of Switzerland) is coordinating layer classification. As a result a revised layer classification is expected, which will be published by the SIA or the CRB and so the chances are good that it will be established in Switzerland.

The models developed by ZIPBau served as basis for the common Workshops, and were adopted in the SIA documentation D506, as also the layer classification of the SSUC, the CAD Layer organisation Proposal 'Structural Engineering' of the AfB, and the ISO proposal, which should become a European standard (ISO 13567).

At the 3rd Workshop of 19. June 1995 besides the abovementioned an interesting variant by the CRB was presented. It is based on the element cost classification (EKG). The proposal, to start from a building classification system, appears right to us. With it, besides the structuring the CAD data, a technically realizable combination between graphical CAD data and the building administration is also possible. Furthermore, the different partial models of the constructional process developed in the research project can best be described by an object-oriented assumption. Using the classification of the individual objects processes can also be better described.

Thus, the logical classification of the building is used for structuring the CAD data. With it CAD systems of the future will also have to structure their data for the individual parts. By incorporating such parts of the building a very satisfactory building model can be produced (object-oriented assumption). A building is composed of different floors, the individual floors are composed of rooms, these again of external and internal walls and fittings, etc. Thus, in this way, the complete model may be structured and described. Thereby the organization of the graphics elements is much clearer and readily standardized.

000 Property, site survey 010 official site survey
020 regional planning
030
040
050...
060
070
080 situation planners
090 reserve
100 Preparation, special civil engineering works,
renovation, surroundings 110 construction site equipment
120 demolition
130 safety measures
140 renovation
150 lifelines (electrical, etc.) on plot of building land
160 excavation support, groundwater control
170 special foundations
180 garden, games and sports facilities
190 reserve

200 General civil engineering, traffic structures 210 traffic planning
220 basic documents
230 earth moving works
240 structures
250 geometry of traffic structures
260 highway construction
270 railway construction
280 hydraulic structures and river engineering

290 reserve

300 Shell (or carcass) of building 310 excavated material
320 floors
330 walls, supports (load-bearing)
340 walls, supports (non-load-bearing)
350 staircases, ramps, elevators
360 ceilings, roofs, underbeams of floors
370 other building shells
380 building plumbing
390 reserve

400 Sanitary engineering, heating, ventilation, air conditioning, cooling 410...
420 sanitation
430...
440...
450 heating
460 ventilation plant
470 cooling systems
480...
490 reserve

500 Electrical power plant, telecommunications 510 heavy current
520 heavy current plant
530 lighting, lamps
540 electrical equipment
550 telecommunications
560 general light current plant
570 safety and monitoring systems
580 special plant
590 reserve

600 Construction 610 metal construction
620 joinery
630 partition walls
640 wall linings, tiling
650 ceilings
660 floor coverings
670 surface treatment
680...
690 reserve

700 Fittings, installations, equipment 710 industrial fittings
720...
730 farming equipment
740 transport facilities
750 conveyor systems
760 warehouses
770 building furnishings
780 surroundings
790 reserve

800 Lifeline construction, land registers
810 basic documents for lifelines
820 sewage
830 drinking water
840 gas
850 electricity
860 telecommunications
870 community antennas
880 district heating
890 reserve

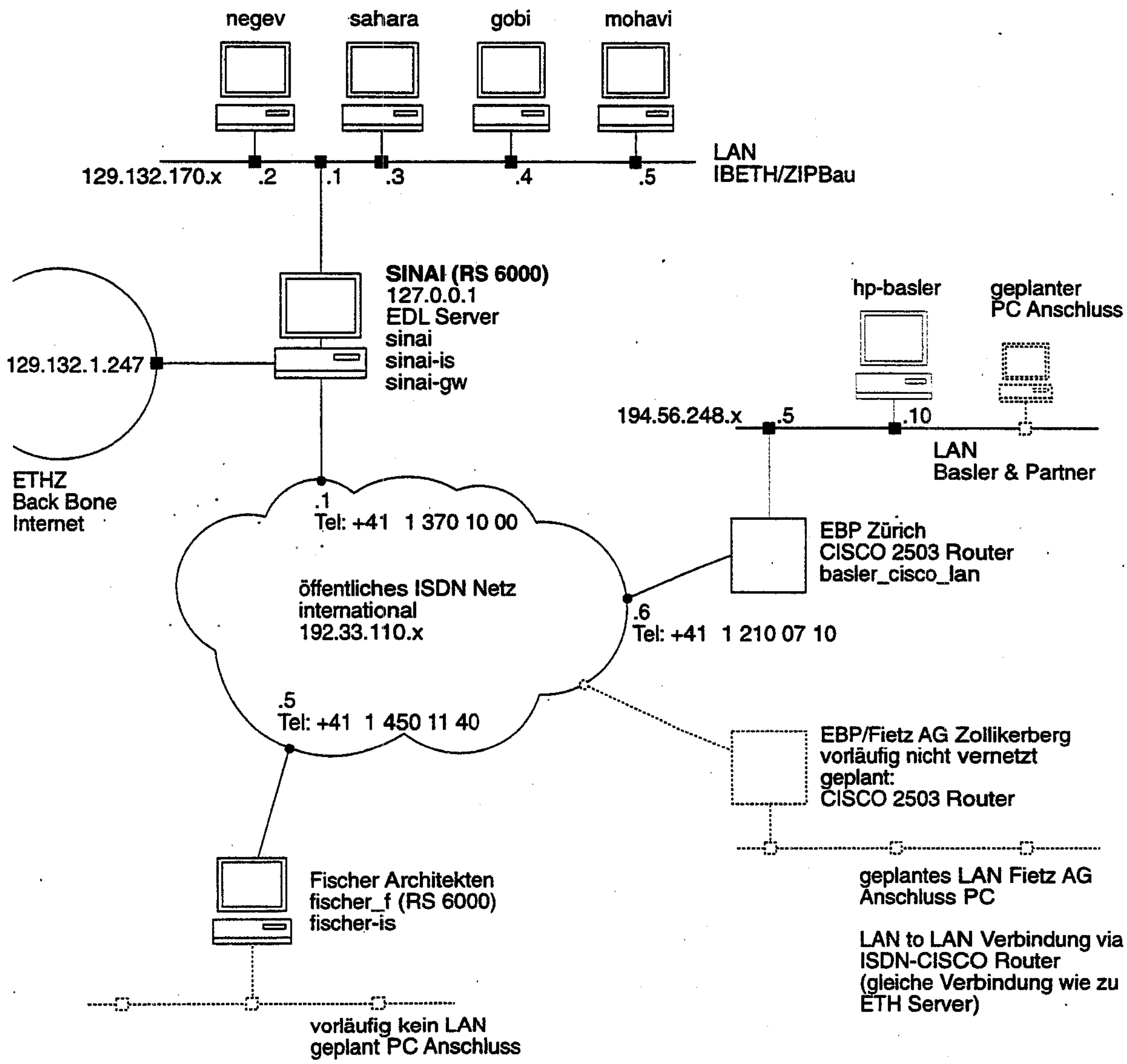
900 Reserve

4. Communication systems

4.1 Network diagram /case study model

The figure presented below shows the construction of the network for the project partners of the ETH:

For a TCP/IP data transfer each node in a network is addressed by means of a number. With it the connection is established to a such node and each node belongs to a computer. In fact, one does not communicate with the computer itself, but with its interface (e.g. ethernet card). In the case of our ISDN connections the selection of the telephone number is also made according to this figure. One gives a name (e.g.: sinai-is), this name is then translated into an Internet number (in the case of sinai-is to 192.33.110.1) and this Internet number is assigned a telephone number in the ISDN configuration. In this way the name leads to the assignment of the corresponding connection.



The following network protocols are involved:

TCP/IP (UNIX)
IPX (Novell)
Ethershare (PC/Mac)
AppleShare (Mac)
PPP (ISDN LAN to LAN)

4.2 EDMS: Engineering Data Management System

The Engineering Data Management System EDL of the firm Control Data used in the ZIPBau project consists of a multitude of single programs, which cover the different aspects of data management. The individual programs, for example the 'Networked Object Manager', the 'Desktop Manager', the 'Process Manager' or the 'Administrator Manager', just to name a few, are employed by the user for the different tasks of document management, process control and data exchange. I shall start with the processes, which will appear in the data exchange for the case study.

The abovementioned CAD layer organisation and document classification are adopted in EDL and serve as for structuring purposes.

EDL is essentially a data management system, which manages all local, central and decentralized data. For this reason communication is an integral part of EDL and is not treated separately.

The functionality of EDL by far exceeds that of an ordinary computer file system. A computer file system stores the individually managed documents in hierarchical directories and retrieves the documents by using their name. For each document a few attributes, like creation date and time, change of date, size and access rights, are stored. The management of the documents is carried out only for a local workstation, for a closed file system or for a network..

