The RATAS project -

developing an infrastructure for computer integrated construction

Bo-Christer Björk
Professor of Information Technology in Construction
Royal Institute of Technology
Department of Building Economics and Organisation
S-10044 Stockholm
Sweden

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Abstract

Computer Integrated Construction (CIC) is a target state for construction computing characterised by extensive digital information flows between computer applications. Fully developed CIC requires an infrastructure of data structuring and transfer standards, digitised construction information services, changing patterns of organising projects etc. The creation of such an infrastructure is currently a high priority area for research and development in many countries.

In Finland this work has been organised as a fruitful co-operation between industry and researchers. The process known as the RATAS-project was initiated in 1983 and is still continuing. This paper describes the background of the project, its organisation and major phases, and gives brief descriptions of a number of its technical subprojects. The paper ends with an evaluation of the impact of the project on commercial software development and practice.

1. Introduction

Computer-integrated construction (CIC) is a term which describes a future target stage of the utilisation of information technology in construction. The key factor in CIC is the integration of the different computing applications used in the life cycle of a building (for instance CAD, engineering analysis, production planning, facilities management). Such integration will take place via automated digital data transfer between applications.

Despite the interest that CIC has received in the academic world, there are rather few examples of practical development efforts on the industry level, which are based on explicit long-term strategies for moving towards CIC.

The Finnish construction industry can provide one such example. Discussions concerning a national IT-integration strategy for the construction industry started already in 1982, and appropriate organisations (in particular the RATAS-committee) have been created to ensure the continuity of these discussions and the R&D activities which have followed [Enkovaara & Al. 1988]. The effort is still going on. This article attempts to give an overall summary of what has been achieved in the project and to what extent the targets formulated in the earlier stages have later been realised.

2. The infrastructure of the RATAS-project

2.1 The commitment of the industry

The small size of the Finnish construction industry has been a positive factor working in favour of the RATAS-project. The whole turnover of the industry is of the same order of magnitude as the turnover of one of the big Japanese construction companies. In most countries, due to the fragmentation and size of the construction industry, it would be impossible to get a large enough share of the decision makers that set the course of the IT-developments of the industry to sit down at the same table to discuss co-ordination of their strategies. In Finland, this has been possible.

The interest groups which have participated in RATAS-work are shown in table 1.
Bringing all of these together in a joint effort has not occurred coincidentally but as the result of a conscious strategy by the RATAS committee and its predecessor the RACAD board. The Technology Development Centre of Finland (TEKES), which is the major source for public R&D funding, has also had an important role in bringing about co-operation between research and practice. The argument is that often the commitment which can be achieved through the active involvement of industry experts in research projects, is as important as the quality of the research results for ensuring later commercial application of the results.

The research partner in RATAS activities has during the whole project been the Technical Research Centre of Finland (VTT). Due to its relatively large size, compared to the size of Finland, VTT has been able to bring together a critical mass of researchers and provide the initial funding for launching research into this area.

The RATAS committee currently numbers around 20 individuals. For each project that it initiates the committee appoints supervisory boards consisting of experts from industry. The committee meets once every month or two, and is regularly kept up to date with developments in the projects it co-ordinates.

2.3 The phases of the RATAS project

The RATAS project has been organised in phases. Phase I was a prestudy carried out in 1985 as committee work by a number of researchers and industry experts [Sarja and Leppänen 1987]. In parallel with the the RATAS-project another project focusing on a very narrow application domain, the computer-aided design and manufacturing of prefabricated concrete components, was started. This so-called BEC-project has both been influenced by and influenced RATAS-work and has produced some detailed standard proposals as well as resulted in commercial software in use in the industry [Hannus, Järvinen and Åström 1991].

Phase II of the RATAS-project lasted from the beginning of 1987 until the spring of 1988 [Enkovaara & Al. 1988]. The work done by the four technical committees of this phase has been very important for later developments.
Phase III (1988-91) consisted of a number of technical projects. Currently running projects are managed in a different fashion, with the RATAS-committee only loosely co-ordinating independent projects managed and financed by third parties.

Table 1. The principal actors in CIC strategy definition in Finland.

People in key positions	Influence on CIC development
The R&D directors and the directors of IT-development of the major ***construction companies, consulting engineer***s and *construction materials manufacturers*.	These executives control substantial development budgets and make decisions concerning the majority of the IT-investments of the industry.
The officials in charge of ***government funding*** to construction industry ***research and development***.	Through their funding decisions these officials have a strong influence on the direction of the industry's research efforts.
Representatives of the major ***construction clients*** and ***facility owners***, both public and private.	Building end users may not yet invest much in IT themselves, but they can make demands on the firms they do business with, for instance concerning data exchange standards.
Representatives of commercial ***construction information services*** as well as government officials in charge of the issuing of ***building regulations***.	These parties directly control the dissemination of general construction information of interest in CIC.
Representatives of the ***professional association***s which look after the interests of the different types of enterprises making up this very fragmented industry.	Such associations have a strong say concerning standard forms of contracts, standards for documentation, inclusion of computing costs in fees etc.
IT experts from ***software firms*** specialised in construction industry applications	They implement the ideas from research and possible standards in commercial software
Construction IT experts from ***research institutions***	They inform industry practitioners about the possibilities of CIC, but also warn about what is unrealistic.

Phase II: Key elements of CIC (1987)

3.1 Definition of a framework

The four committees involved in phase II were dealing with general data bases, standards for data exchange, the building product model concept, data needs and output documents. All of the subjects treated were deemed to be vital ingredients of the future computer-integrated construction process.

3.2 General data bases

Already in 1987 it was clear that construction materials vendors and general construction information services world-wide would start to convert their paper-based information distribution into electronic formats. Available technologies which were considered at that time were centralised data bases which are accessed via telecommunication networks, laser disks and CD-ROM devices, expert systems etc. The report of this committee made a survey of such techniques as well as a survey of the types of general construction information available in traditional paper format.

