Information models for performance driven computer integrated construction

Matti Hannus
Technical Research Centre of Finland (VTT), Laboratory of Structural Engineering
P.O.Box 26, SF-02151 Espoo, Finland, Tel: int + 358 0 4566948, Fax: int + 358 0 4567003

ABSTRACT

A generic information model for computer integrated construction is presented. The viewpoint is performance driven design and construction, quality management and computerised information management over the life cycle of a building. The building information management process is divided into subprocesses by means of hierarchical activity models. Accordingly, conceptual data models controlling each subprocess are presented. For instance, the design process is controlled by a design data model. The data models also illustrate integration of traditional classification approach into product models.

1. INTRODUCTION

1.1. Background

The early adoption of open building systems based on modular co-ordination in 1960's contributed to the evolution of industrialised building in Finland. About 80% of all multi-storey buildings are built of prefabricated concrete components. Recently the portion of steel frames has also increased. During 1980's the requirements of more variable architecture lead to decreasing productivity and highlighted the need for flexible manufacturing methods and customer oriented control systems. Industrialised methods need to be adopted broadly into the fabrication of all components and, especially into assembly on site. The current trend is now to reorganise the construction process so that decisions are made by whom they concern. This is expected to release barriers for competition and active product development.

Controlling building projects has traditionally been a nightmare. The unique combination of local conditions, client, design, site, project team etc. make it extremely complicated to apply similar control systems as other industries do. The building industry has also been in many ways protected from international competition. The emerging open European market has emphasised the importance of quality management systems as strategic competitive tools. In a series of interrelated research projects quality systems are being developed in accordance with the ISO 9000 standard to the building industry.

Since mid 1980's several research projects have been carried out on computer integrated construction (CIC). In the Finnish tradition the concept of a generic i.e. application independent conceptual data model has been dominating research activities. An industry standard BEC [1] based on this idea was published for precast concrete in 1987. The concept of a generic building data model was then enhanced in the national RATAS-program [2] and a number of subsequent projects. Commercial software based on the product modelling concept has been developed by a number of companies (e.g. Cadex Oy, Optiplan Oy and Schema Oy). A series of development projects in the RATAS-program deal also with various other aspects of CIC e.g. distribution of digital data of building products via a value added network, EDI messages for building industry etc. Recently a national committee was nominated to propose and prepare national industry standards for computer integrated construction. Some resources have been allocated to follow up and contribute to the ISO/STEP development.

1.2. Necessity of information models

This paper is related with on-going research projects on computer integrated construction, industrialised building and quality management in construction. A systematic development concerning these aspects should be based on a common understanding i.e. models of buildings and the process that produces them.

It has been observed that without adequate analytical methodologies human communication between specialists of the different subdomains of construction industry remains unprecise and therefore largely unfruitful. The precision of traditionally adopted terms and concepts does not suffice when essentially new approaches to the construction industry are being developed. It can be very frustrating and confusing that different disciplines frequently use same verbal terms but assign different semantic meaning to them.

Information models provide a foundation for mutual understanding and synergy among development teams. This paper presents some information models that are being developed in various projects. The aim is to achieve a wide national consensus between different development teams on the core models. Using popular modelling tools also allows international information exchange.

1.3. Modelling the construction process

Figure 1 is illustrates nonformally the information management process that we are about to model. In an ideal computer integrated construction process all data needed by various parties is available in computerised form.

Traditionally, schedules of the various phases of building projects has dominated the way in which professionals perceive i.e. model construction processes. In parallel, organisational schemes are used to show the contractual relationships between various parties. Unfortunately, these "models" are highly project dependent and do not remain valid if essential changes are introduced into the process. The lack of more abstract models has thus frozen the industry's procedures to traditional ones.

