MODEL-BASED RE-ENGINEERING
IN THE
EUROPEAN CONSTRUCTION INDUSTRY

T. Allweyer, T. Babin-Ebell[1], S. Leinenbach, A.-W. Scheer[2]

Abstract: Due to increasing competition, the European construction industry is forced to improve their business processes and support them with integrated information systems. Approaches for Business Process Re-engineering (BPR) from stationary industries need to be adapted to the specific requirements of the construction industry. For being successful, BPR requires the use of powerful methods, tools and procedures. The Architecture of Integrated Information Systems (ARIS) is presented as a framework for BPR, integrating business aspects with IT development. BPR projects can be improved by the use of pre-defined industry-specific reference models. The application of the ARIS framework to the construction industry is currently demonstrated in the European research project CORE (Construction Companies Processes Re-engineering). The CORE approach and its results are demonstrated with examples from project planning and management.

Keywords: Business Process Re-engineering, Information Systems, Reference Models

INTRODUCTION

Business Process Re-engineering (BPR) is currently one of the most popular catchwords. Companies hope to break the "magic triangle" of costs, time and quality by streamlining their business processes. So far, most BPR projects have concentrated on stationary industries, mainly manufacturing. Others, such as the construction industry, have not gained as much attention yet, even though there is a high need for reducing costs and improving the effectiveness in this industry. Increasing customer demands towards quality, speed and flexibility, tough competition from international companies, and reduced public spending have created a difficult situation for many companies.

The principles of BPR, i.e. the fundamental rethinking of the way things are done by a company, can be applied to the construction industry, as well. However, it is not possible to use the experiences from the stationary industry without any changes, but it is necessary to take the industry-specific requirements into account and to develop new solutions for construction companies.

In the first paragraph, we discuss some of the most important characteristics of the construction industry. Companies of this industry face a high complexity which makes it difficult to re-design and manage the business processes. On the other hand, this complexity

---

[1] Dipl.-Ing. Thomas Allweyer, Dipl.-Kfm. Thore Babin-Ebell
IDS Prof. Scheer GmbH, P.O. Box 10 15 34, D-66015 Saarbrücken, Germany
Email: ids@ids-scheer.de, WWW: http://www.ids-scheer.de

[2] Dipl.-Inform. Stefan Leinenbach, Prof. Dr. August-Wilhelm Scheer
Institut für Wirtschaftsinformatik, University of Saarland, P.O. Box 15 11 50, D-66041 Saarbrücken, Germany Email: iwi@iwi.uni-sb.de, WWW: http://www.iwi.uni-sb.de

increases the need to improve the business processes and to develop integrated solutions for supporting these processes with information technology.

The second paragraph summarises the BPR concept. Important aspects for ensuring the success of a BPR project are discussed. For documenting, analysing and developing business processes, powerful methods and tools are required. As an example for a framework integrating different methods, the Architecture of Integrated Information Systems (ARIS) is presented in paragraph three. A way for storing industry-specific knowledge and making results from earlier projects available, is the use of reference models, which we describe in the fourth paragraph.

In the fifth paragraph, the application of the presented BPR methods in the construction industry is demonstrated, within the Esprit-Project "Construction Companies Re-engineering" (CORE), that brings together construction companies, consultancies, IT providers and research institutes from Spain, England and Germany. Examples from project planning and management are presented in the last paragraph.

1 REQUIREMENTS OF THE CONSTRUCTION INDUSTRY

Compared with many other industries, the construction industry faces high complexity, high uncertainty and discontinuity, as well as many restrictions (cf. Barrie/Paulson 1992, Thompson 1989). For re-designing business processes in this industry, it is necessary to take these special requirements into account and develop solutions that help contractors to cope better with these challenges, thus improving the companies' competitive standing.

The high degree of complexity results to a large extent from the high number of different - mostly small - companies taking part in any single project. People and resources are at the same time part of two (or even more) organisations: their respective company and the project organisation. Therefore, a high effort is required for coordination and communication, especially since the amount of exchanged information is rather high, and there may be large distances between a work site and the company offices. BPR should therefore deliver effective coordination processes that support easy communication. Good solutions require the implementation of entire processes throughout different companies. This is not easy, especially since each cooperation is only temporary. Evolving concepts for a tighter integration, such as partnering, give some ideas of how inter-company business processes could be improved (cf. Wegelius-Lehtonen 1995).

