

CIB W55



**International Workshop on
INFORMATION SUPPORT
FOR
BUILDING ECONOMICS**

Organised by

Professor Peter Brandon and Margaret Ashurst

Edited by

Dr. Les Ruddock

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L. Ruddock

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INTRODUCTION

The title of this report on Information Support for Building Economics raises questions about what we mean by “*information support*” and what we mean by “*building economics*”. These questions have no precise answers but the contribution to this report covers a wide range of analyses and viewpoints on both topics and on the combination of the two.

The research needed in the coming years to promote the application of information technology, seems to be related to the way of organising construction projects and the collaboration between the involved partners. We cannot view technology itself as a hindrance for improved application of information systems. The most serious obstacle for utilizing information technology in the construction sector is probably not computer technological nature but is due to norms, structure and culture in the sector. It is, in my opinion, vital for the construction industry that information systems for construction are designed to give continuously improved measures on productivity and quality aspects on construction.

This is an essential aspect of building economics. In my contribution to this report I attempt to encircle the concept of building economics by tracing back the work of the CIB W55 commission. Building economics may be characterised as the application of economic policy, science and techniques on the various fields of practice in the industry such as: Projects, Design, Construction, Housing, Infrastructures, etc. This gives an interesting platform for studying and developing the various field of work in this commission, of which one field is the information systems that support the strategic and planning issues of construction. The other two main fields of research in the Commission are the perspectives for the construction industry world wide as the one and the other is assessment and construction.

Research in the combination of information systems and building economics is dealt with in this report. It embodies an unavoidable and powerful combination of objectives in building research that may raise prosperous perspectives for the development industry.

The CIB W55 commission is pleased with this report, issued in collaboration with the Royal Institution of Chartered Surveyors, UK, to present the contributions of this workshop organised by the Research Centre for the Built and Human Environment, University of Salford UK.

Dan Ove Pedersen

Co-ordinator of CIB W55.

FOREWORD

The themes of this special CIB W55 Workshop are information support and an exploration of the leading edge technologies, which will provide this support for advances in Building Economics over the next decade.

The state-of-the-art papers presented in this volume represent a collation of wide ranging ideas about information support for Building Economics and both researchers and practitioners interested in the shape of information support and technology in the years to come will be interested in this collection of papers.

Interpretations of information support and the needs of the Building Economist vary considerably.

A brief description of each paper indicates this range of interests, which include such subjects as international data sources, international benchmarking, integrated construction and estimating systems.

In his preface *Brandon* gives a an overview of the development of informing technologies together with an interesting perception of future developments in this area.

Consideration of the importance of information technology in construction is a major theme. *Aouad* reports on the implementation of an information model, which can support the concept of 'computer integrated construction'. *ICON* addresses the issues of information modelling at the strategic and detailed levels, whilst *OSCON* is aimed at developing demonstrators for application with a central database. *Bang and Nielsen* explain the 'Telebuild' project for the implementation of IT on building sites. *Betts and Brandon* describe the UK Construct IT Centre of Excellence, a central organisation to promote co-ordinate and evaluate the use of IT in construction. *Yashiro* presents a discourse on the potential of project base development of IT tools for construction, whilst *Katovic et al* are concerned with IT application - an information system for monitoring and controlling activities associated with building maintenance.

Rosenfeld and Warszawski report on the state of automation in construction and *Sacks et al* deal with automated structural design.

Watson and Watson evaluate a document retrieval system in their report on the CAIRN project and *Watson and Perera* report on a case-based estimating system.

Kelly et al present a paper on the "International Benchmarking of Value Management" project, whose objective is to benchmark the performance of value management methodologies.

On information services, *Khosrowshahi* deals with the need to improve the accessibility to sources of information and investigates and catalogues the major sources of research information and *Ruddock* looks at information services available to the researcher concerned with macroeconomic issues. *Westcott et al* report on a project designed to facilitate information exchange for construction students and *Tempelmans Plat* deals with information on investment decisions.

Pedersen assesses the work of the CIB W55 commission on Building Economics over almost three decades and the roles that researchers have played in the development of information systems applied in the assessment of construction.

I am indebted to all the authors of individual papers, whose command of their respective areas of specialisation, has provided this volume, which will provide stimulus for thought and guidance on direction to its readers, and I am also grateful to the panel of reviewers who gave of their time and expertise so that these proceedings could be put together.

I must also thank my co-organisers of the workshop:

Professor Peter Brandon, Pro-Vice-Chancellor and Head Of the Research and Graduate College
and

Margaret Ashurst, Executive Officer, Department of Surveying
without whom the workshop could not have gone ahead.

Les Ruddock

Research Centre for the Built and Human Environment,
University of Salford

PREFACE

BUILDING ECONOMICS AND THE INFORMING TECHNOLOGIES

BY

PROFESSOR P S BRANDON

PRO-VICE-CHANCELLOR

UNIVERSITY OF SALFORD

"We are all beginning another great journey. We aren't sure where this one will lead us either".

Bill Gates.

The Road Ahead

The Penguin Group, USA 1995

Gajaraj Dhanarajan, President of the Commonwealth of Learning, made this statement last year: "We are the first generation that know for sure that we do not know what the future will be like". The pace of technological change has been so great, in the last decade, that businesses, nations and individuals, are having to rethink the way in which they behave and work in all aspects of their lives. Nations are having to come to terms with the fact that the geographical boundaries that defined them previously, are no longer relevant when the new information highways do not recognise such boundaries. Businesses are beginning to understand that they are part of a global economy and interdependent upon each other within this new context. They cannot ignore the impact of external competition to their organisation, management and activity. Individuals too, now have access to the widest range of knowledge and information that any group of persons has ever known in the whole of history. The internet provides all of us with access all over the world, and this is forming new relationships, new perceptions, and new views of what the future might hold.