EDL consists of 3 databases:

Database with all menu items of the program
Database with all project definitions, like users and groups, processes
Database with the exact specification of the managed documents

EDL extends the computer file system. For each registered document a database entry is made. For each document a record is stored in the database, which has either free and fixed fields. The individual fields correspond to an attribute. A value can be input to each field. The subdivision into a category defines solely the selection of the attributes.

Only the individual records of the database are transferred over the network. In this way there is a minimum of network traffic and all planners have access to all documents. Because the database entry contains all information about the registered document, while the document itself, however, is only provided with a link to the effective location, these database entries are designated as metadata.

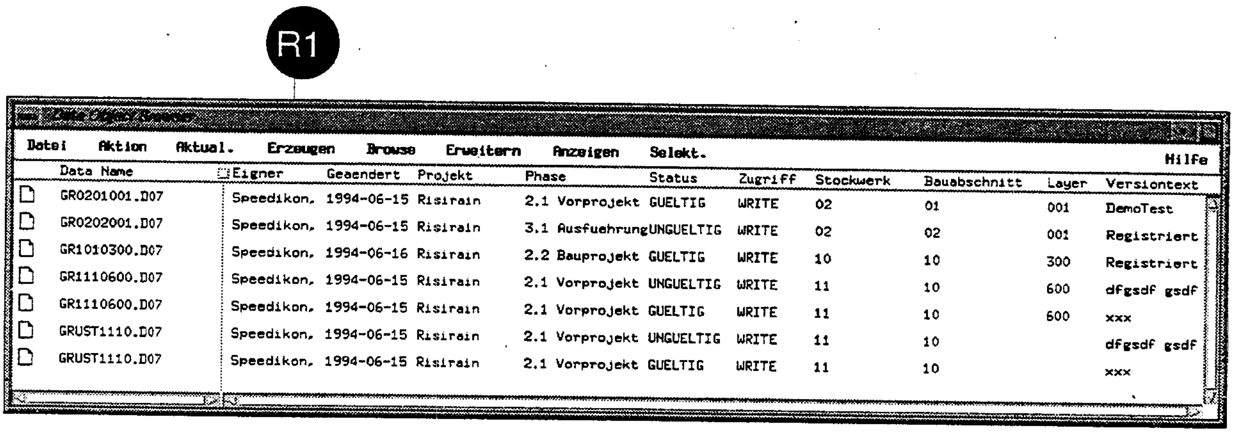
The individual processes in EDL are:
Registering files
File information
Search for files
Attribute lists
Search for/register files from file system

I would like to show as an example the procedure for the registration of a document:

EDL can register a document by means of 2 possibilities.

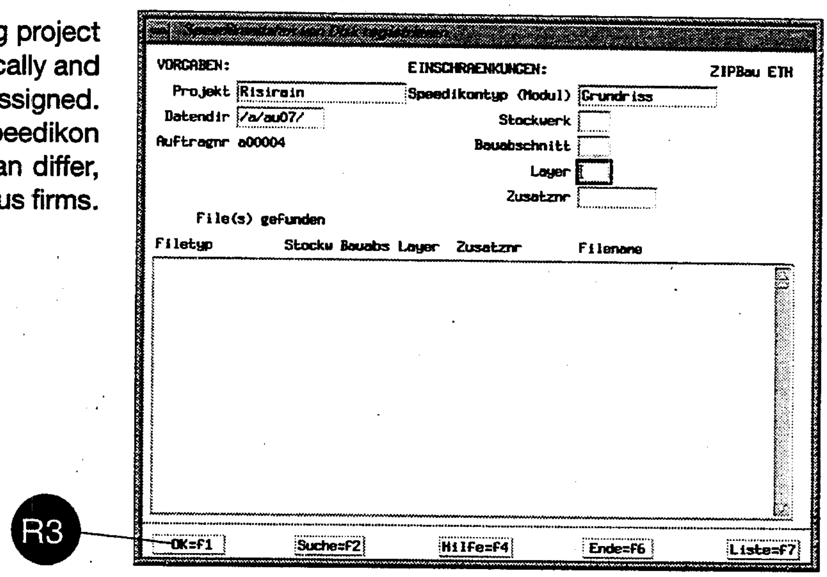
If the application is integrated, as is the case with AutoCAD, the registration is carried out directly in the program when creating the document.

Each document, which is created by an application and is copied locally onto the hard disk, is registered in EDL.



R2

With the choice of the building project a data list is choose automatically and an order number has to be assigned. This number is assigned by Speedikon and cannot be changed. It can differ, on the other hand, in the various firms.

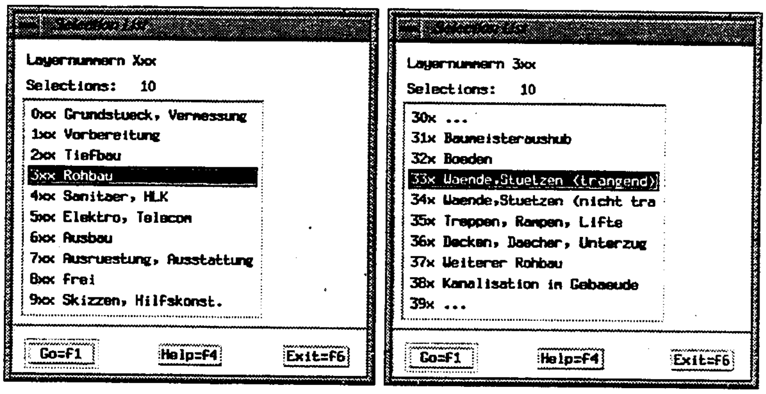


With these constraints the following search criteria can be entered.

The Speedikon type corresponds to the modules of the program: 3D construction, 3D structure, front view, reinforcement, DXF, roof, floor, complete drawing, outline, measurements, plan administration, rooms, section, temporary, staircase, dimensioning, vision. If the field is left empty or deleted, then with a list all selection possibilities are offered.

Floor: analogous to Speedikon structure.
Construction section: analogous to Speedikon structure.

Layer: Layer organisation. The empty field with list F7 helps the user to search down from the whole structure to the definitive layer.



If all constraints have been entered, the documents on the hard disk can be shown using the key search=f2 .

Additional constraints can still be made until the document or the documents, which one wants to register, are found.

R3 The registration of the selected documents is done by using the key ok= f1. Now the user is asked, as with each registration, for a category and then to entrer values for the corresponding attributes.

5. Summary

Many of the results expected from the case study could only be tested in a very limited way in practice. In the fall this project will be followed by another project, in which the fundamentals developed here will be verified. We hope that the transition from the present project will be smooth.

The requirement of the case study presents at the same time the main difficulty. Only in the operational phase is it possible to draw realistic conclusions regarding the usefulness of a system in practice. In the middle of this phase, however, it is difficult to test something, because the project partners have little sympathy for the experiment. In the operational phase this always means a delay and that costs money.

This presentation of our project, as well as various other ONLINE publications on the same theme can also be found on the WWW under:

http://caad. arch. ethz.ch/~sarbach/zip/zip. html

Integrated Product and Process Modelling for Facility Management

Peter Staub
Institute for Construction Engineering and Management
Swiss Federal Institute of Technology
CH - 8093 Zurich, Switzerland
staub@ibb.baum.ethz.ch
http://caad.arch.ethz.ch

1. Abstract

The economic situation in many enterprises is becoming more and more difficult. To stay competitive all these enterprises need to increase the performance of buildings for greater productivity, health, and safety of occupants, to improve the reliability of facility operation and the level of occupant satisfaction with their work environment, and to decrease the cost and environmental impact of facility operation. The purpose of this article is to present an information system that will allow owners, operators and the public to gain benefits from substantially improved performance of their facilities. The Facility Management System will use advanced information technology to provide life cycle information for all relevant key processes. Existing organization structures, division of responsibility and computer support tools are only partially suitable to meet the new requirements. New ideas are required not only for business processes but also for computer-supported data processing tools. This article identifies and structures the business processes for the use phase of a constructed facility and it includes the different points of view necessary to define the requirements for a multifunctional information support [51,56].

2. Introduction

The exchange of information is an essential basis for the fulfillment of all tasks during the whole life cycle of a construction. In all these phases the mutual exchange of knowledge regarding conditions or changing realities from project and realization for use and demolition must be ensured. The following figure clearly shows the information in function of time with two curves during the entire life time of a construction. The first curve describes the actual state of the information today. The phases from "owner planning" to "completion" is marked by a greater quantity of redundant information. The main reason is a redundant data management from all participants involved in the construction process. Shortly before completion the available information quantity rises to a maximum. After that the curve sinks to a minimum essential information quantity for the initial organization[39].

