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Business Process Re-engineering in the Construction Industry

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1 Introduction

Business processes re-engineering (BPR) has evolved during the last years as one of the leading concepts for re-organising companies.[1] Other than previous concepts, BPR focuses on the design and the improvement of entire processes through the company, such as the fulfilment of customer orders from the first contact with the customer to the finished product. For example, organisational structures are changed in order to integrate previously separated functions along process chains, non-value adding activities are removed, and information systems are re-designed to efficiently support entire processes rather than single functions. Many companies can only stay competitive if their business processes are well designed and managed, so that they can meet the steadily increasing demands towards quicker reactions, lower costs, and higher quality.

Most BPR-efforts concentrate on stationary industries, such as the automotive industry and the chemical industry, but also the banking and insurance sector. In these industries, many business processes can be found which are highly repetitive and which vary only to a limited degree. Examples for such processes are customer order processing and fulfillment in the automotive industry, or processing of credit applications in a bank.

So far, in the construction industry BPR has been much less popular than in the stationary industries, even though the need for significant cost reductions and quality improvements in the construction industry is at least as high as in many other industries. Important reasons for not applying BPR to construction are the specific characteristics of this industry, such as the extreme form of one-of-a-kind production, or the difficult conditions found on construction sites.

The basic ideas of BPR can - and should - be applied as well to the construction industry. Due to the specific requirements of this industry it is not possible, however, simply to apply existing approaches and solutions which have been developed for the needs of stationary industries, but it is necessary to develop new solutions which take into account the specific conditions found in construction.

In this paper we describe possible approaches for improving a contractor's business processes, concentrating on the core activities required to win a contract, to plan and to manage a construction project.[2] In chapter 2 we briefly discuss specific requirements of the construction industry and their consequences for designing and managing business processes. The third chapter contains a description of possible process improvements. First, an overview of the entire construction project is given. In the subsequent paragraphs, improvement approaches for tendering, project planning, project management and procurement are discussed. Chapter 4 describes requirements for an integrated information systems support of entire construction processes. In chapter 5, a summary and an outlook are given.

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[1] cf. *Harrington 1991*, *Davenport 1993*, *Hammer/Champy 1993*, *Johansson et al. 1993*, *Scheer 1994*, *Berztiss 1995*, *Krickl 1995*, *Österle 1995*.

[2] These approaches have been developed in the CORE project ("Construction Companies Processes Re-engineering") which has been funded by the Commission of the European Communities in their ESPRIT-programme (project no. 20.777). For information about the CORE project see *Allweyer et al. 1996* and http://www.iwi.uni-sb.de/research/core/core-e.html

2 Specific Requirements in the Construction Industry

In this chapter, we describe some of the most important characteristics of the construction industry which distinguish this sector from many stationary industries and which have to be considered by construction-specific approaches for business process re-engineering.[3]

2.1 High Number of Different Partners

Every construction project brings together many different partners, among them the client, architects, engineers, a general contractor (or a consortium of contractors), and many subcontractors and suppliers. Typical projects of average size and complexity may include 5 to 15 companies during the design stage, and 40 to 100 companies during construction, as well as several suppliers and service providers.[4] The composition of partners is different in each project.

This leads to a high complexity and a huge co-ordination effort, and it therefore makes planning and managing construction projects rather difficult. Since many business processes involve several partners, a fundamental BPR effort requires the re-design of inter-company processes. Any improvements of one single company's internal processes will only provide limited benefits, since the overall process remains basically unchanged. Naturally, re-engineering efforts across company borders are more difficult to perform. In other industries this has been done successfully anyway (e.g. the tighter integration of suppliers in the automotive industry), but in the construction industry inter-company process re-engineering is much more difficult due to the fact that partners usually do not work together for a long time, but only for a single project.

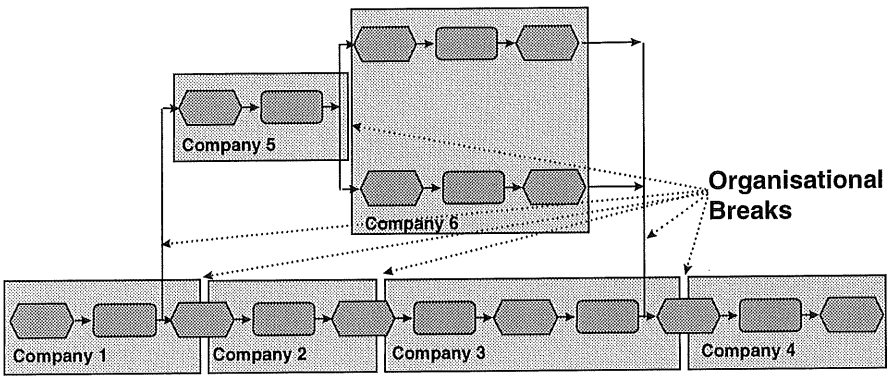

Fig. 1: Organisational Breaks Between Many Different Partners

Fig. 1 shows the problem caused by too many different partners: The different activities within a process are performed by different partners, so that within one single process there may be several organisational breaks. Each of these organisational breaks is connected with the following problems:

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[3] cf. *Pfarr 1984, Ashford 1989, Thompson 1989, Barrie/Paulson 1992, Bauer 1994, Fleischmann 1997.*

[4] cf. *Halverson 1995.*

- It is not sure whether the work of the preceeding partner is done with the required quality and finished at the right time.
- If the general contractor wants to avoid such problems, he is required to carry out diligent controls of the work of each partner.
- Each time a new partner is involved he needs some time and effort to get to know the respective task and the current status of the work.
- The co-ordination of the different partners requires a lot of effort.
- A delay at one point may affect several different companies.

Therefore, each organisational break causes a significant amount of non-value adding effort, and it delays the execution of the process. It is therefore desirable to reduce the number of such organisational breaks within the project and within each business process by giving larger parts of the work to each single subcontractor, as it is shown in Fig. 2.

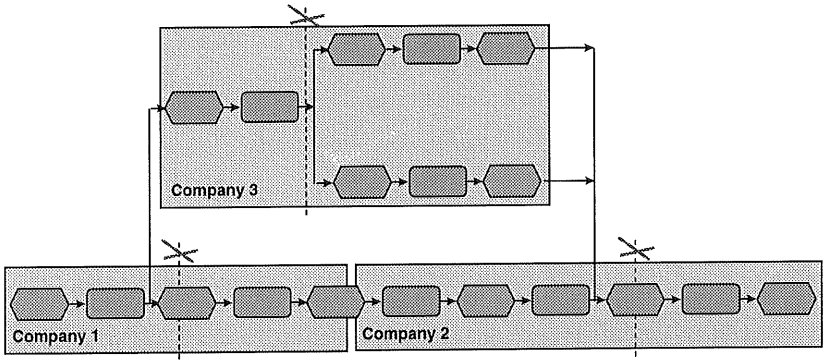

Fig. 2: Reduction of the Number of Organisational Breaks

In many projects, there are not only a general contractor and his direct subcontractors, but the subcontractors again give parts of their work to other subcontractors who may involve further subcontractors etc. For actually reducing the number of organisational breaks it is therefore not sufficient that the general contractor reduces the number of his direct subcontractors, but the overall number of subcontractors needs to be smaller, because otherwise the additional efforts and potential problems caused by organisational breaks are still there, only hidden from the general contractor (cf. Fig. 3).

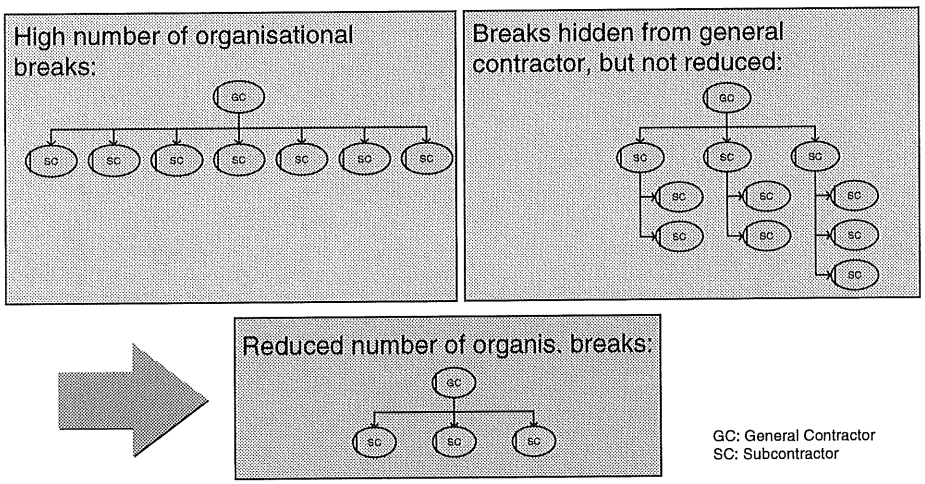

Fig. 3: Reducing vs. Hiding Organisational Breaks

The reduction of the number of different partners is only possible to a certain extent. For the remaining organisational breaks, a more efficient design and management of inter-company processes is required. This may involve improved IT-support (see paragraph 4), but first of all a tighter co-operation between the different partners.

Such a closer co-operation of the different partners involved in a construction project is aimed at by the partnering concept.[5] The idea of partnering is to establish common procedures to avoid and solve problems jointly by all partners, i.e. the client, the architect, the general contractor, subcontractors and suppliers. The most important condition is the serious commitment of all partners to co-operate with each other.

A construction project using the partnering concept usually starts with a partnering workshop in which the most important objectives, tasks and problems of the project are identified and clarified. Communication structures are defined, as well as the procedures to follow for solving problems and conflicts, and regular partnering meetings are scheduled. During the project, these meetings are used for assessing the progress and discussing questions and problems. Problems and conflicts arising between these meetings are solved according to the defined procedures, e.g. directly between those partners which are involved in a certain conflict, by special meetings etc. If most of the conflicts and problems within a project can be avoided or quickly be solved, the overall project costs are reduced, and it is more likely that the project can be finished in time.

Partnering only addresses the co-operation of partners within a project, but neither the selection of partners nor the creation of long-term relationships which could enable partners to develop and improve their intercompany-processes. If two partners work together only in one single project, it is not feasible to put a large effort into analysing the current processes, and into developing and implementing new processes. However, if there are long-term relationships between a contractor and large subcontractors and suppliers, and they work together in many projects, such an effort may pay off, and it is possible to design more effective overall processes.[6] Therefore it can be worth while for a contractor to reduce the number of suppliers and subcontractors in favour of improved relationships with selected suppliers and subcontractors, allowing for jointly re-engineering the common business processes, such as material ordering and delivery.

2.2 Separation Between Design and Construction

In most stationary industries product development and production can be found within the same company. It is therefore possible for such a company to improve the entire process from the first idea to the introduction of the new product on the market. More and more, the development does not only focus on the properties and the design of the product itself, but also on the processes required to manufacture this product, so that the design can be improved in favour of easier, cheaper and more reliable production processes.

Such an integrated product and process development is much more difficult to realise in the construction industry, since usually there is a strong separation between design (produced by an architect) and construction (done by contractors). The traditional way of placing

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[5] cf. *Hellard 1995*.
[6] cf. *Wegelius-Lehtonen 1995*.

construction contracts is based on completely worked out designs and bill of quantities (BOQ), i.e. the contractor is only selected after the design phase is already finished. Therefore it is not possible for the contractor to influence the design in favour of an easier and better construction process, and the architect does not have a specific interest in helping the contractors improving their processes. For these reasons, it is difficult to improve the entire process from the client's project idea to the finished building.

During the last years, design-and-build contracts have become increasingly important. These kinds of contract enable one company to manage the entire process including the design and the construction phases. They offer therefore more possibilities for fundamental improvement efforts. However, the actual work in each of the two phases is usually done by different companies which work together on a project-basis, so that an overall process re-design is still difficult.

2.3 Extreme One-of-a-Kind Production

Most construction projects are unique. Even similar types of objects can lead to significant differences in the respective projects, due to differences in ground conditions, local infrastructures, client-specific requirements etc.

This means that most processes will differ from project to project, so that for many tasks it is not possible to define standard processes, which could be carried out many times without any changes, as they can be found in most stationary industries. It is difficult to recognise and to correct basic problems, since the next time a process is carried out, it may be under significantly different conditions, and it is not possible to analyse several instances of a more or less identical process, or to test and incrementally improve process changes over many process instances.