The subject of Building Economics is not immune to such changes. It too must learn to adjust and adapt to the new world. The human limitations which were the origins of many of its techniques are now disappearing, and the data on which so much depended, is now more freely available. Christopher Evans, in his book "The Mighty Micro", Gollancz, 1979, drew attention to the fact that the professions were in terminal decline. He took the view that these professions were exclusive repositories of information. This information is the power base from which they work and from which they get their status. As the information becomes more public and more accessible, then the

professions will begin to lose the mystique, which has kept them in their present position. Those professions which guarded the knowledge relating to the building cost and design economy, are finding themselves less exclusive as the information becomes more readily available through the information superhighways, and through the computer-aided design methods, which often include cost as part of their database. This raises real challenges to the future of those professions, and to the subject of Building Economics. Can such a subject stand alone from the total management of the construction process in which it plays such a part? Will the span of control exercised by a Project Manager now encompass the cost knowledge which can be gained over the superhighways, without the necessity for an intermediary? Will the routine work of computation, sorting and classification be something which is relegated to a computer system with technician support? To what degree can the judgements exercised by a Building Economist be encompassed within a knowledge based engineering programme on a computer?

It has been interesting to observe the development of the Information Technology alongside the development of Building Economics over the past three decades. Much has been said about the information revolution, but the pattern of development has been one of automating the manual processes involved in estimating cost planning and cost control. The benefits of speeding up the process and of reducing human error has been beneficial to the subject, but these have been marginal because of the attachment to the previous techniques. So where are we aiming? It could be argued that the ultimate computer programme will be one that is close to the attributes that we normally expect from human intelligence and human behaviour, but with the added benefit of precision, capacity, and computational ability of the machine. As the information revolution advances, it is clear that geographical location is not a consideration. The concept that we needed a centralised database, with a gathering together of all project knowledge in that database, has been superseded by the concept of objects held over communication networks in different locations which can be accessed as and when required. For building objects, there seems to be no bar to holding the cost of those objects on the internet, linking them up to the objects in a different location, and then using them to provide estimates and control mechanisms normally related with Building Economists. I am conscious that the above relates to design economics focused largely on the building as an object. The other aspect of Building Economics, where models attempt to predict future economic performance of industries and of firms and organisations, also require information which has to be analysed, classified and used in an informative way for the benefit of those who need to make decisions, which are of a more strategic nature. The principles however are the same, Information Technology will permeate all that we do.

Technologies which have led to these challenges to our previous way of thinking are an important part of the change process. However they are of little value, unless we can do something with the information itself. "Cost Planning of Buildings", (Blackwell Science 1991, P257) I suggested there were five possible ways in which we could improve our cost information. These are:-

- Provide cost information quicker

- Provide more information so that a more informed decision can be made
- Provide more reliable cost information, which will introduce more assurance into the decision making process
- Provide information at an earlier stage in the design process
- Provide information in a more understandable and useful form

If we can develop new techniques to suit the new technologies, then it is likely that we will achieve the improvements we seek. Even existing techniques can be enhanced by the power, reliability and accessibility of the computer but we will not realise the full potential of the machine. If we are to have a real breakthrough, we need to consider what we need to do with the information, to ensure that the technology can be used profitably. There are a number of key issues which we have to address. These can be summarised as follows:-

- Our modelling techniques must be improved, so that we can identify all the key features which reflect building cost. Now that we are no longer bound by the limitations of human limbs and the speed at which humans can work, we can think of new ways in which we can model construction cost. In particular, we need to consider the issue of process within our models. So many of the techniques we have developed relate to physical objects as placed in the building but it can often be the organisation and process of a building project, which have the major impact on its cost.
- Standardisation of these models is absolutely critical if we are to take advantage of the information highways and exchange information without ambiguity. Information Technologists will argue that this is a temporary requirement because, in time, machines will be able to interpret the data that is fed to them in a similar way to human beings. However this is some way off, and in the meantime we can speed up the process and obtain the benefits by standardising our procedures. It will also enable us to act across traditional boundaries, either national or professional, which had previously been a hinderance to us. A number of organisations are already working on this matter, but further developments needs to be undertaken to suit the particular needs of Building Economists.
- There must be a willingness to cooperate on the development of our technologies and techniques. If we are going to reap the benefits of the information revolution, we must work together for this mutual benefit. It is not possible for one firm to develop a particular technology and expect the rest of the world to follow. The possible exception to this might be Microsoft, or one of the major software houses who use their market power, but that does not appear to be a strong possibility at the present time. Hence we need to get government and industry working together to develop the tools that will allow us to reap the benefits quickly. The role of government is

critical in bringing together the parties and providing the pump priming investment.

- We must seek ways of reducing the cost, not only of the technology, but the means by which we gather information and place it in the machine. Perhaps the major cost of running software systems is the data capture required to provide the benefits we desire. As manual systems transfer to automated systems, then data capture will become easier, but nevertheless there is considerable research to be done to determine how to do this efficiently and effectively.

There have been a number of attempts to provide a smooth transition from manual processes, to those processes engaging Information Technology. However, looking back over the last thirty years, it is possible to see a stop/start pattern, which is not conducive to the well being and future benefit of the construction industry. A familiar pattern is for there to be a new technology brought to the market, a considerable hype which leads to rapid investment by research funding bodies, too high expectations in terms of deliverables, disappointment sets in, investment is withdrawn, and a period of some years elapses before the technology is taken up again and used profitably. It must be in the interest of all of us to avoid this pattern and to enjoy a smooth transition and take up of the technology, related to the user need. A recognition of this problem and a method of managing the problem is essential.

