THE DEVELOPMENT OF A CONCURRENTLY ENGINEERED PROCUREMENT PROCESS

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Many of the problems encountered during the construction phase of a project are as a result of poor project development during the front-end phase of the project planning process. This paper examines the interaction of construction professionals with clients during the design and pre-tender stages and identifies poor client briefs, pre-project planning and uncoordinated design strategy as contributory factors to poor project performance. A macro model is presented, aimed at optimising the working processes within a construction project, developed with techniques adapted from the design sector of the manufacturing industry. Combined with an understanding of the complex personal interaction of construction professionals/clients, and the realisation that the better a plan and design is defined, the greater the reduction of risk, an enhanced approach to construction procurement is forwarded. The proposed new method of working involves using I.T., including networked information dissemination via current INTERNET technology, not only to enable concurrent design and procurement, but also to indirectly generate and develop an inter-professional/institution understanding between parties to the construction process. The proposed new method of working makes use of the ISO9000/1/2 requirement for in-house "*Document-Control-Centres*" which can provide ready made data-base repositories for specific project information which can be made accessible to other project partners.

Keywords: Internet, manufacturing, optimisation, procurement, risk.

INTRODUCTION

An improved means of communicating with clients to the industry has been deemed essential by many practitioners (Latham 1994). The products of such improved communication would be better informed clients, with more realisation of the intricacies of construction, and also improved detailed client briefs which would reduce the effects of design alteration after construction commencement. Access to the client brief by all professional parties involved in the project planning process is seen by many as an essential pre-requisite condition. Breakdown of the staged structure of the project planning process is also seen as a means of encouraging cross-fertilisation of ideas and collaborative relationships. Also it would reduce the risk of generating cumulative internal impacts, as individuals would be capable of accessing plans during development and also be in a position to critically examine decisions before they are made absolute. The introduction of an audit capability to complement the entire project planning process has been suggested by consultants. Introduction of such a procedure, it was envisaged, would create a more stable, risked reduced project plan and heighten the "*group/team*" confidence of all the parties to the project plan (Jamieson 1997).

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Maximising client participation in the design process from inception through to consideration of a constructor, is increasingly seen as an imperative for improved project success. The current accent on the team based approach to the building procurement process is likely to make client involvement and participation more critical than ever.

LEARNING FROM MANUFACTURING

Construction receives much criticism from the client base it purports to serve. Many critics argue that the industry is ignorant of client needs and should learn from the manufacturing sector as to how clients should be treated and products developed. Although construction is project based, with each project possessing unique characteristics, involving different suppliers and new construction teams in differing geographical locations, the actual underlying processes of project planning and development (design and construction) remains constant. Therefore the possibility to re-engineer such processes utilising adaptable techniques and methods which may be found in current use within manufacturing is explored.

Whilst it is not feasible for construction to adopt in total the practices of management and production within the manufacturing industry, there is a possibility for adoption and adaptation of certain practices which may be beneficial to the overall process of construction. Already the UK and Irish (in part) industries have adopted TQM and a new parental relationship approach to suppliers is yielding results for Japanese construction contractors.

Noted benefits of Concurrent Engineering Practices

Research was carried out in the form of interviews and a survey to appraise how Irish construction practitioners marketed their core services and interacted with clients. It was discovered that of the top 100 construction firms, 43% have in-house design teams. All rely to some extent on independent architects and design practices. Although some firms specialise in particular types of work, design and build services cover the full range of building and civil engineering work including water treatment plants, hospitals and roads. Several firms claimed that design and build provided one of the most effective ways of reducing building times and gave impressive examples of the reduction in time and cost of building shopping centres, industrial facilities and commercial premises. This was especially the case when they worked with regular clients whose standards and approach to business were well understood and where there was a close rapport with the professionals employed by the client. Clients confirmed the benefits of such close working relationships in achieving fast building times. A few companies were able to obtain over 50% of their work from long-term continuing clients, much on a negotiated basis. Continuing clients were able to insist on faster building and reduced costs. Such improvements to the project planning process were identified by clients as being attributable to the familiarity between the project-involved organisations. Contractors and designers identified much improved client-briefs due to familiarity with previous projects as being a major factor. Overall: conflict was reduced; there were no major surprises; responsibilities for design and construction were not split; and the original price was more likely to be adhered.