On the other hand, the fact that every project is different does not mean that all detailed business processes within a project will be totally different from those of other projects. For example, material procurement is rather similar in every project. Basically, the type and amount of the required material need to be stated, a supplier must be selected, an order must be placed, etc. This can be done in the same - or at least in a very similar way - in most projects. Therefore it is possible to re-engineer and standardise the material procurement process, as well as many other processes. Project-specific requirements can be taken into account by defining several alternative processes (e.g. one procurement process for small sites and another one for large sites with their own site office) from which the best fitting one can be selected and adapted to actual site requirements.

2.4 Geographical Distribution of Construction Sites

Most contractors work on a large number of construction sites at the same time, which are geographically distributed. Since many business processes involve both the respective construction site and the company's headquarters or regional offices, they require appropriate means for communication, co-ordination, and data exchange. It must be possible to establish these means in an easy and flexible manner since construction sites only exist for some time,

and new sites are set up frequently. This can only be realised with modern communication technology, e.g. easily accessible computer networks and mobile computing.[7]

The project team should be granted a high level of autonomy and self-responsibility. Since those processes that are partly carried out on site and partly in the company's offices contain organisational breaks, it should be analysed whether it is possible to assign these processes entirely - or at least larger portions of them - to the project team. Since the actual value adding takes place on site, the site teams should play leading roles in the contractor's organisation. It should be checked which of the organisational units in the company headquarters and regional offices are actually necessary, and those that are necessary should be organised as service providers for the project teams (cf. Fig. 4).

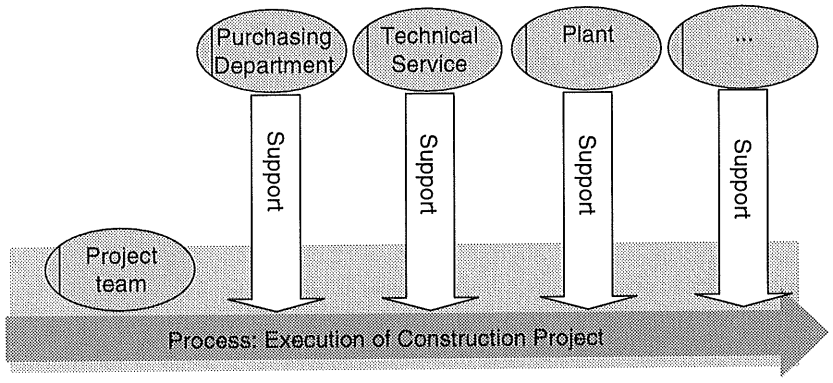

Fig. 4: Leading Role of Project Team

2.5 Uncertainty and Changes During the Project

The high degree of uncertainty in construction results from the fact that there are many influencing factors which cannot be foreseen. For example, bad weather conditions may interrupt the work and cause delays or it may be necessary to take special measures for protecting the work. Other unforeseen disturbances may be caused by difficult ground conditions or ground water. Another important factor is the large influence of the client during the project. He can make changes even after the contract has been signed and the actual construction has already started.

Both the natural uncertainties and the possibility of clients' change requests during the running project make it necessary to reach a high degree of flexibility for managing the project and the respective business processes. If, for example, an unexpected period of bad weather interrupts the works on the outside of a building, it may be possible to carry out other work inside the building in the meantime. This does not only mean a change in the sequence of activities in the programme, but it also has consequences for business processes connected with these activities. For example, the invoked procurement processes for the outside work should be stopped or delayed, while the procurement processes for the inside work need to be started and sped up, if possible. It is therefore not only necessary to design good processes, but also to establish a powerful process management system[8] which allows for monitoring invoked business processes and changing them easily, if necessary. For example, it should be easy for

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[7] cf. *Reichwald et al. 1995*.
[8] cf. *Scheer 1996*.

the site manager to find out about the current status of any procurement process related to his site, even if it is carried out in the company's offices. This will help him to decide about changes in the programme, e.g. by knowing which material orders still can be changed, and by allowing him to stop such processes which are not necessary anymore after a programme change.

2.6 Difficult Working Conditions on Site

The working conditions on construction sites are rather difficult. They are characterised by exposure to the weather, dirt, heavy materials, and still a high degree of heavy manual work. Any system for supporting and carrying out business processes must be manageable under these conditions. This is especially important for implementing computer systems. The hardware must be robust against influences, such as extreme cold or rough handling.

Due to the difficult working conditions, the qualification of most people working on site (except the site manager and a few engineers) is usually focused on the practical aspects of the work rather than on the use of management and information systems. This means that the user-interfaces of the information systems used on site should be rather easy and intuitive to use, if other personnel than the managers and engineers are to use the system, e.g. for data capturing.

2.7 Large Amounts of Information

For planning and carrying out construction projects, large amounts of information are required, such as drawings, specifications and different kinds of documents. For designing improved business processes it is therefore necessary to define how the different types of information can be efficiently represented, stored, transferred, processed, and made accessible. The use of information systems and telecommunications technology can help to address this issue. On the other hand, the large amount of different kinds of information as well as other construction-specific requirements, such as the geographical distribution, makes it rather difficult to design and implement an integrated information system, which equally supports all aspects and all steps of a construction project.

3 Business Processes in Construction

In this chapter, we describe important business processes in construction industry. We mainly concentrate on the internal processes of the contractor but also consider the relations to the processes of subcontractors and suppliers. First we give an overview of the typical way construction projects are carried out. After that we pick up the most important project phases and describe the underlying business processes in a more detailed way. For the phases tendering, project planning, project management and procurement we describe the actual processes, their weak points and show appropriate approaches for improvements.

For the description and analysis of the business processes in construction industry we use the methodological framework ARIS (Architecture of Integrated Information Systems)[9]. With the help of different methods which are part of the ARIS framework, processes can be described from different views and on different levels concerning the proximity to information technology. In order to give the overview of construction projects, a value chain is used in the next subchapter. The other - more detailed - processes which are described in this chapter, are modelled with Event-driven Process Chains (EPC).

3.1 Overview of Construction Projects

Fig. 5 shows the value chain describing the main processes during a construction project.

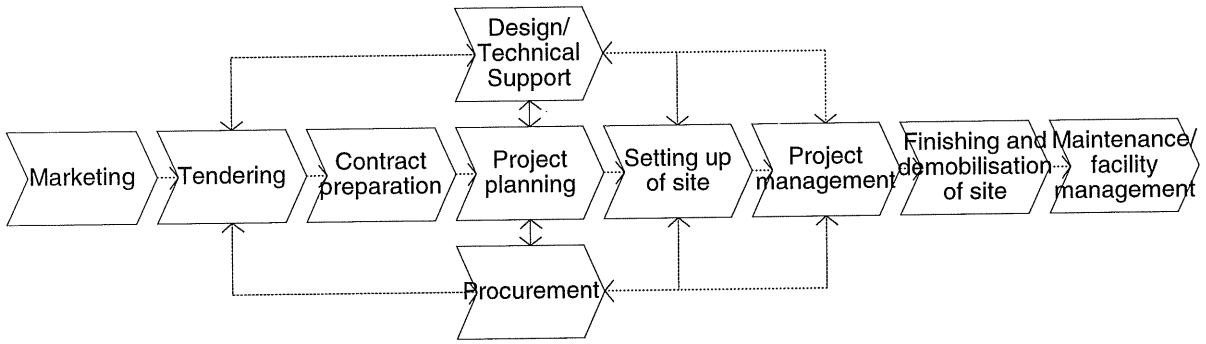

Fig. 5: Value Chain of Construction Project

Marketing includes all activities to find both private and public customers, especially finding out about calls for tenders. This process consists of a set of continuous activities (such as evaluating newspapers and announcements) rather than one sequential process.

The *tendering* process includes all activities that lead to the submission of a tender to a potential customer. This process starts after the detection of a potential customer and the decision to tender for that project and finishes with the submission of the proposal.

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[9] *cf. Scheer 1992, Scheer 1994.*

After the submission of the tender, the customer may ask for further information or adjustments in the tender before deciding about the project appraisal. This may already include negotiations about a possible contract. After the approval, further negotiation and adjustments may be necessary before the contract is signed. The *contract preparation* process finishes with the signing of the contract.

The *project planning* process usually starts after a contract is signed. It includes the contract review and the project planning for the entire project, preparation of buying activities for the work site. Only the activities for the first months are detailed. Project planning is a continuous activity, the plan is revised once a month, i.e. necessary changes are made and the next activities are detailed.

Setting up of site includes those activities concerning the erection of the site office, providing the initial equipment and security installations.

The project may consist of several major phases, each of which requires a *project management* ordering required items, preparing and supplying material, co-ordinating the team, including subcontractors, as well as the control and the physical execution of the project.

Finishing and demobilisation of site basically consists of clearing up the site and handing over the building to its owner. After the project is finished, the project data and experiences are evaluated and documented for further projects.

Maintenance and facility management includes services related to the finished construction object. These activities are not part of the actual construction project.

Design and technical support includes processes and functions of the central or branch offices which are not directly part of the construction project, but support the project at the site.

Procurement considers activities concerning selecting suppliers and subcontractors, making contracts and ordering supplies. For special materials, skeleton agreements are made. Some procurement activities (those for bulk materials and supplies needed at the beginning of the project) have to be carried out during project planning. Other supplies and subcontracts are arranged during the running project, according to the schedule defined by the project management.

In the following subchapters, the most important processes concerning tendering, project planning, project management and procurement are analysed and discussed in a more detailed way.

3.2 Tendering

3.2.1 Overview

Fig. 6 shows the different functions to be performed during the tendering process and their control flow as an event-driven process chain (EPC). After a Bill of Quantity (BOQ)-based call for tender is received (in this document we only consider BOQ-based tenders and contracts as opposed to design-and-build contracts), the contractor triggers different preparing activities starting with some decisions like whether the project actually should be tendered for, and which estimator should be responsible for it. It finishes with the analysis of the tender documents including BOQ, textual descriptions, drawings and specifications.

After the analysis of the tender documents, three partial processes are triggered: Preparing the BOQ-based estimate mainly means to take off necessary materials and subcontracts, to determine appropriate suppliers and subcontractors, to ask for their prices and to cost the BOQ.

In order to prepare the plan-based estimate, first of all the necessary information has to be collected. In this context, one or more site visits may be necessary. After that, the programme has to be technically planned, that means methods to be used have to be defined, temporaries have to be designed and a draft programme has to be created. Based on this, the plan-based estimate can be completed by mainly determining and costing requirements concerning plant, suppliers and subcontractors, labour, preliminaries, services and infrastructure, method-related extras and insurance. An EPC documenting the creation of a plan-based estimate is shown in Fig. 7.

In parallel to the BOQ-based and plan-based estimating process, additional supporting information including certificates concerning reference projects, qualifications and so on is prepared.

Finally, after the BOQ-based estimate and the plan-based estimate are completed and additional supporting information is prepared, the final tender can be completed. For this purpose both estimates have to be correlated and summarised and commercial adjustments have to be made. Then the final tender can be submitted to the client.