In the paper in this volume written with Martin Betts, we have identified key areas or themes, which might form the focus for research in the future, harnessing Information Technology for the construction industry. These themes are also relevant to Building Economics. The difference may be that Building Economics may well find itself subsumed into design activities, at least as far as cost forecasting is concerned. In management, the control of cost might be subsumed into the project management activity for the construction of the building. It will be interesting to see what patterns develop in the structure of the industry, caused by the new technology over the next twenty years. If we were painting a picture of a typical design process in the future, it may be as follows:-

- The brief would be prepared using a knowledge bank of information from previous projects and the needs of a client.
- The brief would be interpreted by the machine to provide a framework within which the creative designer supported by the machine would investigate the spatial arrangement and massing of the building.
- This spatial arrangement and massing might be done using Virtual Reality techniques, whereby the participants in the design process gather round a table, in which the objects which form the building are projected onto the horizontal surface and viewed in three dimension with 3D glass. They design and create the building by manipulating the virtual objects and then they have the opportunity to 'walk around' the building they have created using a virtual environment to test

it's ability to meet the clients demands. The objects themselves will have knowledge and data attached to them, so that it will be possible to focus on the cost of those objects and investigate the composite costs of the building at the touch of a button. The above will change the whole nature of the design process and may well begin to de-value the role of the creative designer for routine buildings. However it is unlikely that the human flair for innovation thus creating new and interesting design for one off projects will be challenged for the foreseeable future.

- As design develops the specific objects that comprise the building will be collected from remote places via the internet, placed on the table and then positioned in the virtual building model. That will allow further refinement of cost, because each object will come with an expected valuation.
- At each stage it will be possible to evaluate, using knowledge based systems, the building from different perspectives, whether it be structural, management, day lighting, energy, cost etc, and visual output of this evaluation of this can be provided in a more interesting and useful way.
- The detailed model thus created will be used as the basis for the tender, which will be arranged over the internet with the contractors organisation interpreting the model from their own management perspective. This will allow their own particular management processes to be applied to the design. (This assumes that open tendering or selective tendering will still be appropriate. It may be that there will be no need to have a general contractor undertaking these tasks in the future, and that one management team can control the whole process, engaging suppliers and sub-contractors supported by the machine).
- Eventually the building will be constructed with the machine automatically informing suppliers and sub-contractors of when they are required on site and their resource needs for the activities in which they are engaged.
- The progress on site will be photographed and checked against the virtual image of the building and automatic evaluation for payments and progress will take place.
- It will be possible for site workers to access the virtual image in three dimensions from the site, to ensure that they are building the building correctly, or to check that they have the full information in three dimensions regarding physical objects.
- At each stage throughout the design process and construction, a knowledge base will be accessed to ensure compliance with regulations and requirements.

- At the end of the project, a virtual model of the building will become the base for any future adaptations in the future. It will include information on the cost of items, the manufacture, the method of assembly, and the quality control that was exercised. This will form the archive on which future adaptations and change will take place.

This outline procedure is not unrealistic within the next ten years. Whether it will become a reality depends on the willingness of funders to support applied research and the willingness of all of us to accept some form of standardisation and collaboration together. That will, appears to be growing year by year. Therefore it is difficult to predict the speed at which such technology will develop. Of this we can be sure, it will happen one day. The barriers are not those of technology, but of finance, human energy and endeavour, and a vision which will bring us together for mutual benefit.

The papers included in this volume are there to demonstrate the knowledge that is already there in various countries throughout the world, and to provide examples of current work that is being undertaken. The Centre for the Built and Human Environment at Salford has played a major role in developing techniques and technologies, which support the UK Construction Industry. These include new protocols for the construction and design process, intelligent systems, virtual environments, and integrated databases based on true object-oriented technology, which provide the platform for future development. We hope we can be of service to our industry, not only in the UK, but worldwide for many years to come. I trust these papers will provide new insight which will be of benefit to all who are interested in this remarkable information revolution, which is affecting all our lives.

INTEGRATION: FROM A MODELLING DREAM INTO AN IMPLEMENTATION REALITY

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Abstract

Many modelling efforts have been undertaken in the construction sector in order to develop information models which can support the concept of “computer integrated construction”. However, very few attempts have been made to implement such models. This paper argues that by adopting the prototyping approach, models can be developed and implemented in a gradual and evolving way. The work presented in this paper is based on two research projects undertaken at the University of Salford. The projects described in this paper are ICON (Integrated Construction) and OSCON (Open Systems for Construction). The experiences learnt so far from these two projects are highlighted and discussed. The ICON project addresses the issues of information modelling at the strategic and detailed levels with its primary aim to investigate the feasibility of establishing a framework for integrated information systems in the construction industry, whereas OSCON aims at developing demonstrators for applications such as architectural design, cost estimating, and planning integrated within a central database. The main contribution is the development of a set of interfaces between an object oriented database (object store) and commercial products such AutoCAD 13, Superproject, and netscape navigator in order to allow the sharing of information and to allow for more user friendly interfaces using virtual reality technology. The ICON and OSCON projects are very much interlinked, and this has allowed for a transitional phase from modelling into implementation. As both projects are steered by industrialists with representatives from the major professional institutions (RICS, RIBA and CIOB), it was easy to adopt the aforementioned prototyping approach where models and demonstrators were driven by the industry needs, and quickly implemented and tested. The iterative approach of re-visiting the information models for better demonstrators implementation will be described. In addition, the identification of case studies and implementing them has been of great help. This approach has allowed the models to expand naturally resulting in much improved demonstrators. This will also be described during the course of this paper.

1. Introduction

The undertaking of a building project involves a large number of participants from different construction disciplines. This results in the production of a huge quantity of complex information which is often managed inefficiently. In order to improve efficiency and enhance the integration of information within the construction industry it is necessary to establish an appropriate information structure. This paper reports on the modelling and integration of construction information within the context of integrated databases as a means of improving integration. The contextual and conceptual modelling of project integrated databases is covered. The feasibility of developing software demonstrators is also addressed.

