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PROCESS SUPPORT FOR VIRTUAL PROJECTS IN THE CONSTRUCTION SECTOR

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The construction sector has for some time been working in a virtual enterprise fashion but with little technological support. As pressures are increasing in the industry to improve on cost-effectiveness and quality there is a growing need for adequate process support. Currently available process support technologies tend to be difficult and time-consuming to set up to support such projects and are therefore not very practical despite their potential benefits. The paper reports on current research into a user operated process design approach that will allow the easy generation of process support tailored to a particular project and which will generate the infrastructure of a virtual enterprise for a given construction project and help manage the project execution phase.

1. INTRODUCTION

Long before the concept of a virtual enterprise had been invented, the construction sector has been a natural example of this way of working, bringing a group of individuals from a group of enterprises together in a temporary association to the fulfilment of a business opportunity. In the parlance of the construction sector this is equivalent to a contract held either by a main contractor and a number of sub-contractors or a partnership, likewise with a set of sub-contractors and suppliers. What makes the construction sector an interesting case is the fact that construction projects of any significant size can be quite complex, often following a number of standard models, at the same time with seemingly infinite variations and are strictly limited in time for the duration of that contract only.

A useful definition of virtual enterprise states that it is a temporary network of independent institutions, enterprises specialised individuals that through the use of information technology spontaneously unite to utilise an apparent competitive advantage (Ivalo, 1998). A similar situation exists in the construction sector, but one significant difference is the relatively underdeveloped use of information technology, which would appears to be key to the operation of a Virtual Enterprise. That the use of IT in the construction sector has been less progressed from any other sector has been argued amongst others by (Betts, 1992). He argues that the reason the construction sector has lagged behind is its comparative complexity.

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In the construction sector there are organisational issues and procedural issues that significantly affect the successful execution of a project. With respect to organisational aspects there are a number of established, alternative procurement methods currently in use, such as, Traditional, Design and Construction, and Management (Pilcher, 1992) and which predominantly affect the high-level organisation and interaction as well as major components of the project. There are also a number of variations and numerous sub-types currently in use and which may be dictated by the project in question.

Construction projects of significant size are also usually awarded following a tendering process especially in the case of public works. The procedural issues involved are therefore dependent on the procurement chosen by the awarding organisation and may require procedures to be followed and involve third parties such as consultants working on behalf of the awarding organisation. This makes for a dynamic situation and makes the application of ICT much more difficult rather than other sectors. For examples of the latter in manufacturing and concurrent engineering frameworks for designing and operating a Virtual Enterprise already exist see (Katzy, 1998)

2. BACKGROUND INFORMATION ON CONSTRUCTION

A number of surveys have been carried out to investigate the use of Information Technology in the construction sector and the potential investments that the relevant companies are willing to make for the future. An interesting survey in this respect is (Bjoerk, 1998), and which investigated these issues in Denmark, Finland and Sweden. The results from this survey are shown in Table 1 below:

Table 1 – IT Investment

IT Services	Denmark (%)	Finland (%)	Sweden (%)
CAD	58	50	40
Document Handling	47	52	70
Product Models	4	5	11
Accounting Systems	48	45	45
Cost Control	22	30	30
Tech Calculations	21	25	18
Project Management	20	3	31
Internet/Web	46	41	64
EDI	6	2	28
Virtual Reality	2	2	12
Portable Equipment	11	10	12

From this table it can be resumed that the top four areas of interest for investment in the construction sector for all three countries are predominantly centred on Computer Aided Design, Document Handling, the Internet/Web and Accounting systems. Leaving aside the CAD and Accounting, the other two areas are indicative of the administrative/bureaucratic overhead that currently exists in the sector and that characterises project from beginning to end. IT can be very effective to support the reduction of these, and lead to process improvements, with consequent reduction of costs and time as well as quality improvement.

Another survey carried out by Salford University examines the major areas of need of IT in the construction sector (Aouad, 1998). Three different professions and academic institutions were asked in their estimation, which IT services the sector needs were the four most important in ranked form and are shown in Table 2.