THE TOTAL DESIGN PARADIGM

Research, through interviews and literature review, established that manufacturing firms approach design in a fundamentally different way to construction professionals.

In manufacturing, much greater emphasis is placed on establishing the market/user need (in construction this would be the client) and incorporating this fundamental requirement into the "*Total Design*" process (Cooper 1994). At all future stages of product development, constant referral is made back to the market/user product brief. The total design process encompasses product, process, people and organisation. This is sometimes called the "*Product Development Process*" (PDP) (Pugh 1990) and is similar, in outline, to the project planning process used in construction.

All design starts with a statement of need. From this statement - the product brief - a "*Product Design Specification*" (PDS) is formulated - the specification of the product to be designed (Pugh 1990). Once this is established, it acts as the mantle that envelops all subsequent stages in the design core. The PDS thus acts as the control for the total design activity, because it places the boundaries on the subsequent designs. Conceptual design is carried out within the envelope of the PDS, and this applies to all succeeding stages until the end of the core activity, which is usually referred to as the "*Design Core*". The main flow of design information is an iterative process, constantly reviewed and updated if new concepts emerge. At all stages the design core activity is operated iteratively, yet can appear to be passed through sequentially. The main design flow is capable of reversing at any point in the design activity, and some iteration is inevitable, but operating the design core rigorously and systematically minimises iteration.

Iteration occurs because of change and improvement. This causes interaction between the design core and the enveloping PDS, leading to the evolution of the PDS. A PDS must be comprehensive and unambiguous. In construction, designers do not spend enough time defining the client brief with the client and do not produce a PDS as is common within the manufacturing sector. The PDS, as used in manufacturing, acts in part as an audit check to the design process.

DEVELOPMENT OF PROCUREMENT PROCESS MODEL

The research had identified a number of inherent inadequacies in the formal structure of the project planning process, especially in the areas of client brief preparation, pre-project planning, and design. Such inadequacies were cumulative generators of problems further along the project planning process, especially during the construction stage. Acknowledgement of the complexity of the passage of information between the diverse parties involved in the construction process indicated that the use of I.T. could act as an aid to an improved construction process. The next stage for the research was to develop a draft generic briefing and design (procurement) process model which would incorporate both a PDS type method of concurrent manufacture and I.T. into the model structure.

METHODOLOGY

It was decided that due to the complexity of the industry structure, and it's multi-component composition, that IDEF-0 methodology was the best suited to modelling construction processes. Professor E.K. Chung (1989) of the Computer Integrated Construction (CIC) Research Project, Pennsylvania State University championed this method and identified that to model construction processes a model needed to be: 1) hierarchical, 2) modular, 3) standardised in structure and 4) capable of representing the complex processes of the construction industry.

MODEL EVOLUTION

The model developed has two layers: **Layer 1** The Overview Model (Figure 1) provides an overall graphical representation of the complex inter-relationships (displaying inputs, project development, paths of communication, participant involvement & knowledge acquisition) within the project planning process. It utilises a "*total design*" approach (cyclical in nature) to project planning with input at each stage of the design core processes from the elements identified in the product design specification (PDS). Core input information, encompassing acquired "*experience*" is encapsulated within the framework of the PDS.