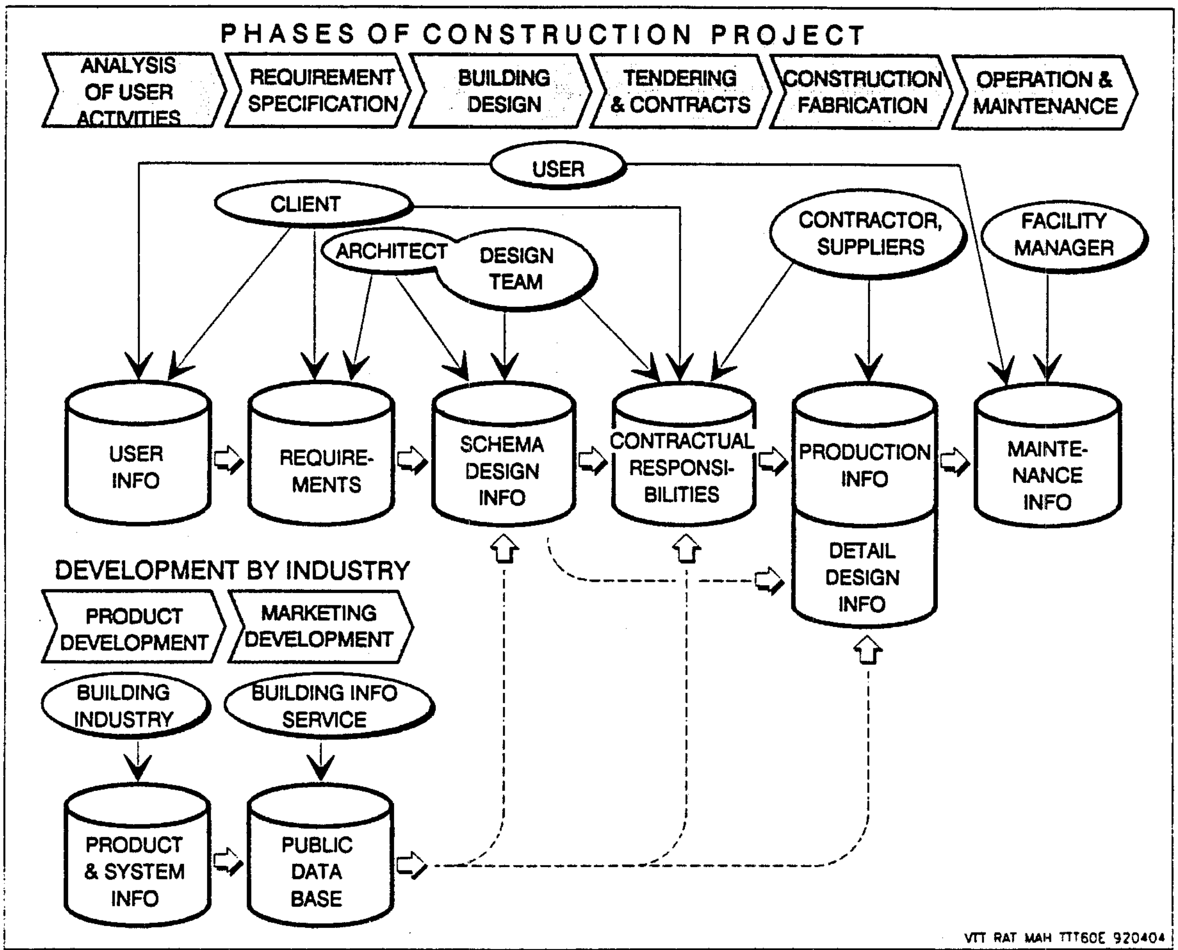

Fig. 1. Information management in the construction process

Information technology provides a set of formal modelling methods. Activity models define the activities that use and/or create data, the organisations and systems that perform these activities and the controls that effect/guide the process. Conceptual data models define the logical structure of data. Commonly used methods for activity/process modelling are IDEF0 [3] and SADT [4] which are nearly identical. Popular data modelling methodologies are IDEF1X [6], NIAM [7] and EXPRESS [8]. In this paper SADT and EXPRESS diagrams are used.

Figure 2 illustrates the interrelationships between some methods to describe various aspects of construction. The two bottom-most boxes show project dependent instances of organisation and time schedule. These are the most common ways how professionals "model" construction process. Several alternative organisations and schedules may be applied in any specific project. Therefore organisation and schedule are shown as changeable modules that may be "plugged in" to a more generic activity model in the centre. Such a project independent activity model describes the generic activities that may occur in any real world process. Above the activity model in figure 2 is a conceptual data model that defines the data structures that control (information management in) construction processes. Finally, the topmost box in figure 2 illustrates the definition of the semantic meanings of the underlying concepts.