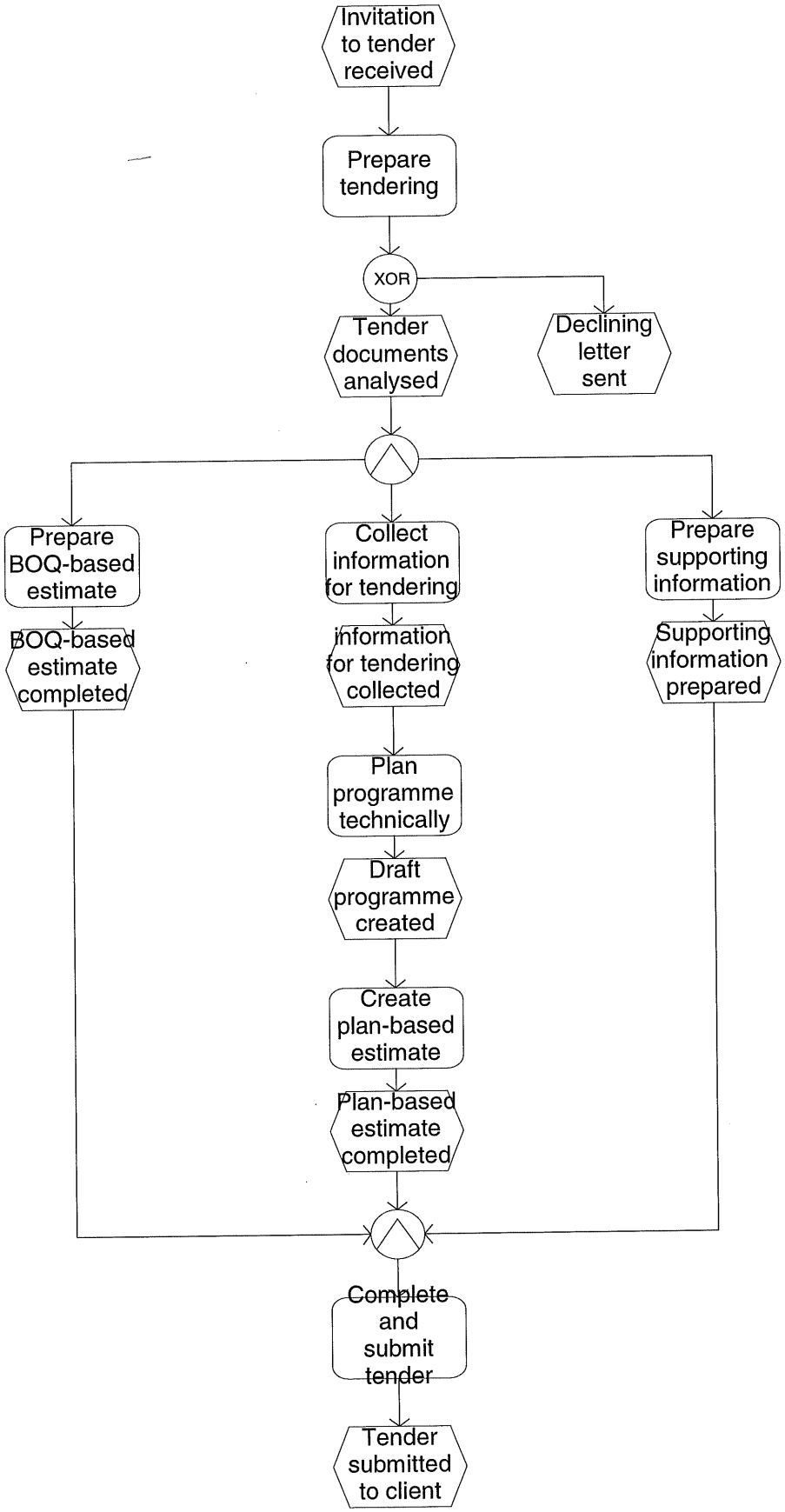

Fig. 6: Tendering

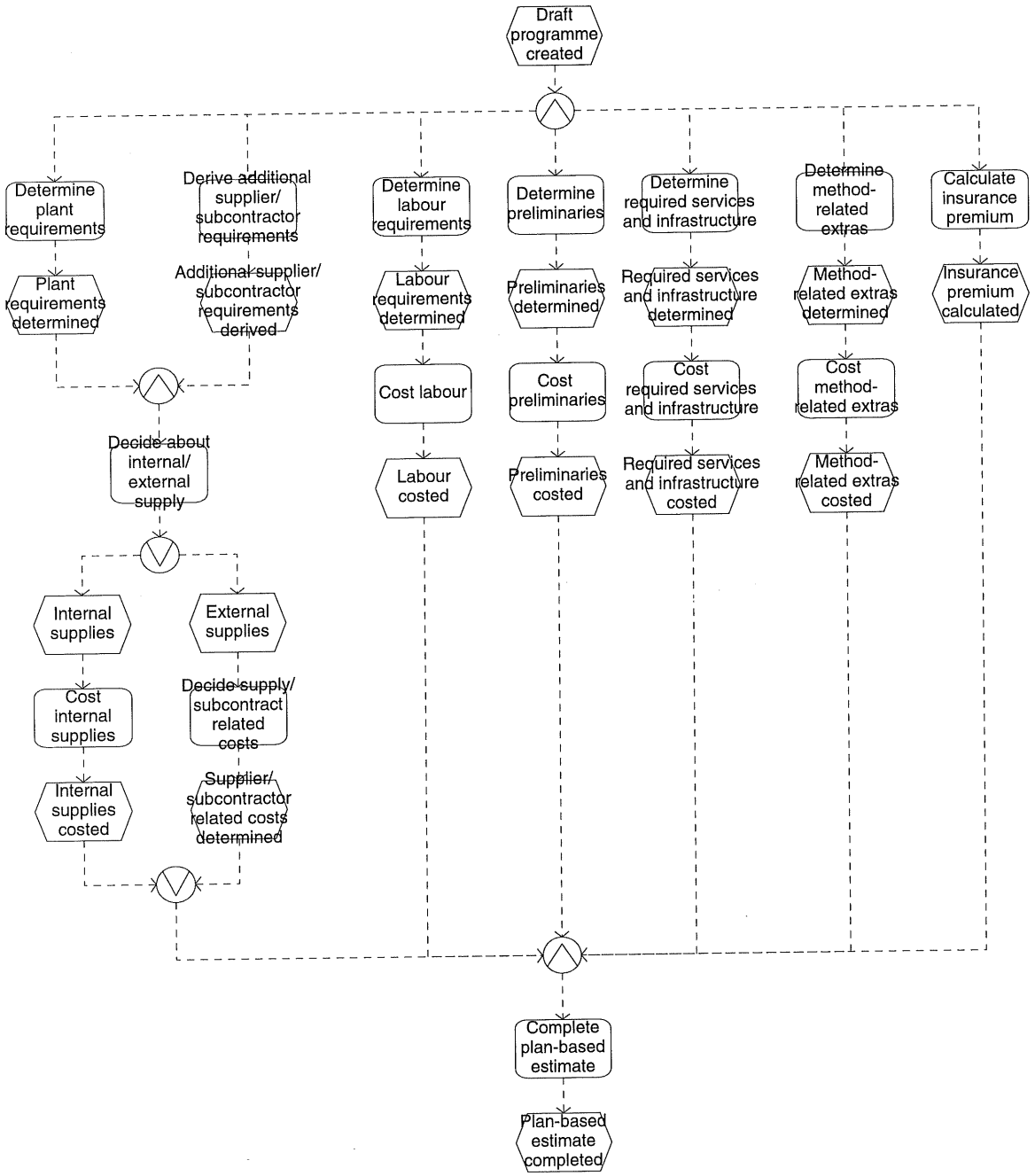

Fig. 7: Detailed Process: Create Plan-Based Estimate

3.2.2 Approaches for Improvements

A critical problem within the scope of tendering is the missing link of the two calculation bases Bill of Quantity (BOQ) and programme (cf. Fig. 6 and Fig. 12). This missing link becomes obvious because of the fact that at the end of the tendering process both calculations, the BOQ-based estimate and the plan-based estimate, have to be correlated. Another indication is the fact that the two calculation processes are supported by different information systems. Even if there are project management systems integrating costs and resource requirements in addition to times and durations within their project step description, there is

no relation to single BOQ items. The definition of such links is indeed very difficult, because there is no 1:1 relationship between the items of the BOQ and the activities of the programme, but a many-to-many relationship. To face this problem, the BOQ should be interpreted as a client-related view (cf. Fig. 13) of an integrated project description (cf. Fig. 10 and Fig. 11), which is presented in the next chapter discussing project planning. By relating the planned activities, resources and costs to the BOQ items in the scope of tendering, and by the following relation to actually executed activities, actually required resources and actually occured costs in the scope of project management, the quality of a tender can be judged not only by the ratio of submitted tenders and received contracts, but also by corresponding comparisons of planned and actual data. Such analyses representing important experiences and expert knowledge can be used during future tendering processes.

Exactly this lacking reuse of information and knowledge concerning former tenders or projects provides another chance for improving tendering. An important factor for not re-using data and experiences from former tenders is the low degree of IT-support. Even within the organisational unit which is responsible only for tendering it is often not possible to realise an electronical access to successful and profitable tenders in order to get an appropriate starting point for a new tender concerning a similar construction project. Secondly there is no electronical access to information concerning project planning, i.e. to the detailed programme, or concerning project management, i.e. to actual data. For this reason it is not possible to assess the quality of the tendering programme and estimates in respect to the actual project based on this tender. Therefore a reuse of this non-existing findings in the scope of new construction projects is not possible. One possible solution, which is presented in a more detailed way in the next chapter, is an improved functional integration of tendering, project planning, project management and project evaluation based on a common logical data structure representing an integrated project description (cf. Fig. 10 and Fig. 11).

Especially the missing integration of tendering and project planning is responsible for the need to do a significant amount of work twice. For example, the planning of activities and times and the costing of supplies and subcontracts is done both by the tendering department and by the site manager. This causes unnecessary costs. This important point is treated in the next chapter in a more detailed way.

Saving time and costs during the tendering process could also be supported by a better use of computer networks and electronic data interchange (EDI). Both the telecommunication with clients and suppliers or subcontractors could be improved by the use of the World Wide Web (WWW). Supporting the communication with clients, the WWW could be used for a fast access to calls for tenders and the corresponding information, i.e. drawings, specifications, BOQ and so on. Supporting the communication with suppliers and subcontractors, the WWW could be used to find price information via appropriate online product and service catalogues of the suppliers and subcontractors. By this, the time-consuming call for formal tenders could be replaced at least during the tendering process.

3.3 Project Planning

3.3.1 Overview

After the contractor has been awarded a project, the project needs to be planned, i.e. the relevant technical and financial aspects need to be determined and scheduled. Before the work on site begins, it is also necessary to select the main suppliers and subcontractors for the project.

Fig. 8 shows the required activities and their possible sequence as an event-driven process chain (EPC). After the contract is signed, the site organisation needs to be defined, i.e. the site manager and the other members of the site team and their responsibilities. The job is then handed over to the site team, including all documentation, such as the contract, drawings, specifications, the tender etc. The site manager and his team have to collect all information necessary for planning and carrying out the job. This includes mainly analysing the project documentation and visiting the site. If further information is required, the site team contacts the client or the architect. On the internal contract commencement meeting, the site manager discusses the project with the contractor's responsible managers and specialists. Specific requirements and problems of the project are discussed and necessary decisions are made.

After the internal contract commencement meeting, the site manager can start planning the project. He can be supported by specialists from the company's offices, but usually the site manager is responsible both for planning and carrying out the project. Project planning includes both technical and financial aspects. During technical planning, the site manager defines the methods to be used, and he works out the programme, i.e. the required activities, their sequence, their starting and finishing times, their cost rates, their required resources etc. In some cases the contractor may want to develop construction alternatives for parts of the original design in order to achieve better results and to reduce costs. This is done by the contractor's own architects and designers. Further planning tasks include the definition of the site layout, the design of temporaries, the planning of the site office layout, and the creation of a quality plan and a health and safety plan. An EPC for technical planning is shown in Fig. 9. This EPC is a refinement of the function "Technical planning" in Fig. 8. The other functions of the project planning process of Fig. 8 can be detailed in a similar way.

Financial planning is basically concerned with costing the BOQ and determining the expected cashflow. Since the expected costs depend on the results of technical planning, the financial planning function follows the technical planning function in the EPC of Fig. 8. However, the results of financial planning also influence technical planning, e.g. other construction methods may be required if the original methods turn out to be too expensive. Therefore a loop has been included in the EPC, allowing to go back to technical planning, if necessary. This is a simplification, since in reality it is not necessary to finish all parts of technical planning before financial planning can start, but there can be significant overlaps, and several iterations of technical and financial planning steps, before the final versions of the plans are produced.

From these plans, the job requirements can be derived, concerning required labour, plant and equipment, accommodation, services, infrastructure. It is then possible to schedule the use of these resources. In the external pre-contract meeting, the site manager and the company managers discuss the project and the developed plans with the client and the architect. Pre-construction buying activities concern the procurement of materials and other resources and the placement of subcontracts which are either needed already at the beginning of the project or which are important for the entire project.