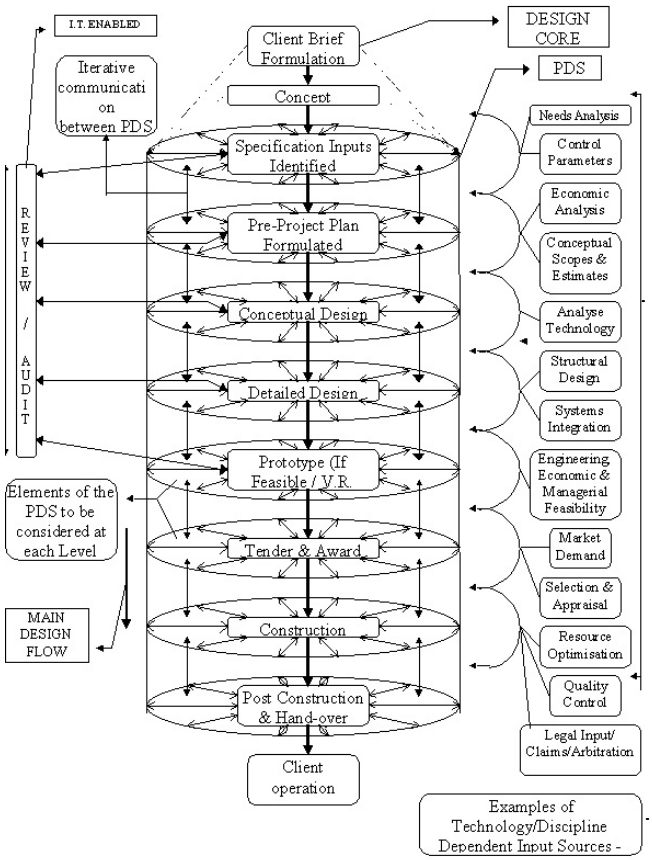


Figure 1: The overview model

Communication between PDS levels is iterative. The model represents the life-cycle of the project planning process up-to and including hand-over to the client. The Overview Model was presented at ARCOM 97 and further detailed information is available from the proceedings (Jamieson 1997).

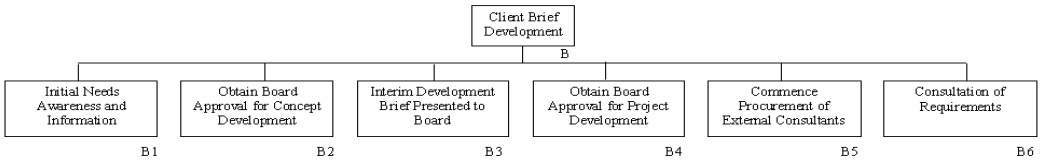


Figure 2: Primary and secondary levels of the model schematic only

Layer 2 The Procurement Process Model has been developed using the IDEF-0 methodology and concentrates on the client development of a construction project brief, including the retention and subsequent interaction with consultant professionals in the industry. Additionally the model has been extended to incorporate a hybrid version of the Sanvido Design Process Model (Sanvido 1990) which has been redesigned to incorporate knowledge acquisition features and communication channels enhanced with IT. In total there are 8 levels to the Process Model with 252 identified functions. Figure 2 demonstrates only the primary and secondary levels of the Model schematic with each level broken down further into sub-functions of the preceding level. (Further detail would be illegible within the format of this paper).