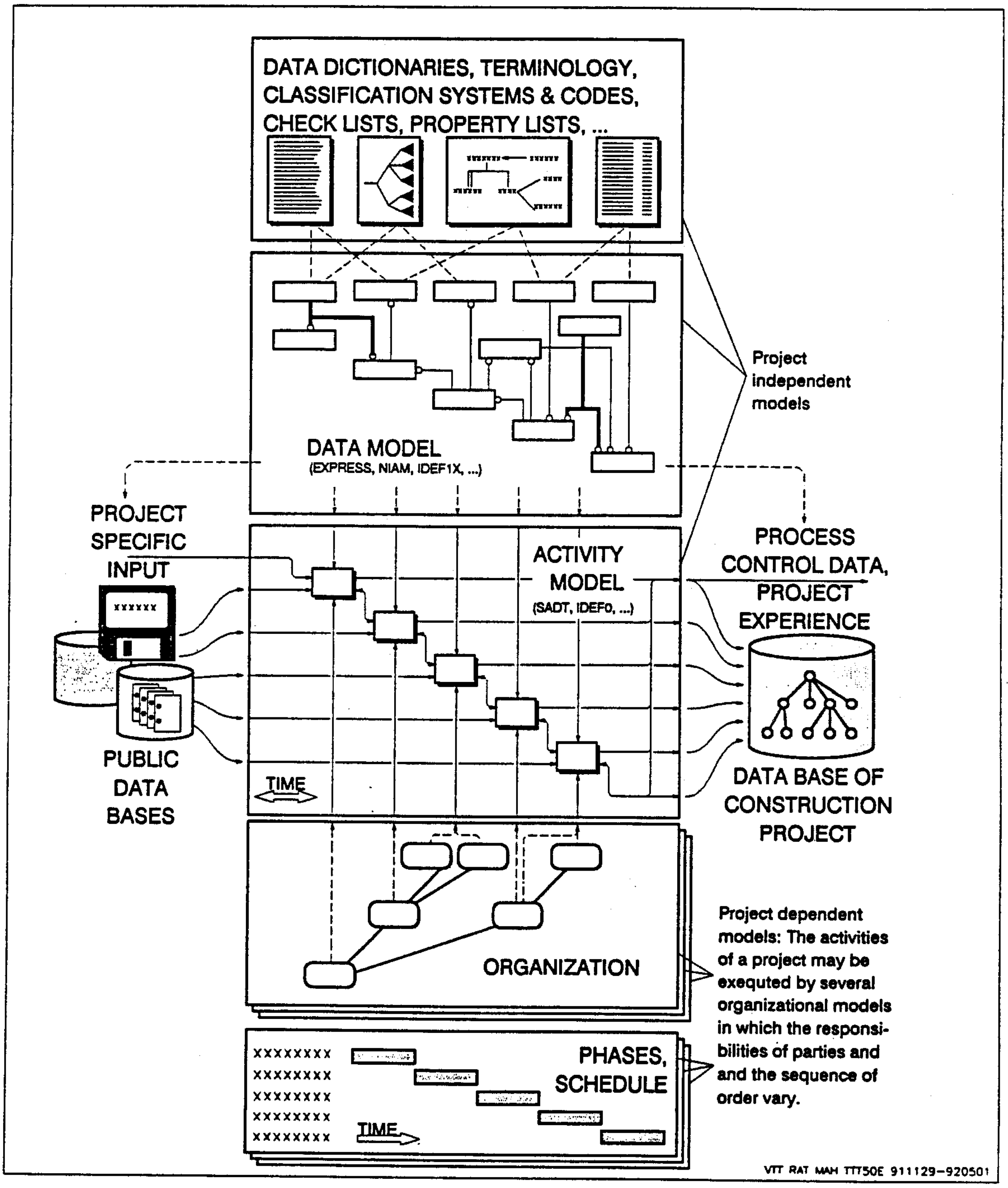

Fig.2. Modelling various aspects of construction with different techniques

2. INDUSTRIALISED BUILDING

A common practice (in Finland) is that detail design is performed and building permission is issued before contracts are made. Thus the contractor and suppliers will be faced with ready made designs which do not allow company specific technical solutions.

In order to adopt industrialised methods in construction is necessary to change this process so that product and process development are encouraged. A technical solution should be selected by the supplier based on functional requirements rather than predefined details. Associated with this freedom is increased responsibility on detail design, work planning and assembly on site.

Consequently, currently prevailing complicated interdependencies in work organisation on site must be simplified. Furthermore, this calls for remodularisation of the building as a composition of systems and parts from various suppliers. (It should be noted that composing buildings from independent modules serves other strategic aims as well: customer orientation, life time flexibility, recycling etc.)

3. LIFE CYCLE OF A BUILDING

The present activity models aims to provide a uniform basis for such remodelling in building industry. The model should describe traditional and modified processes as well. The viewpoint of the models is computer integrated construction. Therefore information management has been isolated into its own submodel. Activity models with a broader scope have been presented in [9].

The models are presented as SADT diagrams [4] in which feedback between two activities can be shown with double-ended arrow notation. Otherwise the method is nearly identical with IDEF0 [3]. Combined inputs & controls are presented as inputs while conceptual models are presented as controls. This is in order to make distinction between computer manageable data and conceptual models of it.

Figure 3 illustrates how the building process is related to users business or other activities. The building process has been subdivided into an information process (computer integrated construction) and a physical construction process (logistics). The model describes the life cycle of a building as a recursive process of construction, renovation and demolition. The purpose of this model is to define the context of the information process (box A0) which is shown in more detail in figure 4. The users business and the physical construction process are outside the scope of this paper and are not shown in more detail.