Uncertainties and risks are caused by weather and site conditions, as well as by the fact that many projects are subject to changes after the work has already started. Due to the singularity of each project, there is always some degree of unpredictability involved. This means, that business processes, although to some extent standardised for efficiency reasons, must provide enough flexibility and robustness to cope with unexpected situations and changes. For example, procurement activities can be standardised and automated to a large extent. This leads to reduced effort for processing procurement documents and communication with the supplier, as well to a lower number of mistakes, i.e. to higher quality. However, for special supplies or very urgent needs, it must be possible to do whatever is necessary to get a required material or service, without being forced to follow the standard procedures. Such exceptions should not lead to great disturbances in the system.

Since there is usually a clear distinction between designing and planning on one side, and project execution on the other side, it is very difficult for a single construction company to improve the overall project, since many important decision have already been made when the contractor enters the project. Many advantages can be achieved, when it is possible to integrate the planning and execution phase more tightly and improve the overall processes involving designers, engineers and contractors as a whole.

2 SUCCESS FACTORS FOR BUSINESS PROCESS RE-ENGINEERING

The organisation of most companies is still structured according to the principle of function-orientation. Based on that principle, organisational units are responsible for a small number of activities which they perform for the overall spectrum of products and services in the company. Thus we may find departments for production, procurement, sales, accounting, etc. Traditionally, each of these departments has its own specialised information system with its own database.

In such a function-oriented organisation, a business process, e.g. the process from a customer order to the shipping of a finished product, crosses many departmental borders. This leads to inefficient, time-consuming, and expensive process execution, and it increases the number of errors. The paradigm of Business Process Re-engineering (BPR) therefore leads to a fundamental re-design of the organisation and its information systems. Organisations are structured according to business processes rather than functions, i.e. one organisational unit is responsible only for a small number of products or services, but for all or most processes related to them (cf. Scheer 1994).

Information systems need to be re-designed, as well. Isolated, function-oriented systems are to be replaced by integrated systems supporting the entire business processes. Centralised, mainframe-based systems cannot meet the demands of modern, process-oriented, decentralised organisation. Such organisations require flexible solutions, such as client-server systems.

In the construction industry, the picture is more complex. On the one hand, we find functionally oriented company structures, e.g. the administration and central services of a company. On the other hand, there is the project organisation for each construction project, with a temporary character, involving many different companies, each of which also has its own structure. It is therefore not as easy as in the stationary industry to re-structure a company's organisation according to the principle "process instead of function", but a thorough analysis of the processes is required to develop adequate structures and systems for each company.

Although the BPR approach has been connected with promises of drastic improvements (such as cost reductions as high as 70%), there have been many projects which did not fulfil the expectations, because important aspects have not been considered. The main success factors for a BPR-project are:

- Management commitment
- Detailed analysis of customer requirements
- Development of concrete strategies and quantifiable objectives
- Sufficient resources for the project
- Early involvement and participation of all people in the company

- Development of process-oriented thinking in the company's culture
- Systematic procedures (procedural model)

The last point is of great importance. The procedural model should include the following project stages:

- Definition of strategy and objectives
- Identification of core processes
- Analysis of weak points
- Definition of business process owners
- Detailed development of processes
- Implementation of processes
- Evaluation and improvement of processes

For the analysis of weak points and the development of new processes, methods and tools for modelling business processes are required (cf. Scheer et al. 1995).

3 A FRAMEWORK FOR MODELLING

To get a full understanding of a company's business processes, many different aspects need to be modelled, such as organisational structure, data structures and flows, functions, and the logical control flow. Semiformal methods can be used for modelling these aspects. Since it is not advisable to include all mentioned aspects within one diagram, and there are different modelling methods for each of them, a set of different diagrams is required for the entire description of a process. For integrating these different types of diagrams, which represent only different views on the same processes, the "Architecture of Integrated Information Systems" (ARIS, Scheer 1992) has been developed.