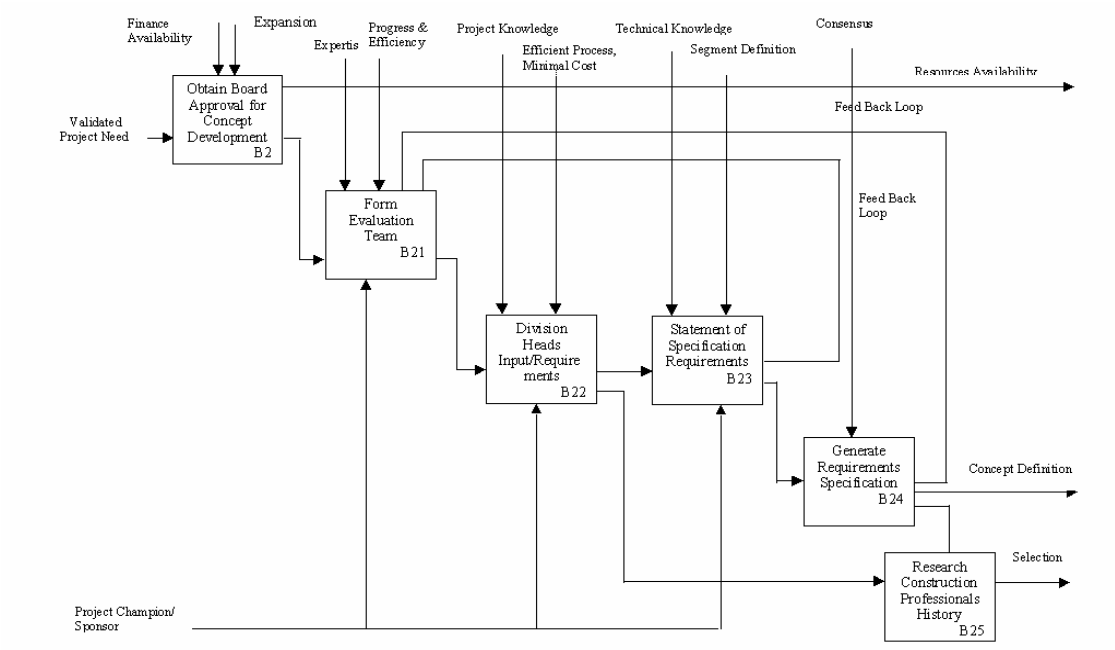


Figure 3: Example of function B2 board level approval for concept development

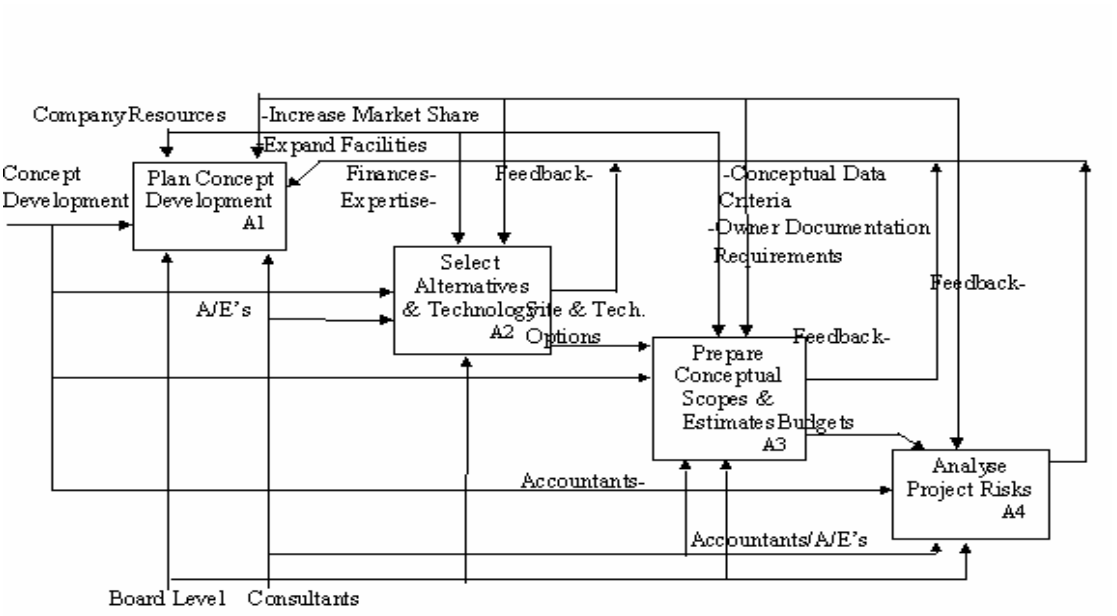


Figure 4: Example of concept development function

Each level diagram can be further decomposed to represent in greater detail with individual functions, activities, inputs, outputs, constraints identified.

PROCESS MODEL DEVELOPMENT

The procurement process model protocol developed provides a diagrammatic overview of the construction procurement process to the client organisation. Fundamentally, it enables the client to:

1. Step-by-step initiate the complex and abstract process of construction for a facility or other product they require.

2. It provides to the client a level of unbiased control, which previously was the domain of the chief architect, engineer or project manager.