Table 2 – IT priorities in the construction sector

Quantity Surveyors	Architects	Contractors	Academics
Communications and Networking	Communication s and Networking	Communications and Networking	Communications and Networking
Databases	CAD	Computer Aided Planning	Computer Aided Planning
Computer Aided Estimating	Databases	Strategic Planning	CAD
CAD	Integration	Databases	Databases

The results would suggest that communication and planning support are a key requirement for construction projects in general and should also rank highly in virtual projects and enterprises.

In this paper we propose a solution of how virtual projects can be supported with the necessary process support. The paper presents a method that enables the user to setting up a process support solution tailored to the needs of the project in question, and which will provide the basis for the communication and interaction of project partners in the virtual project.

3. PROCESS SUPPORT IN VIRTUAL PROJECTS

In public procurement construction contracts are usually awarded following a tendering process. Procurement is highly regulated and there are formal procedures to be followed. Briefly, the major steps that are involved start with an indicative note of intent, over publishing the call for tenders and then, depending on the type of tendering process chosen, it may involve pre-selection and end in the tenders being submitted, evaluated and the winning contractor being announced. Tendering organisations usually have to make a formal expression of interest to bid for that contract and which may include a process of qualifying as an approved organisation the public authority can do business with. The formal sealed tender proposes in detail how the construction project will be carried out including schedules and detailed cost analysis. Also, the preparation of the tender is usually time consuming often involving several person-months of effort to put together. As the nature of the project may include specialisms the main contractor does not have it may involve collaboration with other construction engineering companies that will be involved in the project. Furthermore, as the tender document is the basis for the execution of the project, the terms may have to be agreed with named sub-contractors and the tender preparation becomes a mini-project in its own right, involving several collaborators from different organisations. During the project execution there is also a need for efficient and effective communication between the project partners to guarantee an effective and timely evolution of the project.

It would appear reasonable to support the operation of virtual projects with process support technologies, that will facilitate the collaboration of the potential project partners. According to (Betts, 1998), the main reason why construction organisations are not using such technologies is due to their inflexibility for supporting project-based scenarios as well as high maintenance costs.

Workflow systems instantiate or execute a number of predefined processes/procedures. The processes have to be designed carefully at the requirements analysis stage in order to produce a usable system. The nature of these systems is that they are static procedures executing during the operation of the system. This also means that the focus is entirely on formal procedures omitting the informal practice (Symon, 1996). The dynamic nature of construction projects and the fact that no two projects are exactly the same is not very helpful for the development of an accurate workflow system and during the project unforeseen changes may occur which may affect the procedures for the execution of the work and therefore the tasks may change. It is therefore not possible to accurately predefine a system that can deal with the vast range of project variants and cope with any enventualities. Therefore we have to move away from the situation where an analyst and programmer have to set up the system to a situation where the users can systematically define the processes they require. We also have to move away from a static workflow approach to a more dynamic one and which will accommodate the need for changes during execution, requirering the processes to be redefined. This means that the system must be able to control the actions of all the users and also be able not to loose control (Reichert, 1998).

4. A SEMI-DYNAMIC WORKFLOW APPROACH

A fully dynamic workflow approach we would argue requires processes to be changed while in execution whereas in a semi-dynamic approach the system may have to be stopped and changed before being restarted. In order to instill consistency into the design of a process support solution and to enable the user to design such a solution there is a need for a methodical approach. We propose such a method. There are two major stages in this method, namely the design of the processes and in the second stage the design needs to be translated into an executable form which a workflow engine can execute.

As far as the first stage is concerned, we propose three cycles in order to be able to produce a systematic specification for a workflow system. These cycles will have to be carried out in succession and with an approval and revision process at the end of each cycle to ensure correctness and assent by the parties involved. The three cycles are described below:

Cycle 1 – Roles and Responsibilities: In the first instance the project participants have to be identified and the relationships and respective responsibilities established. This would appear to be somewhat similar to developing an organogram, where persons in the organisation are specified together with their responsibilities and place in the organisational structure. Construction projects are not much different as participants such as sub-contractors will have specific responsibilities and be answerable for a particular contribution to the main contractor who in turn is responsible for the whole project to the customer. This means that each participant has to be registered in the system and their respective role and responsibilities be specified. Particular procurement methods may restrict the organisation at the top level, i.e. how the contractor and customer interface and may require the specification of a consultant who will act on behalf of the customer. The diagram below shows a sample organogram of a project involving a main contractor, three sub-contractors and several suppliers. Cycle 1 finishes when the participants have been specified and they have agreed to their involvement in the role and responsibilities assigned to them.