The ARIS framework has two dimensions (Fig. 1): The views and the subsequent stages of the software lifecycle model. The stages of the software lifecycle model allow for the integrated description of business and information system structures. On the requirements definition level, structures and processes can be described entirely from a business perspective, without defining yet what kind of information system will be used. On the second level, design specification, the description is detailed according to the kind of information system to be used (e.g. a relational database for the data view), but still without implementation details. The third level contains a system-dependent description that can be used directly for implementation. Based on this lifecycle model, it is possible to support the entire process of
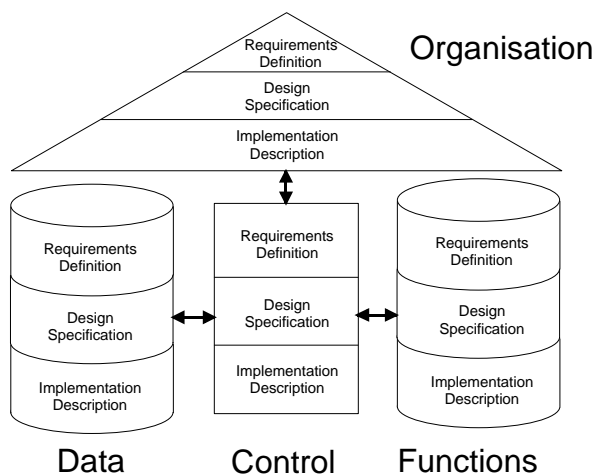

Fig. 1: ARIS (Scheer 1992)

developing new software. However, for the purposes of BPR and the adaptation of standard software, usually only the requirements definition is important for an end-user company, while software developers may use all three levels.

The concept of views makes it possible to model the different aspects of business processes and information systems in an integrated way. The function view is used for describing a company's activities and their decomposition, e.g. with a functional tree. In the data view, the logical structures of data are represented. Entity-Relationship-Models (ERM) or similar diagrams can be used for that purpose. The organisation view may contain organisational charts for defining the company's structure. These different views are integrated via the control view. Here the logical control flow can be

Fig. 2: Elements of the Event-Driven Process Chain (EPC)

modelled, showing for any business process which functions need to be carried out, as well as their logical sequence. The functions are identical to those of the function view. It is also possible to define for any function the data required or produced, as well as the organisational unit that carries out that function. By this mechanism, the contents of the data view and the organisation view are integrated to the other views. For this view, the method of "Event-Driven Process Chains" (EPC) has been developed, which consists basically of functions and events, as well as logical connectors, for defining the control flow. The models of the other views are integrated by connecting the elements of these models (e.g. organisational units or data objects) to the functions in the EPC (seeFig. 2).
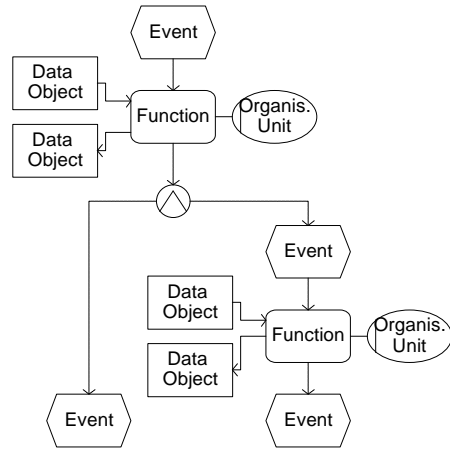
The ARIS framework has been used successfully in many BPR- and IT-projects. It is supported by a powerful modelling tool (ARIS-Toolset) that helps creating and handling large and complex models. The integration of different diagrams is reached by the use of only one internal representation of each object which can be referred to from many different diagrams. It is therefore possible to answer questions like "Which processes use a specific data object?" or "Which functions are performed by a selected organisational unit?". Functions and modules for analysing and simulating business process models, as well as for process-oriented cost calculation are also available.

4 REFERENCE MODELS

The execution of BPR projects seems to be an easy way to gain more competitiveness by reducing costs and times. However many BPR projects have not been successful, because these projects have required too much time and costs and the improvements did not have the quality the companies have expected. The reasons for the inefficiency of many BPR projects are often the missing of an integrated approach, of a structured procedure and of industry-specific knowledge.