Not only is each phase described but the inputs of how, when, where what and by whom are identified, with the necessary output and level of detail required also depicted. Such an overview provides to the client that which is often stated as being missing - that is an understanding of the consequences of alterations to the developing plans and the importance of reducing as much ambiguity of the requirements as possible and as quickly as possible. Also it provides the client with a basic interpretative means of developing a detailed specification. (A primary recommendation of the Latham Report)

PROCESS INTEGRATION

Additionally the process model interacts with that developed by Sanvido (1990) dealing with the process of construction planning, and can aid significantly to the selection of construction partners during the tender process.

DEVELOPMENT OF A PROTOTYPE PROCESS MANAGEMENT TOOL

The process model developed acts as a map to the client of the initial processes required to develop a successful construction project. With the use of computer technology and the application of newly developed commercially available, and most importantly simple-to-use software, the protocol can become the basis for an integrated project control tool (Model Browser) for use by the project management team, the client and all the other parties involved in any particular construction project.

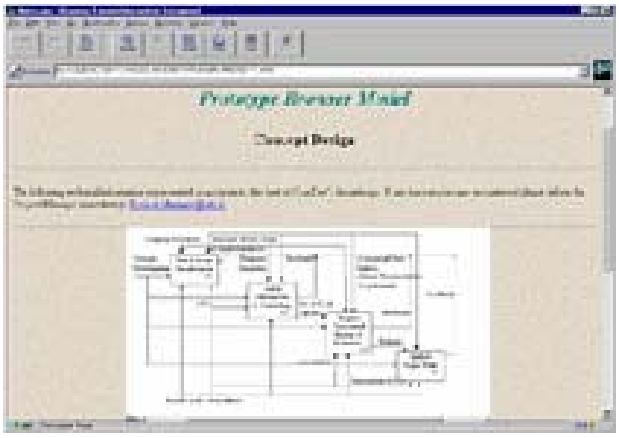


Figure 5: Prototype model browser

During the early brief formulation and planning/design stages of the construction process, broad estimates are the norm. The use of the model will assist in reducing the level of errors and increase the accuracy of predictions and schedules. The process model developed enables a client (be they first time, or experienced) to understand the requirements and processes for initiating a complex construction project. The model provides a basic generic concept package that can be customised to individual user needs. In construction terminology, the process model protocol is a "*method statement*". Developed using the basic IDEF-0 methodology, the IDEF-0 model layers and each activity were encoded with HTML code. The HTML code enables cross platform inter-communication. The model can be displayed on an INTERNET browser such as *MS Explorer* or *Netscape*, and the user can click on each activity to see its layered component tasks and inputs and outputs. In this way the user can track the process of establishing and developing a project plan and design and ensure that all aspects have been undertaken and reviews implemented when

recommended. What is now produced is a "*Base Electronic Method Statement"* for managing the briefing and design stages of the project inception.

As the model is now browser-enabled it introduces several new aspects to project management interface. Attributes of the use of a browser are:

1. The model can be viewed with a simple-to-use GUI, simulating an electronic "*brochure*" interface, which can be understood by even minimally trained personnel.
2. Secondly, the model, through the browser can be integrated with any text or graphically based data that is HTML enabled.
3. Thirdly, the model can be distributed on-line and therefore accessible to all members of the client's project team for analysis.
4. 4.The HTML enabled process model allows for information/data of a specific type at a specific level of technical complexity to be accessed by those who require it. For example, a services engineer does not need to know the entire project plan, only which jobs (activities) require his skills, where, at what time of the project, and which services plans/schematics are needed for that particular job (M. Hannus & P. Huovila of VTT Building Technology, Finland, refer to this process as "*information filtering*").

The use of HTML allows for the creation of numerous documents that can be enhanced with graphical and CAD images and data, that can be displayed, and altered via the browser, as well as allowing for on-line transfer of data when required. HTML allows standardised document transfer and project specific templates for forms and cover documents can be standardised for all project participants.