Improving communications in the construction industry through the development of contextual and conceptual integrated models is an urgent task. This industry has suffered in the last few decades a lack of proper exploitation of the emerging information technology methods and tools. Systems have been developed in the past to meet requirement specified as end products. Not much emphasis on the process itself of producing these systems has been considered. Such a process could be highly complex as it entails factors such as environment, cost and time implications, etc. However, the technology in terms of software and hardware is available now to facilitate such a task. It is vital, nevertheless, to stop thinking in terms of end products when developing information systems. It is the whole process which should be considered if we want to avoid developing ad-hoc applications of limited use.

One of the main obstacles in modelling information and achieving integration in the construction industry is the large amount of information and the complex relationships between the information. In addition, when a business is analysed, the problem domain is often too vast to understand using traditional techniques such as data flow diagrams. Dividing complicated processes into manageable chunks aids the understanding of complex situations. It is therefore vital for the construction industry to employ techniques which allow the scoping of the area being analysed. This ensures that integration is achieved within a framework rather than on ad-hoc basis.

In addition, it is of crucial importance to implement models in the form of prototype demonstrators. This will help to identify and overcome problems occurring at the implementation stage. This will also help in refining and improving the models supporting a particular application.

2. Previous Work

A large amount of work has been carried out in the area of Computer Integrated Construction (Sanvido et al, 1991, Howard 1991, Bjork 1991, Reinschmidt et al 1989). Some form of integration has been

achieved through product modelling undertaken in Scandinavia, France, USA, Netherlands, UK (Brandon & Betts 1995). It is the author's view, however, that product modelling on its own is not enough to establish an integrated environment. It is the combination of product/design, procedure/contract and process/production modelling which should establish the structure of the integrated database. Integration through the establishment of standards data exchange is also progressing under various groups: EDICON and AEC STEP Committee (Brandon & Betts 1995, Bjork and Wix 1991). However, a common standard is not currently available.

In addition, there have been many efforts undertaken within the context of construction information modelling. These include the work done within STEP, COMBINE, ATLAS, COMBI, CIMSTEEL and other projects (Svensson & Aouad 1997). The recent IAI (International Alliance for Interoperability) initiative is also involved in modelling together with devising a library of exchangeable objects. Some efforts have also been undertaken within an implementation context. These include, South Bank University (Tah et al 1996), CIFE (4D project, Fischer 1997), and Taylor woodrow and SPACE (Al-shawi 1996). The work described in this paper is the result of five years of research which involved both modelling and developing prototypes software. The core of the development is an object oriented database with VR as its interface to information stored in this database. This is a novel approach which gives the construction industry a real opportunity to invest in project integrated databases.

3. ICON/OSCON Background

The ICON (**I**nformation/**I**ntegration for **CON**struction) is a research project sponsored by the EPSRC (Engineering and Physical Sciences Research Council) undertaken at the University of Salford in the United Kingdom in order to define contextual and conceptual models for an integrated database (Aouad et al 1994). This project mainly deals with developing a framework and methodology for design, procurement and construction management. ICON's primary aim to assess the feasibility of establishing an integrated database for the construction industry.

OSCON is a DOE funded project which mainly aims at developing demonstrators for applications such as architectural design, cost estimating, and planning integrated within a central database (Tracey et al 1996). The main contribution is the development of a set of interfaces between an object oriented database (object store) and commercial products such AutoCAD 13, Superproject, and netscape navigator in order to allow the sharing of information and to allow for more user friendly interfaces.

Both projects have been developed by a group of researchers from IT and construction backgrounds, assisted and guided by a steering group of industrialists and representatives of the major professional institutions in the UK (RIBA, RICS, CIOB) and representatives of building standards (NBS). The

prototyping approach has been adopted for both modelling and implementation. This has allowed the models and applications to be driven by the industry needs.

3.1 The ICON/OSCON model

Figure 1 gives a schematic representation of the model adopted by ICON/OSCON. It is clearly shown that ICON deals with high level modelling whereas OSCON addresses the issue of implementing models using object oriented databases. This model will be described in the following sections.