As digital information sources start to appear on the market a crucial feature from the end user's viewpoint is the minimisation of the number of different user interfaces he needs to learn. The recommendation issued within the RATAS project was therefore to aim at one co-ordinated construction information service for the whole Finnish industry. The user interface and the access method to this "master database" would be uniform, but the origin and updating responsibility for the data could be decentralised to the different organisations and firms which already today publish the information in question.

3.3 Standards for data exchange

A proposal for netral RATAS data transfer standards for different categories of information was developed, partly based on results from the earlier BEC-project. The categories of data which were covered were:

- unstructured and hierarchical text
- tables
- vector graphics
- raster graphics
- bar codes
- knowledge
- product model objects

For the majority of these information categories the recommendations were for the construction industry to start to use already existing general standards, such as ASCII for text, CODE 39 for bar codes and Postscript for raster graphics.
For vector graphics the project recommended the use of a Finnish standard developed in the BEC-project [Hannus 1987].

The two last categories of information contained in the recommendations differ radically from the others, since they represent categories of information which in the future may be an important element of information transfer in CIC, but which today are lacking in commercial software used in construction.

The transfer of knowledge could be a useful technique for the integration of different knowledge basis and expert systems. In the future general data bases about construction components and methods could contain knowledge which via such a transfer mechanisms could be integrated into the knowledge based application programs of individual firms. A knowledge description language based on production rules and the frame data model was proposed in the project.

The recommended standard for the transfer of product model data is based on the notion of transferring objects one at a time. A syntax closely resembling the LISP language was recommended.

3.4 The Building product model

The basic premise of this working group was that there was a need to transfer data about the building and its components in a database form rather than as documents derived from such a database. During the project the object-oriented approach for structuring data was recognised as appropriate. On-going related research abroad, in particular in France, the Netherlands and the United States was studied. As a synthesis of this a conceptual data model for the basic organisation of data describing a building was defined [Björk 1989].

The RATAS product model framework adheres to the Entity-relationship data model enhanced with the notions of generalisation and specialisation. On top of this basic data model the RATAS model superimposes the generic object classes needed for describing a building. The basic features are an abstraction or decomposition hierarchy going from the building object down to detail objects. The other dimension consists of the categorisation of attributes and relationships between objects into different categories. Attributes can be numbers, strings and even raster graphics pictures, quite near to the hypermedia approach. Relationships are subdivided into two generic categories, part of relationships and connected to relationships. Figure 1 illustrates the idea of an abstraction hierarchy as well as typical information collected in an object. The final report of this working group contained numerous illustrations of possible more detailed object classes (i.e. floors, windows, slabs) and the attributes typical for them, but didn't provide a detailed recommendation using a formalised conceptual modelling language.

3.5 Data needs and output documents in different phases of a construction project

The fourth working group focused its work on the information needs of different participants in a construction project during its different phases. The analysis was partly based on how the use of computers can enhance traditional documentation practice, partly on how new innovative kinds of documents can be extracted from building product models. Very useful for possible application developers are the examples of new kinds of documents which were included in the report of this group. A small example consisting of the information related to two rooms was modelled as objects and this model was used for generating a selection of room cards illustrating surface treatment, lighting fixtures, furnishing etc.