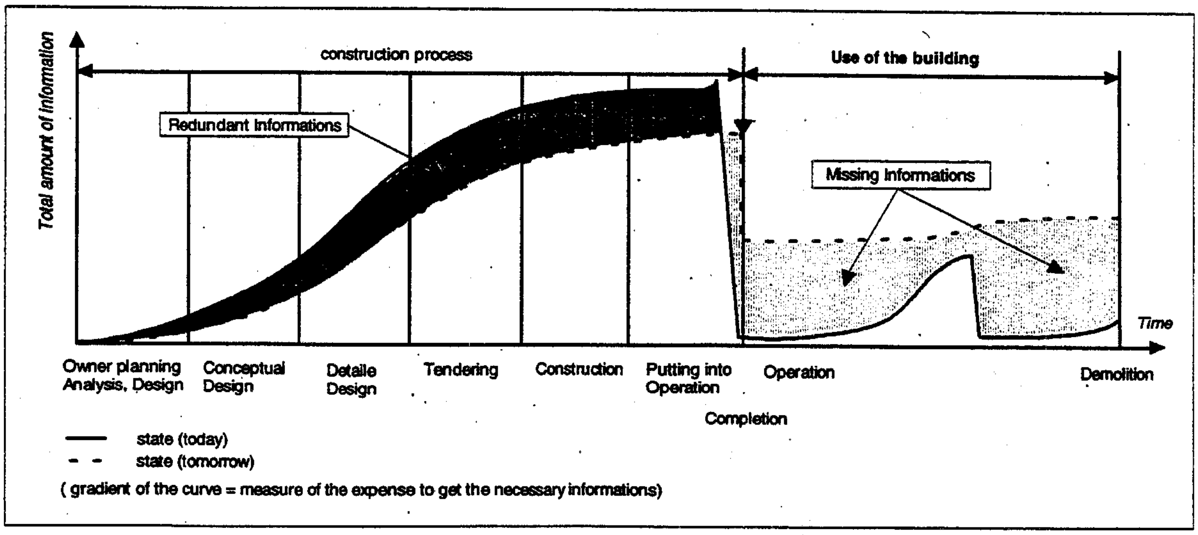


Fig. 1 Information about a building during the whole life cycle

The operator of a construction is usually unable to build a good basis for an efficient operation, even if the information gained during the planning and realization processes is well organized and specifically delivered to him. The data from the building process must be available for a possible reconstruction or a change of use of the object. It is costly to procure or to prepare them again, if this data is not easily available. After such tasks similar errors are often made as after the realization of the whole construction due to a lack of discipline in documentation, so that the newly gained information status cannot be preserved. In the "conclusion and commissioning" phases, the SHOULD-curve shows a quantitatively smaller amount of information in contrast to the IS-curve due to the elimination of the redundant data. For the transformation into the use phase a level of necessary data which must be submitted is defined. For possible structural measures or use-related activities required for their optimum functioning the necessary data can be taken from this quantity since the required information status is preserved during the entire life time of the construction. Up till now a large part of the research was concentrated on planning, design and construction of structures. In these areas the research work made an essential contribution to the increase of the quality and yield of a construction. The use phase was often neglected. However, here also strengthened efforts in the area of information processing are necessary. It is not enough to consider the care of a construction as completed when it has been put into service. The information created during the construction process has to be maintained for the new status and must not be lost, since a possible loss can prevent an efficient running of the facility.

Procedure

A multitude of institutions with quite different interests is involved in the operation of construction facilities. According to this diversity there are also very different views concerning these problems. Many solution processes already fail due to a lack of understanding of the same problems. Therefore, in a first step it was tried with a broad approach to record and to structure possible processes during the use phase in a model. Thereby, the chosen procedure differs in some respect from conventional attempts, where as a rule a certain problem is focused and its solution is then compiled in detail. However, integration means in fact the contrary, which is the joining of individual elements to build a whole. The integrated consideration of the operation of construction objects, therefore, stands clearly in the foreground with the chosen attempt. During the investigation of the above mentioned processes it becomes obvious that a model for information processing must be very open and has to consider the dynamics of the system. In a second step such a model is presented and explained under different aspects. In conclusion an attempt is made to present a partial process and a part of the operation with the developed methodology, respectively, and the further procedure to an integrated system development as an example.

3. Management of Facilities

A construction facility is supposed to fulfill different purposes in its life time according to the goals of all the parties involved. This use of the facility, however, forms just one aspect of the integrated observation during the period when the facility is built and when it is demolished. In order to have a structure which can be optimally used within a desired period, it must also be maintained, developed and modified according to the changing realities, i.e. it must be taken care of. Finally, a facility should never be considered separately, because it is always embedded in an environment which must accept or integrate the facility. These three characteristic views reflect the interests of the major participants in the use phase of a construction facility.

Viewpoint of the owner: Care

Construction objects are major assets of an institution. This investment must be safe during the expected life time and must perform with the required efficiency. In the center of this viewpoint, which can be characterized as care, is the construction object with its structural parts. By the strategic planning process, as an important subprocess of care, a much longer period of use must be considered and long-term observations carried out in contrast to the construction phase. A further aim of care is to provide the optimal use of the construction object. This requires efficient operation. However, use can change over time, thus requiring structural and operational adaptations. The flexibility of the construction object regarding such changes of use is already heavily influenced during the creation process. The subsequent users and operators should be involved in the organization of the construction from the beginning. Adaptation for other uses during the operating phase may result in interferences in the structure which raises the costs significantly. Of course, it is unavoidable that certain construction objects are limited to a specific use. Finally, a lot of administrative work arises in relation to purchase, leasing, financing and documentation of an object.

The care of facilities requires to a great extent a long term observation of all the activities related to the development of the facility, since the phase of use, e.g. of construction objects, takes, in principle, several decades. Certain factors cannot be recognized or influenced in the short term and can only be observed in a long term view, i.e. in the future. To accomodate these factors strategies are established which do not define specific measures, but rather, they identify only fundamental methods of treatment which enable us to accomplish our goals.