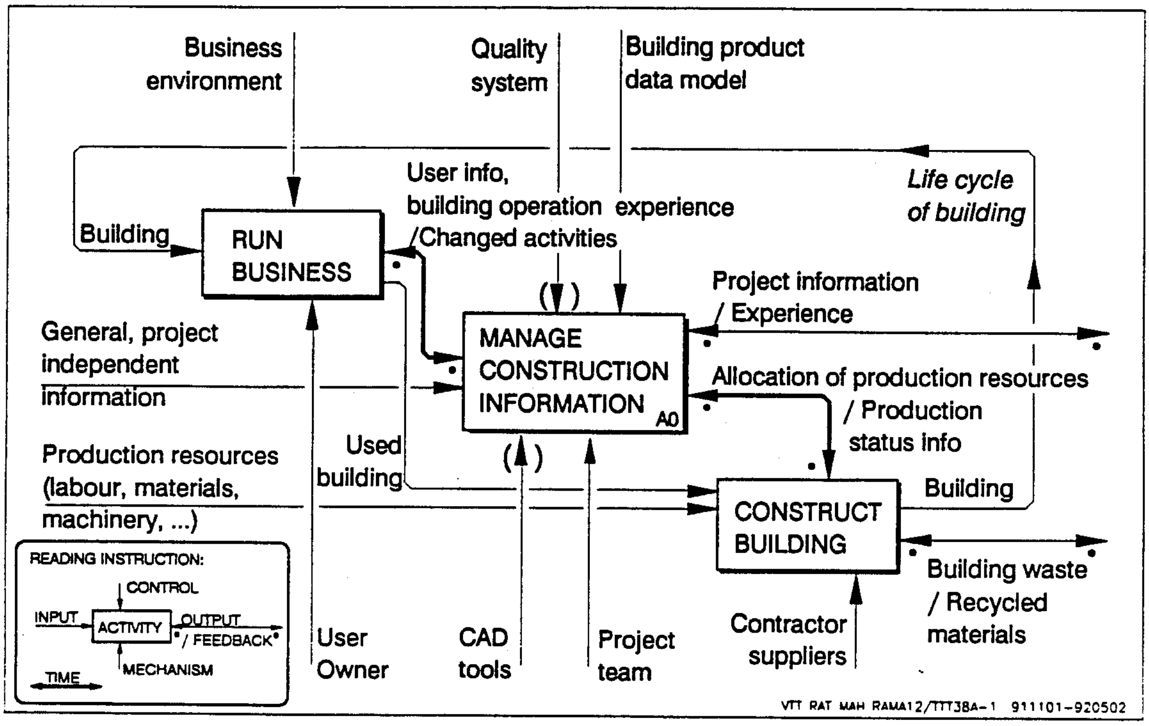

Fig. 3 Construction process as part of users business

4. INFORMATION MANAGEMENT IN CONSTRUCTION PROCESS

Figure 4 shows in more detail the information process, i.e. box A0 in figure 3.

The process is controlled by the quality system and by building product data models. Quality system controls the execution of the process. Data models control the contents and structure of all data which is managed in the process. Input to the process consists of project dependent information (of users, site conditions etc.), project independent general information (e.g. available products and technical solutions), experience from previous projects and feedback from the on-going project. The output from the process consists of initiatives to change the users activities, design and planning data and production recource allocation data. The process is performed by the participants of the building project using computer aided tools.