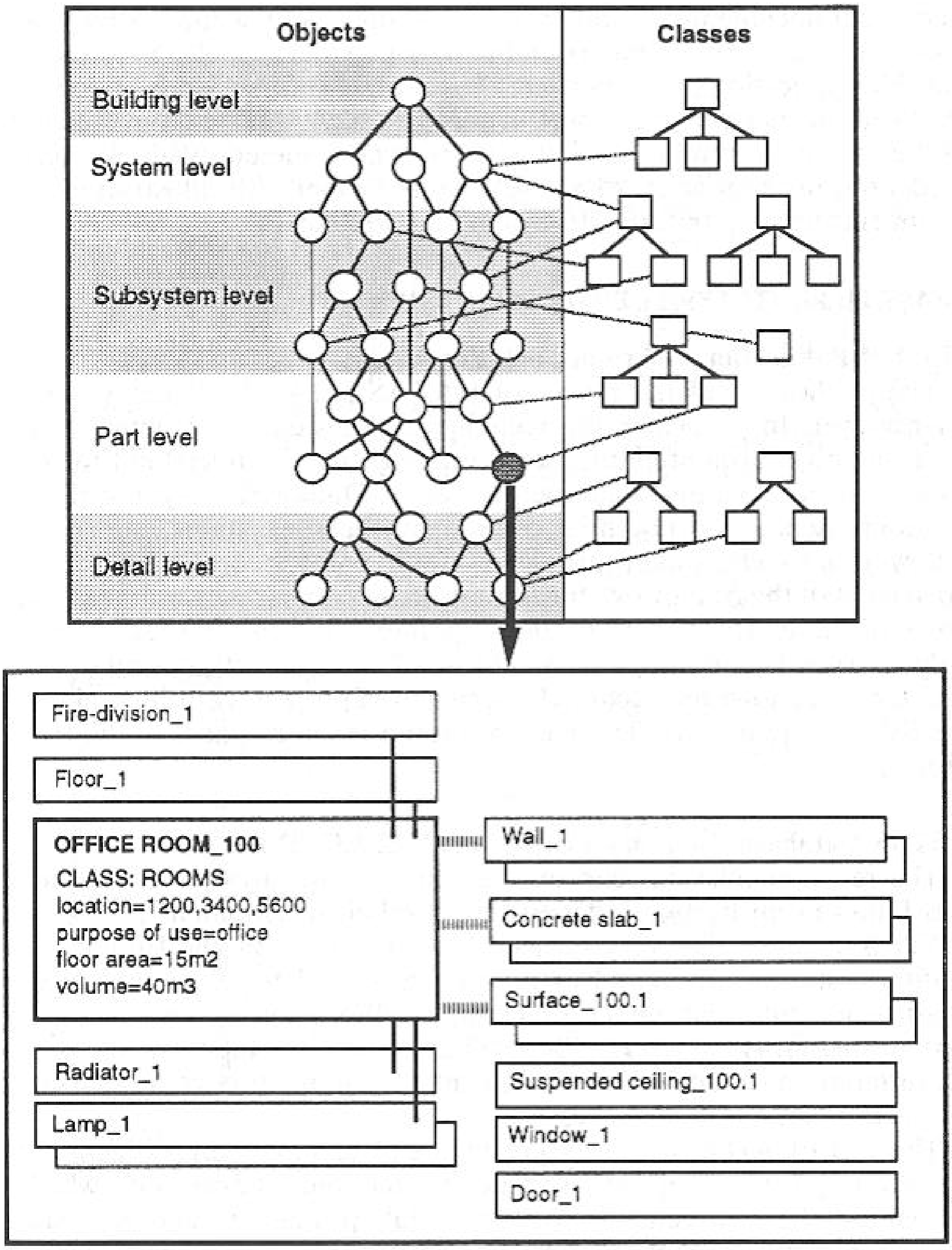

Figure 1. The basic abstraction hierarchy of the RATAS product data model [Björk and Penttilä 1989]

4. Phase III: Prototype development (1988-91)

4.1 Effect of the publication of the framework proposal

The publication of the results of RATAS phase II left many questions unanswered. In particular the technique which was suggested for structuring design data, the object-oriented approach, was difficult to understand for people with no formal training in computer science. Quite a few organisations did, however, realise the potential offered by the suggestions, and launched follow-up projects which through prototype and theoretical work developed parts of the framework further towards commercially usable solutions. Some of these efforts were funded separately and the RATAS board was only informed of their progress. Most of the projects described in this chapter were, however, included in a cluster of projects co-ordinated through the RATAS committee. This cluster formed the third phase of the RATAS project.

4.2 The RATAS database directory project and the TELECAD project.

The recommendations concerning general data bases which was issued in phase II was followed up by two independent parallel development projects. The RATAS database directory project was carried out by the Building Information Institute and aimed at producing a shell for the uniform digital construction information services project. Work on a construction information thesaurus, which can be used as a basis for index searches across the different information categories contained in the service was carried out in this project.

The TELECAD project was a commercial development project financed by two major producers of construction materials; Partek Oy, which has the largest share of cement-based materials production and Rautaruukki Oy, which is the market leader in steel structures. Partek has already traditionally produced a lot of information aiding designers, notably a book of recommended wall structures and a guidebook helping designers to check compliance with the requirements of the Finnish fire regulations.

The TELECAD prototype system included AutoCAD drawings of wall structures, information about building materials and an expert system for fire regulations which is linked with the materials information [Tuominen 1991]. The system was based on a central computer to which designers are in contact via modems and telecommunication links.

From the start the adopted strategy was to build an open solution which would also include materials information from other vendors and other types of information. The assumption was that the best way of making the information service a success would be to include a large share of the information the client needs in it rather than making it merely a substitute for traditional sales brochures.

4.3 Optiplan's CAD pilot project

During 1988-89 a number of commercial development projects which aimed to test how the product model recommendations could be implemented in practice were launched, partly financed by TEKES. In a prototype developed by Optiplan, the design and CAD-development subsidiary of Puolimatka Oy , one of the four large construction companies in Finland, a limited number of object classes which had been suggested in the building product model report of RATAS phase II, were implemented. The software platform was the combination of a CAD-system and a relational database. Examples of implemented classes were building, floor, door, room etc. A few part-of relationships were also implemented. Thus rooms belong to apartments, doors to walls etc. Two examples of connected-to relationship types were also implemented (adjacency of rooms, connectivity of wall segments) in the relational data base. The graphical equivalent of these and the other objects were symbols in the CAD system.

The system was used in the design and construction of an apartment house and found useful. In particular the possibility for selective querying the data base made it possible to automatically produce door-, window- and roomcards, following suggestions from subtask 4 of the RATAS II project . An example is shown in figure 2. In addition the facilities for producing structured bills of quantities was studied.

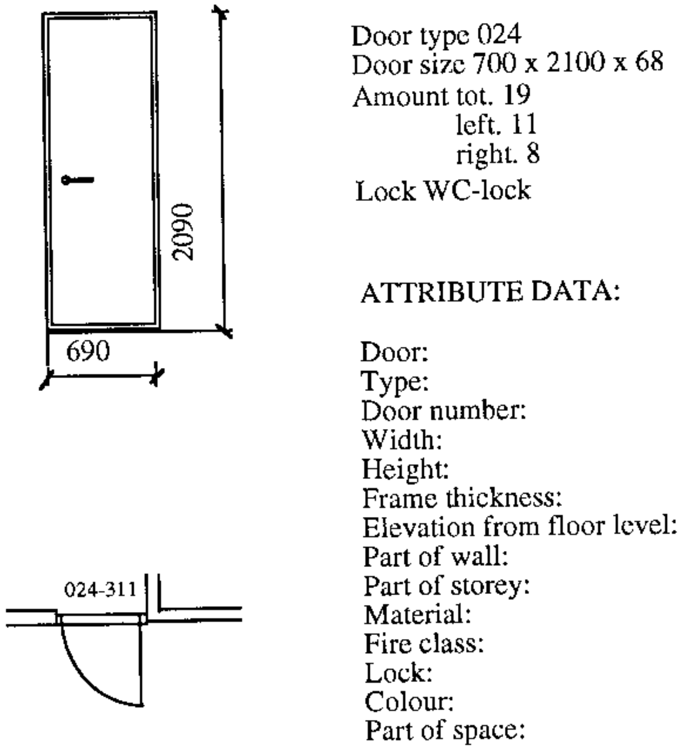

Figure 2. A door card produced from information in a relational data base in Optiplan's prototype

4.4 VTT's product model project

During 1988-91 VTT carried out a project which developed further the theory of the building product model and tested it by developing prototypes. In addition to the actual research work this project also provided the means for VTT's researchers for following the development of the emerging international product model standard STEP [ISO 1988]. A direct result of these activities was the establishment of a Finnish national STEP-committee, which has a broader basis than only the construction industry.