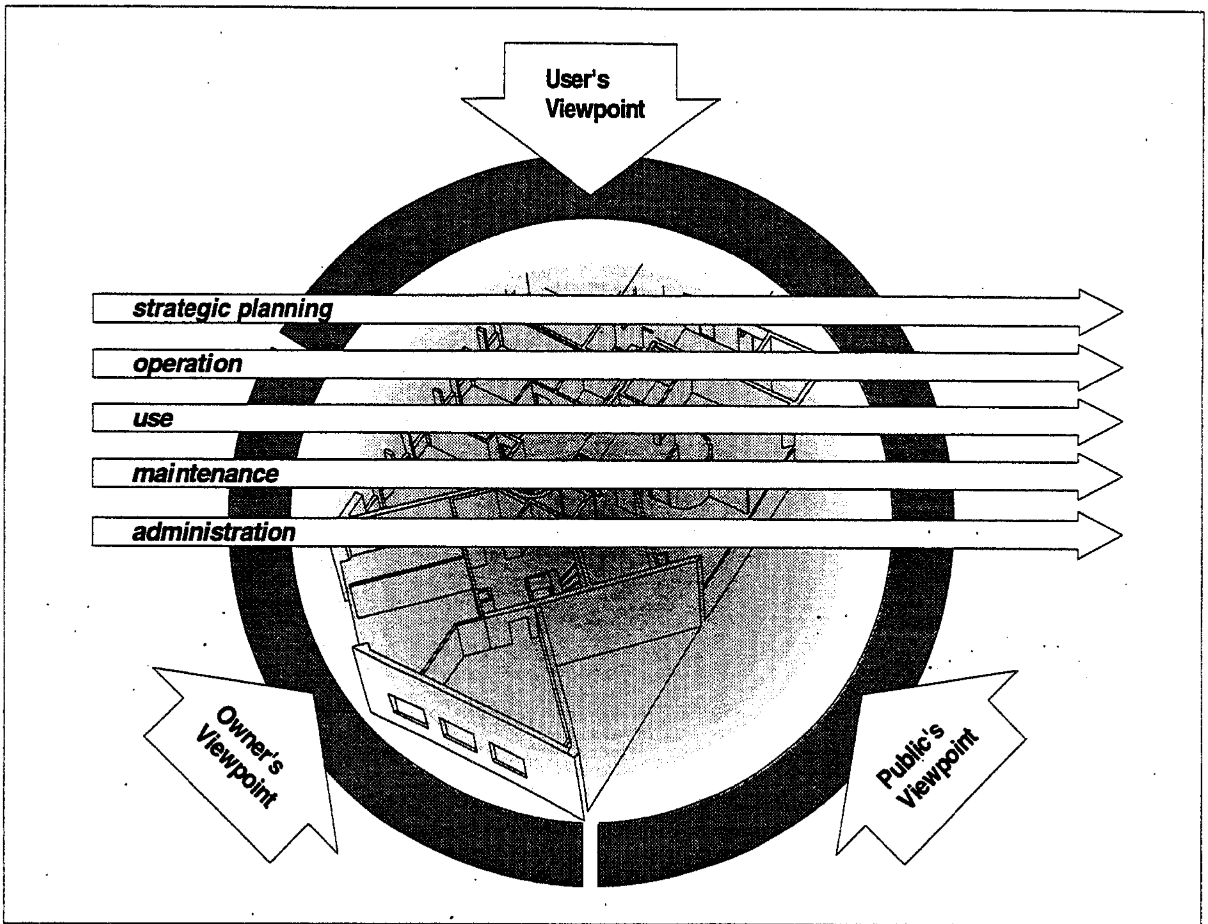


Fig. 2: Processes of Facility Management

The operation of the facility creates the necessary requirements for a smooth satisfaction of the objectives defined for the facility. In the operation here, the supply function dominates in comparison with the execution function. If the expression "operation" is used in connection with an object, then it is, in the first place, meant to be the acquirement and optimum use of resources, the disposal of waste materials and the minimisation of emissions considering specific needs of the supervisor, the user and the public. The expression "maintenance" refers to all the measures within the framework of facility care which ensure and develop the continued existence of the object and its value. Maintenance is divided into three areas of activity namely "supervision", "preservation" and "renovation". The activities of "administration" consist mainly of administrative tasks like financing of the facility, its buying, selling or leasing as well as bookkeeping in relation with the care of the facility.

Viewpoint of the user: Use

In general, use means to utilize something according to its purposes. The purpose of an object is basically determined by the type of use for which the object was conceived. Possible use categories can be found for example in German and Swiss Norms (living, teaching, education, research, industry, trade, technical facilities, etc.). From this classification, it can be seen that the use of an object can be very versatile and that, accordingly, the requirements imposed from the point of view of the user on the form and functionality of the facility can vary to a great extent. Since for the user, the facility is only a means to accomplish his goals, his most important aim is not to maintain the facility, but to be able to use the facility for his purposes in an optimal manner, i.e. he considers how he could use the facility for his purposes in the best possible way. As a result, he may have to modify the facility according to the specific use. Similar to strategic care planning, the future requirements of the facility must be formulated from the point of view of a specific use of the facility and the long term planning. For this purpose, the long term goals are formulated considering the economic, social and ecological developments in the environment of the facility. The strategic planning for use, furthermore, consists of the same areas of responsibility as the strategic planning for care. The difference with strategic planning for care, however, is that the solution of the problems should be performed considering the aspects of use and the organization participating in the use. It has been seen that it is desired to be able to change the ways of use in the course of time. This requires that the creation and care of the facility is not just based on a specific use, but rather, they enable a certain degree of flexibility with regard to the use. For this reason, certain concepts have been followed in the last few years, e.g. in the area of industrial and trading facilities. Here, flexibility is ensured, e.g. by conceiving the structure in an open way where the parts of the construction which are heavily dependent on the use are connected to the load carrying structure in such a way that in the case of a possible change in use, the corresponding sections can be replaced with minimum expense. The maintenance and development of facilities which depend on use belongs to the central tasks of facility use. Some typical administrative works are realized in relation with the use of a facility. Among these are, e.g., describing in which way the facility can be used. Other tasks relevant to the administration of use consist of documenting the relationships of the user organization with the facility. This includes the data related to the facility for staff, contract and insurance .

Viewpoint of the public: Integration

Every facility must be integrated in its environment throughout its life time. All these tasks, which must be fulfilled by the members of the environment, can also be identified as integration. From the functional point of view, integration can be separated from care and use, because despite the fact that integration can largely influence care and use, its primary goal definitions are different. The primary goal in integration is to influence the facility or shape the environment in such a way that the facility can be embedded in the whole in a positive way. This includes the provision of the necessary infrastructure for the supply of the facility. The realization of any facility in our world means simultaneously its birth in the area of influence of a society in which certain rules of behavior exist. These rules manifest themselves as laws, regulations, standards and guidelines. The legislation and the imposition of regulations is dealt with differently according to the nature of the political state. Interests specific to facilities, however, can also be formulated by certain groups of the population, e.g. through interest groups, engineering societies and organizations. In principle, these groups have no political character but they can be taken into account in the form of standards or guidelines by the legal bodies. Other remarks in the form of recommendations or as technical publications only have the character of advice.

As a member of the community, the facility must be supplied with the vital means for its existence and also be released from its waste materials. For construction facilities, we speak about infrastructure, which, in technical terms, summarises the necessary economic and organizational means. It includes the supply of operational, communication and transportation means as well as the disposal of waste materials. The infrastructure of a facility can be very complex. If we consider, as an example a high technology building with all its supply, disposal and its communication systems, we realize that the technical requirements for such a construction and its environment are very high, because not only the building itself consists of high-quality structural components, but also the public networks for the infrastructure consist of such units. In the same way, as the technology changes inside of the facility, the means in its area of influence must be modified accordingly. This requires a development of existing structures in addition to the usual measures for maintenance .

Table of Terminology

Describing processes by using three characteristic aspects allows the recognition of typical activities for all areas as shown in the following definition matrix [46]. The strategic row is an essential factor, to keep track of the long-term planning. The operation row consists of the dynamic component and the maintenance row contains the value-preserving and value-increasing components. Finally, every aspect includes specific administrative activities. Recognizing this structure allows the representation of the management process as an orthogonal matrix.

Facility Management

	Facility care (owner's viewpoint)	Facility use (user's viewpoint)	Facility integration with environment (public viewpoint)
Strategic planning	**Strategic facility planning** Define owner's long-term objectives for facility by considering facility status and condition along with external influences on the facility (social, ecological, technical, economic)	**Strategic planning of use** Define the user's long-term objectives for facility by considering user's acitivities and equipment and external influences on the facility	**Definition of interests** Define the public interest by considering facility influences on its environment and external influences on the facility
Facility operation and use	**Facility operation** Operate facility to meet user needs based on resource availability and economy of use (e.g. power, water, cooling)	**Facility use** Perform effective user activities consistent with user objectives and facility capabilities	**Operation of utilities** Operate utilities for effective resource supply and disposal to satisfy owner and user needs and public interest
Facility maintenance	**Maintenance of building core objects** Develop and assure acceptable functioning of building core objects (structure, systems)	**Maintenance of user equipment** Develop and assure acceptable functioning of user-dependent operating equipment and furnishings	**Maintenance of utilities** Develop and assure acceptable functioning of building utilities and services to satisfy owner and user needs and public interest
Facility administration	**Facility administration** Support and document object operation and use, including financing, contracting, insuring	**Administration of use** Allocate resources for facility management consistent with owner objectives and user needs	**Operational compliance** Comply with laws and regulations concerning facility operation and use

Fig. 3 Table of terminology

Construction Process

The special view of construction processes related to a facility is missing in the matrix shown. Nevertheless, construction is obviously regarded as an important process in the entire life time of a facility. In contrast to other assumptions, the construction process is investigated here as a repetitive process, which runs along similar lines to the creation process, but with other preconditions. According to the SIA [43] and from the constructional point of view, the entire life cycle of a construction facility is divided into the six major phases of strategic planning, preliminary studies, planning and design, realisation, use and demolition or in the ten sub-phases of strategic planning, preliminary studies, preliminary stage of project, construction stage, preparation for execution, execution, putting into operation, completion, use and demolition. There is an emphasis on the construction process in this model of the construction facility and, therefore, it is structured in greater detail. Strategic planning plays a central role in the entire life time of a construction facility. In particular, it determines during the phase of use whether demolition or maintenance measures [41] should be employed.

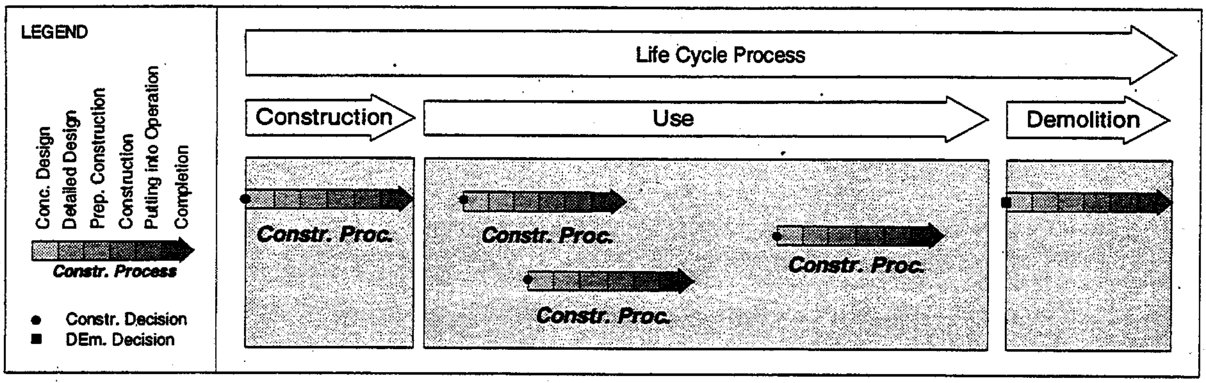


Fig. 4 Bauprozesse über alle Lebensphasen

3. Information Modelling

Exchange procedures in the form of materials, energy and information is possible among the elements of a system [44]. The investigation of the information relationships is the main issue in the information system which can also be viewed as the subsystem of the communication system. The major aspects which have to be investigated are concerned with the participating organization units, the analysis of the processes and the necessary product information for the processes [19].