An efficient way to reduce the risks of BPR projects and to increase the quality of the results is the use of reference models (cf. Hars 1994). These are formal or semi-formal descriptions

of business knowledge such as business processes, data structures, handling rules and organisational structures. Reference models reflect the experiences and results of diverse projects in a structured way and make these results available for further projects. As a consequence of the use of reference models in a BPR project, the industry-specific knowledge and the knowledge about procedures - especially the knowledge of the project team - can be increased in an easy way. The basic idea of reference models is to describe complex business processes, to illustrate special problems of certain business areas or to demonstrate existing or planned software systems. Due to these purposes there is made a distinction between three different kinds of reference models: Procedural models, industry-specific reference models and software-specific models.

The aim of procedural models is to save time during the project planning and realisation. In order to achieve these targets procedural models have to deliver a pre-structured frame for the realisation of BPR and software implementation projects. A procedural model is the basis for discussion and a common procedure in a project and has to give a documentation of necessary phases during a project. The most important steps of a procedural model for typical BPR project has been listed in paragraph2.

Industry-specific reference models contain knowledge which is typical for a certain industrial branch. Company-specific solutions are not part of such a reference model. Industry-specific reference models include industry-specific requirements, typical processes and structures, common problems and industry-specific terminology. The main properties and purposes of industry-specific reference models are:

- the saving of time, costs and capacity by providing pre-defined processes for planning and optimising business processes
- pre-defined structure and conventions
- basis for the selection of standard software
- basis for the development of individual software systems
- basis for training
- basis for workflow systems.

By providing general industry-specific knowledge, the use of industry-specific reference models within a BPR project helps to concentrate on company-specific topics. It is then much easier to identify the parts of a company which are not similar or equal to other companies and require therefore specific attention (cf. Remme et al. 1994).

Industry-specific reference models are normally used during the development of new processes. Based on the analysis of the current situation, the industry-specific reference models enable an efficient development of optimised structures and processes.

Another type of reference models are software-specific reference models. They describe processes, functions and data structures of standard software solutions. The main purposes of software specific reference models are:

- software selection
- planning of standard software implementation
- planning and documentation of the customised processes and data structures of standard software systems
- configuration of workflow systems

- configuration of standard software systems
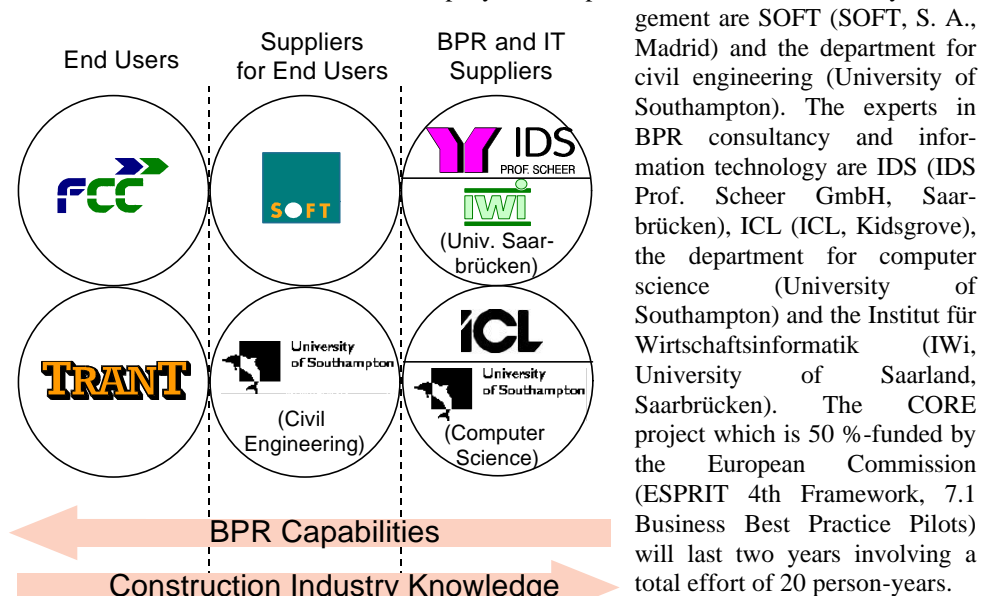- tool for training.