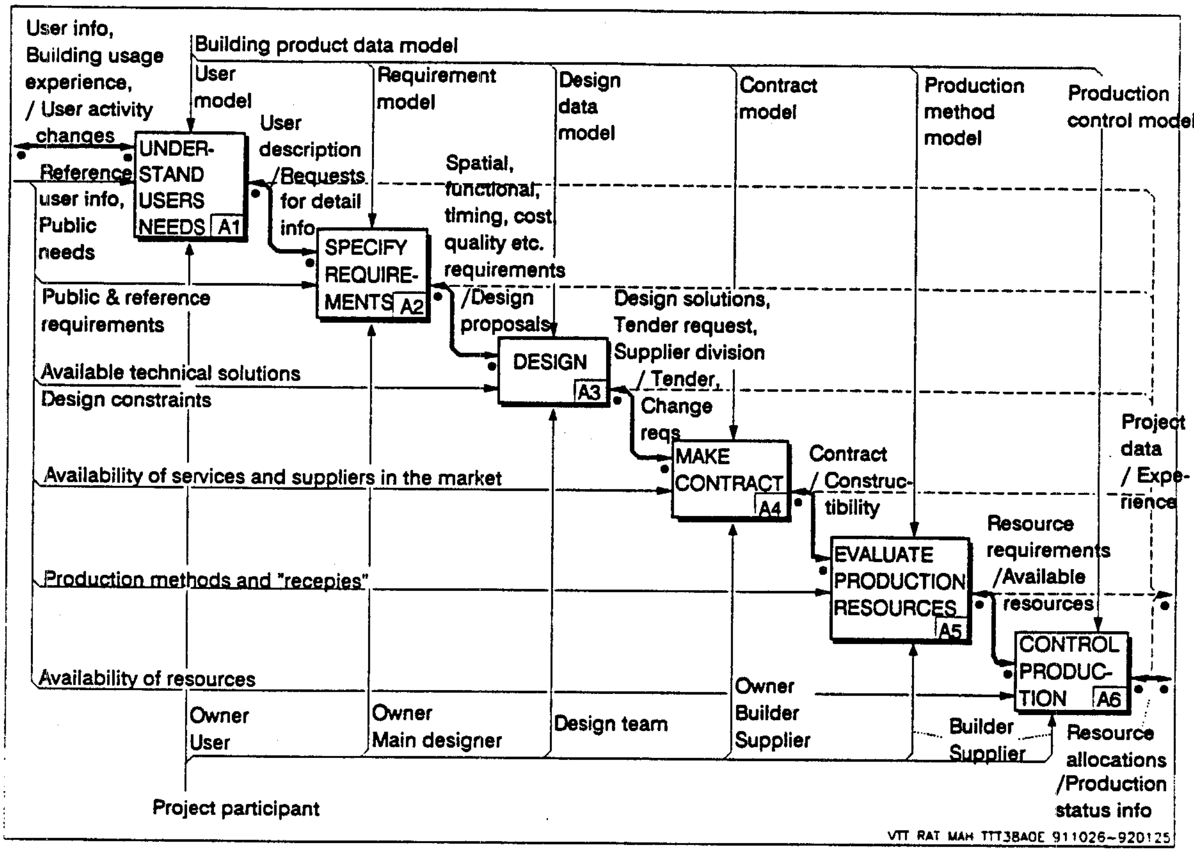

Fig. 4 Manage construction information

The division of information process into six subprocesses provides a framework for development in limited domains. The model is generic in the sense that it describes activities which occur in all building projects. The actual order in time of activities as well as the contractual responsibilities may naturally vary.

Short descriptions are given on each subprocess. For each subprocess the basic structure of the governing data model is shown.

5. USER ACTIVITIES

As a starting point understanding of the users' activities and needs must be achieved. This activity (box A1 in figure 4) is controlled by a data model of user activities, figure 5. The input consists of information about actual users and reference users, public needs, experience of using current buildings, requests for more detailed information to the on-going project and experience from previous projects. The activity is performed by owner and user. The output consists of user description to the on-going project and as changes to the users activities (e.g. due to constraints/opportunities of the emerging design solutions) as feedback to the users business.

User needs may be analysed based on classification of users and their activities. Check lists, reference data, statistical information may be organised according to such classes.

Users' organisational structure and communication needs are analysed.

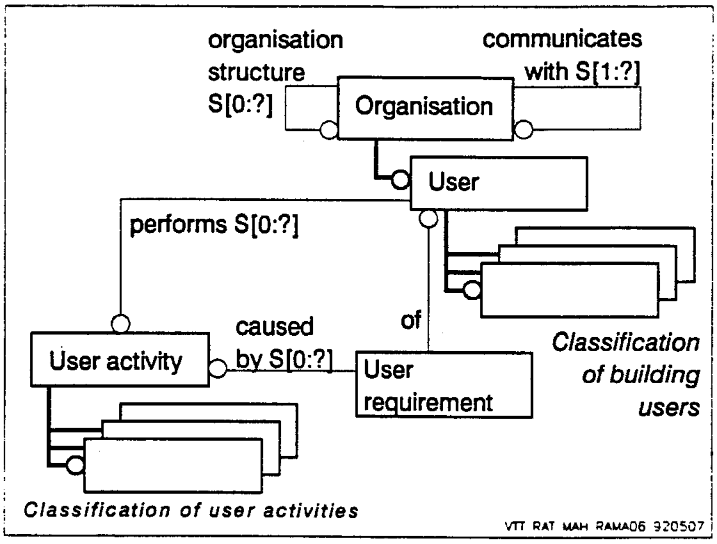

Fig. 5 User data model

6. REQUIREMENTS

Requirement specification activity (box A2 in figure 4) is controlled by a data model of requirements, figure 6. The input consists of user descriptions, reference requirements (e.g. general quality standards), alternative design proposals from the on-going project and experience from previous projects. The activity is performed typically by the owner assisted by the main designer (architect). The output consists of requirements on space, functions, time and cost.

Requirements are set by and satisfied by project participants (e.g. a user). The target of a requirement is defined by a scope definition. The target may be a group (e.g. all doors), a specific object (e.g. a specific door) or a property of an object (e.g. door width). Requirements are classified into subtypes.

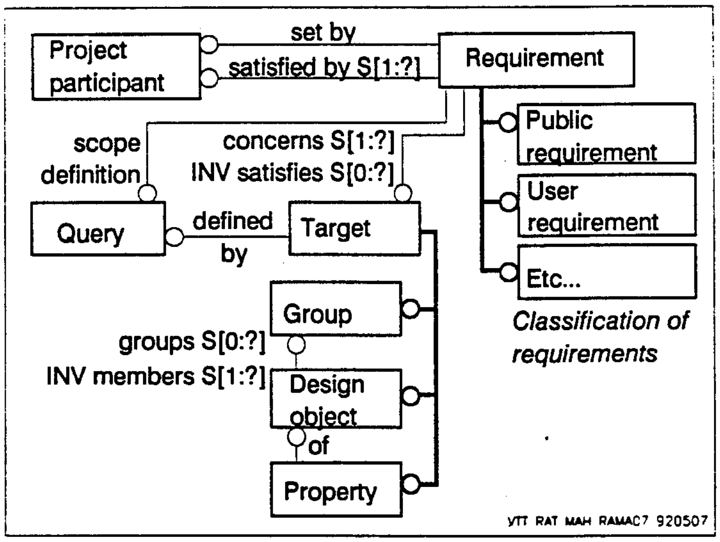

Fig.6 Requirement data model

7. DESIGN

The design activity (box A3 in figure 4) is controlled by a data model of building design, figure 7. The project dependent input consists of spatial, functional, economical and timing requirements. The general input consists of building regulations, data of available products, reference cost information and experience from previous designs. The activity is performed by the design team and the owner/client. The output consists of design information, tender requests and division of responsibilities between contractors and suppliers.