The results of VTT´s project emphasised the careful choice of fundamental data model as well as the possibility to support upwards mobility from earlier more generic conceptual models to later more detailed models [Björk and Penttilä 1989]. The use of type objects for describing components which reappear as numerous instances in many parts of a building was one important research subject. Another issue was the implementation of relationships using relational data base tables. The approach was tested by building four prototypes using an increasing variety of software types used in combination [Björk and Penttilä 1991]. The software types used were relational data bases, hypermedia and CAD-systems.

The project produced two reports, one state-of-the-art survey of building product model research abroad, and a final report which fulfils the role of a tutorial and guideline for the developers of more detailed building product model specifications and for developers of commercial software. The results of this project have directly been used in spin-off projects where the product model approach has been applied to energy-conscious design. After an initial national prestudy in 1989 VTT became involved in the COMBINE project, a multinational project funded by the EC Joule research programme [Augenbroe 1991]. VTT participated in the definition of the aspect product model in COMBINE, the Integrated Data Model, in addition to developing one of the six prototypes in the project in co-operation with a HVAC design firm [Talonpoika and Rissanen 1991].

The COMBINE project has been mentioned in this context because it represents a vital link between Finnish efforts and efforts on an international scale. The work in COMBINE showed that it is absolutely essential to use formalised conceptual modelling techniques in product modelling projects, especially in efforts involving many participants with different backgrounds and previous know-how.

4.5 A product model application for quantity management

The RATAS committee wanted to test the usefulness of the product model approach for the management of data describing the quantities needed for bidding and construction management . The project was carried out by the VTT [Penttilä and Tiainen 1991].

A prototype was developed using a combination of a commercial CAD system, a relational data base system and a hypermedia program. The prototype run on a Macintosh II. The application which was developed relied heavily on the use of type-objects typical for the Finnish prefabrication-oriented construction industry (i.e. hollow core slabs). Data about a real building, a small office building was used for testing the application and for illustrating the results. Heavy emphasis was placed on showing the ability of the product model approach to enable the contractors to obtain the data they needed from a designer in a data base format (the relational data base) and for restructuring and viewing the information in ways they are used to (the hypermedia user interface). Figure 3 illustrates this prototype.

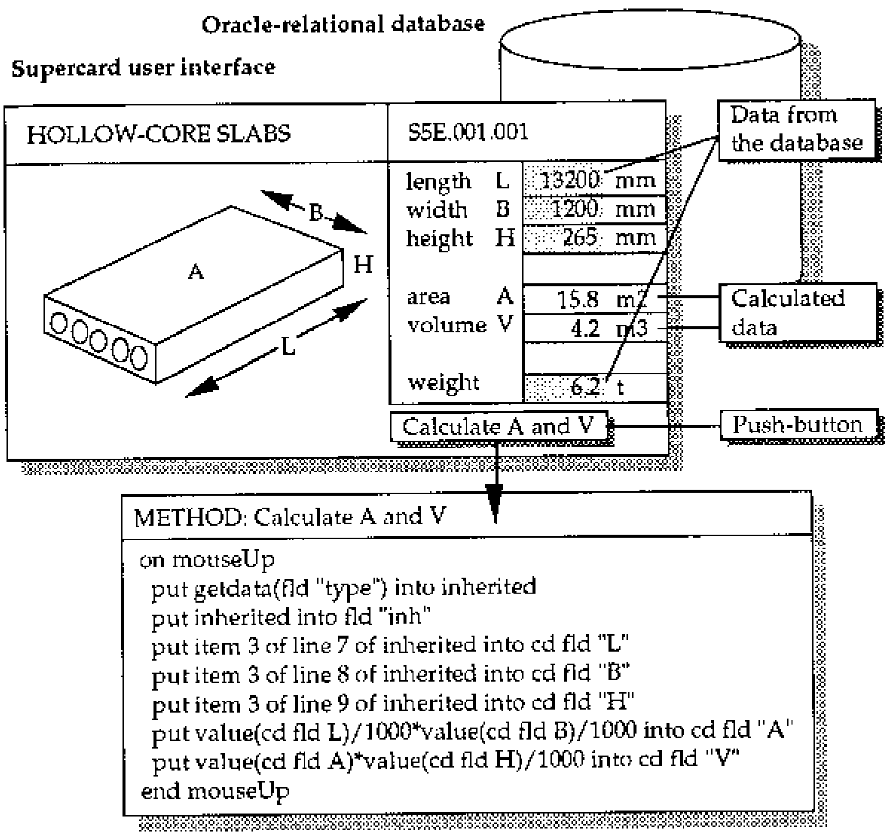

Figure 3. In VTT's quantity management prototype the notion of type objects was a cornerstone [Penttilä and Tiainen 1991].

4.7 EDIFACT messages and a product coding standard

The definition of EDIFACT messages for commercial transactions in the construction industry is currently going on in many European countries, partly in the form of international co-operation. In Finland the RATAS committee has assumed responsibility for this task.

The first phase of this work was carried out in 1990, in a project called REDI. The project had three partners, VTT as co-ordinator and in addition two software consultants who have specialised in EDI applications. The primary aim of REDI was to identify information flows in the construction process which by their information content and their frequency lend themselves for EDI-standardisation. The emphasis was in particular on the information flows related to the procurement of construction materials. The following messages types were recommended for further standardisation:

- purchase order
- purchase order response
- purchase order change
- delivery note

In the framework from 1987 a particular bar code convention had been recommended. In one of the projects of phase III of RATAS a standard for marking building components and materials in a uniform way for identification was agreed to. This standard can for instance be used in bar codes but it also has other applications

5. Further theoretical work (1988-91)

5.1 The computer integrated construction project

A project studying the strategic aspects of computer integrated construction was carried out by VTT in 1990-91. The aim was to report on developments in Finland and abroad for a larger readership. The final report (which is only available in Finnish) was written as committee work by five researchers from VTT.