For BPR projects all three kinds of reference models can be relevant: A procedural model for defining the way the project is carried out, an industrial-specific model for the faster development of new process structures, and software-specific models for matching them against the new process model, and selecting and customising a software system that will support the new processes.

5 APPLYING BPR TO THE CONSTRUCTION INDUSTRY: THE CORE PROJECT

The main objective of the CORE (COnstruction companies processes RE-engineering) project is to apply BPR methods and tools to the European construction industry. Therefore the CORE project aims to carry out comprehensive transformations of important business processes within two European construction companies and to derive industry-specific reference models that can be used throughout the construction industry.

The project requires expertise in the construction industry, in BPR, in process modelling, in software engineering and in project management. CORE therefore brings together two construction companies as CORE end users with experts in construction industry management and with experts in BPR consultancy and information technology (see Fig. 3).

The two construction companies are FCC (Fomento de Construcciones y Contratas, S. A., Madrid), a large Spanish building company, and TRANT (P. Trant Ltd., Southampton), a medium-size UK based construction company. The expterts in construction industry management are SOFT (SOFT, S. A., Madrid) and the department for civil engineering (University of Southampton). The experts in BPR consultancy and information technology are IDS (IDS Prof. Scheer GmbH, Saarbrücken), ICL (ICL, Kidsgrove), the department for computer science (University of Southampton) and the Institut für Wirtschaftsinformatik (IWi, University of Saarland, Saarbrücken). The CORE project which is 50 %-funded by the European Commission (ESPRIT 4th Framework, 7.1 Business Best Practice Pilots) will last two years involving a total effort of 20 person-years.

Fig. 3: CORE - Construction Companies Processes Re-engineering

The analysis and redesign of the relevant processes within a construction project -from the

first customer contact until the finished building- will include all levels, from a strategic planning level to the tactical process management level and the details of carrying out the process steps, including the process implementation. The project will concentrate on specific business processes, namely tendering and project planning and management. The construction companies involved expect significant improvements and competitive advantage from the re-engineered processes. The involvement of the two different end-users makes it possible to validate that the results are suitable for other companies and countries as well.

A further objective of the CORE project is to develop a prototype of the necessary IT structure to support the redesigned business processes using modern technology which accepts the integration of existing systems.

6 IMPROVING PROJECT PLANNING AND MANAGEMENT

An example of the use of modelling for improving a construction company's processes can be seen in Fig. 4. This shows the most important planning activities at the very beginning of a project. For better under-standing, the real process of an actual construction company has been simplified.
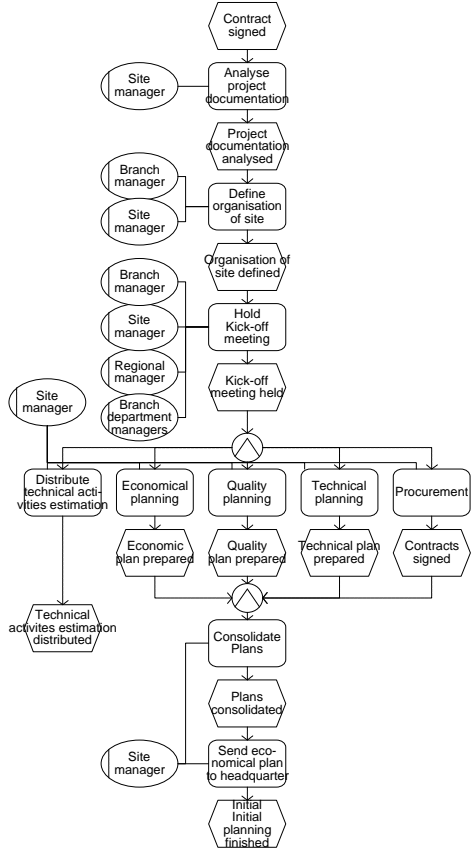
Fig. 4: Process chain: Initial planning of project