Project planning and integration

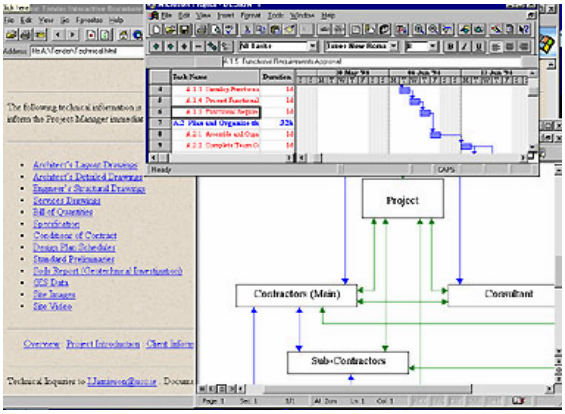


Figure 6: Accessing schedule information via the model browser

The HTML enabled model can be integrated into the real-time planning process. For example, activity B03 requires that an implementation plan be developed as a sub-process. The plan would be developed using a project management package such as *MS Project* and *MS Schedule*. Old versions of both of these programs can be accessed from the Model Browser through automatic initiation were the program is booted from a HTML command and the associated file, held in a sub-directory of the Model HTML data, is automatically opened into the program. Thus the Model browser allows seamless interconnectivity with the additional programs (provided they are installed on the host platform). The latest HTML enabled program versions allow the associated file to be read and accessed directly from within the browser. To introduce centralised multi-accessible control of the planning process required firstly that project specific data and information could be inputted, altered and managed via the Model Browser.

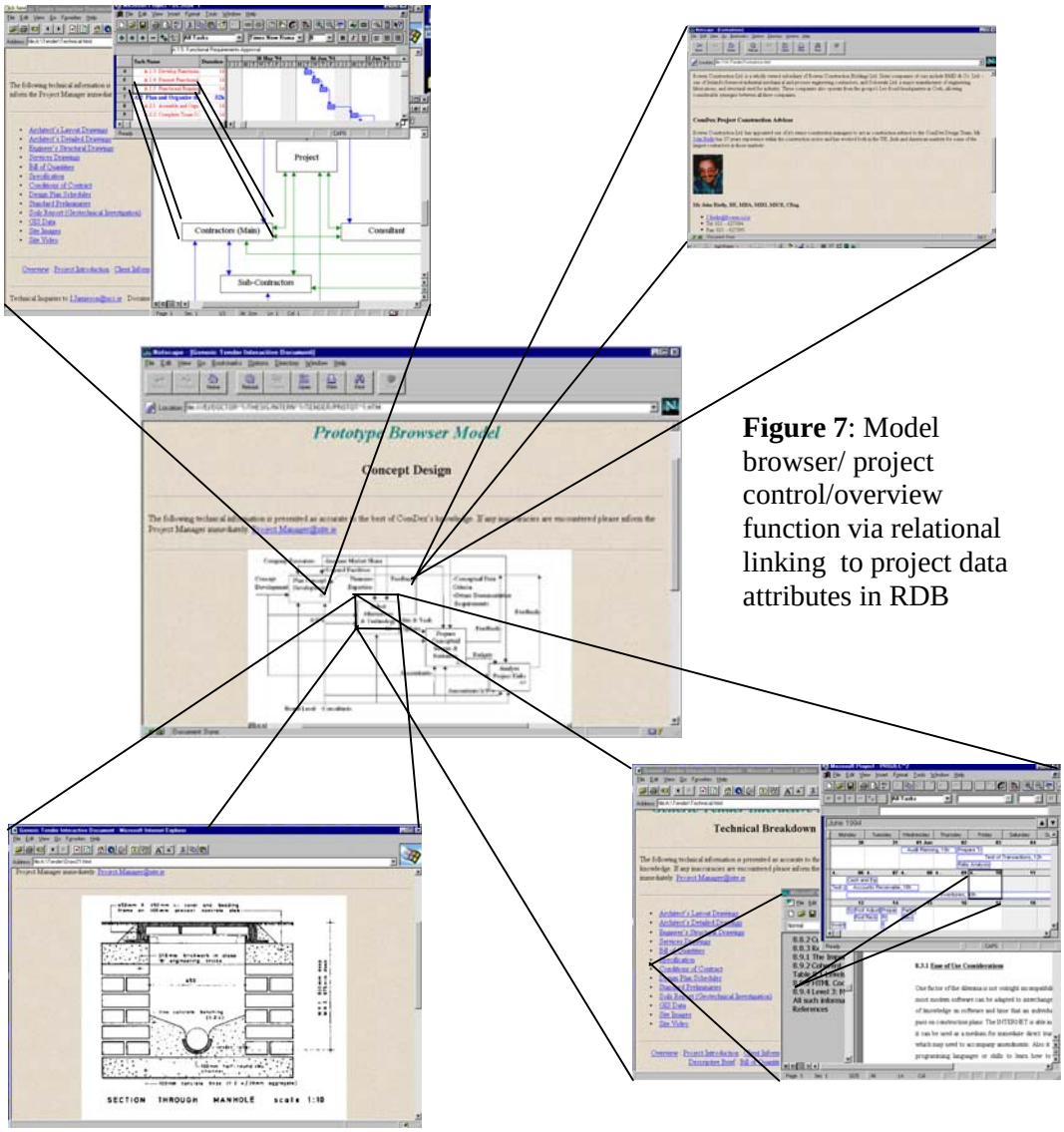
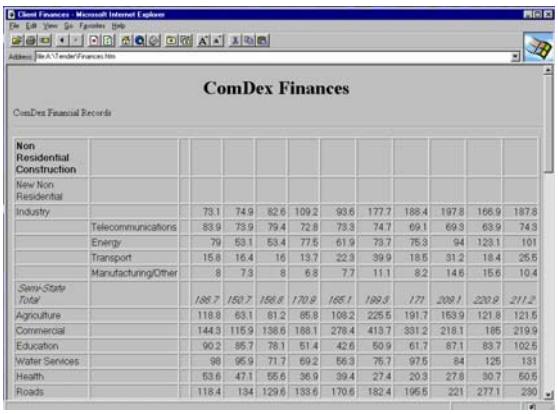