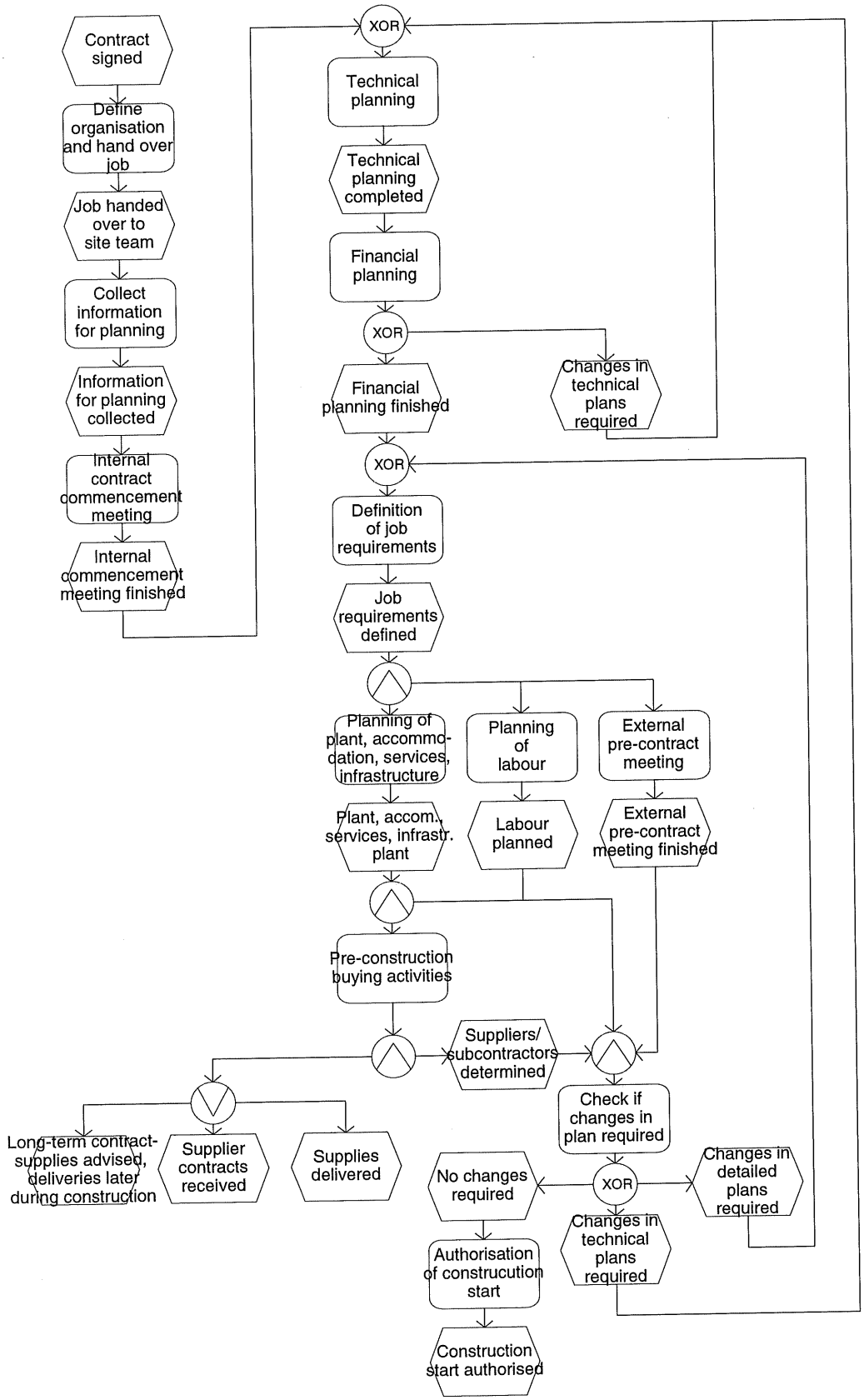

Fig. 8: Planning of Project

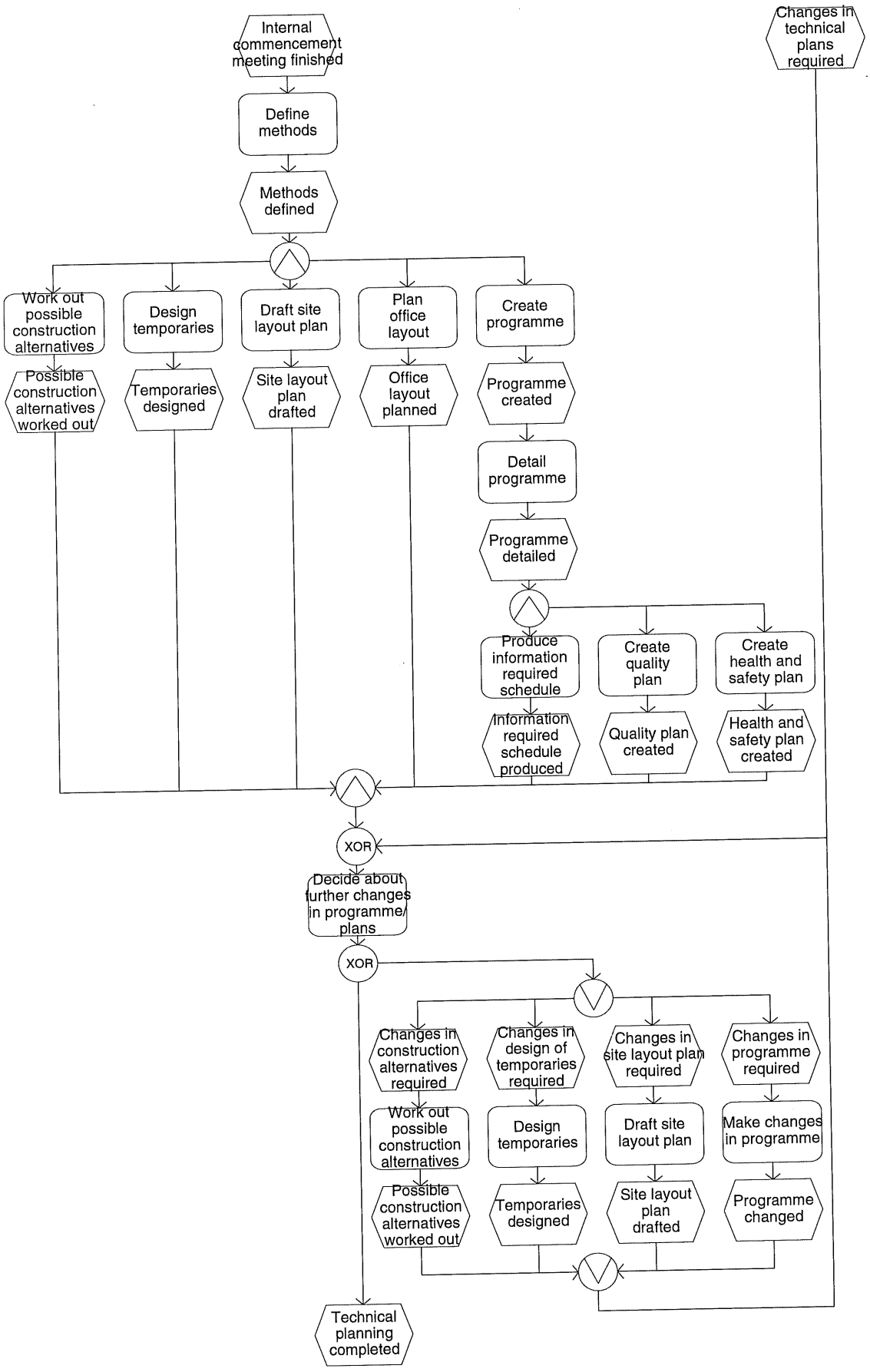

Fig. 9: Detailed Process: Technical Planning

During these activities it may turn out that further changes in the technical plan or the financial plan are required, so that parts of the planning activities have to be repeated. If no further changes are necessary, the responsible company manager authorises the site manager to start construction.

3.3.2 Approaches for Improvements

One of the most important problems of the current practice of project planning is the strong separation between different planning activities. For a project several different plans are required, such as the programme, the financial plan, the quality plan, the health and safety plan. Although these plans are not independent of each other, because they describe different aspects of the same project, they are usually treated separately. Most of the plans have different structures, and they are produced using different computer programs. The activities of creating these plans are separated from each other. In many cases, the connection between the different plans consists only in the site manager's knowledge of the overall project and of the contents of the other plans, but neither are these dependencies documented nor are there systematic procedures of developing these plans in accordance with the other plans.

Due to this strong separation between different planning activities it is difficult to make sure that all of the plans are consistent. Therefore certain kinds of problems cannot be detected during the planning phase, but only later during the project. This leads to higher costs, since the corrections of problems tend to be the more expensive the later they are detected. Detecting inconsistencies is even more difficult because of the different logical structure of the plans, especially of the programme and the financial plan. The programme is based on the activities and their sequence, while the financial plan usually is structured according to the bill of quantities (BOQ), which includes different kinds of items, representing rather used resources and partial results of the contractor's work than activities. Developing such different kinds of more or less independent plans in a consistent way is expensive and takes rather long.

These problems can be solved by an improved functional integration of the different planning aspects which should be based on a common logical data structure. Such a logical structure for an integrated project description can be based on activities and their precedence graph, as it is used by many project management tools for scheduling and producing gantt charts. The use of this structure needs not to be limited to calculating times and durations, but it can also be used for assigning cost rates, resource requirements, work instructions etc. (cf. Fig. 10).

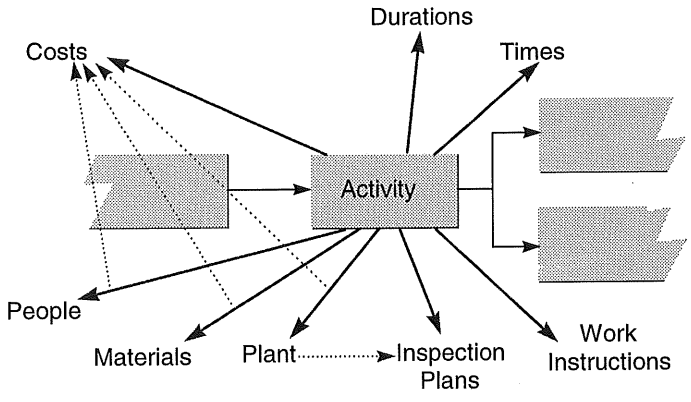

Fig. 10: Integrated Project Description

Such an integrated project description can therefore be used for all planning activities, such as costing, scheduling, procurement planning and quality planning (cf. Fig. 11). For all items not only planned data but also actual data can be stored. Therefore, such a structure can be used as a basis for an integrated information system (see chapter 4) not only for project planning but also for site management.

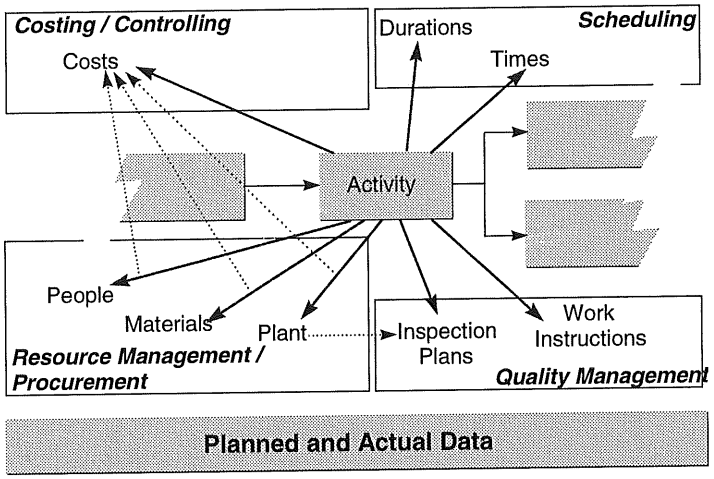

Fig. 11: Use of Integrated Project Description within the Project

With such an integrated description, project planning does not consist anymore of several independent planning activities which are linked only by the site manager's implicit knowledge, but it is possible to develop the integrated project description in an iterative way. Specific documents, such as a cost plan or a quality plan, can then be derived automatically. This procedure is indicated in the process chain for technical planning (Fig. 9), where the term "programme" stands for an integrated project description as described above.