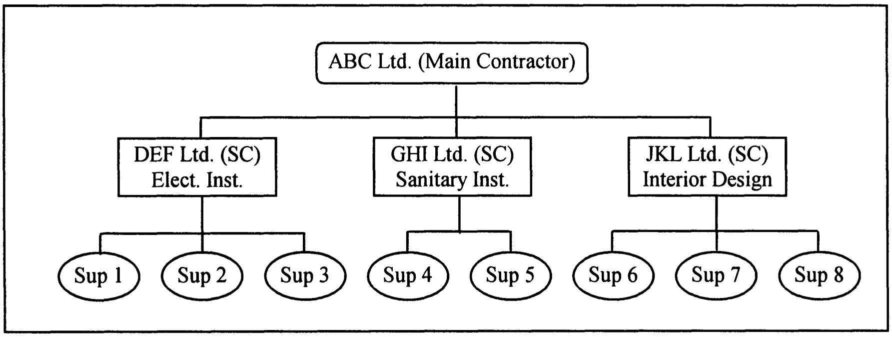

Diagram 1 – Sample Cycle 1 Project Organogram

Table 3 – List of Participants and their Respective Roles and Responsibilities

Actors & Roles	Responsibilities
ABC Ltd. (Main Contractor)	• Design & Contruct • Project Management
DEF Ltd. (SC) Elect. Inst.	• Electrical Installations
GHI Ltd. (SC) Sanitary Inst.	• Sanitary Installations
JKL Ltd. (SC) Interior Design	• Interior design
Supplier1-8	• Supply materials to respective sub-contractor

Cycle 2: Task Specification – Following the unilateral approval of cycle 1 a task-group will be assigned to each participant and who will in turn have to specify the respective sub-tasks that need to be carried out to fulfill their respective obligations. The initial set-up of task-groups will be based on the responsibilities specified and will be equal to one task-group per responsibility listed in the Roles and Responsibilities table. Each organisation has to produce a plan on how they intent to perform their contribution into the project. This can be done in a structured and iterative fashion as the overall task-group can be further broken down into sub-groups before individual tasks are identified. Each task will also require the user to specify not only its objective but also the resources needed including effort and

materials as well as the projected duration. This means that each organisation will have to prepare task groups and tasks that describe their contribution. Again this may be subject to negotiations and there will be another approval process where both the participants and main contractor have to approve individual contributions. The following table schematically shows this (resource allocation, and duration not shown):

Table 4 – List of Participants and their Respective Roles and Responsibilities

Taskgroups	*Tasks*
TG1: ABC: Design & Construct	T1.1: Building Design
	T1.2: Building Contruction
TG2: ABC: Project Management	T2.1: Project Management
	T2.2: Liaison with Customer
TG3: DEF: Electrical Installations	T3.1: Installation of cabling
	T3.2: Fitting of fusebox
	T3.3: Fitting of lights
	T3.4: Fitting of sockets and switches
TG4: GHI: Sanitary Installations	T4.1: Installation of pipework
	T4.2: Sewage connection
	T4.3: Installation of sinks
	T4.4: Installation of toilets
TG5: JKL Interior Design	T5.1: Plasterwork
	T5.2: Flooring
	T5.3: Decorating
Supplier1-8 ...	Etc. ...

Cycle 3: Task Dependency Specification – Once the tasks have been identified and approved in the same way as in cycle 1, the tasks need to be interconnected to show their dependencies and to ensure that notification of the completion of one task is communicated to a named individual responsible for the next task that can start at this point. The objective is to specify a realistic sequence of events that ensures a timely execution of the whole project – i.e. all the tasks identified. Each task therfore needs to specify a starting event and who needs to be notified when the task is complete. In addition to the tasks stated there are two special events, namely the start of the project and the end of the project. Again cycle 3 finishes when the organisation assigned with the role of management has approved the cycle. After the approval of cycle 3, a workflow platform is automatically produced based on the data enter during these three cycles earlier. The diagram below shows a task dependency specification for our current example:

The consecutive execution of these three cycles will allow the users to specify the overall project organisation and a single pass through this process should deliver a complete project specification. Approval processes at each stage will ensure that all parties concerned are in agreement about the modalities and this should in each case cause the specifications made to be locked. As it is intended that the parties will enter into agreement and collaboration on the basis of the project as specified with the tool it is important that no changes can be made except with the renewed agreement of those directly involved or impacted. At the same time there may be changes in circumstance that necessitate changes and there must be a way to make changes in an organised fashion.