Figure 7: Model browser/ project control/overview function via relational linking to project data attributes in RDB

Relating activities, activity attributes to contract, locations, drawings, specifications etc.



ComDex Finances

ComDex Financial Records

Non Residential Construction												
New Non Residential												
Industry		73.1	74.9	82.6	109.2	93.6	177.7	188.4	197.8	166.9	187.8
	Telecommunications	83.9	73.9	79.4	72.8	73.3	74.7	69.1	69.3	63.9	74.3
	Energy	79	53.1	53.4	77.5	61.9	73.7	75.3	94	123.1	101
	Transport	15.8	16.4	16	13.7	22.3	39.9	18.5	31.2	18.4	25.5
	Manufacturing/Other	8	7.3	8	6.8	7.7	11.1	8.2	14.6	15.6	10.4
Semi-State Total		*186.7*	*150.7*	*168.8*	*170.8*	*165.1*	*199.8*	*171*	*209.1*	*220.9*	*211.2*
Agriculture		118.8	63.1	81.2	85.8	108.2	225.5	191.7	153.9	121.8	121.5
Commercial		144.3	115.9	138.6	188.1	278.4	413.7	331.2	218.1	185	219.9
Education		90.2	85.7	78.1	61.4	42.6	50.9	61.7	87.1	83.7	102.5
Water Services		98	95.9	71.7	69.2	56.3	76.7	97.5	84	125	131
Health		53.6	47.1	55.6	36.9	39.4	27.4	20.3	27.8	30.7	50.5
Roads		118.4	134	129.6	133.6	170.6	182.4	195.5	221	277.1	290

Figure 8: Project data generated on-line through RDB

In order to control and keep track of the documentation and the data produced via programs such as *MS Excel*, *MS Project* and MS *Schedule*, a database repository was necessary. To allow the Model Browser to not only display the documentation and project data developed at each activity stage but to allow for its manipulation, a database had to be capable of being accessed from the Model Browser and therefore also had to be capable of functioning on-line in real time. Introducing a relational database (RDB), that up-dates in real time, not only relates activities to specific locations, contracts and attributes, but also permits the project actors to access and up-date the project information instantly.