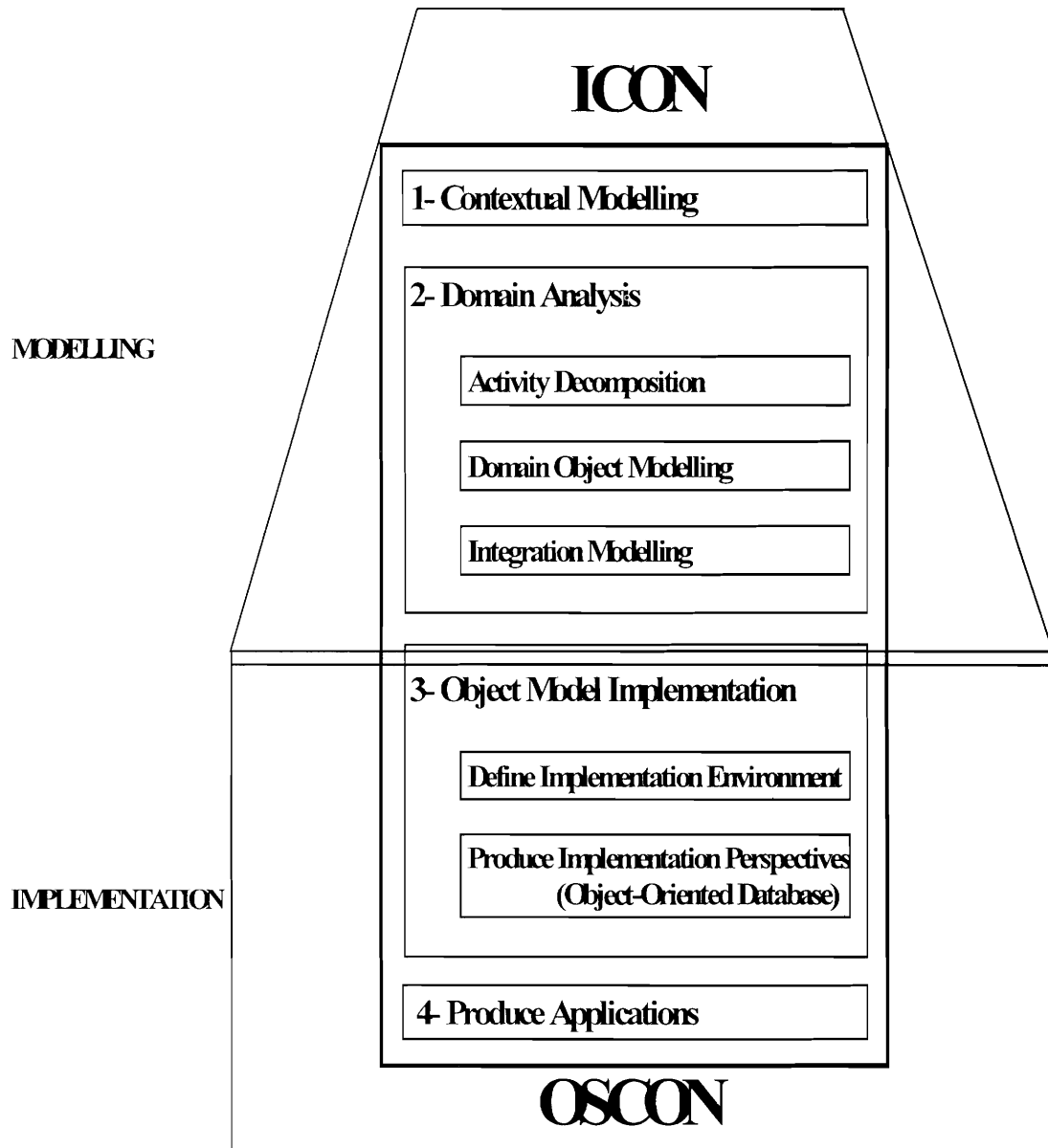


Figure 1 The ICON/OSCON Model

3.2 Contextual modelling in ICON

Contextual models help in defining areas or pools (top level models) of information which can be automated or integrated. For instance the two applications of planning and estimating which tend to share a large amount of data should be clearly identified using the techniques described in the following section.

The ultimate result of contextual modelling is the definition of a top level model of areas or activities which exist independently of the nature of the discipline involved. The technique described in this paper is that of clustering and affinity analysis matrices using the Information Engineering Facility (IEF) CASE tool which is based on the Information Engineering Method (Martin 1986, Reinschmidt 1989, Richmond 1992, Aouad et al 1993) . Using such techniques, the analyst can map the functions to be performed by the business/industry/project against the information required to support these functions in the form of a matrix . Every function is then analysed in order to establish whether it will Create, Update, Read or Delete the data associated with it. The result of such a task is known colloquially as the CRUD matrix.

Following the establishment of the CRUD matrix, a clustering algorithm can be used to cluster areas rather than functions (highly populated areas within C, R, U, D) to show areas which are suitable for automation and integration. This mechanism is very helpful in prioritising potential areas in terms of information requirements. It also helps in identifying departments which can share information about certain aspects of a project. The problem of communicating between several firms in the construction industry can be facilitated as areas of responsibilities can be highlighted using the matrices.

Another technique which can be used is to cluster areas suitable for automation and integration using the affinity matrix. This matrix is based on affinity numbers which can be established between functions sharing the same information. The IEF uses a computerised algorithm to calculate the affinity between the functions . It then groups them into clusters of high affinity (See Fig 2). Functions of high affinities are identified as potential candidates suitable for integration.

Matrix Cluster Analysis

Cell Values:																										
1	2	3	Business Function	ESTABLISHING CONST PROGRAM	DETERMINING CONST TASKS	MANAGING CONST PLAN	ISSUE INSTR AND VARIATIONS	EVALUATING WORK	SETTLE FINAL ACCOUNT	MANAGING CONST COSTS	MANAGING DOCUMENT CHANGES	ASSEMBLING DOCUMENTS	PRODUCING FINAL DOCUMENTATION	COMMUNICATING DOCS AND CHANGES	PREPARING TENDER DOC	SUBMITTING OFFER	PERFORMING TENDERING PROCEDURE	SUGGEST PROCUREMENT SYSTEM	MANAGING BUSINESS AREAS	COORDINATING MGT FUNCTIONS	EST CLIENT REQ	PERFORMING FEASIBILITY STUDY	CARRY OUT STRUCTURAL DESIGN	CARRY OUT TECHNICAL DESIGN	CARRY OUT SPATIAL DESIGN	
4	5	6																								
7	8	9																								
Business Function																										
MANAGING DOCUMENT CHANGES				6	9				6	8	9	6	5	5												
ASSEMBLING DOCUMENTS					5						6	9	9	9	6	5										
PRODUCING FINAL DOCUMENTATION								6		5	9	9	9	6												
COMMUNICATING DOCS AND CHANGES					5					5	9	9	9	7	5				5	5						
PREPARING TENDER DOC											6	6	7	9	8	7										
SUBMITTING OFFER												5		5	8	9	9	5								
PERFORMING TENDERING PROCEDURE															7	9	9									
SUGGEST PROCUREMENT SYSTEM																5		9	5	5						
MANAGING BUSINESS AREAS									6					5				5	9	9						
COORDINATING MGT FUNCTIONS														5				5	9	9						
EST CLIENT REQ																					9	7				
PERFORMING FEASIBILITY STUDY																					7	9	7	7	7	
CARRY OUT STRUCTURAL DESIGN																						7	9	9	9	
CARRY OUT TECHNICAL DESIGN																						7	9	9	9	
CARRY OUT SPATIAL DESIGN																						7	9	9	9	
FINALISING REQUIREMENTS																					6	7	9	9	9	
ESTABLISH MAINTENANCE POLICY																						5	8	9	9	
EST AND OBTAIN PLANNING REQ																										

Figure 2 an ICON affinity matrix (Aouad et al 1996)

It is worth mentioning at this stage that the production of the CRUD and affinity matrices is probably impossible to be carried out manually specially for large organisations. However, over the last decade, CASE tools which can automate the development of information systems generally, and matrices in particular, have started to emerge.