Aspect of Products

Integrated observation of a machine-made product during its entire life cycle led to the idea of the product model [14]. The product model describes all information related to a product during its entire life cycle, especially during its use. The product is modified during this life cycle by the processes. The manner in which these changes take place is described under the aspect of the processes within the information system.

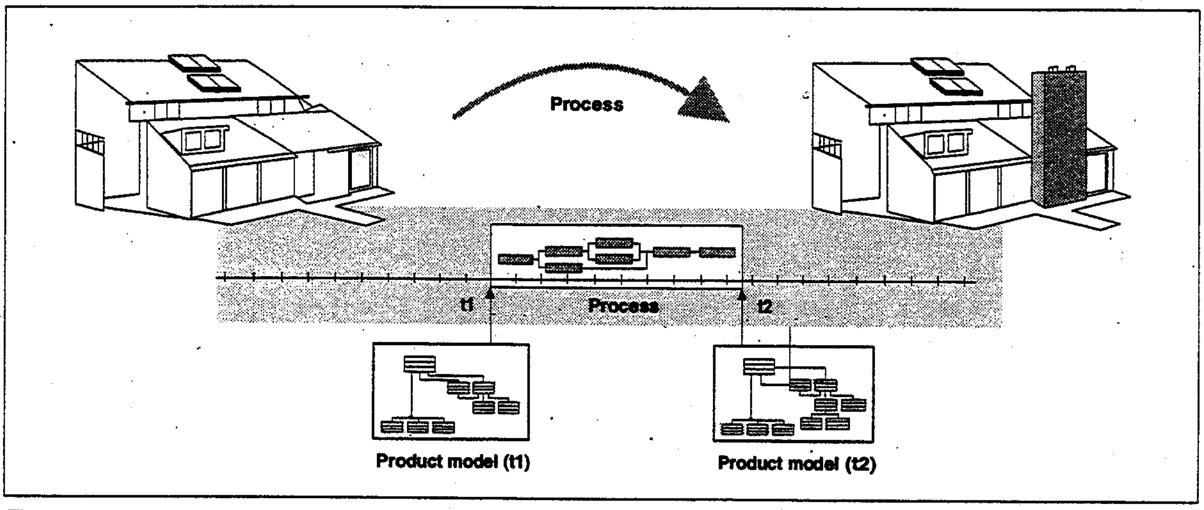


Figure 5: A process is a transformation function from one state of a product to another.

Experience from the computer-supported production of parts in the manufacturing industry is also very important for facility management. Manufacturing of parts cannot be directly compared with the products of facility management processes. But especially for modelling the building itself ideas concerning a product model are also useful for the description of the data in relation to its life cycle. Several research approaches are known in that area as well as standardization efforts (e.g. ISO 10303 "STEP") [22,23].

Provided that basic concepts of integration such as functional and phase integration are to be considered, then an object oriented model is necessary because the observation of product models on the basis of their application requires a combined observation of the data and methods [2, 24,25]. The entire object set for describing a product can be classified according to the object oriented model. It consists of both material as well as non-material objects. The material objects can be further subdivided into the visible and tangible physical and non-physical objects [54]. Every object which is necessary for the illustration of the product information must either be assigned to such a class or be instantiated from it.

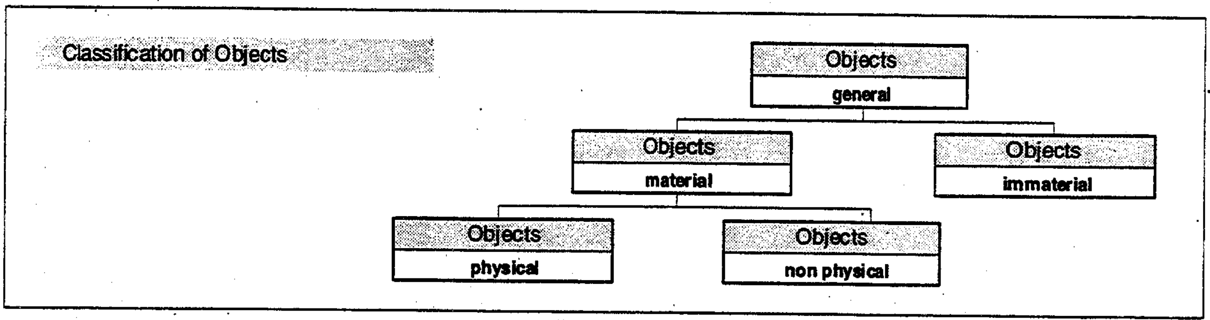


Fig. 6 Classification of Objects

The entire information content of a product model can be described by subsets, the so-called partial models, where each partial model comprises *a set of products with semantically similar characteristics* [20]. Product models for construction facilities must describe a facility for its entire life time, which covers the phases of creation, management and demolition. The aim in developing such product models is to describe all relevant functional aspects during the life time from different points of view. It is not the responsibility of this work to investigate the phases of creation and demolition of construction facilities, rather the emphasis is on carrying out the specifications of product models for the phase of use and the phase of management. The development of the product model for a construction facility must, therefore, take place in such a way that using the partial models of the product model, the product "construction facility" can be fully carried out from the point of view of care, use and integration. In the literature, different models can be found [31,32,34], in order to describe the creation of a construction facility as a product model with partial models. The creation of a construction facility, i.e. the actual construction process, however, is not the major issue for facility management, rather it is its maintenance, operation, administration, etc. The product model of the structure, therefore, must be extended towards the product models of the products of management processes. This will be demonstrated as a model for the maintenance process in the next section "Maintenance".

Classes, Attributes, Methods

The complete description of products related to a process is done according to the object oriented paradigma by classes describing the objects, the characteristic attributes and the behavior of encapsulation methods [30,37,42]. The latter are related to the product according to the principle of encapsulation and basically result by their execution in a change of the properties of the product. Consequently, in the product model, the description of classes, their relations, properties and methods of material and non-material system components follows the description of the product considered. In addition to the properties and methods mentioned above, the product model contains information about other properties like the function and status of their classes. Under a specific product model point of view, these perform a certain function and have different statuses within their life time. The status of a class instance is defined by the value of its object attribute, while the function of a class, as long as it deals with a persistent relationship, can be modelled, for example, by association. Non-persistent relationships are, for example, message passing among classes. A hierarchical system view will be explained in more detail in the next sections. Most OOA methods support the observation of a class structure as a hierarchy and corresponding concepts like total-partial-relationship, generalisation, specialisation and inheritance are available. On the other hand, easily understandable concepts for the methods are considerably lacking today. In the most OOA methods, the described methods do not have to correspond to the so-called elementary methods which can be further subdivided and executed. Similar to class hierarchy, it is usually inevitable for the process modelling to subdivide processes into subprocesses or to aggregate subprocesses into a whole process. This procedure can be basically accomplished by different criteria [40].

The object oriented organization of a method into submethods deals for the submethod with performances on the same object. The process oriented organization deals with performances on different objects and finally in functional oriented organization we have the same performances on different objects. The process oriented organization can also be viewed as a result of object oriented methods. The instance of such a class together with the method to be executed forms an elementray part of the process steps. Each non-elementary method of a class can further be refined by an object oriented and process oriented observation. In the process oriented view, the creation of more classes, to which the corresponding methods are assigned, will be necessary in principle in the design. The functional oriented division deals with a relationship which should be considered under the concept of inheritance because as with properties, methods can be inherited as well. The methods are described in the product model in a clear manner up to the level of elementary methods based on the object oriented approach. During the process modelling, the methods specific to classes will then be related to the executable and controllable components of the organization model using the workflow. Which method of the product model will be eventually used, depends on the product and the degree of accuracy of the results required.