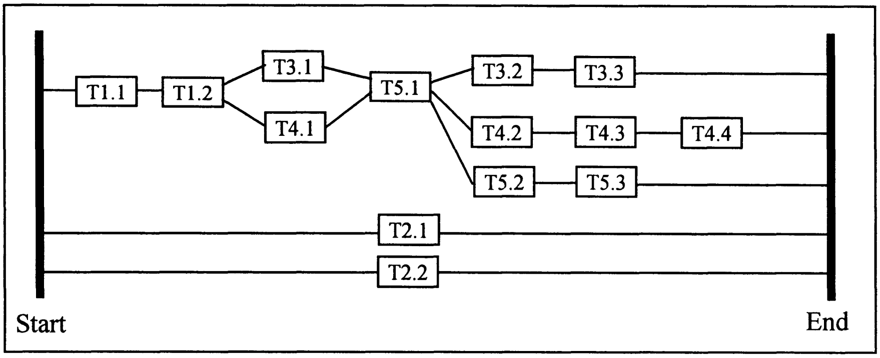

Diagram 2 – Task Dependency Specification for Sample Project

Following the successful specification of the three cycles of Stage 1, Stage 2 of this method will take the specifications and produce the workflow platform based on the tasks and their interdependencies. A great deal of emphasis has been given to the gathering of requirements in Stage1 and which is important as this is the design from which processes will be generated automatically. Tasks should represent a single job in each case that needs to be carried and where there is no good reason for further decomposition in to sub-tasks. Task group is a collection of tasks for a specific participant that are related to a particular area of responsibility of the participant concerned. Having defined tasks and task-groups we can start defining the term process within a project. Therefore a process can be defined a linear execution of tasks, with tasks having one and only one dependency.

The above method for designing and operating a semi-dynamic workflow draws on a method for building an office workflows, consisting of four different phases (Jackson, 1997):

a. **Entity Model:** The entity model is the data model; the back end of the system (database).
b. **Business Interaction Definition:** A process model that describes the interaction between the participants/people/users within the project and others the project interfaces with.
c. **Business Tasks Definition:** This is the phase in which the tasks are listed and the rules that govern each one of them are specified.
d. **Workflow Definition:** The management of tasks is defined as opposed to how they are performed automatically by the machine or leave the users to be able to choose whichever they want to perform.

In the semi-dynamic approach phase implemented by software engineering and therefore they are responsible for the Entity Model which is going to take place. The rest of the phases are supported and executed by a system, which uses the method presented earlier.

5. BENEFITS AND CONCLUSIONS

The benefits that result from this method are in our view threefold. Firstly, in terms of Organisational learning, important for the formation of the virtual enterprise. Participants learn about the totality of processes and their inter-relations and therefore have a better understanding of the overall project and their role in it. Secondly, the project planning and control will be more efficient. The project specification thus produced will describe all activities, their dependencies and timing and this will help the project manager to monitor progress and assess performance during the execution of the project. The assessment of critical paths is also made easier and backup plans can be made in order to avoid project delays or failure. Finally, end users will be able to design their own process support and modify to fit new requirements, by using a set of easy to use tools and generate a workflow platform without the need for in-depth technical knowledge and skills.

To conclude, we looked at the similarities between virtual enterprises and the traditional mode of operation of construction projects. Using the construction sector as an example we have presented an approach to help end-users design process support systems for virtual projects and that can be used also as a basis of contractual agreement and collaboration of the participants. The process support for virtual projects in our view needs to be flexible to allow changes to be made to the processes in the course of a project. To make process support more usable there is also a need for a systematic method that is easily understood by the users and which will guarantee a complete and comprehensive specification of the project. Tools need to support the method to ensure its proper execution with the added benefit that the system produced can be used as a basis for contract between the parties involved, detailing their roles and responsibilities as well as ensuring their effective interaction to the successful fulfillment of the project.

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