The report discusses the benefits that can be achieved via computer integrated construction. It also places IT into context as one of the means that are available for developing the construction process, other important ones being automation systems, the development of systems building and quality systems. The report discusses a number of concrete proposals for actions which can be taken both at the construction industry level, the subdiscipline level, the level of individual construction projects and the level of the individual firm.

5.2 Relationship to traditional classifications systems

The officially adopted building classification system in use in Finland is House-80, which can be seen as a descendant of the SfB system. This classification system has primarily been designed for the needs of the cost management of the main contractors but it is also used for structuring master specifications, information about standard details and product information etc. There had recently been some criticism of certain features of the system and the committee which supervises the classification system performed a study on revision needs [Tiula 1988] about the same time as the results of the RATAS phase II became public . A serious defect from the product modelling point of view has been the absence of the notion of space in the House-80 classification system. This is due to the fact that for the contractor space is a by-product of the construction process, but doesn't directly cause costs. Due to the influence of the RATAS work, there currently seems to be a willingness to include the concept of space in coming versions of the classification system.

In an attempt to build a synthesis of the product modelling and the classification approaches a conceptual model was designed including information categories such as resources, activities and results (covered by some traditional classification systems). In addition concepts such as organisations, documents and agents were included in the model [Björk 1992]. This modelling effort was done by VTT as a part of the computer integrated construction project presented above and was formalised using the IDEF1X method. In figure 4 a slightly revised version of the generic model is presented in EXPRESS-G.

Work on this issue is in fact at present continuing in the form of international co-operation. A synthesis of VTT's proposal with some other models in the same domain, the Information Reference Model for AEC, has been published in 1993 [Luiten et al 1993].

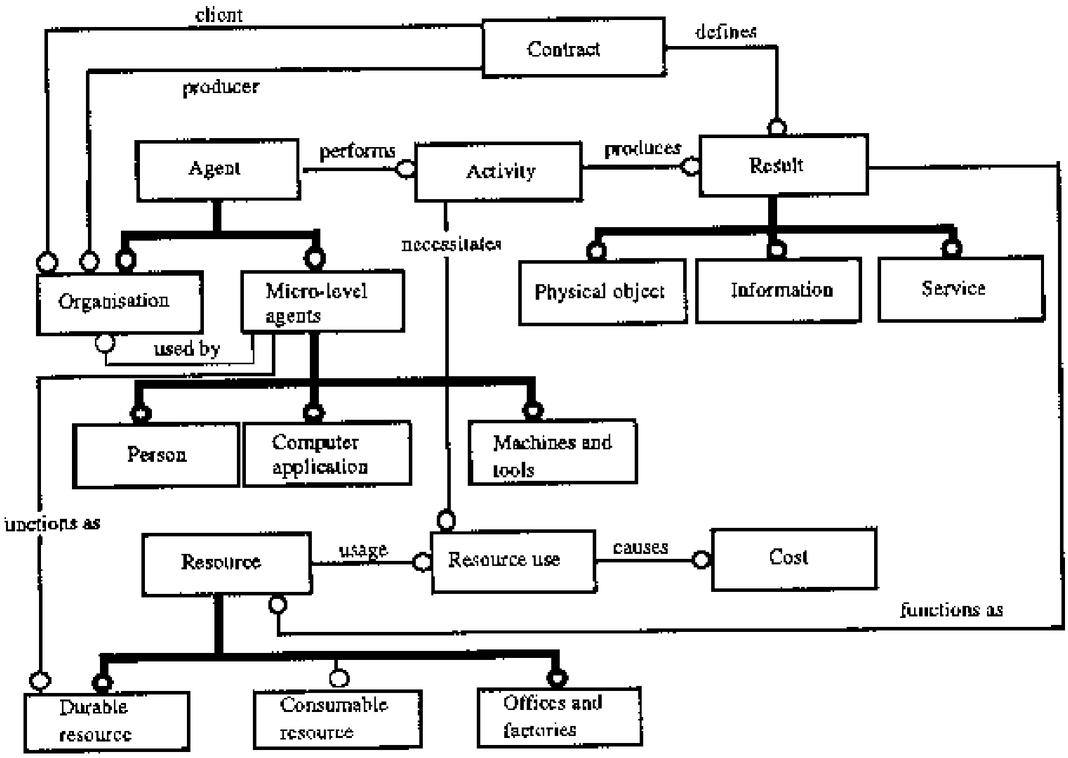

Figure 4. A generic conceptual model of construction project information

6. Commercialisation stage (1992-)

6.1 Changing emphasis to commercial applications

Since 1990 the association of the building clients, which recently has started to take a more active interest in IT, has received more influence in the RATAS-committee. At the same time the committee has assumed a more passive role by not trying to organise funding for projects itself as much as before, but by instead assuming the role of co-ordinator of projects initiated by third parties. From the beginning of 1992 the committee has the right to submit national standard proposals dealing with construction computing to the Finnish national standardisation organisation.

The Technology Development Centre TEKES continues to play a key role in setting guidelines for subsequent development work in Finland since a substantial proportion of commercial software development takes place with its support. In 1992-93 TEKES was funding several projects developing product model based applications for different subdisciplines of the design and construction process (for instance structural engineering, HVAC design, building maintenance). In order to co-ordinate such projects the RATAS committee has appointed a subcommittee for product modelling activities. The task of this subcommittee is to set up a quality assurance system for product modelling software. It has therefore recently defined guidelines for projects and applications that claim to be RATAS-compatible. The RATAS committee has in fact registered the trademark RATAS, which consequently can be used only with its consent.

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The guidelines prescribe the use of conceptual data modelling languages (i.e. EXPRESS) for documenting the data structures of the applications. In addition software developers need to demonstrate how the data structures of the model or application at hand relate to already earlier approved national models (The framework building product model of RATAS II, the generic model of OOCAD (cf. section 6.3), aspect models resulting from such projects as HVAC-RATAS, maintence-RATAS).