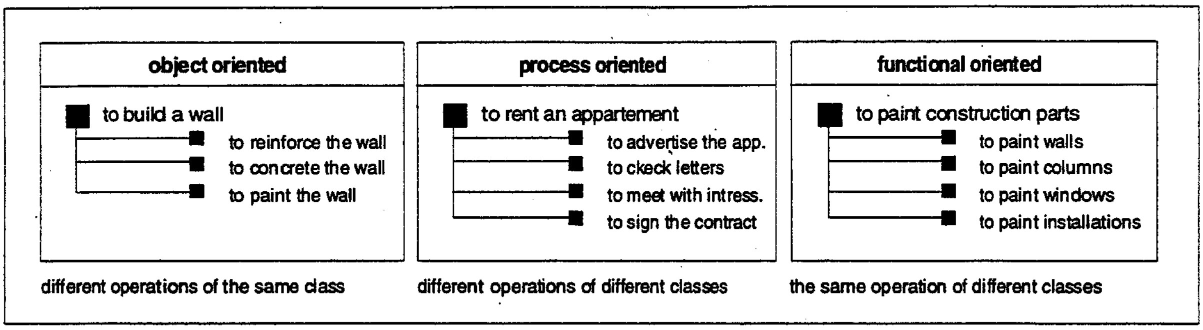


Fig. 7 examples for different organizations of methods

Aspect of Processes

The characteristic key processes of the construction management of facilities was described in detail in the section "Management of Facilities". The creation and the demolition process were deliberately ignored in view of well-known models. According to the chosen model, the processes correspond to transformation functions where the key processes do not deal with sequentially ordered subprocesses of the management process, but instead with a mainly parallel course of events. As a result, the processes are not only connected to one another by their chronological order but also specifically through common events! These can be, e.g. in the framework of a specific key process, the *decisions* made, which can also extend its influence on other processes or *states*, which are relevant to several processes. The modelling of processes, therefore, correponds to modelling the dynamic system behavior of object oriented systems. This includes, for example, the modelling of the process steps and the behavior in specific circumstances or by the coming true of predefined states as well as the examination of specific aspects from the organizational point of view. In this form, an object with an object oriented model can be understood as the *result of operations in a system of parallel active objects.* Here, the objects represent the persistent components of the system under consideration. Concepts for modelling the dynamic behavior are the steps and the behavior of the objects taking into account time and control aspects, like e.g. *states and events.* The process model will be investigated in the following sections under the aspects (behavior, steps, workflow) which are necessary for the description of the dynamic system behavior.

Behavior

Each class of the product model can be in different states in its life time and these states can change during a process. According to the object oriented model, the attributes of a class and therefore its states can only be changed by methods specific to classes. For every class with a nontrivial behavior, the methods relevant to state transitions throughout the life cycle of the class are identified and depicted in a *State-Event-Diagram.* The consistency of the diagram can be examined by controlling whether each state can be described by the class attributes and whether it can be changed only by the methods specific to the objects. The state diagrams specific to the classes are associated with one another by commonly used events and exhibit, in this way, the behavior of the whole system [40].

Process steps

The communication among instances of object classes consists of mutual calls of methods specific to classes and a hierarchy of communicating objects. This functional oriented view of the system is referred to as the *steps* and contains in addition to the description of the *possible message passing* (scenarios) among the objects, the specifications of the participating methods.

Workflow

The partial models of the process model, based on the object oriented analysis methods, have offered so far no possibilities to specify the relationships between processes and organizations. In order to fill this semantic gap, a workflow model is also introduced such that the assignment of organization units "directing" and "executing" to directing and executing objects as an additional dynamic system aspect can be modelled. The assignment of working units to organization units is dynamic and specific to the process. This view is also represented by M. Rusinkiewcz und A. Shet, who define workflow as "activities involving the coordinated execution of multiple tasks performed by different processing entities". The definition used is similar to the one given previously and is based on the works of Georgakoupoulos, Hornick und Sheth: Workflow comprises a series of ordered, organized working steps necessary for the fulfillment of the goal of the process, which have clearly defined positions and means for their execution. This view of the workflow as the connection joint between the process element and the organization unit exceeds the usual view that workflow only corresponds to informative processes that can be automated *[13,41]*

Aspect of Organization

We distinguish between *human* and *machine* responsibilities in a socio-technological system. Human responsibilities are based on persons as members of the organization in that field of activity, whereas machine-based communication are based on computers. The computers, which are used extensively today for collection, transfer, processing, storage and application as electronic supports, belong, together with the software, to the resources of an organization. The project participants also need documentation for their work, which can be interpreted as data views on paper. The documents can also be viewed as an interface from the users to the data of the product model, since they represent the form and the collection for the data for an effective use.

PPO-Model

The consideration of the information system in the separate aspects of the processes [6,7,16], the products and the organizations is not based on their independence, but only helps in the *simplification* of the examination of a complex information system. The organization model, the product model and the process model are closely connected to each other. Together, they define the characteristic properties of an information system. The model described below is based on these submodels and is therefore referred to as the PPO-model [46].

Components of the Model

model	*content*	*object oriented concepts*
❑ **product model**	*description of the product on the basis of the data from different points of view for the entire life cycle of the product*	*object model*
classes	*definition of classes forming the structure*	*class diagramms with class identification, attributes, generalisation and specialisation relationships, aggregational relationships*
properties	*definition of the characteristic properties of a class*	*attributes specific to classes*
methods	*definition of the executable, encapsulated methods*	*methods specific to classes in class diagrams*
❑ **process modell**	*description of the dynamic behavior by specifying the key processes*	*dynamic model*
steps	*definition of the process steps as a result of process chains controlled by events, specification of the activities*	*event path, event flow diagram*
behaviour	*behaviour of a class in ist life cycle, synchronisation of ist life cycle (connecting states and events through synchronisation)*	*life cycle diagram (state-event specific to classes), concepts of synchronisation (synchronisation of state-event diagrams specific to classes)*
❑ **organization model**	*description of executables and directives in the course of a process as well as their ressources*	*object model*
positions	*description of positions as a component of the organization*	*modelling of positions and their relationsships analogous to the concepts of the product model (classes, attributes, methods)*
function units	*description of function units as a component of the organization*	*modelling of function units and theit relationships analogous to the concepts of the product model (classes, attributes, methods)*
materials	*description of materials as a component of the organization*	*modelling of materials and their relationships analogous to the concepts of the product model*

Fig. 9 Aspects of the PPO-Modell

Procedure of model development

The development of product, process and organization models is a part of the development of information systems and therefore also goes through the phases of planning, analysis, design and implementation. By developing object oriented technologies and the related concepts of object oriented analysis and design, it is much easier today to develop all models with the same methodology and to produce the relationships between the process, the product and the organization models throughout the entire life cycle with an object oriented view of the system. A principal assumption for the understanding and the application is the simplicity of the method since the development of such a system always proceeds in close collaboration with the participants, who are experts in a specific field and are seldom familiar with methods of information processing.

- ❑ Process definition
- ❑ Establishing Classes
- ❑ Establishing Attributes
- ❑ Establishing Methods
- ❑ Establishing Behavior
- ❑ Establishing Process steps
- ❑ Establishing Workflow
- ❑ Refinement