Most standard software packages for project management provide the possibility for working not only with times and durations, but also with costs and resource requirements. However, they do not support other required functions, such as producing a priced BOQ for the customer or a quality plan according to the ISO 9000 ff. standards. Therefore, the respective data are usually stored in other systems than the project management system, and the required information integration is not achieved in practice. It is therefore necessary to integrate these different information systems, based on a common project description.

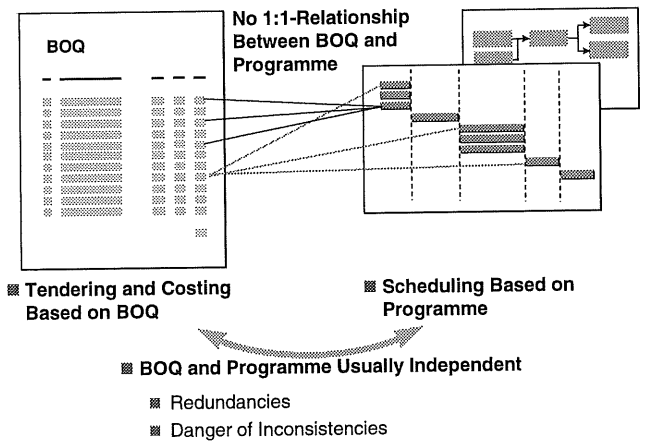

Fig. 12: Missing Link between BOQ and Programme

Although such an project description could be used for all planning activities, most customers require the presentation of costs and prices in a BOQ. One of the reasons that different types of planning tools for construction have not been fully integrated yet, is the fact that there is no 1-to-1 relationship between the items of the BOQ and the activites of the programme, but a many-to-many relationship (cf. Fig. 12).

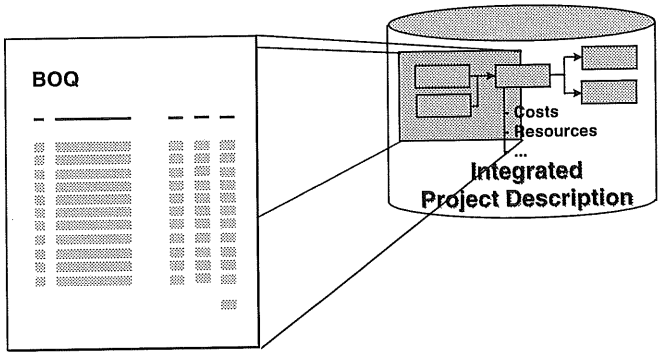

Fig. 13: BOQ as a Client-related View of the Integrated Project Description

To overcome these problems, the definition of the BOQ as a client-related view of the integrated project description is proposed (cf. Fig. 13). This means that at the beginning of the project, the dependencies between the BOQ and the integrated project description are defined, e.g. in terms of what proportion of a certain resource usage in a selected activity goes into which BOQ item. The effort for defining these dependencies can be reduced by using standard templates as a starting point. With the definition of these dependencies it is possible to use internally only the integrated project description, and to automatically derive the BOQ whenever it is required. Unfortunately, so far there are not any standard software packages available providing the described possibilities.

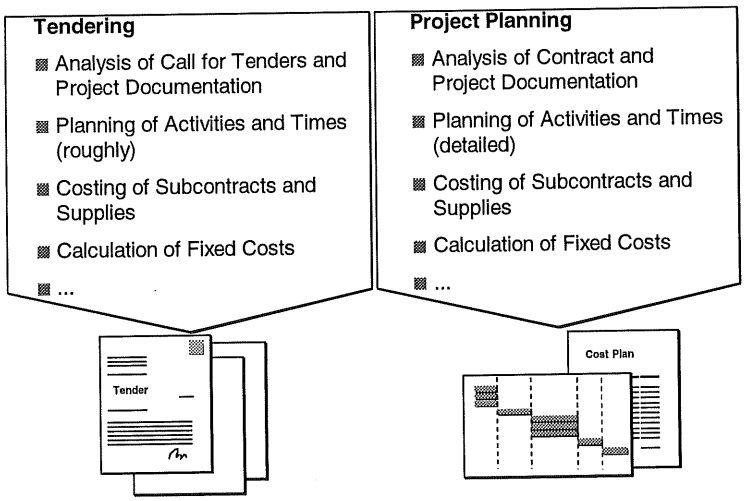

Fig. 14: Parallelities between Tendering and Project Planning

Another problem is the fact that in many companies project planning usually starts from scratch without re-using results of the tendering phase, although there are many parallelities in the tasks required for developing a tender and for planning a project (cf. Fig. 14). In both phases it is necessary to analyse the project documentation, such as the drawings and the specifications, to define the required activities and estimated times, and to calculate the project's costs. The most important difference is the level of detail. For creating a tender, it is

neither feasible nor necessary to schedule every detailed activity in a very accurate way, whereas actually planning the project requires a higher level of detail and accuracy.

Due to these parallelities of both activities and the overlappings between the results, it would be desirable to integrate tendering and project planning to a higher degree. It is still common practice that tendering and project planning are strongly separated. The tendering department is only responsible for creating as many successful tenders as possible. When a contract has been won, the project documents are "thrown over the wall". The site manager then needs to plan the project from scratch, not exceeding the costs determined by the tendering department. With this approach, a significant amount of work is done twice: by the tendering department and by the site manager. Knowledge about the project gained during tendering is not re-used during project planning, and there is only little feedback from project planning to tendering, e.g. about problems caused by inaccurate or unrealistic cost estimations in the tender.

For closing the gap between tendering and project planning, both organisational integration and improved information system support are required. Following the principles of process-oriented organisational structures, it would be desirable to have the same people being responsible for the entire project - from tendering to project planning and management, so that the experience from managing earlier projects could be used to produce better and more feasible tenders, and that the people who gain a lot of knowledge about the project during tendering can use this knowledge for planning and managing the actual work. Since only a part of all submitted tenders are followed by a contract, it is usually not possible to have the same people developing the tender and managing the project. Therefore it should be tried at least to improve the co-operation between the tendering people and the site people, e.g. by involving the person who was responsible for a certain tender, into planning the project. This person can support the site manager by providing his knowledge from the tendering phase, and he gets insight into the projects following his tenders, so that he can use this experience for further tenders. It could also be useful to regularly exchange staff between the tendering department and site management.

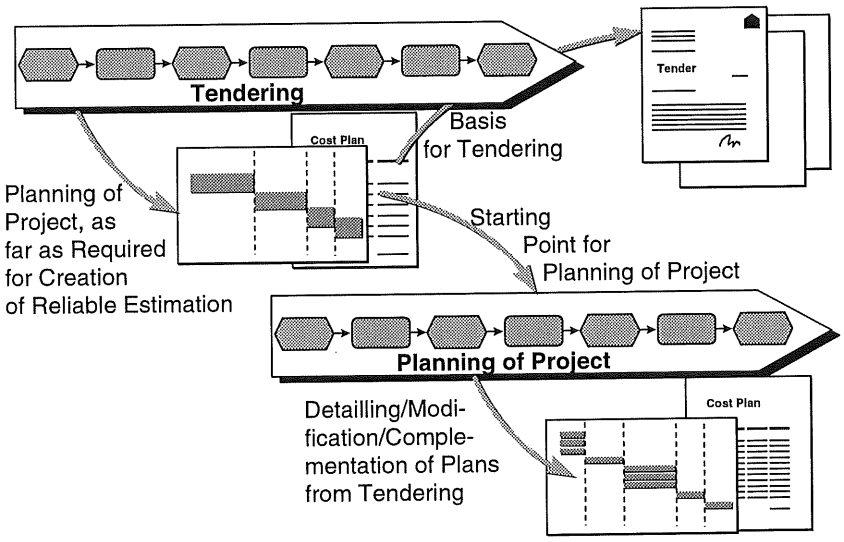

Fig. 15: Integration of Tendering and Project Planning

Such organisational measures for integrating tendering and project planning should be accompanied by improved information systems support. A possible solution is shown in Fig. 15. During tendering, the project is planned as far as it necessary to create a reliable

estimation of costs and times. If this is done with a system using an integrated project description as described above, the result is a first version of a project plan, including activities, times, costs etc. From this integrated project description, the tender documents can be derived according to the structure required by the client. For project planning, the site manager does not need to start from scratch, but he can use the existing project description as a starting point. The final plans are created by detailing, modifying and complementing the tendering plans as required. Such an integrated information system support reduces the amount of redundant work, and it encourages the tendering people to create their rough and estimated plans more thoroughly, so that the feasibility of the tenders increases. The integrated project description also documents the assumptions of the tendering people about how the project will be structured and carried out, so that the site manager receives more information about the project from the tendering phase.

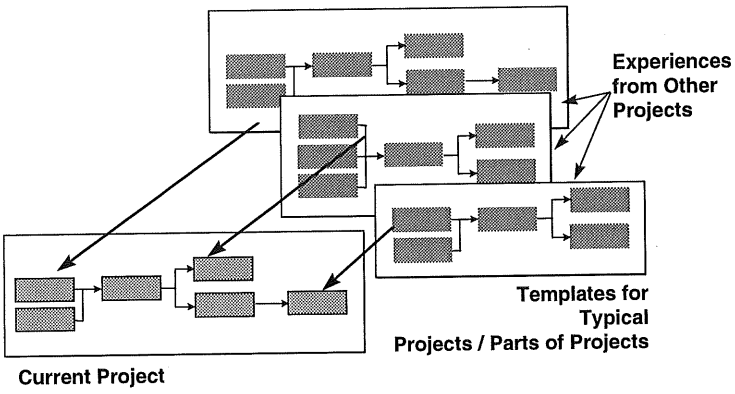

Fig. 16: Use of Templates

If all stages of a construction project are supported by the same integrated information system, it is also easier to analyse the project data from finished projects and to use these results for improving tendering and planning of future projects. Based on the data of finished projects, it is also possible to develop generic plans for certain kinds of projects which can be used as templates for faster creating new project plans (cf. Fig. 16). Such a system should also provide the possibility for easy access to the data of any project, so that a site manager can find out about finished or ongoing projects which are similar to his current project, and he can learn about typical problems and solutions and improve his projects by using experiences from other projects. Fig. 17 summarises the use of the computer-based integrated project description for documentation and evaluation purposes.

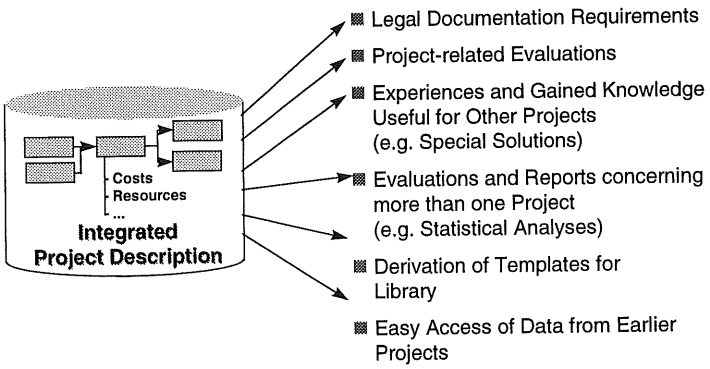

Fig. 17: Use of Integrated Project Description for Documentation and Evaluation

3.4 Project Management

3.4.1 Overview

Other than for tendering or project planning, it is not possible to define one single process chain describing the typical sequence of management activities during the project. This is due to the fact that every construction project is different from each other. The exact overall sequence of activities therefore depends on the project plan. On the other hand it is still possible to describe, analyse, and re-design business processes on site, since there are a lot of tasks which are handled in the same way on every site, such as recording finished work or purchasing material. These tasks are carried out either in regular intervals (such as updating the project plan) or according to the requirements of the project, such as purchasing material which needs to be done soon enough to ensure reception of the material when it is required on site.