6.2 TELERATAS

During 1991 an agreement was reached between the Building Information Institute and Partek Oy to merge the RATAS data base directory project and the TELECAD projects. TELERATAS was chosen as the name of the merged project. A first version of TELERATAS was issued to pilot users in the winter of 1992 and it became commercially available in the summer of 1992.

The overall architecture of TELERATAS is based on a central repository for the information combined with the possibility for users to download as much as possible of slowly changing types of information to their own hard disk. Recently a CD-ROM version of the system has become available. In this version a yearly updated CD-ROM contains all the information which is used locally. Quickly updatable information is also in this version obtained via networks from the central computer.

TELERATAS is a Windows application and starts with a directory menu (shown in figure 5) which offers access to the different types of information included in the system.

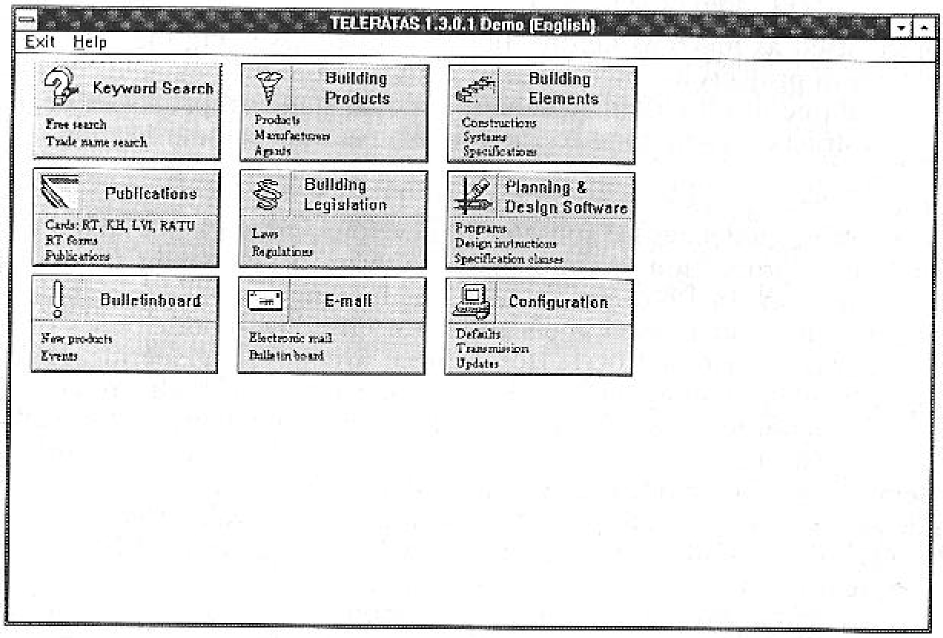

Figure 5. The main menu of the TELERATAS building information service

6.3 OOCAD

The aim of the OOCAD project was to produce a general purpose product model based software environment which can easily be adapted to the specific needs of different application domains. The project, which traces its origins to both the BEC and the RATAS projects, was carried out at the Technical Research Centre of Finland during 1991-92 [Serén et al 1992].

The basic premise of OOCAD is to enhance basic software types which are already available to ordinary design offices and run on industry standard PCs with product modelling capabilities. OOCAD includes a basic generic conceptual model of product description data as well as a neutral data exchange file format implementing this conceptual model.

In the conceptual data model the distinction between type objects and instance objects is the key feature. In addition to the substantial saving in storage requirements that type objects offer they also correspond closely to the way designers think and construction companies use prefabricated components. In OOCAD the location and orientation of a building component is always given at the instance level, but for other parameters the user has the choice to give them either at the instance or type object level. Another important feature is the notion of attribute sets, which can be predefined and combined freely to produce the attributes of a given object.

The tools used for implementing the system have in the first instance been a CAD-system (AUTOCAD), a relational database system (dBase IV) and an object-oriented programming environment (Actor). The data structures in the conceptual model have in each program been implemented using the programming tools typical of the programme in question (for instance in the case of AUTOCAD blocks, attributes, inserts and layers have been used). Figure 6 illustrates one type of user interface included in the OOCAD system, the product model browser.

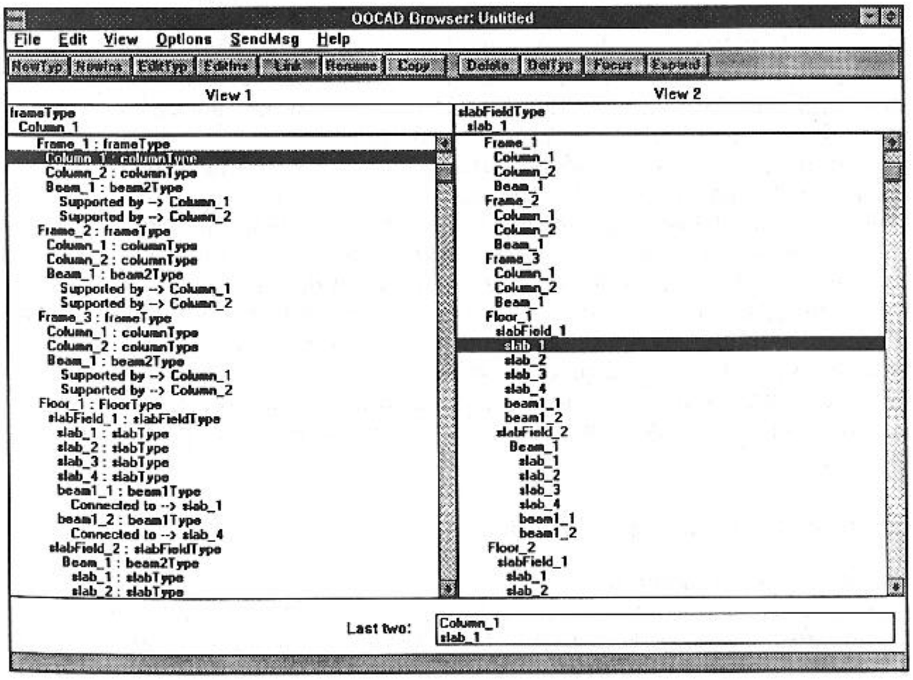

Figure 6. An object-oriented browsing tool from the OOCAD generic product modelling system

The three separate program modules communicate via OXF files. An OXF file is a sequential human readable ASCII file which has a list structure. The OXF lists have a nested structure where each item can be replaced by a more complex item in parenthesis. This structure has also been used to directly implement Part-of or existence dependency relationships between objects. Child objects are embedded in their parent objects. An interesting side-effect of the generic conceptual model is that it is possible to include application specific definitions of attributes and attribute sets (on the conceptual level) in the transfer file itself, which is in contrast to the data transfer file format used in the emerging STEP standard.
The software created in the OOCAD project is currently being tailored to a number of applications ranging from structural engineering to quality assurance tools for building clients.