4. Maintenance

Aspect of the Processes

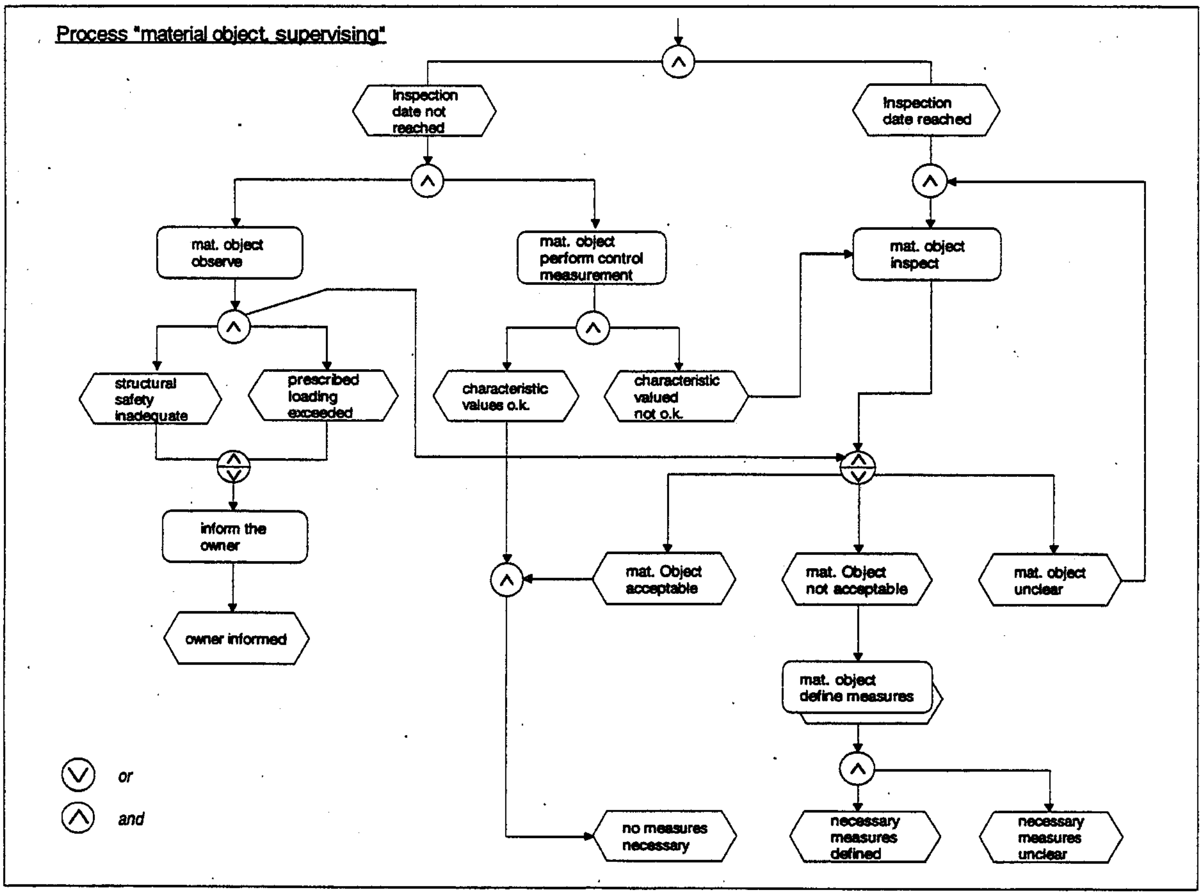


Fig. 9: Example Process "Supervising"

The definition of key processes for the management was valid for all types of construction objects. The further examinations are limited to the maintenance of the building. By definition, key processes belong to those procedures which are aimed at achieving the principal goals of those responsible for the process. The aims of the maintenance of the construction facility is to ensure their continued existence and value, where the expression "continued existence" refers to the continued existence of the material structure of the construction like e.g. the securing of their proper functioning. The necessary steps for process analysis are influenced on the one hand by the execution of other tasks as well as by the social, economical, technical and ecological constraints. This results in a complex network of possible relationships, whereby it is not necessary to have mutual relationships between all the tasks. Wherever relationships exist, they are formulated as mutual requirements both on the processes as well as on their results (products). The requirements specific to the maintenance imposed on the building and its construction parts include the proper functional efficiency, durability, serviceability while the maintenance specific requirements imposed on the maintenance process and its subprocesses correspond to the categories of costs and dates. The figure above shows a sequence out of the process "maintenance".

Aspects of the products

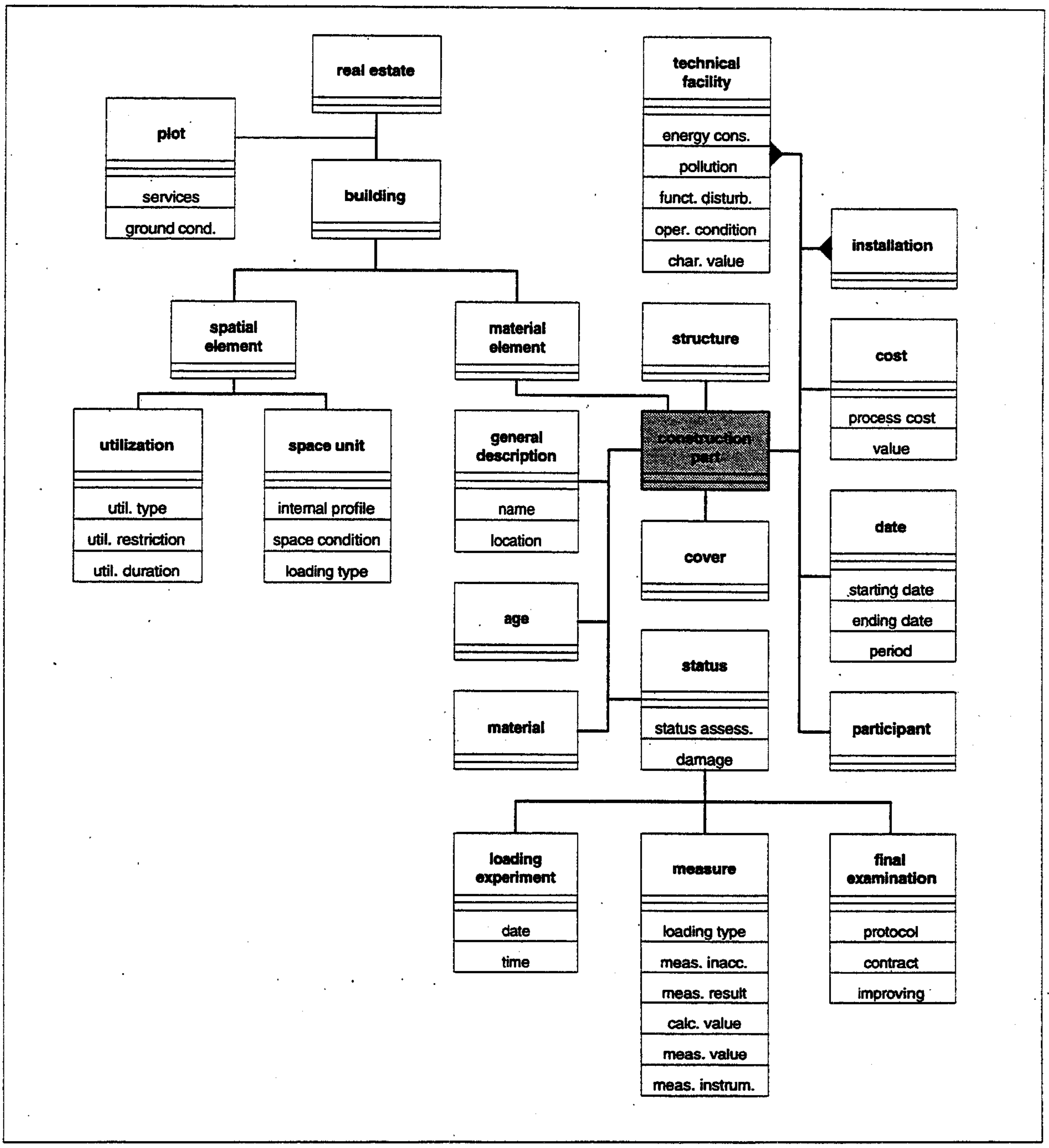


Fig. 10: Choice of properties of the class "construction part"

The classes relevant to the maintenance process are identified in the product model. These are described on the basis of their properties and methods where the *physical material objects* are the most important aspects for the maintenance project. The methods are formulated as independently as possible from the structure or structural part so that it is possible for them to be inherited in the product model. The inheritance is performed in a class structure which describes the building in which the classes are connected to one another by their whole, their parts and the generalization and specialization relationships. *The generally acceptable organization of a building in its parts is an essential requirement not only for the general understanding, but especially for the encapsulation of the maintenance methods with the classes of construction parts.* Some endeavours are being carried out today for establishing such standards.

class "Physical, non-material Objects"

The organization of a building in parts is not only possible on the basis of the elements but also according to space criteria [48]. An organization on the basis of space, however, is less relevant for the maintenance than for other key processes of construction management.

Aspects of the organization

So far, the participating functional units and the documents arising in the process have been determined for the examination of organizational aspects. The required system support with the consideration of standards [35,36] is under development.

5. Conclusion

The key processes of facility management were recognized in structuring the use phase of an object under characteristic aspects. The matrix proved right and may be used for the definition of the specific processes of an institution whereby the recognition of the mutual dependencies is noticeably eased. It is supported by different specialists from institutions that are active in the area of facility management. They were involved in the creation of the definitions used in the matrix. It is important, that the use and integration of an object are no longer considered as frame conditions, but are integrated into the observations with the same weight, thereby allowing a better orientation to the customer and the public needs. The aim of further work is the analysis of the most important key processes and recognition of their mutual relationships. The informative resources should be defined with the help of the product model and structured with object oriented concepts.

This article was based on the results of the analyses in connection with the research project "Integrated Planning and Communication in Construction" at the Institute for Planning and Construction Management (IBETH) in cooperation with the Chair for Architecture and Building Technology (HBT) and the Chair for Computer Aided Architectural Design (CAAD) at the Swiss Federal Institute of Technology.