After the contract has been signed, the site manager analyses the project documentation. He then defines the site organisation, i.e. the people and functions required. In the kick-off meeting, the most important aspects of the project are discussed with the management, and necessary decisions are made and documented in the so-called 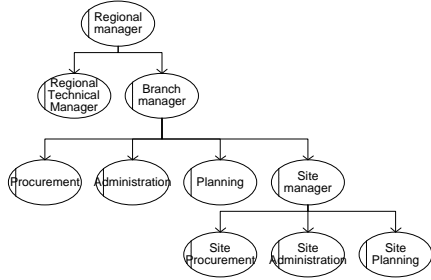"technical activities estimation". After that, the site manager starts working on the economic plan (costs, budget, cashflow etc.), the quality plan and the technical plan, i.e. the project schedule. He also procures required materials and services. In the real model, there are further detailed diagrams for each of these steps. The different plans are then consolidated, and the economic plan is sent to the company headquarters. The initial plans for the entire project are finished, and the actual work can start.
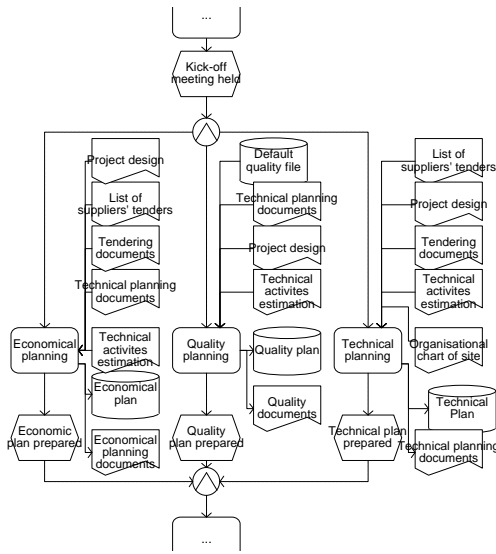
Fig. 5: Part of organisational chart

Fig. 6: Documents and files in initial planning

Of course, there is more planning work to do during the project, especially detailing and adjusting the initial plans.

In addition to the actual control flow, Fig. 4 also shows the organisational units that are responsible for carrying out each function. These organisational units can also be found in an organisational chart, as it is shown in Fig. 5. It is therefore possible to see for each business process, how it is embedded in the company's organisational structure.

In Fig. 6, we have taken a part of the above process and added the information used and produced by each function, mainly documents and computer files. As can be easily seen, this process is connected with a lot of paperwork. It can also be seen that the parallel planning functions are not independent from each other, since e.g. for economic planning, technical planning information is required. Some information, such as the quality plan or the technical plan are stored in databases. However, these are not integrated, and only single steps, such as the calculation of times or the creation of inspection plans are IT-supported. The main medium for storing and transporting information is still a large number of different paper documents.

Although the different types of plans are closely interrelated (e.g. the quality plan with the project schedule), and they provide rather different views on the same underlying project, they are not explicitly linked. Since construction project usually experience many changes, delays, problems etc., frequent changes in the plans are necessary. Such changes are quite difficult if they are based only on paper and some isolated computer files. It would be useful to have an integrated project database which covers all relevant aspects throughout the project lifecycle. This would enable easier changes and updates, it would reduce the risk of errors and provide consistent data. The information created in earlier steps, e.g. tendering, could be already included in the project database and be used as a
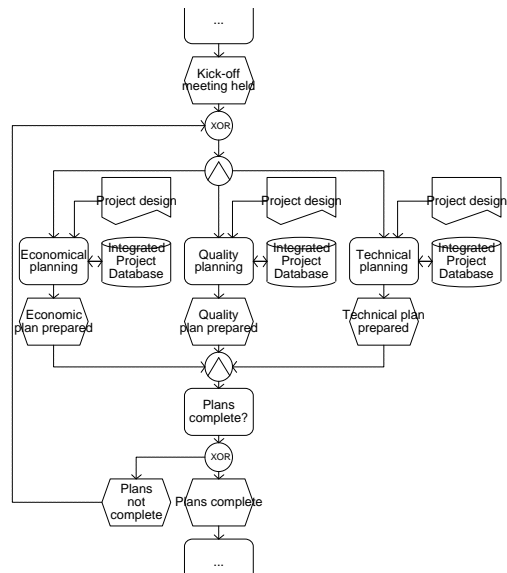

Fig. 7: Initial planning with integrated project database

starting point for the actual planning phase.

