A Case Study of a National Building Industry Strategy for Computer Integrated Construction

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ABSTRACT

Computer integrated construction (CIC) is a future state of the use of IT in construction characterised by the extensive use of computers for all kinds of application as well as by the transfer of information between such applications in digital form. CIC necessitates an infrastructure of data structuring and transfer standards, computer networks, digital information services for construction, etc. This paper presents the efforts made during the last ten years by the Finnish construction industry to develop strategic parts of such an infrastructure, the RATAS project. In addition to a survey of a number of technical projects, the paper also presents the organisational aspects of the project and attempts to evaluate the results that have been achieved so far.

<u>Key Words</u>

computer integrated construction; product model; standardisation; data exchange; object-oriented

INTRODUCTION

Co-operative research, development and standardisation efforts are needed in order to steer the construction industry towards a future state often described as computer integrated construction, CIC. In Finland the professional associations representing the different participants in the construction process have in co-operation launched a number of research and standardisation projects which aim at providing parts of the infrastructure needed for CIC. In particular these projects have addressed the needs for data exchange standards and co-ordinated digital construction information services.

In this paper the origins, aims and results of the RATAS project (RATAS stands for the Computer aided design of buildings) and some closely related projects during the years 1984-92 are presented. In the earlier phases the RATAS project defined some vital ingredients needed for CIC. These included the notion of one single user interface to general construction

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information and the basic framework of a building product model for the exchange of data concerned with a particular building project.

In later stages of the RATAS project, sub-projects have studied the product model approach more in detail. In addition pre-standardization work for the definition of EDI messages for the construction industry has been carried out. A commercial electronic construction information service, TELERATAS, was launched in 1992. In parallel with the RATAS project, both research and development of commercial applications have been initiated, partly influencing RATAS work; partly being influenced by it.

THE ORIGIN OF THE RATAS-PROJECT

Discussions about the integration of IT applications in construction started in Finland in 1982. A number of large engineering firms who had purchased turn-key CAD-systems were the first to recognise a need for methods and standards that would enable the transfer of design information in digital form between designers. As a result of these discussions an association called the Construction Industry Council for CAD in building, RACAD, was formed. A yearly membership fee of app. 2000 USD restricted membership to bigger organisations, such as professional associations and government branches, who saw the agenda of RACAD as important for their own strategies. A board headed by a full-time employed secretary general was responsible for day-to-day activities.

During its existence (1983-86) RACAD served two main purposes. Firstly, it provided a good forum for discussions and organised a number of seminars, where the latest news and development ideas were exchanged. Secondly, it set out to plan a large co-ordinated research, development and standardisation effort, which later turned into the RATAS-project. RACAD also established contacts with similar associations abroad.

The first R&D programme proposed in 1983 by the RACAD board had a budget of almost 8 mill. USD, which in view of the targets of the programme and later experiences from R&D projects would have been quite realistic. After almost two years of difficult negotiations the budget of the programme was reduced to app. 600,000 USD, of which 40 % as a research grant from the Technology Development Centre of Finland, TEKES. The participation of the major contractors in the funding was crucial for the launching of the project.

Simultaneously with these negotiations RACAD was dissolved and some of its functions were inherited by the project organisation which was formed under the Building Information Institute for managing the initial R&D effort. This institute is a private non-profit umbrella organisation formed by a large number of the professional associations representing different branches of the construction industry and has a near-monopoly on the dissemination of general construction information in Finland. The acronym chosen for the project, RATAS, stands for *computer aided design of buildings.*

OTHER RELATED ACTIVITIES

A number of other R&D programmes related to CIC, which have had a strong interaction with the RATAS project, should be mentioned at this point.

The BEC project has influenced the RATAS project by providing an example of integration efforts in a more narrow application domain of particular interest for the Finnish construction industry - the computer-aided design and manufacturing of prefabricated concrete components [Hannus, Jarvinen and Åström, 1991]. The most interesting results of the first phase of BEC were a standard for the exchange of 2-D draughting data [Hannus, 1987] and a standard for the exchange of product data about structural components. Based on these two standards commercial software has been developed.

The other major influence on the RATAS process has been the research and technology transfer carried out by the Technical Research Centre of Finland (VTT). VTT started its CAD activities with a state-of-the-art survey in 1982, followed by a more focused study of integration techniques in 1983. Many of the research proposals made in the latter study were incorporated into the RATAS-project. In two instances (1984-86) and (1988-90) VTT has carried out large research programmes studying the techniques of construction computing [cf. Anon, 1991].