In the past, contextual information modelling has tended to concentrate on either the data or process aspects of information independently of each other. The information presented in the matrices,

however, indicates the interactions between the processes and the data. The use of such a two-dimensional technique can be helpful in establishing the ways in which processes act on data and in discovering what changes are made to the data. Use of such an approach could ensure the design and implementation of appropriate information structures which will improve the integration of information within the construction industry as a whole. Figure 3 shows the high level contextual model derived from the matrices.

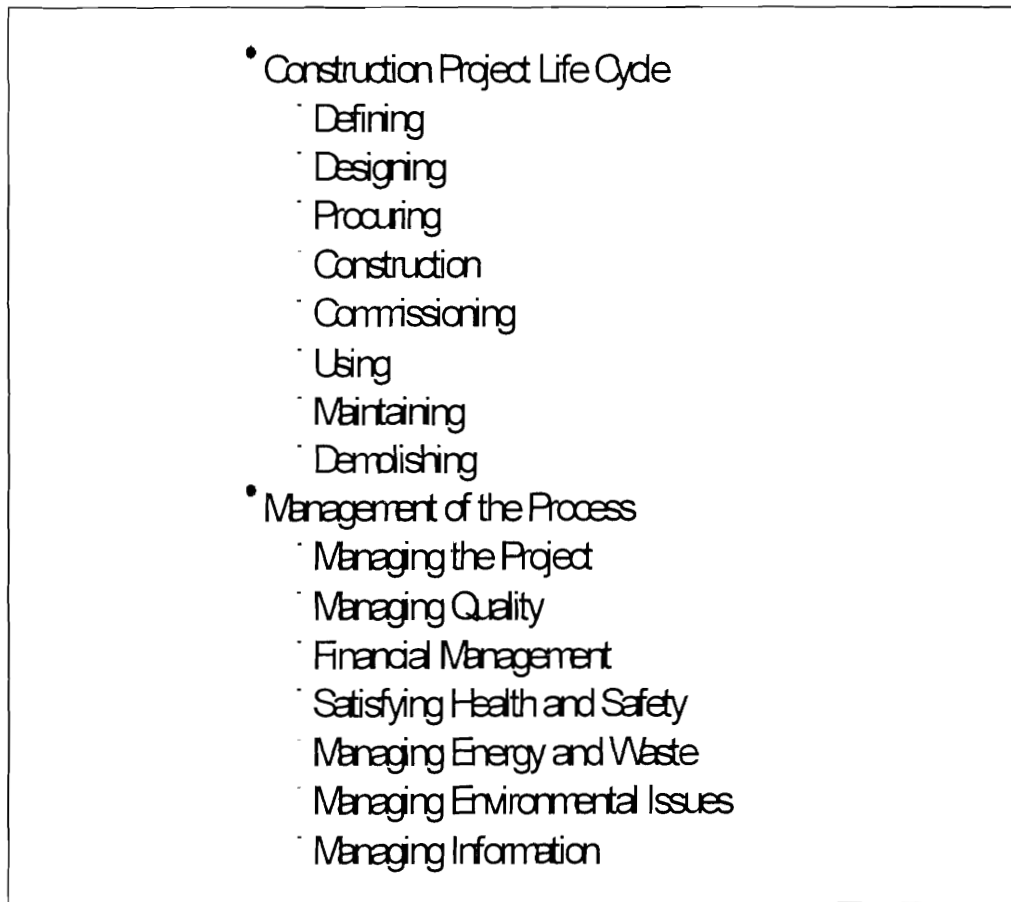


Figure 3 ICON high level contextual model

3.3 Conceptual/Domain Modelling in ICON

Once a contextual model for the integrated database has been established, the next phase of modelling was concerned with the conceptual modelling of the areas of design, procurement and management of construction using object oriented techniques (these areas are within the scope of the ICON project). Having performed an activity decomposition, a stage has been reached where object oriented models have been added. Unlike traditional data modelling techniques, the object oriented paradigm models reality as a collection of objects talking to each others using messages. The behaviour of one object may result in changes in another object. This is done through message sending. The object oriented

paradigm also supports the notions of encapsulation, abstraction, inheritance and polymorphism (Martin and Odell 1992, Aouad et al 1995) which were considered as a must to handle the complex task of information modelling. Encapsulation permits objects to have properties (data) and actions (operation). For instance, an object "beam" can have properties such as "length", "width", etc and behaviours or actions such as "move beam", "calculate load on beam" etc. Abstraction allows the analyst to abstract information according to requirements. For instance, the information about a beam can be abstracted in terms of properties, shape, materials, etc. Inheritance allows information in the parent object (beam) to be inherited by the child object (Cantilever beam). Polymorphism allows objects to have one operation which can have different implementations. For instance, an operation "calculate area" can be attached to an object called "beam". However, the implementations of this operation are according to whether the beam is a "rectangular beam" or "T beam", etc.

Another major benefit of object orientation is the support of the notion of reusability. Using such a notion, integrated databases can be developed from re-usable object oriented components which can be assembled as required. This is very similar to the way a building designer uses re-usable plans that can be configured to his/her requirements.