The main task of design is to find a technical solution to the clients requirements and decompose it into parts on which contracts can be made. In the logistics chain a similar decomposition occurs recursively at all levels between client and supplier.Design as a generic design activity covers both the "overall" design performed by one organisation and the "detail" design performed by another. From modelling point of view there is no distinction between the two. Thus the role of "design team" may be assumed as well by the architects and engineers as by the contractors, suppliers and fabricators.

In the design view a building is decomposed into functional systems which are often designed by different groups. Each system can be hierarchically decomposed into smaller units. At any level the design objects may be physically or logically connected. Most connections occur at part level.

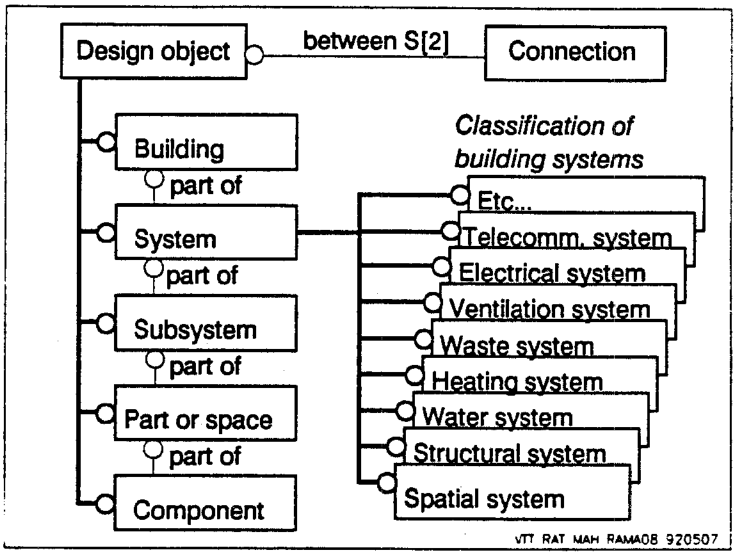

Fig. 7 Design data model

8. CONTRACTS

Making contracts (box A4 in figure 4) s controlled by a data model of project organisation and building decomposition, figure 8. Input consists of tender requests, design information from higher level of building decomposition and feedback from production on costructibility (e.g. cost and time estimates, availability of production resources etc.). External project independent input consists of availability of products, services and suppliers in the market and experience from previous projects. The activity is performed by client (e.g. owner) and supplier (e.g. contractor, supplier, fabricator etc.). The output consists of tenders, agreements and orders to start the production.

Contract is between a client and a supplier. In the logistics chain any project participant may assume the role of both. Contract concerns a delivery defined by design objects which are described in documents appended to the contract. Document classification helps to organise document management in building projects.

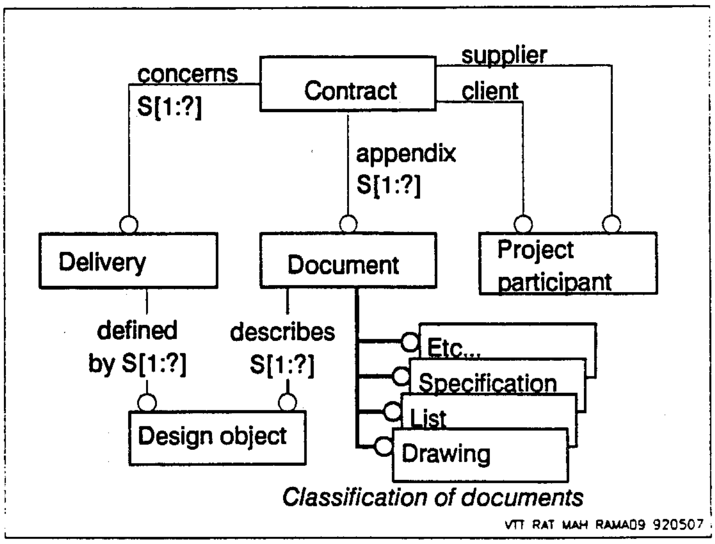

Fig. 8 Contract data model

9. PRODUCTION RESOURCES

The evaluation of production resources (box A5 in figure 4) is controlled by a data model of production methods and costs, figure 9. The input consists of orders issued by received tender requests or orders, availability of production resources and experience (e.g. cost statistics) from previous projects. External input consists of general reference cost data (e.g. price lists, building cost index, etc.), production methods ("recipes", product structures). The activity is performed by the supplier (this may be any organisation in the logistic chain, e.g. contractor). The output consists of constructibility (e.g. cost and time estimates) and resource requirements to the production planning.

Based on design, the production methods may be selected. Each production method consumes resources. The required resources per production unit (e.g. m, m^2, m^3, etc.) can be estimated based on statistical data from previous projects. Similarly, unit costs of classified resource types are available from experience or from price lists.