A PROPOSAL FOR KEY ELEMENTS IN CIC

The first phase of the RATAS project was done by a committee and tried to identify key elements of what is now known as computer integrated construction [Sarja and Leppänen, 1987]. Phase 2 studied these elements more in detail and was carried out in four separate sub-projects, each one of which had around ten participants, representing both research and industry. The themes of these four sub-projects, as well as the main results, are described in table 1.

The results of this work was reported in detail in four technical reports in Finnish. The only overall report available on the results of this phase has so far been the English translation of the summary report on RATAS II [Enkovaara, Salmi, Sarja, 1988].

A NEED FOR FURTHER R&D

The second phase of the RATAS project had defined a number of key elements needed in CIC, but its recommendations needed further testing by prototypes and refinement to be useful as specifications for the development of commercial software. During 1988 a number of activities started which aimed at providing a more solid basis for such implementations. Most of these, although not all, were organised as phase III of the RATAS-project, and managed under the supervision of the RATAS-committee. Another feature was that almost all of these have received some funding from the Technology Development Centre (TEKES), which through its funding decisions has carried out a clear strategy supporting the introduction of CIC elements into the Finnish Construction Industry. TEKES sees information technology as one of a number of key factors which could make the Finnish construction industry more competitive [Saarnivaara, 1990].

In the following sections the follow-up of the recommendations of RATAS phase II are briefly reviewed.

Table 1. The four technical committees of RATAS phase II and their main results.

Theme	Main results
General databases	**A strategy for the development of digital construction information services:** * Centralised distribution of information * Decentralised information production and maintenance * A single uniform access mechanism and user interface
Data exchange standards	**Proposed standard formats for the exchange of:** text, tables vector graphics, raster graphics bar codes knowledge, product model objects
Building description in database form	**Basic generic structure of a building product model using an object-oriented approach:** * Major decomposition hierarchy on five levels. * "Part of" and "connected to" relationships.
New documentation formats and the design process in CIC	**Proposals for new types of documents:** * Documents which can be automatically extracted from building product models (e.g. room cards). **A scenario for a gradual movement towards full CIC**

GENERAL CONSTRUCTION INFORMATION SERVICES

The recommendation to create one single uniform user interface to all kinds of general digital construction information services was followed up by two independent 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 service. Work on a building information thesaurus was also carried out in this project. The other project was initiated by Partek Oy and Rautarukki Oy, two major manufacturers of building materials. Partek has 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 prototype system included Autocad drawings of wall structures, information about building materials and an expert systems for fire regulations which is linked with the materials information included in TELECAD [Tuominen, 1991].

During 1991 an agreement was reached between these parties to merge their projects. TELERATAS was chosen as the name for the synthesis of the two projects. The system was issued to pilot users in the winter of 1991 and has become 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 information that do not change quickly to their own hard disk to speed up access and save on telecommunications costs. For larger firms there is also a network version of the program available. 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. A example of the user interface of TELERATAS is shown in figure 1.

DATA EXCHANGE STANDARDS

The data exchange standards which were proposed in RATAS phase II have so far had a very limited impact on practice. The transfer format which was adopted for 2-D drawings and which originally had been developed in the BEC project, has been used to some extent. Pre- and post-processing software for BEC were developed for a number of leading CAD-systems in the late 1980's.

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. The work on the object transfer standard has continued in the form of the OXF transfer standard used in the OOCAD system [Hannus, 1992].

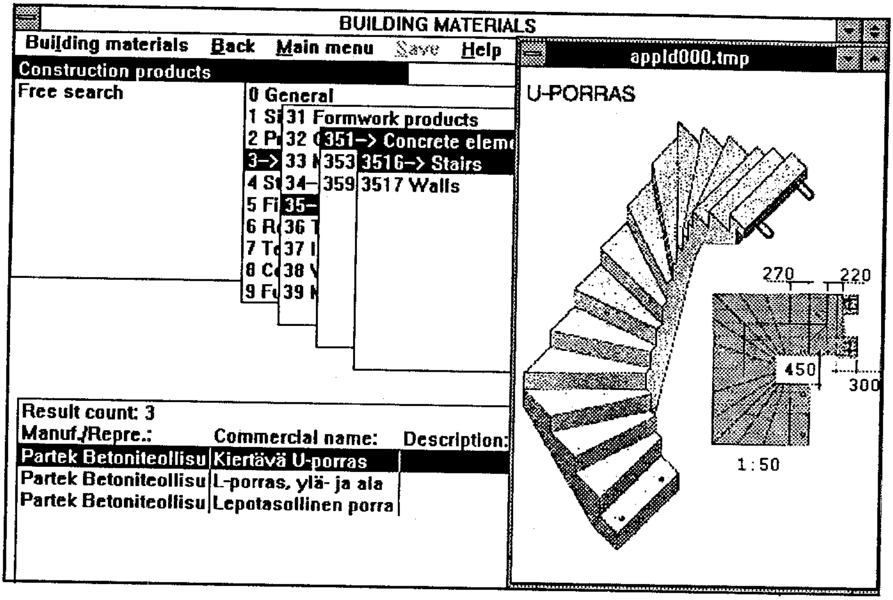

Figure 1. An Example of the User Interface of the TELERATAS Building Information Service