Fig. 18 shows the main functions of project management,[10] each of which can be described by one or several process chains. Several functions are concerned with procurement from external suppliers. Buying activities during construction are required for selecting and making contracts with suppliers and subcontractors for those supplies and jobs which are not being procured before the start of the project, e.g. minor supplies which are not yet required at the beginning of the project. The process of finding and selecting the best and cheapest suppliers is similar to the respective processes for getting suppliers' prices during tendering (cf. paragraphs 3.2 and 3.5) and to the pre-construction buying activities during project planning (cf. paragraph 3.3), although for smaller supplies the formal call for tenders may be omitted, and supplier quotes may be collected simply by phone. For certain materials which are required in large amounts and many times during the project (such as concrete), supplier contracts are made for the entire project, so that each delivery simply needs to be called off some time before it is required. Upon delivery, the process for the reception of supplies is started. This includes checking whether the right amount of the right material has been delivered, comparing it with the delivery ticket, inspecting the quality, and moving the material to the right location on the site.

Another important activity is the assessment of progress which is carried out in regular intervals and provides the data for other site management activities, such as updating the plans, subcontractor settlement, or requesting payments from the client. Within the process for updating and detailing of plans, planned values (times, costs etc.) are compared with the actual progress, adjustments of plans are made if necessary, and the plans for the next few weeks are detailed. Based on these detailed plans, the exact amounts of required materials, labour, equipment etc. can be determined. These requirements are used for purchasing and calling off supplies and for managing the own resources.

Plant, equipment and material on site need to be managed, for making sure that the required resources for every activity are provided at the right time and place, that the plant is utilised efficiently, that inspections and repairs are carried out, that the material is stored properly etc. The respective processes are parts of the functions "Management of plant and equipment" and "Management of material" in Fig. 18. "Reception and payment of invoices" includes checking

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[10] cf. *Fisher/Yin 1992, Menkhoff 1993*.

the correctness of suppliers' invoices and paying them, while "Subcontractor settlement" refers to the valuation and payment of subcontractors' work.

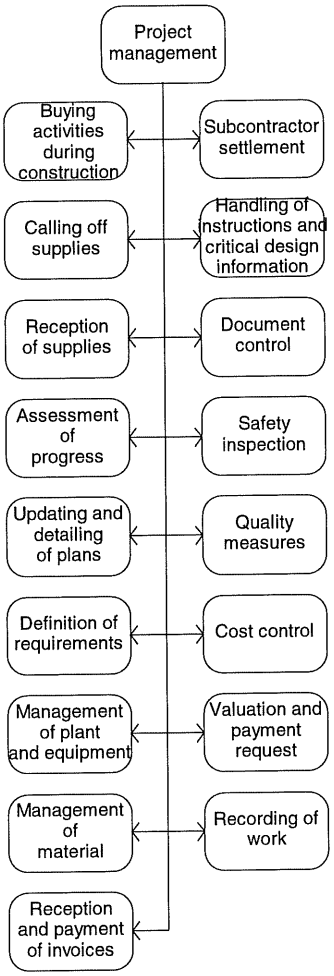

Fig. 18: Main Functions of Project Management

In many cases, the client or his architect request changes to the original design. Therefore it is necessary to make sure that their instructions and critical design information are analysed on site, and that the required changes to the project plans and documents are made and distributed to the staff and the subcontractors without delay. Document control is required for keeping track of who has a copy of which document, so that whenever a document (e.g. a drawing) is changed, all copies can be withdrawn (or be stamped as invalid) and replaced by copies of the new version of the document.

Further site processes include regular safety inspections and quality checks. If necessary, corrective actions have to be taken according to the inspections results. Quality checks are not only carried out at regular intervals, but also on the arrival of supplies, during difficult work, after finishing an activity, etc.

Cost control is closely connected with the assessment of the progress and the updating and detailing of the plans. Actual spending for the project in the past and projected costs for the remainder of the project have to be monitored conscientiously to make sure that the actual costs do not exceed the project's budget. At pre-defined milestones, the contractor's work is valuated. He then issues a payment request to the client.

Recording of work includes regular activites, such as documenting times, costs, working hours, progress etc. in the site diary, providing important data for the assessment of the progress, updating and detailing of the plans, subcontractor settlement etc.

3.4.2 Approaches for Improvements

Rather than discussing every single site business process in detail, we concentrate on pointing out some important issues most of which are relevant to more than one process.

The organisational issues discussed in chapter 2 - such as the reduction of the number of different partners, the increased autonomy and self-responsibility of the project team, and the partnering concept - are especially relevant for the business processes on site. For example, the reduction of the number of different subcontractors reduces the effort for subcontractor settlement and for quality controls. The increased autonomy of the site team allows to move processes entirely on site which currently involve both the site team and the staff in the contractor's offices, e.g. buying or cost control. Thus, the co-ordination effort between different organisational units, waiting times, potential errors etc. are reduced.

If longterm-relationships with important partners are established, it is possible to improve site processes involving more than one partner, e.g. reception of supplies, and subcontractor settlement. For example, in a longterm-relationship, the Total Quality Management (TQM) approach can be applied. The contractor and his suppliers can jointly design the overall processes for ordering, producing, delivering and using certain kinds of construction materials according to highest quality standards, so that the contractor can be sure that he only receives correct supplies without any quality problems. It is then possible to skip additional quality controls on site, thus saving time and money. Since the TQM approach - if applied succesfully - significantly reduces the number of wrong, late, or defect deliveries, it especially helps to avoid delays in the project and to ensure a high quality of the final construction.

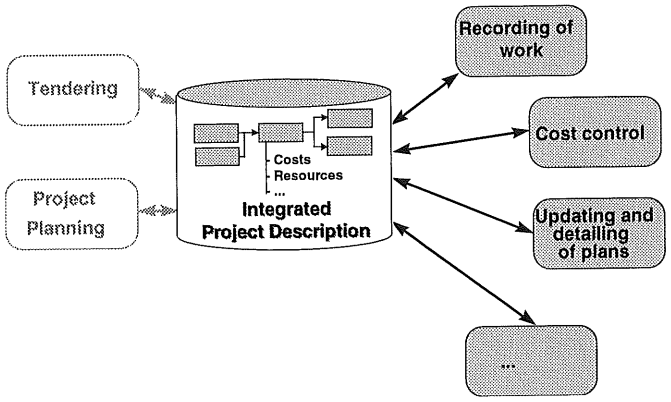

Fig. 19: Use of Integrated Project Description During the Project

Since many processes involve the site team and the staff of the contractor's offices while others involve the site team and partners, these processes can be improved by the use of a powerful telecommunications infrastructure. Today, many sites are still only connected with the company offices and other companies by phone and sometimes by fax, although with today's technology it is not difficult anymore to connect site computers with a company network. Possible uses of such a telecommunications infrastructure range from simple electronic mail and file transfer to sophisticated support of both well-structured business processes (e.g. standard procedures for purchasing, such as invoice checking and payment, can

be supported by workflow-systems and electronic data interchange) and flexible ad-hoc processes, such as working out and discussing possible solutions for a client's change request, which can be supported with groupware systems, video conferencing etc.

The integrated, computer-based project description as it has been proposed above for tendering and project planning should also be used on site, since this integrated project description represents the plans for carrying out the project, i.e. almost all business processes on site rely on information stored with the integrated project description, e.g. concerning start and finishing times, specifications etc. (cf. Fig. 19). Within the process for updating and detailing of the plans, basically the same tasks have to be carried out as in project planning, however with an already existing plan and with actual data from the ongoing project. The integrated project description therefore provides a useful basis for managing the project on site. Actual data as recorded on site should be stored with the integrated project description as well, so that the progress can be assessed easily, and differences between planned and actual data can be detected.

Currently, most construction sites are managed mainly with paper-based systems, and only some functions are supported by computer-systems. Such paper-based systems involve a high effort for creating all the different kinds of required documents, and they make it difficult to find and relate different kinds of information to each other. If it was possible to replace the large paper-file cabinets found in most site offices with computer-systems based on an integrated project descriptions, a much clearer picture could be provided of all aspects of the current project situation, as well as of the previous work and of the plans for the rest of the project. Such a system can help the site manager to make the right decisions since he can easily check all consequences of different alternatives. Necessary changes to the plans can also be made much more easily, since the integrated data structure provides for consistency. It is then, for example, not possible that there is a gap between the project plan and the financial plan. Neither can it happen that the starting time of an activity is advanced without advising the suppliers to advance the respective deliveries accordingly. Therefore, the integrated project descriptions increases the reliability and flexibility of the project management.

3.5 Procurement

3.5.1 Overview

The different partial processes of procurement are triggered during different phases like tendering, project planning and project execution within a construction project. For this reason the overview of the construction company's procurement activities is given by a function tree and not by an event-driven process chain (cf. Fig. 20).

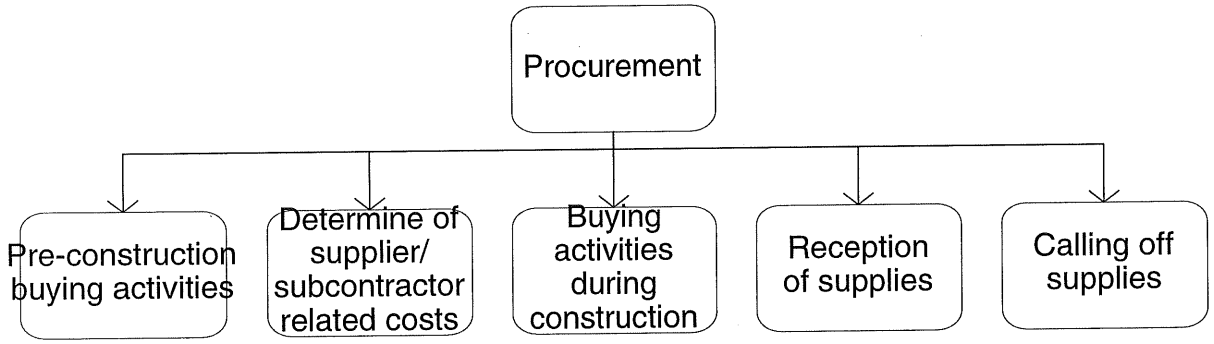

Fig. 20: Procurement Activities

The pre-construction buying activities are triggered by the initial planning process and summarise those buying activities which have to be performed before the actual construction start. These activities can concern urgent or very special supplies and subcontracts or bulk materials. The required supplies or subcontracts can be purchased in two different ways. If there is a long-term contract, the supply or subcontract simply needs to be called off. Otherwise, an already known or a new supplier has to be selected, the qualification of the last one has to be checked, negotiations have to be done and an appropriate contract needs to be signed, before the required supplies or subcontracts can be called off.

The determination of supplier- and subcontractor-related costs can be triggered both by the tendering process and by the initial planning process. There are four cases to be distinguished:

1. If the required supply or subcontract can be procured according to a long-term contract, the corresponding costs can be derived from this contract.

2. If it is not necessary to determine the costs exactly - e.g. during tendering - they can be estimated without calling for formal tenders or informal price information.

3. The third possibility refers to the case that exact and binding cost information has to be collected and requires appropriate calls for formal tenders.

4. The last possibility refers to the case that exact but not necessarily binding cost information has to be collected. In this case, simple price information - e.g. quotes collected by phone - can be used to determine the costs of the corresponding supplies or subcontracts.

The detailed process model (EPC) of the determination of supplier- and subcontractor-related costs is shown in Fig. 21.

The buying activities during construction are triggered within project management and comprise those activities which have to be performed during the running construction project. The different ways supplies and subcontracts can be procured during the project are quite similar to the ways already described in the scope of the pre-construction buying activities. The main difference is that these buying activities are triggered either based on the programme or by the material stock sinking below a defined minimum.

The reception of supplies relates both to the check of the delivery itself concerning contents, quantity and quality and to the check of the delivery note. Deliveries which are totally or partially rejected have to be sent back and cause a correction of the delivery note which also has to be sent back to the supplier. Deliveries or parts of them which are okay have to be unloaded and can cause further activities to be performed before they can be used at the work site. Some parts of the delivery have to be stored, other parts have to be set-up or mounted or require special maintenance. Some delivery items may require a further quality control which can lead in the worst case to a later rejection of the item. After sending back the rejected parts of the delivery, a decision about an appropriate replacement of the rejected part has to be made. Either a new delivery is requested from the same supplier or new „buying activities during construction" have to be triggered.

Calling off supplies simply means to order the required supplies according to an existing contract either by phone or by letter or fax, monitoring the supplier's confirmation of order and the following delivery.