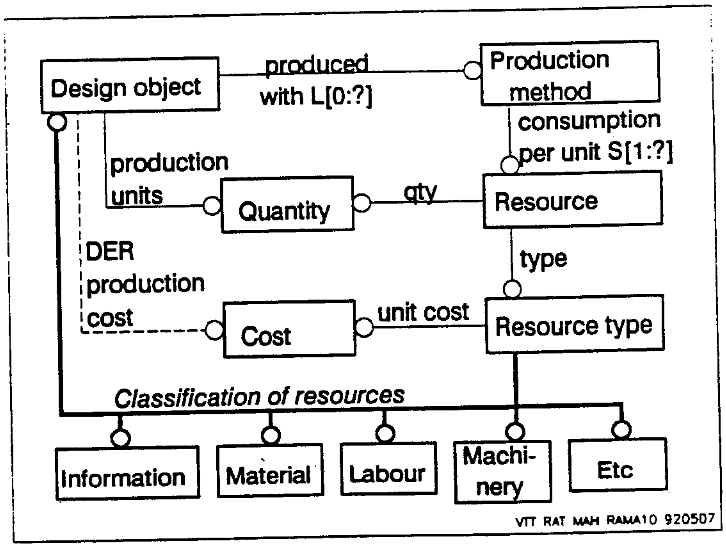

Fig. 9. Resource data model

10. PRODUCTION PLANNING

Production planning (box A6 in figure 4) is controlled by a data model of production, figure 10. The input consists of resource requirements, availability of external resources (e.g. labour, materials, machinery, etc.) and status of production. The activity is performed by the supplier. The output consists of availability and allocation (e.g. work orders, purchase orders etc.) of production resources.

Production activities are performed by project participants. Documents describing the design objects to be (physically) produced are used as instructions. Each production activity has a start and end time depending on its precedence to previous and succeeding activities. Production allocates resources.

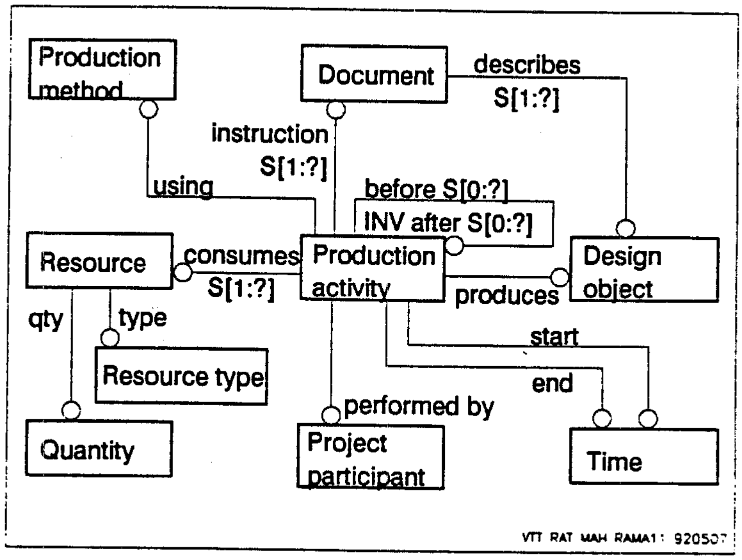

Fig. 10. Production data model

11. QUALITY ASSURANCE

The activity model in figure 11 shows a generic quality management view of construction process. The process runs parallelly with the construction information management process described in figures 3 and 4.

External input to the process consists of functional requirements, public requirements (e.g. regulations, law), project independent data, production resources and request to modify technical solution. The process is controlled by public quality management standards (e.g. ISO 9000) and a product data model. The GARM model [5] addresses the aspects quality management as part of a generic product data model. The activity is performed by client and supplier using quality management systems and tools.