In addition to the standards originally defined in 1987 a need for the definition of standards for the digital transfer of commercial messages had arisen. An effort to find the definition of EDI messages for 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 primary aim of the REDI project, which was carried out by VTT and some private firms in 1990, 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. A number of message types, such as purchase order, delivery note, etc. were recommended for further standardization.

In the summary report from phase 2 [Enkovaara et al, 1988] 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.

THE PRODUCT MODEL APPROACH

During 1988-91 VTT carried out a project which developed further the theory of the building product model and tested it by developing prototypes [Björk and Penttilä, 1989]. The approach was demonstrated by building four prototypes using increasingly complex basic software [Björk and Penttilä, 1991]. The software types used were relational data bases, hypermedia and CAD-systems. Figure 2 shows an example of a hypermedia user interface to product model data.

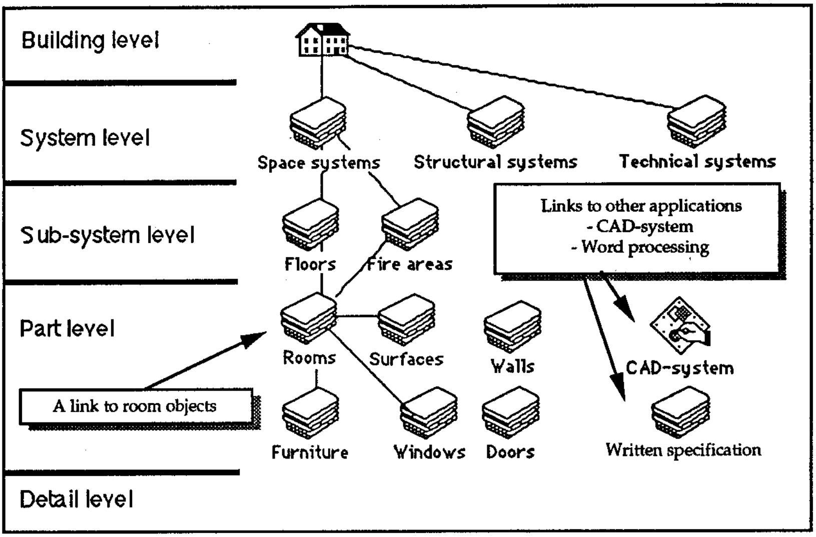

Figure 2. A Hypermedia User Interface to a Building Product Model, From One of VTT's Prototypes

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 [Björk, 1989b] VTT became involved in the COMBINE project, a multinational project funded by the European Commission through the Joule research programme [Augenbroe, 1991]. VTT participated in the definition of the typical product model in COMBINE, the Integrated Data Model. In addition VTT developed one of the six applications that were integrated in the project, in co-operation with a Finnish HVAC design firm [Talonpoika et al, 1991]. The application deals with the design and dimensioning of a radiator network.

Another spin-off project was commissioned by the RATAS committee to test the usefulness of the product model approach for the management of data describing the quantities needed for bidding and construction management [Penttilä and Tiainen 1991]. The prototype in this project was developed using a combination of a commercial CAD system, a relational data base system and a hypermedia program. The application which was developed relied heavily on the use of objects describing standardised components typical for the Finnish prefabrication-oriented construction industry (eg. hollow core slabs).

Work on software tools for product modelling has also continued at VTT in the OOCAD project which aimed at producing 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 [Hannus, 1992]. The OOCAD implements product model data structures in a combination of software consisting of a commercial CAD system, a relational database and an object-oriented programming environment. The data exchange between these is handled via files containing objects in list form, the OXF format.

Two of the major contractors, Haka [Laitinen, 1992] and Puolimatka, have tested the product model approach in internal development projects. In Haka's case a powerful knowledge-based environment was used, whereas Puolimatka opted for a combination of a CAD-system and a relational database.