6.4 HVAC-RATAS

HVAC-RATAS is a large industry-driven standardisation and development project which aims at implementing the product model philosophy within the scope of HVAC design and contracting. This will be attempted by defining a more detailed conceptual model and by producing commercial application programs. A prestudy ended in the winter of 1992 and the main part of the project is expected to run for approximately three years.

In the prestudy the IDEF1X conceptual modelling language was used to clarify the data requirements in different phases of the design and assembly of HVAC systems in buildings. Later on EXPRESS-G has been adopted. The major part of the project consists of development of applications for taking off of quantities, bidding and technical analysis, which will be integrated using the common product model for HVAC systems.

6.5 The Computer integrated construction pilot project

In this project, which was financed through a research grant from TEKES, the product model approach was being tested with data from a real construction project. The participants in the project included three laboratories from VTT, the Technical University of Tampere, an architectural design office and a HVAC & electrical design office. The generic conceptual models of RATAS phase II as well as of the OOCAD project were enhanced with the more detailed object class definitions needed for architectural, structural, HVAC and electrical design. The ensuing models were documented using the EXPRESS language as well as using EXPRESS-G schemas. In parallel process models of the design process indicating the flow of information management were defined.

As a separate task a prototype document management system was developed. For this purpose an activity model of the document management process as well as a generic conceptual model of document description data were defined [Björk et Al. 1993]. This model covers all kinds of construction process documents, ranging from contracts, cost estimates and design documents to timetables and meeting minutes. Fig. 7 gives an example of the kind of information which will be attached to the document objects which the system manages. A demonstration system was also developed using a hypermedia environment.

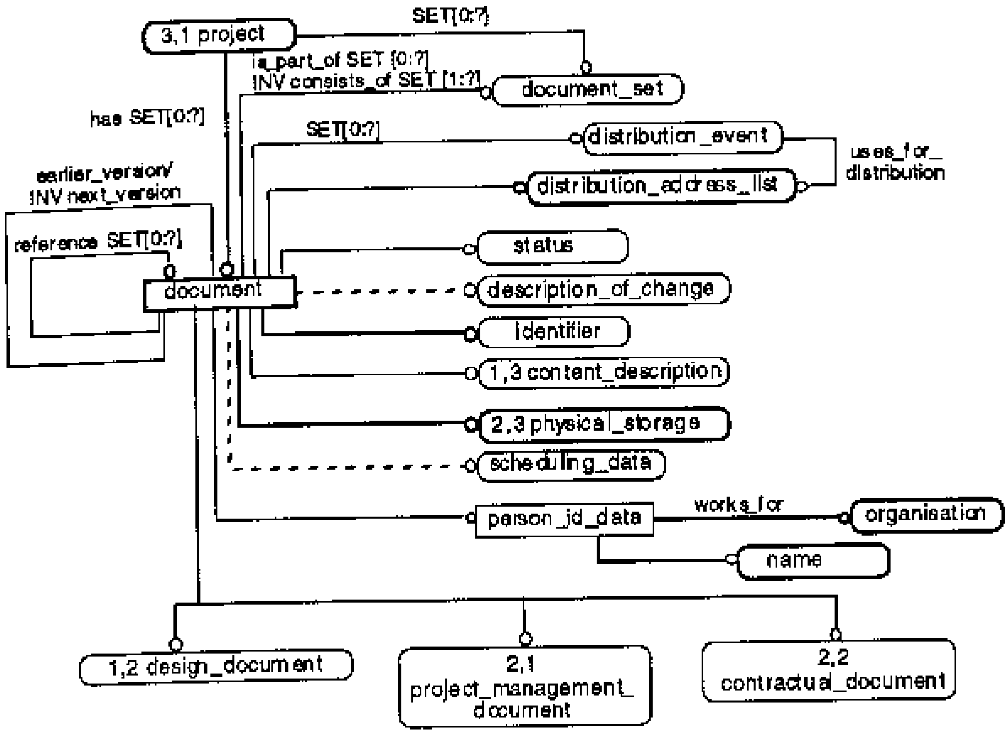

Figure 7. A conceptual model of the information handled by the document management system

7. Critical evaluation of the results

7.1 Framework for evaluation

In a critical evaluation of the results of the RATAS project the time-frame of the effort should be kept in mind. Clearly industry representatives would like to see implementation of the results in practice take place at a faster pace. On the other hand some parts of the infrastructure developed in the project belong to the category of basic research.

A good starting point for an evaluation of RATAS results is provided by a list of key elements of CIC which was defined in the computer integrated construction project presented in section 5.2. These elements included:

- industry-wide and company-specific strategies for CIC
- hardware
- telecommunication networks
- applications for the construction industry
- general data and knowledge bases
- the use of formal modelling methodologies in software development
- standards for the structuring and exchange of data
- An organisational and legal framework which supports CIC
- computer-trained construction professionals

All of these element are necessary for CIC. In some of these areas developments take place as a result of technology push from outside the construction industry (hardware, telecommunications networks). In other areas competition between software vendors specialised in the construction industry will produce better and better tools. This is especially true for tools such as CAD-applications for construction and project management software.