6. Literature

[1] Bullinger H.-J: «Customer Focus und Business Reengineering» in 13. IAO-Arbeitstagung, Neue Impulse für eine erfolgreiche Unternehmensführung, Springer-Verlag, Berlin, Heidelberg, 1994
[2] Coad P., Yourdan E. : «Object Oriented Analysis», Yourdon Press Computing Series, Prentice Hall Building, 1990
[3] CRB: «SN 506 502, EKG Elementkostengliederung», Schweizerische Zentralstelle für Baurationalisierung, 1991
[4] CSI: «Construction Specification Index», Construction Specification Institute, Alexandria USA
[5] Czerny J.: «Ein durchgängiges Vorgehensmodell für Analyse», Entwurf und Implementierung, Geschäftsfeldobjekte, Objektspektrum Nr. 2/1995, SIGS Conferences GmbH, 1995
[6] Davenport T.H., Short J.E.: «The New Industrial Engineering: Information Technology and Business Redesign», Sloan Management Review, 1990
[7] Davenport T.H.: «Process Innovation, Harvard Business School Press», Boston, Massachusetts, 1993
[8] Dittrich K. R., «Datenbanktechnologie für die 90er Jahre», Seminar vom 19./20. Oktober 1992, Universität Irchel, Institut für Informatik der Universität Zürich, 1992
[9] Duppenthaler A., «Bauinformatik», Rudolf Müller Verlag, März/April 1994, 5. Jahrgang
[10] Eichhorst P.: «Objektorientierte Unternehmensmodellierung», Objektspektrum Nr. 2/1995, SIGS Conferences GmbH, 1995
[11] Firmenich B.: «Integrierte Planung mit CAD- und Datenbank-Technologie», AEC-Report Nr. 1, 1995, p.70ff
[12] Frank U.: «Memo: A Tool Supported Methodology for Analyzing and (Re-) Designing Business Information Systems», Institut für Wirtschaftsinformatik, Universität Koblenz, 1994
[13] Georgakoupoulos D., Hornick M., Sheth A.: «An Overview of Workflow Management: From Process Modeling to Workflow Automation Infrastructure», Distributed and Parallel Databases, Kluwer Academic Publishers, 1994
[14] Grabowski H., Anderl R., Polly A.: «Integriertes Produktmodell», Warnecke H.J., Schuster R. (Hrsg.), DIN Deutsches Institut für Normung e.V., Berlin, Wien,Zürich: Beuth, 1993
[15] Hammer M., Champy J.: «Business Reengineering», Campus Verlag, Frankfurt, New York, 1994
[16] Hasenkamp U., Kim S., Syring M.: «CSCW Computer Supported Cooperative Work», Addison Wesley (Deutschland) GmbH, 1994
[17] Held G., «Objektorientierte Systementwicklung», Siemens Aktiengesellschaft Berlin und München, 1991
[18] Heuer A., «Objektorientierte Datenbanken», Addison Wesley, Deutschland, 1992
[19] Hofmann M., Scherer E.: «POA - A Process-Oriented Approach to Modelling Production Structures», Betriebswirtschaftliches Institut der ETH Zürich, 1994
[20] Hübel C., Paul R., Sutter B.: «Technische Modellierung und DB-gestützte Datenhaltung» - ein Ansatz für ein durchgängiges, integriertes Produktmodell, Universität Kaiserslautern, 1989
[21] Hughes J.G., «Objektorientierte Datenbanken», Carl Hanser Verlag München Wien, 1992
[22] ISO 10303-40 Serie: «*Kernmodell und allgemeine Basismodelle*»
[23] ISO 10303: «Product Data Representation and Exchange»
[24] Jacobsen I., Jacobsen A., Ericsson M.: «The Object Advantage», ACM Press, United States, 1994
[25] Kappel G., Schrefl M.: «Object/Behaviour Diagrams», IEEE, 1991
[26] Kim N. (Hrsg.), «The object-oriented database system manifesto», First International DOOD Conference, Kyoto, 1989
[27] Mathis C.: «Object Behaviour Modelling», OOP 93, Conference Proceedings, SIGS, 1993
[28] McCready S.: «There is more than one kind of Workflow-Software», Computerworld, 2. November 1992
[29] Müller R., Rupper P. (Hrsg.): «Process Reengineering: Müri P., Prozess und Führung», Verlag Industrielle Organisation, Zürich
[30] Neumann H.A., «Objektorientierte Entwicklung von Software-Systemen», Addison Wesley, 1995
[31] Nicklisch T.: «Ein Konzept für den ganzheitlichen, rechnergestützten Entwurf von Geschossbauten im Massivbau», VDI-Verlag GmbH, Düsseldorf 1991
[32] Pätzold B.: «Integration rechnerunterstützter Verfahren für die Konstruktion auf der Basis eines objektorientierten Produktmodellansatzes», VDI-Verlag GmbH, Düsseldorf, 1991
[33] RIBA Publications Ltd: «CI/SfB Construction Indexing Manual», RIBA Publications Ltd, London, 1990
[34] Richter R.: «Wissensbasierte CAD-Systemkomponente zum Entwurf montagegerechter Produkte», Springer Verlag, Berlin, Heidelberg, New York, 1993

[35] Rösch M.: «Distributed Objects are Real», Objects in Europe, SIGS Publications, 1994, p. 20
[36] Rösch M.: «OMG-Standards und ihre Bedeutung für die Praxis», OOP 94, Conference Proceedings, SIGS Conferences, München, 1994
[37] Rumbaugh J., Blaha M., Premerlani W., Eddy F., Lorensen W.: «Objektorientiertes Modellieren und Entwerfen», Coedition Carl Hanser und Prentice-Hall International, München, Wien und London, 1994
[38] Rusinkiewcz M., Shet A., Kim W. (Hrsg.): «Specification and Execution of Transactional Workflows, Modern Databbase Systems: The Object Model, ACM Press, 1994
[39] Schalcher H.R.: «Optimale Gestaltung und Nutzung des Kommunikationssystems für die Verwirklichung eines Bauvorhabens», Publikation Nr. 13, Institut für Bauplanung und Baubetrieb, ETH Zürich, 1979
[40] Scheer A.-W.: «Wirtschaftsinformatik», Springer-Verlag, Berlin, Heidelberg, 1994
[41] Schröder J. (et al): «Hauptbegriffe der Bauwerkserhaltung», Schweizer Ingenieur und Architekt, Sonderdruck aus Heft 45/1992
[42] Shlear S. und Mellor S.J., «Object-Oriented System Analysis», Yourdon Press, Prentice Hall Building, Englewood Cliffs NJ, 1988
[43] SIA: «SIA Norm 169 (Vernehmlassung Frist 13. Juni 1995) », Schweizerischer Ingenieur- und Architektenverband, Zürich, 6. April 1995
[44] Sinz J.: «Objektmodellierung betrieblicher Informationssysteme», Objektorientierte Informationssysteme, Stuttgart, 1993
[45] SNV: «EN ISO 9000-1, Normen zum Qualitätsmanagement und zur Qualitätssicherung / QM-Darlegung, Teil 1: Leitfaden zur Auswahl und Anwendung (ISO 9000-1 : 1994) », Schweizerische Normenvereinigung
[46] Staub P.: «Objektmanagement», Institut für Bauplanung und Baubetrieb, ETH Zürich, 1994
[47] Stein W., Balzert H. (Hrsg.): «Objektorientierte Analysemethoden», Wissenschaftsverlag, Mannheim, Leipzig, Wien, Zürich, 1994
[48] Svensson K.E.: «Maintenance Information Management, Based on a Step-Related Building Product Model», Departement of Building Economics and Organization, Royal Institute of Technology, Stockholm, Sweden.
[49] Tegtmeier H.: «Zehn Schritte zu einem wirtschaftlichen CAFM-System», Bauinformatik 1/94, p.22ff
[50] Versteegen G.: «ix, Multiuser Multitasking Magazin», Heinz Heise GmbH und Co. KG, Hannover, März 1995, p. 152
[51] Vetter M., «Aufbau betrieblicher Informationssysteme», B.G. Teubner Stuttgart, 1991
[52] Volkhard F.: «Planung und Steuerung komplexer Bauprozesse durch Simulation mit modifizierten höheren Petri-Netzen», Gesamthochschule Kassel, 1989
[53] Vossen G., «Datenmodelle, Datenbanksprachen und Datenbank-Management-Systeme», Addison Wesley GmbH, Deutschland, 1994
[54] Wiedemann S.: «Kommunikation im Bauprozess», Institut für Bauplanung und Baubetrieb der ETH Zürich, 1994
[55] Wright A.J., Lockley S.R., Wiltshire T.J.: «Sharing Data Between Application Programs in Building Design, Building and Environment», Pergamon Press Ltd., Great Britain, 1992
[56] Zehnder C. A.: «Informationssysteme und Datenbanken», vdf-Verlag, 1989