DATABASE ACCESS AND SECURITY

A trial development version of *MS Visual Interdev* which is an intranet/INTERNET development system, not too dissimilar from *Visual Basic* was obtained. *Visual Interdev* is not a design application but a program that allows the user to bolt a database into a Web application such as the Model Browser via simple drag-and-drop procedures. The program takes care of all the coding that is required and learning time for the program is minimal. Thus a database can be created using either *MS Access* or *Lotus 123* (for example) and used to generate Web pages direct to the Model Browser. In *Visual Interdev*, an ActiveX component is generated to which the user sets the attributes (in the same way as for a *VB* object) which acts as the interface between the Model Browser and the database. Once the database is in place, the *Visual Interdev* coding enables the Model Browser to have a single active Web page which generates new pages on the fly. None of the pages the user sees are real. They are just a stream of HTML that the server sends to the Model Browser. Thus the pages can not be hacked; the data can not be seen or used in any form other than how it is presented in the Web page. With the inter-connection of the Browser and a database established, project team members can view the project documentation and scheduling plans on-line. By accessing, say, the program scheduling plan through the browser enabled *MS Project* as described, a project team member could then up-date the plan and re-save the up-dated file back to the database allowing project team members to access the up-dated version immediately.

Alternatively, HTML forms can be used with fields covering the relevant topic areas. Once these electronic forms are complete they are directly linked to the database for instant inclusion. Additionally, the ActiveX controls are embedded in the HTML page and are thus browser independent. With the *Visual Interdev*, the ActiveX takes place at the server side, so all the browser receives is pure HTML. This function is significant to the security of the project information.

Project participant integration during project planning and design

The majority of engineering consultant practices within Ireland, some 82%, have achieved ISO900/1/2 accreditation which is an all encompassing quality assurance program for business operations and is supported by all governments in the EU and is seen by many clients to the construction industry as a pre-requisite for inclusion on tender lists. A key aspect of the ISO standard is the control of business information within the individual organisation. Each document is assigned a document number, reference number and an issue number (at a minimum, dependent on individual company protocol) to enable complete tracking, control and authorisation of a document and the information and data it contains. To undertake this task a company must introduce and develop a "*document control centre*" which acts as the hub and main processing area for the management, storage and distribution of all documents. Both electronic and hardcopy versions are kept of each document.

System expansion capabilities

The existence of such document control centres, with their ready made database repositories of information and data, relative not only to general company operations but also to individual client projects, lends them readily to inclusion on a distributed on-line network for individual construction projects. Taking the pre-construction and pre-tender stages of the construction process first, it is not inconceivable to develop a project specific distributed on-line virtual workplace. Utilising the process model

developed coupled also with the hybrid-Sanvido process model for design, the project management team selected by the client would be capable of developing a project plan, design, resources and finances and contracts in a concurrent process. Such a research project is now in place.

FUTURE DEVELOPMENTS AND PROJECT BENEFITS

The process models forwarded in the complete research act as the auditor to the process ensuring no stages are skipped, all inputs, actors and outputs are accounted for and correctly associated with individual activities. The potential inclusion of engineering consultants own in-house databases to the project development, through the developed Model Browser Tool, brings into the whole planning system the intangible qualities of acquired knowledge and experience. Reference to previous designs or projects of similar nature in similar geographical locations can reveal problems or solutions that may otherwise be overlooked by a newly constituted project design team, as not every project will utilise the same staff. With previous project data/information available at the inception of the project management team, early conceptual designs to the client's brief, can greatly increase the accuracy of estimates and design elements. Access by designers to the briefing process model would also allow them to view the early conceptual ideas developed in-house by the client prior to hiring of the project management team.

Thus it is now possible to see the recurring loops that can take place during the entire conceptualisation and design phases of the construction project made possible by the process model. Such loops enable all participants to be more informed and therefore more aware of the views, needs and objectives of their new project "*partners*". It also allows the designers, at every level, to be aware of the exact requirements of the client established within the Product Design Specification and up-dated shared data allows for increasingly accurate designs. Ambiguity is greatly reduced and accuracy increased. As the accuracy of the information and data increases and the design is developed along increasingly certain lines with constant referral to the client, possible through the Model Browser Tool, the element of project risk is reduced and therefore the likelihood of a successful project is increased.

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