One important side effect of the tremendous IT-developments during the last ten years should be mentioned. As a result of to the saturation of the industry with such technology a "market demand" for the kind of integration strategies and techniques provided by RATAS is quickly starting to emerge. Compared to the mid 80´s a much larger share of the industry's professionals have had hands-on experience of the problems in exchanging data in digital form and understand the need for standards and co-ordinated actions on the industry level.

The most interesting areas from the viewpoint of this analysis are those where conscious actions and long-term strategies by the construction industry have a strong impact on the end result. The following discussion focuses on such areas.

7.2 Strategies for CIC

RATAS phase II proposed a national industry-wide strategy for moving towards CIC. The final report of VTT's computer integrated construction project in 1991 outlined an even more explicit framework containing goals and actions for the different organisations working in the industry, both on the national, subdiscipline and individual enterprise level. The work of the RATAS committee is de facto a national strategy which is constantly undergoing revision.

On the level of professional associations the contractors' association has carried out a fairly explicit CIC strategy via its funding of R&D. The association of building clients has founded a separate information technology committee which has defined its own strategy. The architects' interests are being looked after by the CAD-SAFA association.

During this period two of the largest building contractors in Finland, Haka Oy [Laitinen 1992] and Puolimatka Oy, have defined company-specific CIC development strategies. An important ingredient of these strategies is to identify the business opportunities that CIC can offer for the firm in question. Haka has in particular stressed the importance of the building product model approach in such a strategy. Partek Oy, the market-leading manufacturer of building materials has been one of the driving forces behind the TELERATAS system.

7.3 General data and knowledge bases

The commercial launch of TELERATAS in 1992 was a significant event, since the system is in line with the recommendations issued in 1987. The inclusion of an expert system for fire regulations in TELERATAS is interesting to note since this indicates a very sensible direction for knowledge-based system development, towards expert system modules embedded in general construction information services.

7.4 Use of formal methodologies for CIC development

The final report of phase II in 1987 included a description of an ideal design process and some suggestions for what ought to be done. Most of this was however in prose form with some tables added. The proposed generic product model was not presented using a formalised data definition methodology but using techniques which illustrated the basic concepts of object-oriented data structuring techniques.

The reactions to these reports indicated a need for more rigorous definitions. Work done abroad has also shown that formalised methodologies could be very useful for defining elements of CIC both on the macro level of design and construction activities and on the micro level of detailed data definitions.

In the further work done at VTT during 1987-91 some of the possible techniques have been tried out, i.e.. SADT for process modelling and IDEF1X, NIAM and EXPRESS [ISO 1993a] for conceptual modelling. At present conceptual modelling techniques are used in several projects both at VTT as well as in more commercial projects such as HVAC-RATAS.

7.5 Standards for data structuring

The standards which were proposed in RATAS phase II have so far had a very limited impact on practice. In the case of text, tables and raster graphics many leading programs nowadays contain data conversion facilities which enable the user to convert his data to a format amenable for transfer to other applications before actually dispatching the information.

The transfer format which was adopted for 2-D drawings, the BEC format has been used to some extent in practice. Pre- and postprocessing programs for BEC were developed for a number of leading CAD-systems in the late 1980's. Due to the dominating position of AUTOCAD on the CAD-market DXF is, however, more or less a de facto standard at the moment also in Finland.

The proposals for the transfer of knowledge and for product model objects were more academic in scope, since no applications based on such techniques were used in practice at that time. It is, however, interesting to note that the object transfer standard is turn functionally near to the STEP file transfer format. In Finland the work on the object transfer standard has continued in the form of the OXF transfer standard used in the OOCAD system.

Until today the product model approach has not yet been used routinely in ordinary building design projects, with the possible exception of some software packages for structural design [Hannus 1990]. The generic model which was presented in 1987 has, however, lead to a number of follow-up projects, many of which aim at developing commercial software.

8. Conclusions

All in all the RATAS-project presents an interesting case-study of co-operation between the research community and industry. This co-operation has been the result of a number of coinciding factors which have all worked in favour of it. The relative smallness of the Finnish construction industry and the ensuing possibilities for setting strategic aims for IT use in computing on the national level has been one such factor. The relatively large size of VTT and its resources for efficient technology transfer has been another such factor.

In many respects the RATAS-project has not fulfilled the expectations of the participants. Despite all the efforts that have been made the dominating mode of integration is still paper copies of documents and telefaxes. The time frame for reaching commercially useful applications has constantly been underestimated, partly from sheer optimism, partly because of a need not to frighten decision-makers providing the finance. The very deep recession which since 1992 has cut the turnover of the Finnish construction industry into less than half compared to a few years earlier also seriously affects the possibilites for any kind of investments in new technology.

Among the concrete results of the project one can mention the following:

- A commercial digital building information service TELERATAS which follows the guidelines set out phase II.

- A common "national" understanding of the basic principles of building product models.

- Demonstrations using prototypes by both research groups and commercial firms of the benefits and feasibility of the product model approach.

- Technology transfer of useful techniques for activity and conceptual modelling from research to practice.

- Standards for the exchange of a number of EDIFACT messages primarily meant for the trade with construction materials.

On the positive side in the balance one can also note the very active participation of industry experts in research projects. This has had the positive effect of creating a willingness in the firms of these experts to apply the results in their internal development work.

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The author of this article was as a researcher at VTT involved in RATAS efforts from their very start in 1982 until 1993, when he took up his present academic position at the Royal Institute of Technology in Stockholm, Sweden. In the yearly years the author was a member of the executive board of the RACAD association, later for many years a member of the RATAS committee. He has actively participated in several of the technical projects mentioned in this article. In particular he was the chief investigator of VTT's project concerning computer-integrated building design (1983) and the manager of VTT's product model project (1988-91).

Many experts have over the years participated in RATAS work and it would be impossible to name all of them here. Matti Pöyry was the secretary general of the RACAD association and helped launch the whole process with his enthusiasm. Markku Salmi has in later years efficiently administered the work of the RATAS-committee as its secretary general. Of all the IT-experts from industry who have participated Matti Hannus has been by far the most influential. He has recently joined VTT to make a second career as a researcher.

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