HVAC-RATAS is a large industry-driven standardisation and development project which aims at defining a detailed conceptual model and at producing commercial application programs. It focuses especially on software for the taking off of quantities, bidding and technical analysis, which will be integrated using a common product model for HVAC systems. Another co-operation project worth mentioning is Maintenance-RATAS which aims at defining the data structures needed in building maintenance and at producing functioning software.

THE OVERALL CIC PROCESS AND NEW DOCUMENT TYPES

A project studying the strategic aspects of computer integrated construction was included in VTT's large research program for Information and Automation Systems in Construction [Anon, 1991]. The final report from this study 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 sub-discipline level, the level of individual construction projects and the level of the individual firm.

One result of this project was a generic conceptual model which tries to build a synthesis of the scope and data structures of both product models and traditional building classification systems. Information categories such as resources, activities and results but also organisations, documents and agents are included in the conceptual model [Björk, 1992a]. The model is shown in figure 3 using the EXPRESS-G notation. Work on such integrated construction information data models is at present being pursued by a number of researchers from different countries [Froese 1991, Luiten and Tolman, 1991].

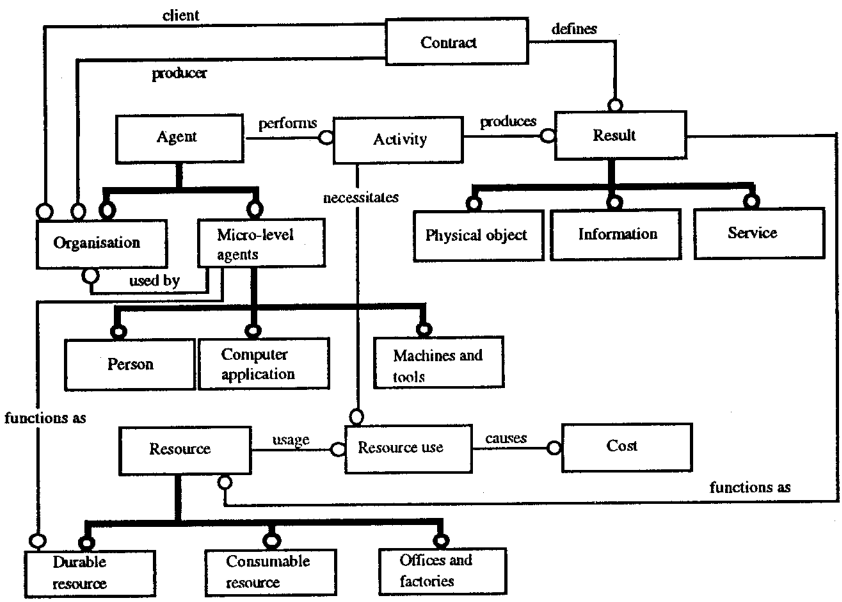

Figure 3. A Generic Conceptual Model of Construction Project Information [Björk, 1992b]

Conceptual modelling techniques can also be applied to the management of traditional building documentation. A demonstration of an integrated construction process document management (ICPDM) system has recently been developed at VTT [Björk, Huovila, Hult, 1993]. The basic idea of the system is to distribute information about the documents and changes that are made to them as messages through a computer network. The documents themselves are only fetched from the hard disks where they reside when they are needed. The prototype runs under Windows 3 on a standard PC.

The ICPDM system covers all kinds of construction process documents and treats documents as "black boxes" which are described by document description objects, the basic units that the system handles. Figure 4 illustrates the type of documents that the system distinguishes between as subclasses.