Object modelling captures the object types (data) within the modelled activity along with the relationships between objects and the operations which can be performed on the objects. In the ICON project, each object model represents a perspective of the information required by a certain domain/activity. In theory, the overall object model for the integrated database contains all the domain/activity object models. Such a model is beyond the comprehension of the user. It is the domain/activity object model which is of concern to a specific user. Fig 4 describes a conceptual core object model for an integrated database. In Fig 4, rectangles represent object types such as component, task, etc plan. The lines joining object types represent relationships. For instance, the line joining design and component defines the relationship between these two object types. This relationship can be read as: a design has one or many components and a component belongs to one design (small line represents one occurrence whereas the crow's foot defines many occurrences).

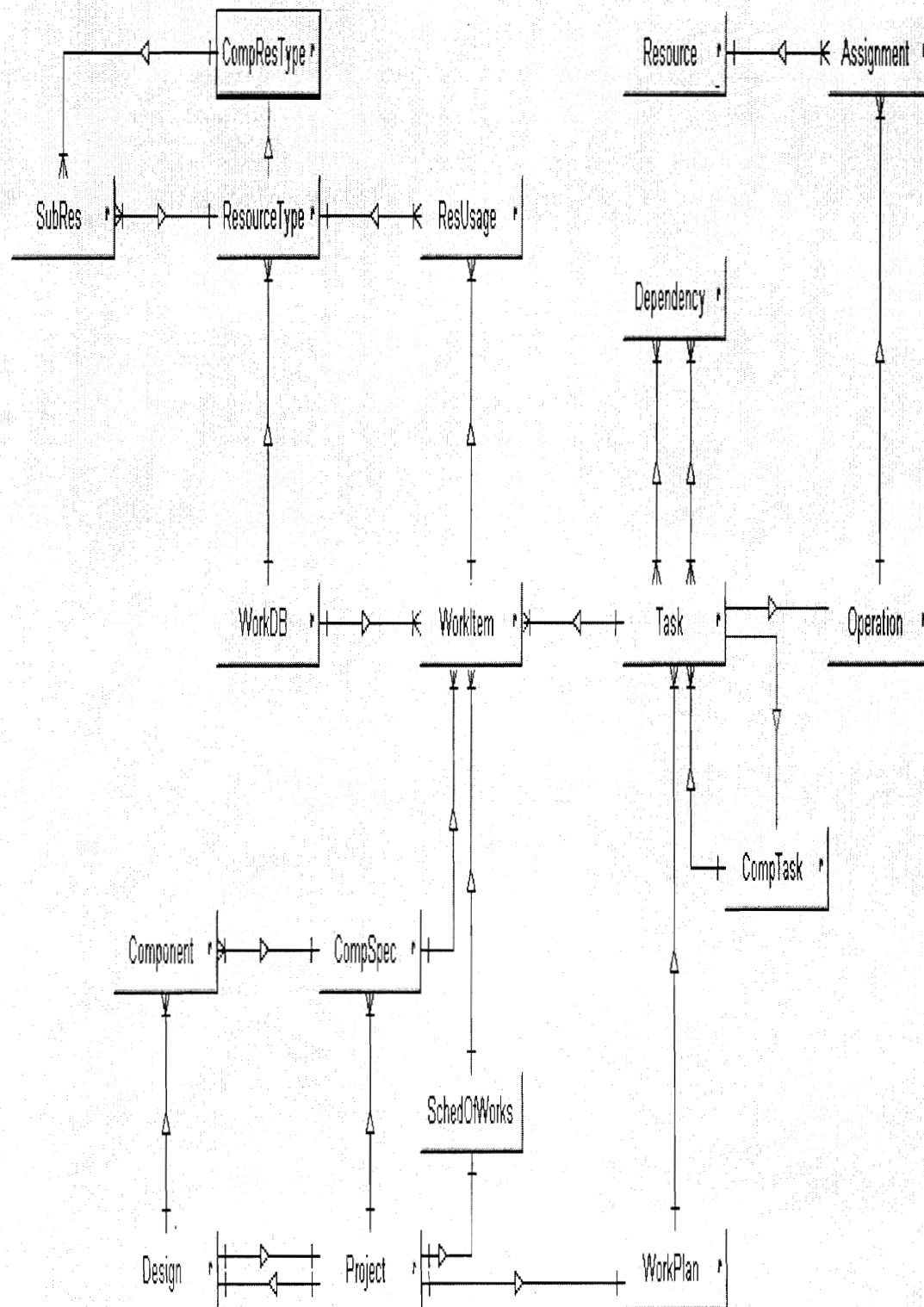


Figure 4 Core model

The core model contains core concepts which are required by the applications incorporated within OSCON. A key concept in the core model is the component and component spec as they are mainly used in defining the work items used by estimating and operations used by planning. Other researchers look at building core models within the context of four concepts: product, process, control and resources. This is used by (Wix and Storer 1996) and (Bjork 1991) and (Luiten et al 1993) in the definition of IRMA. In the OSCON model, the concepts of product, resource and dependency (control) are generic and can be used by other industries or disciplines. It has to be stated from the OSCON's experience that the definition of a core model facilitates the implementation of integrated applications.

3.4 Object model implementation in OSCON

The model developed by ICON has been implemented in the object oriented database. The prototype has been developed in C++ on the PC under Windows NT using the Microsoft Foundation Classes application framework. The ObjectStore OODBMS was used in conjunction with the Object Engineering Workbench (OEW) modelling software to implement the project database. The OEW software was used to automate the production of the object model which can support the applications which are within the scope of the project.

3.5 Produce applications

This section describes the OSCON demonstrators to illustrate how information can be modelled and shared between various disciplines. A case study provided by the industry has been chosen to demonstrate how information can be modelled in AutoCAD, Superproject, and an estimating environment etc, but the underlying information used is stored in the Objectstore object oriented database which has been developed as a means of sharing information. A process management prototype software and a VRML interface have also been developed as part of the integrated database (Marir et al 1997).