Fig. 7 shows the possible use of such a project database. Only a few paper documents will still be required, such as the design, since it is not convenient to use only CAD-files on the job site. As far as other paper documents are needed on the site, it is possible to print them out when they are needed. If an inspection report is required, it will be printed out at the right time according to the schedule, based on the stored quality specifications. The inspection results should again be included in the database.
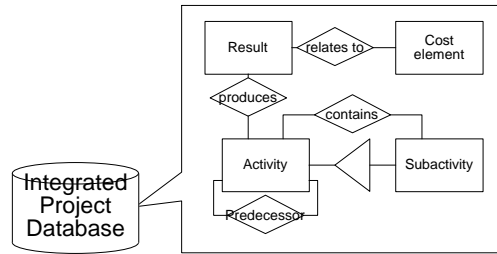

Fig. 8: The project database can be described by entity-relationship models

Due to the close dependency of the different planning activities, it may be more suitable to consider planning as an iterative, incremental creation of an overall plan, rather than treating the single activities as if they were separate from each other. This iterative procedure is indicated in Fig. 7 by a loop that will lead to repeated planning steps until the plans are complete.

For developing an integrated project database, the information required in the different business processes needs to be analysed. It is possible to create an Entity-Relationship-Model and assign it to the project database symbol of the process model (cf. Fig. 8). This is the first design step for reaching full integration of functions and data, a topic which is considered as critically important for project success (Fisher/Yin 1992).

However, business process re-engineering does not mean to create efficient IT-solutions for existing processes, but rather to develop jointly new, improved business processes and the adequate IT-support. This can be achieved by the use of integrated models for all relevant aspects of the business and information systems, such as organisation, data, functions and processes.

SUMMARY

In this paper we have discussed requirements and a possible approach for Business Process Re-engineering in the construction industry. It will not be sufficient to use solutions from other industries, but the construction industry has to go its own way. We have presented a framework for modelling and re-designing business processes and information systems. BPR-projects can be supported by the use of industry-specific reference models.

Such a reference model is currently being developed in the European research project CORE, involving two end-user companies from Spain and England. The use of the presented framework and methods has been demonstrated on a simplified planning process from the CORE project, and the need for integrated information systems has been discussed.

Other than in stationary industries, there are not yet any standard software solutions avaible for fully integrated information systems. This means that users either need to create their own solutions or they continue using the existing, isolated software programs. It has to be hoped that software vendors continue their efforts to integrate their products with each other so that

entire solutions will emerge. Construction companies certainly need to manage excellent business processes and improved IT-support for increasing their competitiveness.

ACKNOWLEDGEMENTS

REFERENCES

Barrie, D. S.; Paulson, B. C. (1992). Professional Construction Management - Including C. M., Design-Construct and General Contracting. 3rd ed. New York et al.

Fisher, N.; Yin, S. L. (1992). Information Management in a Contractor - A Model of the Flow of Project Data. London.

Hars, A. (1994). Referenzdatenmodelle. Wiesbaden.

Remme, M.; Allweyer, T.; Scheer, A.-W. (1994). Implementing Organizational Structures in Process Industry Supported by Tool-Based Reference Models. In: Boucher, T.O.; Jafari, M.A.; Elsayed, E.A. (eds.). *Proceedings of Rutgers' Conference on Computer Integrated Manufacturing in the Process Industries* East Brunswick, Rutgers University. 233-247.

Scheer, A.-W. (1992). Architecture of Integrated Information Systems - Foundations of Enterprise-Modeling. Berlin et al.

Scheer, A.-W. (1994). Business Process Engineering - Reference Models for Industrial Enterprises. 2nd ed. Berlin et al.

Scheer, A.-W.; Allweyer, T.; Zimmermann, V. (1995). Business Process Reengineering with the Architecture of Integrated Information Systems. In: Klittich, M.; Sternemann, K.-H. (eds.). *Proceedings of the 2nd Open Workshop on Business Process Management Based on CIMOSA*. Eschborn.

Thompson, P. A. (1989). Project and Contract Management. In: *Civil Engineer's Reference Book*. 4th ed. London et al. 33/1-33/18.

Wegelius-Lehtonen, T. (1995). Measuring and re-engineering logistic chains in the construction industry. In: Browne, J.; O'Sullivan, D. (eds.). *Re-engineering the Enterprise*. London et al. 209-218.