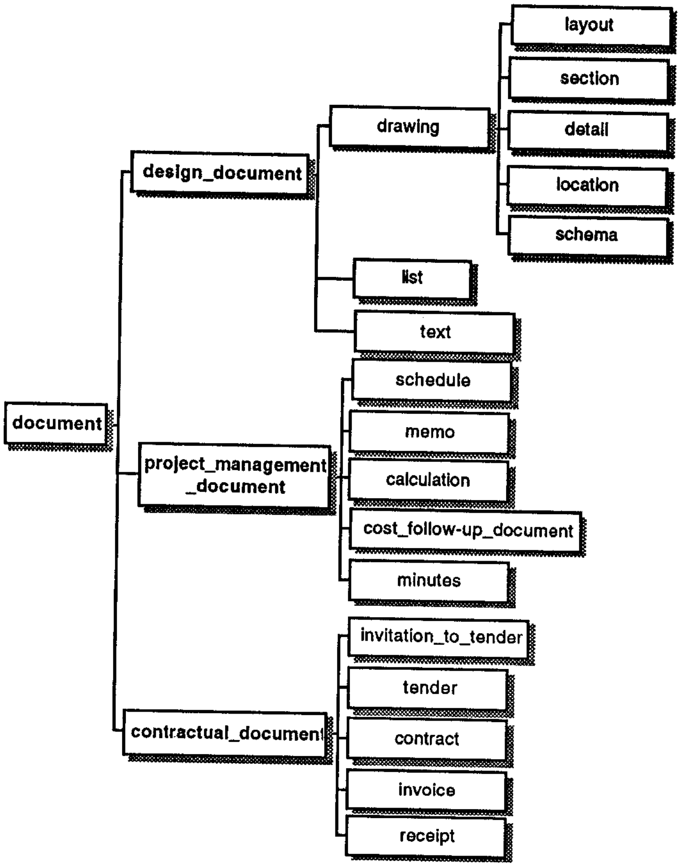

Figure 4. Subclasses of the Generic Document Class in the ICPDM Proposal

In the project detailed EXPRESS and EXPRESS-G schemes have been defined of the data needed to describe documents for the purpose of managing them electronically.

It is hoped that based on the prototype and on-going related commercial development efforts, a system could be created which would form a part of the TELERATAS system. Such a system would be relatively easy to develop, since it adheres to the present way of producing construction documents using word-processors, draughting systems, etc. Such a system could consequently be put to use in construction projects earlier than product model based applications can be expected to appear on the market.

CURRENT STATUS OF RATAS ACTIVITIES

From the beginning of 1992 the RATAS committee changed its status within the organisation of the Building Information Institute. The committee is from now on also officially the organisation in Finland which has the right to submit national standard proposals dealing with construction computing to the Finnish national standardization organisation.

In order to co-ordinate projects developing product modelling applications the RATAS committee has appointed a sub-committee for product modelling. The task of this sub-committee is to carry on the work of defining a building product data model standard and to monitor and co-ordinate the conceptual modelling work done in projects run by third parties. It has therefore recently defined guidelines for projects and applications that claim to be RATAS-compatible. The guidelines prescribe the use of conceptual data modelling languages such as Express [CEN, 1991] for documenting the data structures of the applications. In addition the developers would need to demonstrate how the data structures of the model or application at hand relates to previously approved national models such as the framework building product model of RATAS II, the generic model of OOCAD, and aspect models resulting from such projects as HVAC-RATAS.

EVALUATION OF THE RESULTS

In table 2 some of the achievements which can be claimed for the RATAS project are listed along with some of the setbacks and uncertainties which have been experienced.

Despite some of the setbacks and the difficulties encountered, the RATAS project is relatively unique with respect to its scope, duration and the involvement of the construction industry. Its results should be compared with the results of pioneering activities with similar ambitions in other countries [cf. Anon 1986, Le Quere 1986, Anon 1989, Yamazaki 1990].

The fact that similar projects are currently being set up or seriously considered in many other countries is encouraging and seems to indicate that the RATAS-project has been on the right track. A final evaluation of the results can, however, only be done after a few more years have passed. By that time some of the visions which were described in the mid 80's would hopefully become reality and be in common use in the construction industry.

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This article reports on work spanning almost a decade and involving almost a hundred individuals. The author has been involved as main researcher or project leader in many of the projects mentioned. He has also been a member of both the RACAD board and the RATAS committee. Matti Pöyry and Markku Salmi have primarily been project managers. Matti Hannus has contributed with his technical know-how to several phases of the work. Many colleagues from the laboratory of Urban Planning and Building Design, among them Lauri Koskela, Pär Silen, Mervi Lehto, Hannu Penttilä and Kari Karstila, have also participated in the activities described above.

Table 2. The achievements and setbacks of the RATAS-project

Positive results	**Setbacks and uncertainties**
National consensus concerning some key elements of CIC.	The RATAS committee is losing impetus and funding. Some criticism for slow progress towards software used in practice.
Commercial launch of a single comprehensive digital construction information service.	The commercial viability of TELERATAS has not yet been proven. A critical mass is needed for a breakthrough.
Demonstrations on a small scale of the feasibility and benefits of the product model approach.	Failure (so far) to produce a detailed enough building product data model specification, needed for commercial software development.
Better compatibility of results in different development projects, due to the growing use of similar activity and conceptual modelling techniques.	RATAS is used as a promotional tag for projects which sometimes have very little in common with the guidelines issued.
Close liaison between researchers and industry experts in R&D project, which creates a willingness to adopt the results.	Involving industry experts often leads to a long learning process. Often projects are side-tracked by short-sighted demands.

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