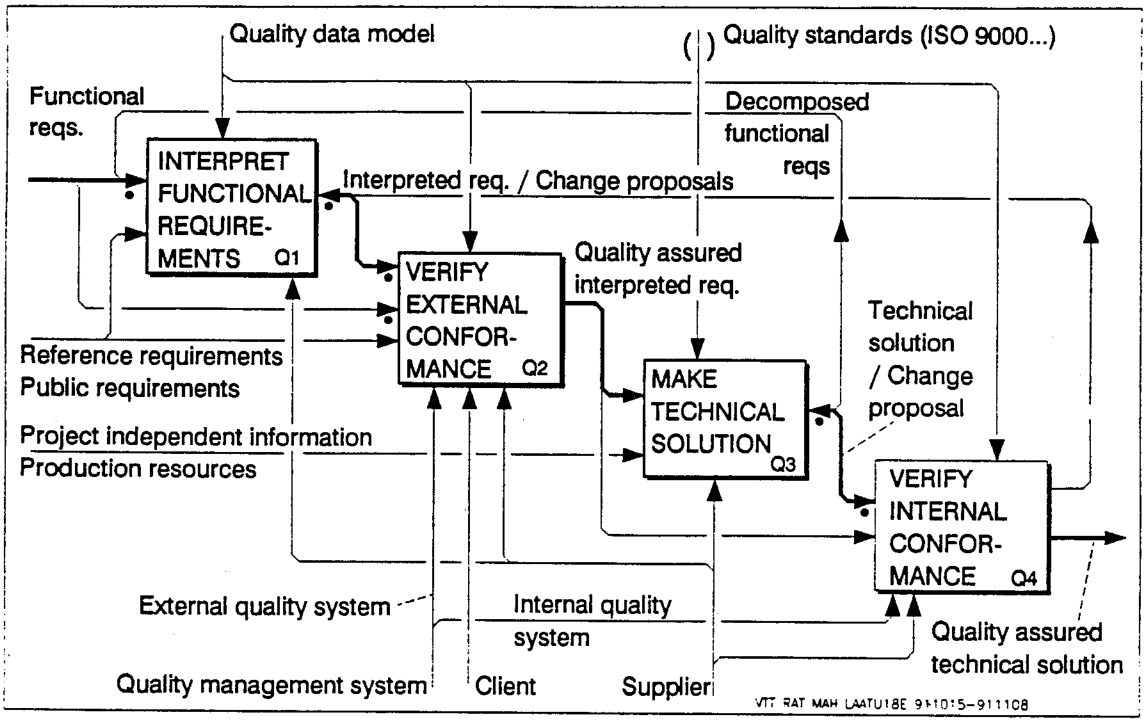

Fig 11. Generic quality assurance process

When an organisation receives an order from it usually needs to interpret the clients requirements e.g. translate them from functional into technical requirements. The suppliers internal quality system should assure that the delivered technical solution complies with this interpreted requirement. In addition, a collaborative quality assurance is needed between the client and supplier to assure that the prescribed interpretation is correct.

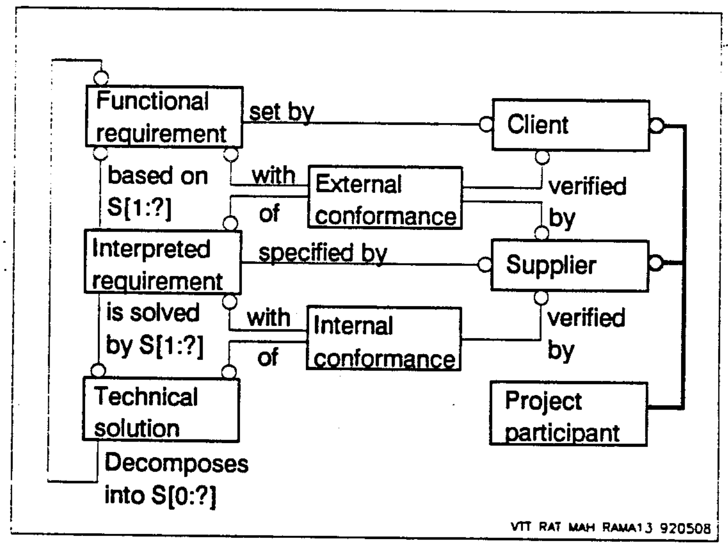

Fig.12 Quality data model

REFERENCES

1. Hannus, M., Järvinen, H. & Åström, G. 1991. G. Exchange of product data of prefabricated concrete structures. Computer integrated Future, CIB W78 Computer Integrated Construction, Eindhoven, 16-17 September 1991. Eindhoven University, Calibra. 10p.
2. Enkovaara, E. et al. (ed.) 1988. RATAS project. Computer Aided Design for Construction. Building Book Ltd, Helsinki 1988, 62p.
3. DTIC 1982. Integrated computer-aided manufacturing ,(ICAM), Functional modelling manual (IDEF0). Architecture Part II, Volume IV. Waltham, USA, Defence Technical Information Center, 167p.
4. Marca, D., McGowan, C.L. 1987. SADT - Structured Analysis Design Technique. McGraw-Hill, New York.
5. Gielingh W.F. 1988. General reference model for AEC product definition data (GARM, version 3), TNO Building and Construction Research, Delft, TNO rapport BI-87-87. 22p. + app. 17p.
6. Anon. 1985., Information modelling manual IDEF1-extended. Manhattan Beach, California, D. Appleton Company Inc. 110 p.
7. Nijssen, G.M., Halphin, T.A. 1989. Conceptual Schema and Relational Database Design, a fact oriented approach, Prentice Hall, Sydney, Australia
8. ISO 10303: Part 11. 1991. EXPRESS language reference manual. ISO TC 184/SC4/WG5/P3, Document N14, Release draft, 158p.
9. Sanvido, V.E. & al. 1990. An integrated building process model. The Pennsylvania State University, Department of Architectural Engineering, USA, Computer Integrated Construction Research Program, Technical report no. 1
10. Karstila, K., Björk, B.C. & Hannus M. 1991. A conceptual framework for the design and construction information. Proceedings of the 1st international *symposium on* building systems automation - integration, Madison, Wisconsin, USA, 2-8.6.1991