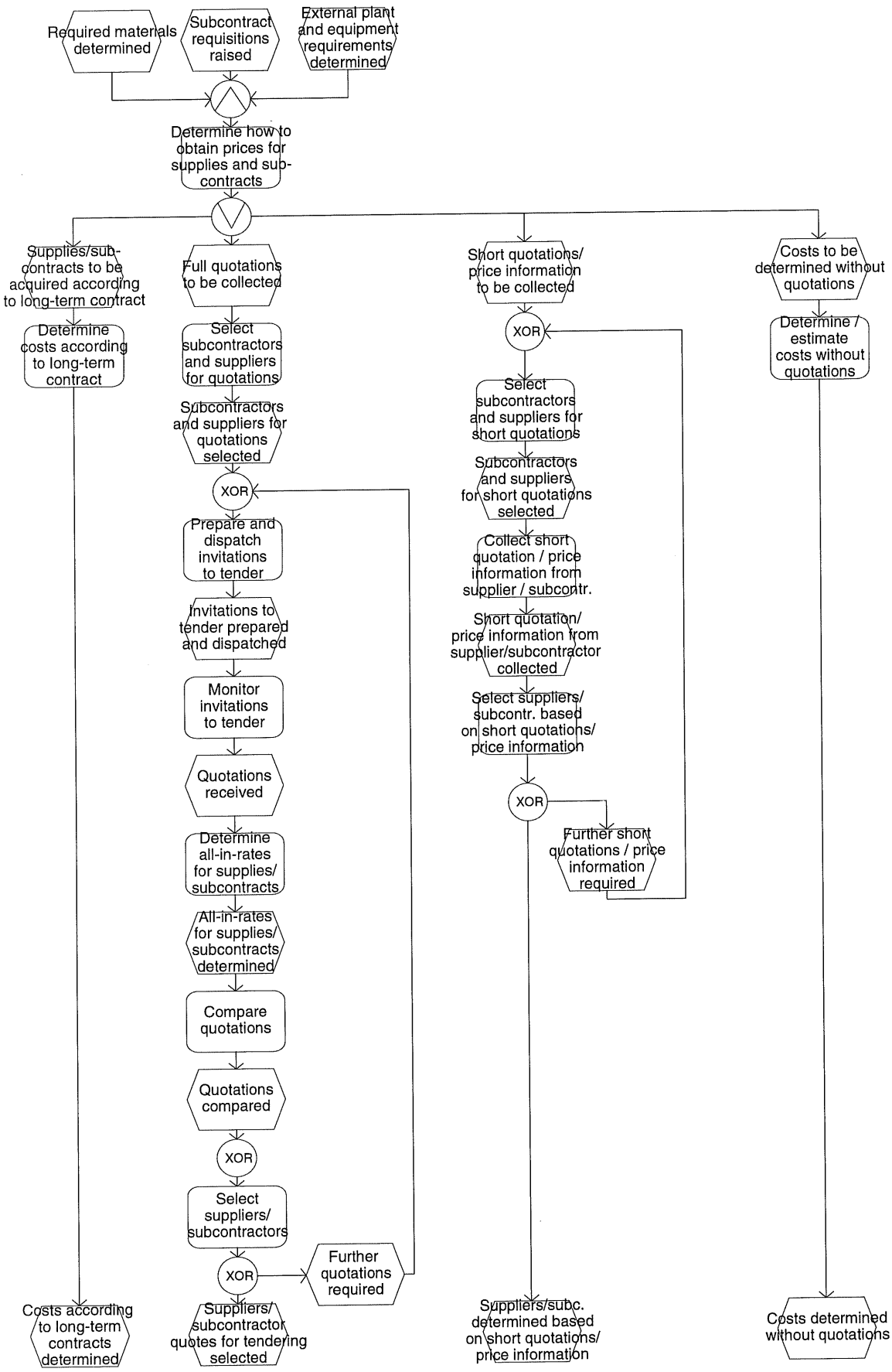

Fig. 21: Detailed Process: Determination of Supplier- and Subcontractor-Related Costs

3.5.2 Approaches for Improvements

The first approach for improvements in the scope of procurement refers to the changing organisational responsibility during the purchasing processes within a construction project. The information system-related breaks, often caused by the organisational breaks during those processes triggering call offs or orders of supplies or subcontracts which are not part of long-term contracts, bring about time delays. Often material requirements of the work site are transmitted to a central procurement department, selecting different suppliers, checking their qualification, negotiating and making an appropriate contract, before the site manager can call off the required material. Increasing the site manager's responsibility could make at least the buying activities during construction easier and less time consuming.

Another approach for improvements concerns the already mentioned functional integration of tendering, project planning and project management now extending to procurement. Based on the integrated project description, the stronger relation to the preceding phases tendering and project planning could make partial processes of procurement easier or even useless. For example, those price information collected during tendering could be the basis for selecting appropriate suppliers or subcontractors and reduce the number of possible candidates right from the start. Furthermore, the formal tenders collected during project planning could be the binding basis for the final contracts and shorten the corresponding negotiations.

Besides the required functional integration of tendering, project planning, project management and procurement along the value chain of a construction project, also the purchasing activities during different projects running in parallel should be supported by an enterprise-wide information system. A central database should be able to give the right information concerning materials and resources required and offered in other construction projects. Supported by an appropriate information system, surplus materials and resources could be distributed among single sites, before new procurement activities are triggered. This simple example shows that in spite of the generally required process orientation, single functions affecting different construction projects - like the distribution of materials and resources - should be co-ordinated across project borders in order to provide the maximum resource efficiency.

The next approach for an improvement mainly relates to an improved IT support of the procurement activities. In the scope of tendering we have already mentioned that the telecommunication between contractor, subcontractor and suppliers should be improved. Again the World Wide Web could be a common platform, in order to realise an access to possible supplier's and subcontractor's online product and service catalogues, and to transmit orders and call offs to the corresponding companies. In table 1 within the next chapter, treating the construction industry's integrated information systems support, the most important arguments proving the suitability of the World Wide Web for the construction industry are summarised. Fig. 24, Fig. 25 and Fig. 26 show examples of a prototype representing an appropriate IT solution.

Finally in the scope of procurement, the enterprise-wide information and document flow between the affected organisational units could be supported by the implementation of a workflow management system. Thus the duration of certain buying activities and the amount of paper-based documents could be reduced. By the use of workflow management systems as control mechanism and the World Wide Web as telecommunication platform also external partners, suppliers and subcontractors can be integrated more closely in the contractor's

construction project. For example, as soon as a certain material is required at site, the workflow system could automatically trigger an appropriate call off via the internet.

4 Integrated Information Systems Support

Currently, there are different kinds of information systems which are typically used for a construction project. On the one hand there are systems for the management aspects of a project, e.g. systems for the financial aspects of purchasing (calls for tenders, awarding and settling of contracts), financial planning systems, and project management systems. On the other hand there are systems for the technical and design aspects, e.g. CAD and specific technical programs.

Most of these systems are either isolated from each other, or they are integrated at a low degree by data exchange interfaces. Usually there is no integration with other information systems in the company, e.g. for accounting or human resources. Only some parts and specific aspects of the entire value chain of a construction project (cf. paragraph 3.1) are computer-supported, other parts are still managed with paper-based systems, so that there are many changes between different media and systems within the project and within its detailed business processes.

Current information system support concentrates on the financial aspects of the projects (i.e. pricing the BOQ, calculating project costs, settling of contracts, and project controlling), while there is less support for the logistic side of the project. In many cases, the full functionality of the tools used is not utilised, e.g. sometimes powerful project management systems are only used for drawing one bar-chart at the beginning of the project, instead of using the tool for actually managing the site activities. One reason for this is the missing integration with other site systems. In many project management systems, cost rates can be attached to activities and resources, so that the costs of the entire project can be calculated, as well as - for example - additional costs caused by a delay or a change in the program. However, if it is not possible to access these costs by the financial planning system, the costing functionality of the project management tool will not be used, because with every change it would be necessary to update the costs in the financial planning system by hand.

An important requirement for construction project information systems - which is not always met by current systems - is their actual usefulness for the project team. If the advantage of such systems is mainly the provision of data to the company accountants and the fulfillment of documentation requirements, they are seen by the project team rather as a burden than as helpful tools. Such systems cannot really help in improving and re-designing business processes.

Usefulness for the project team means that site management is made easier than with the current paper-based systems. Therefore, they should be provide an easy and intuitive user-interface, and they should relieve the project team from routine tasks, so that there is more time for important tasks. Examples of actual benefits provided by a well-designed site information system include:

- A better basis for decisions because of more complete and more accurate information about the status of the project.
- In the case of changes, all resulting effects (such as activities which need to be re-scheduled, additional costs, changed resource requirements) can be recognised and considered immediately.

- Potential and actual problems (such as delays or exceeding cost limits) can be recognised and solved sooner.

In the previous chapter we have outlined a structure for an integrated project description. For meeting the above requirements, a site information system should be based on such an integrated description, bringing together all relevant project data, e.g. data concerning the construction object, the client, the architect, suppliers, subcontractors, materials, plant, labour, activities, costs, methods etc. The integration of these data provides the basis for a system which equally supports the logistic and financial aspects of all processes within the construction value chain, thus removing all - or at least most - changes of media and systems within processes, as well as inconsistencies and redundancies.

Fig. 22 indicates the possible relationship between site information systems and an enterprise-wide information system. There should be one logical data structure for all systems. Every site team owns the data of their site, but they also access data from the enterprise system, e.g. for selecting suppliers from a central suppliers catalog. Rather than re-entering the data of the selected supplier into the site system, a link to the respective entry in the supplier catalog is created. [11] Vice versa, relevant data from the site systems are also accessed centrally, e.g. for payroll calculation or for statistical analyses.

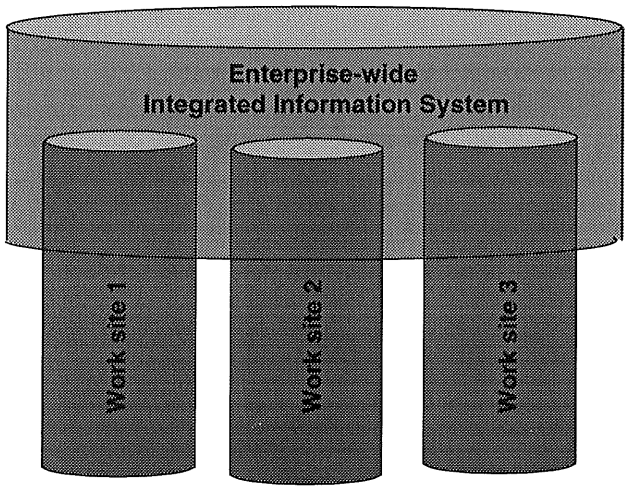

Fig. 22: Enterprise-wide Integrated Information System

The importance of modern telecommunications systems for construction has already been pointed out. The above architecture can only be realised with computer networks connecting different company offices with each other and with each construction site. With larger sites it may be useful to establish permanent on-line connections, while for smaller sites it may be enough to connect to the enterprise system once a day via a telephone line or a mobile phone.

The use of computer networks in construction is not restricted to communication and data exchange within a company, but they are also used for supporting inter-company processes. Examples for telecommunications use between companies are:

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[11] The system may internally replicate required central data in the site system, e.g. for non-permanent data connections, but logically they are still central data, and the data of the different systems are synchronised regularly. Such mechanisms are hidden from the users.

- Publication of calls for tenders in computer networks (e.g. in the word wide web, WWW)
- Data exchange between client and general contractor (e.g. BOQs, specifications, drawings)
- Data exchange with subcontractors and suppliers (e.g. BOQs, specifications, drawings, orders, call-offs, time sheets, invoices).

In most countries, there are national standards for the structuring electronic data interchange (EDI)-messages in construction. With such national, construction-specific standards it is difficult to exchange data with international partners and with partners from other industries. Therefore, EDIFACT as an international, cross-industry standard can be expected to become more important, since EDIFACT also contains messages for the construction-specific types of data exchange.

In recent years, the world wide web (WWW) has gained increasing importance for implementing inter-company processes, and the underlying internet technologies are also used for creating company intranets. Many features of the WWW are very especially advantageous for the construction industry. For example, the high importance of graphical information in construction can be supported by the WWW's multimedia capability (e.g. for photos and smaller drawings) and the possibility to exchange any file formats, including CAD files. Since there are many small companies involved in most projects, and there are different partners in every project, the WWW can be used as a common platform, to which every partner can connect very easily and with low costs. Important aspects concerning the suitability of the WWW for the construction industry, are summarised in Table 1.

Possible uses of the WWW by construction companies include marketing activities, searching for calls for tenders, publishing of calls for tenders, searching in suppliers' on-line catalogues.

Construction Requirement	WWW Feature
Many different partners in each project	WWW as a common basis for communication
Different partners in each project team	Quick and easy access for new partners possible
Some of the partners are rather small	Access to WWW cheap and easy (PC and modem), no complicated interfaces between information systems required
Connection of remote sites	WWW access very easy, only telephone line required
High importance of graphical information	Multimedia features of WWW, easy file transfer

Table 1: Suitability of WWW for the Construction Industry

In several countries, public administrations have already started publishing their calls for tenders in the world wide web.

Fig. 23 shows the architecture of a project specific web server which can be used to support communication and business processes between the different partners within a construction project. There is one web-server for the project, which can either be operated by the architect

or the general contractor. All partners of the project get access to the password-protected site via the world wide web. It is therefore not necessary to establish special connections, the partners only need to have WWW access.

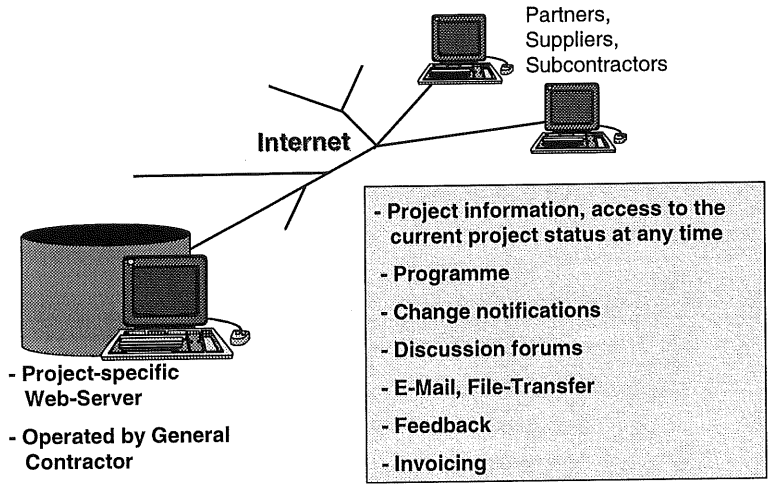

Fig. 23: Project-Specific Web-Server

The site server provides always up-to-date project information, so that every partner can always find out about the current project status and download all kinds of project information which are relevant to him. The programme in its current state should also be accessible via the net, and notifications of any changes can be distributed to all partners easily by e-mail. E-mail is only one way of communication between the partners. Electronic bulletin boards and discussion forums can also help discussing and solving arising issues and problems. The web site can also be used for interactive handling of tasks, such as feeding back data about work done or submitting invoices electronically.

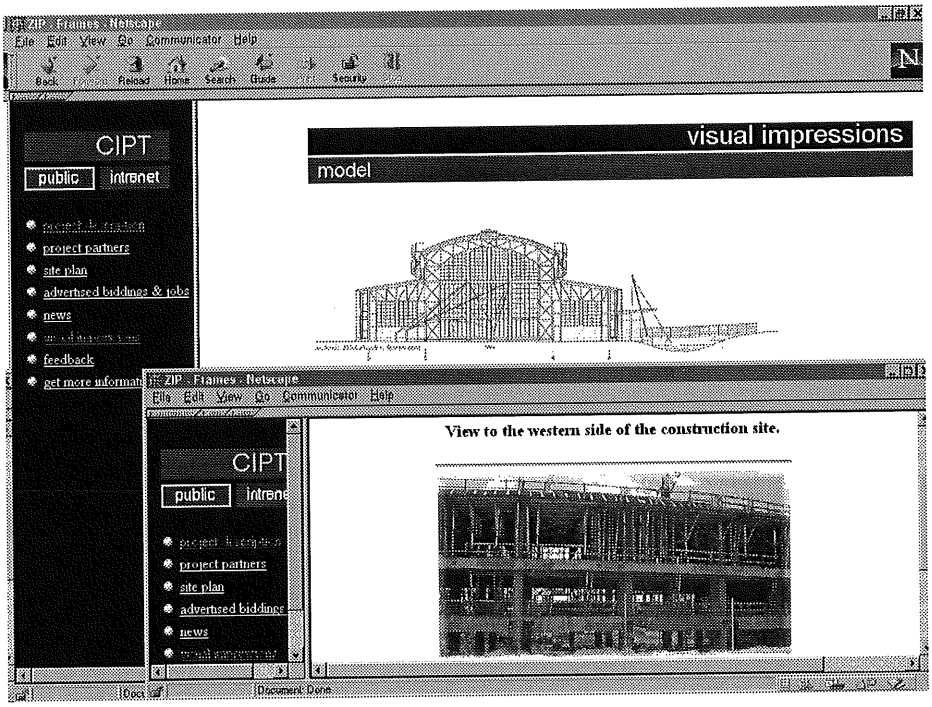

Fig. 24: Construction Site-Intranet

Fig. 24 shows the user interface of a prototype implementation of such a site intranet. The information and services provided are clustered into a public part and an internal part. The public part contains descriptions of the project and the involved partners, a site map, photographs, calls for tenders, job offerings, news of the project, a feedback form for comments and requests for more information. The internal part provides more detailed project information, the programme, the BOQ, feedback forms for subcontractors, invoicing forms, distribution lists, bulletin boards and discussion forums. This is shown in Fig. 25 and Fig. 26.

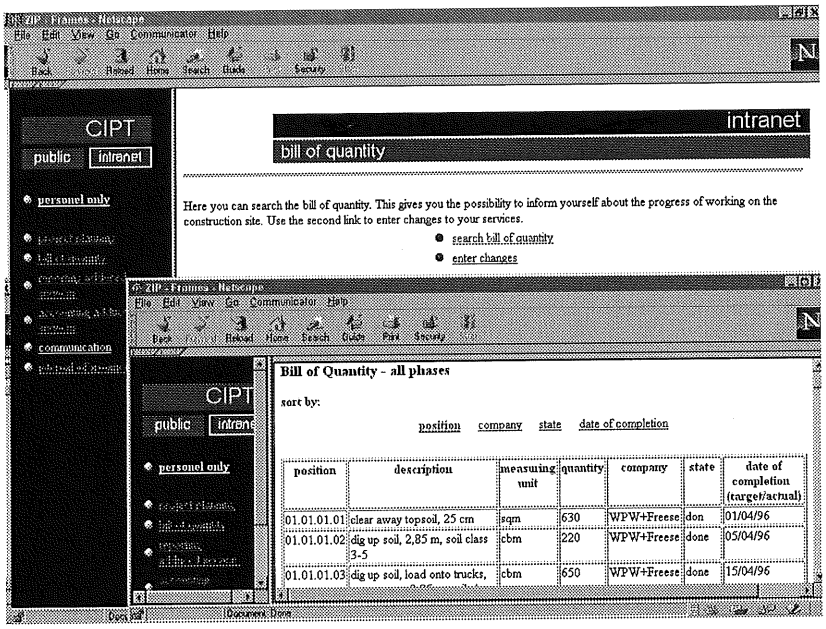

Fig. 25: BOQ on Site-Intranet

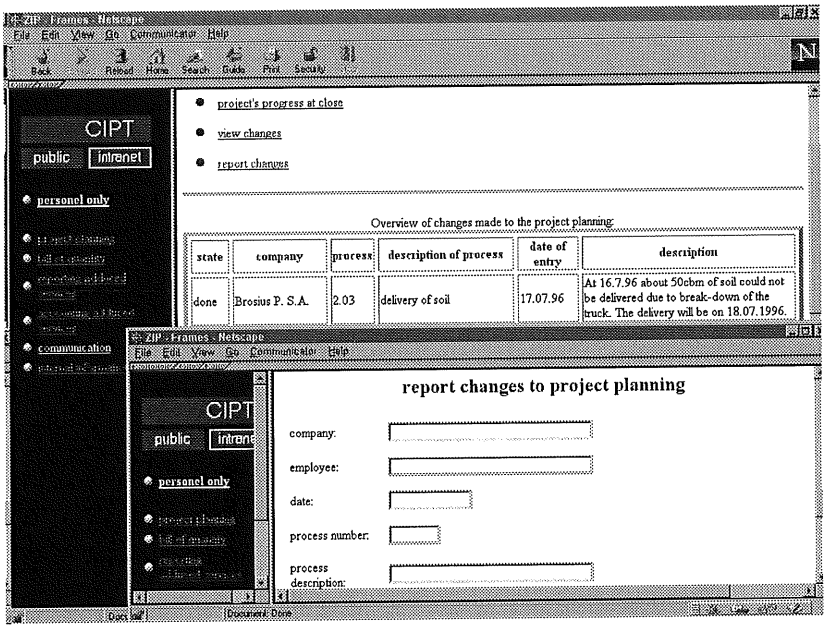

Fig. 26: Programme and Feedback Form on Site-Intranet

With these functions, a project-specific web server can both help supporting inter-company business processes, such as ordering and invoicing, and improving the communication and co-ordination between the different partners, as it is proposed by the partnering concept.

5 Summary and Outlook

In this paper we have outlined possible approaches for re-engineering business processes in the construction industry and for an integrated information systems support of construction industry processes.

Specific requirements of the construction industry have been discussed resulting from characteristics of this industry, such as the high number of different partners within construction projects, the strong separation between design and construction, the extreme one-of-a-kind production, the geographical distribution of construction sites, uncertainties and changes during projects, difficult working conditions on site, and the large amount of information which is required for a construction project. Due to these specific requirements, it is not possible simply to apply existing BPR solutions from stationary industries to the construction industry, but construction-specific solutions are required.

In the main part of the paper, an overview of business processes for a construction project has been given, mainly from the perspective of a contractor. Selected important business processes and functions have been discussed in more detail, namely tendering, project planning, project management, and procurement. For each of these activities, the respective business processes have been presented, and approaches for improvements have been discussed. The proposed changes range from organisational issues, such as assigning some of those processes, which are currently split between the site and the company offices, entirely to the site team, and the establishment of long-term relationships with suppliers and subcontractors, to the functional and logical integration of different planning and management aspects, and to an integrated information system support and the use of advanced tele-communication technology.

Most current information systems for the construction industry are function-oriented, and therefore are not able to fully support entire business processes from start to finish. The information systems used for different functions are difficult to integrate, because they use different logical data structures, such as a BOQ or a project plan. It is therefore necessary to develop an integrated information system support for entire construction projects based on a common logical project description. Such a site information system should be integrated with a company-wide system. Inter-company processes, e.g. with suppliers, can be supported with electronic data interchange. Communication and co-ordination of different partners involved in a construction project can be supported by a construction site-intranet.

The presented approaches for business processes changes in construction do not provide final solutions, but they are meant to be suggestions which have to be developed further on and which need to be adapted to the specific situation of every construction company.

Although the difficult situation of the construction industry in many European countries, the increasing international competition in this sector, and the successes of many re-engineering projects in other industries are good reasons for contractors to start BPR projects, there are still some obstacles to such efforts in the construction industry. One problem is the fact that today there is no fully integrated information system for the construction industry available on the market. While there are several powerful and truly integrated systems available for the discrete manufacturing industry, something similar is still missing for the construction industry. Current initiatives of both integrated standard software vendors and construction

software houses to assemble current systems into integrated solutions for the construction industry may improve this situation.

We already have pointed out that the isolated efforts of any single construction company to improve their own business processes will bring about only limited advantages (which still may well be worth the effort), as long as the inter-company processes between the different partners are left as they are. The largest potentials for improvements can only be realised in a joint effort between clients, architects, contractors, suppliers, public authorities etc. It may be necessary to change traditional structures and customs of the construction industry, and even legal regulations. This can only be achieved by joint initiatives of many companies.

However, these obstacles and problems should not restrain any construction company from improving their business processes and re-thinking the way they are doing their business and the way they are co-operating with other companies. There are a lot of opportunities for process improvements and thus for increasing the own competitiveness.

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Die Hefte 1 - 31 werden nicht mehr verlegt.