3.5.1 The AutoCAD demonstrator

A model describing the design of buildings was developed by the research team. This model contains concepts such as building element, space, etc. This model has been implemented as an object oriented database. Each concept when implemented can be referred to as a class. The classes supported by the object oriented database have their counterparts in the AutoCAD drawing package. For instance, the

user will be creating an instance of the concept "wall" or "space" within AutoCAD, but the information underlying these concepts are defined within the database. These types of concepts can be found in most buildings. The CAD system should be used as a front end to display a graphical representation of the building and its components. The attributes which form part of blocks should be stored in the object oriented database rather than in the block definition of AutoCAD because it is very awkward to manipulate blocks. Drawing primitives such as lines, 3Dface, etc should be used to model the layout of a building. However, the information describing these components is stored in the object oriented database.

An interface between AutoCAD 13 and the Objectstore object oriented database was implemented. The user of AutoCAD interacts with its drawing editor using commands he/she is familiar with. Graphical representations of building elements, etc can be produced within the AutoCAD package. However, the information regarding these elements will be stored in the object oriented database rather than in the AutoCAD drawing database. This approach allows information about the geometry, shape, cost, material, of an object etc to be stored within the same database.

This interface provides a simple environment for designing buildings. The design primitives are walls, windows, doors etc (see figure 5). As design objects are created through the AutoCAD interface corresponding objects are created in the ObjectStore database. The information which is used to draw these objects on the AutoCAD screen comes directly from the instances in the database. This ensures that the screen reflects the design database. This also means that changes in a design could be immediately propagated to other areas of the project database. For instance, if an on-line project planning package was accessing the database then it may be possible to change a part of the design and immediately see the impact these changes would have on the project schedule.

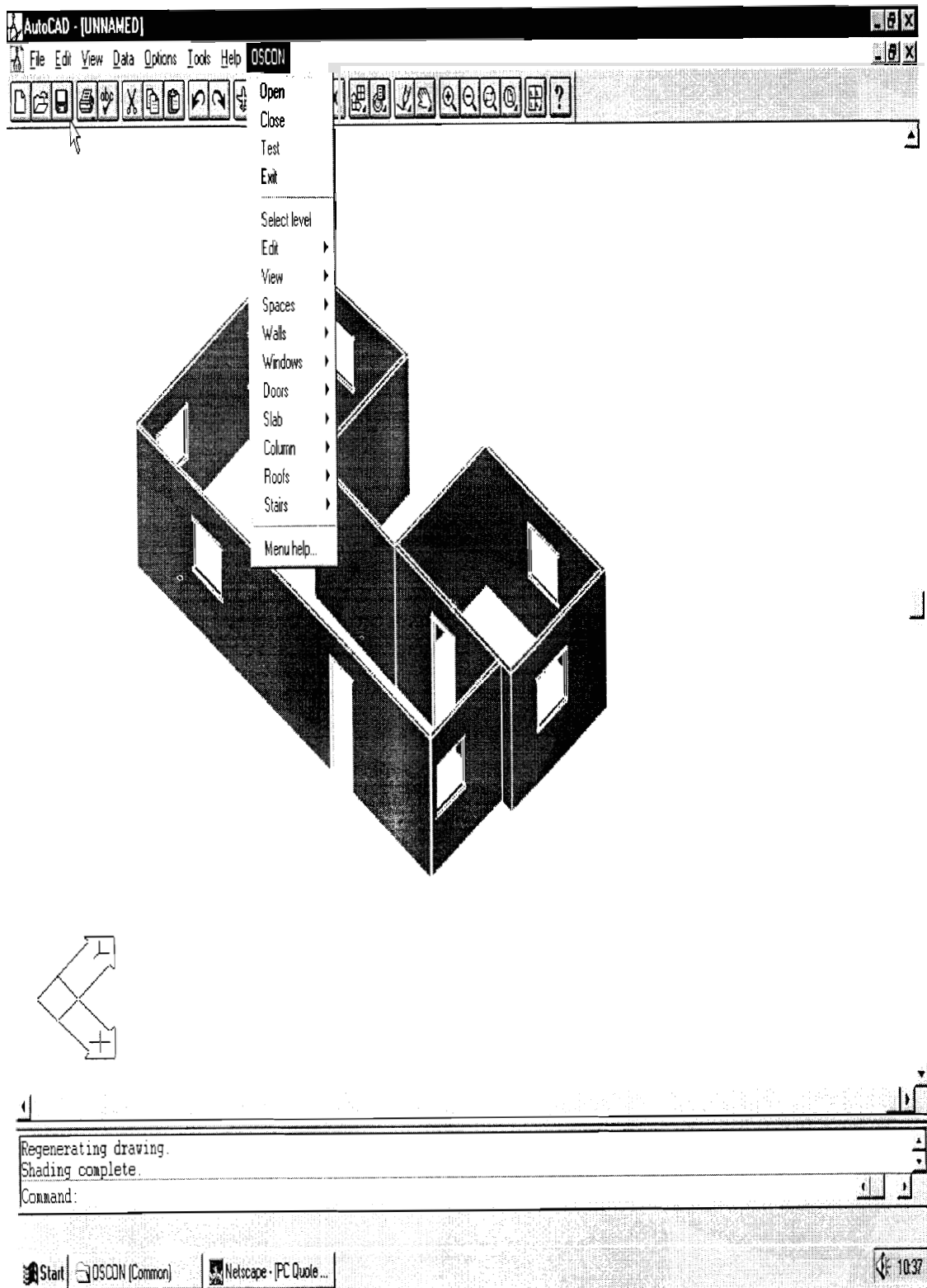


Figure 5 A design view

Figure 6 shows the objectstore browser with information about the design model. This demonstrates that once the design information is created, it is stored in the object oriented database rather than in the AutoCAD database.

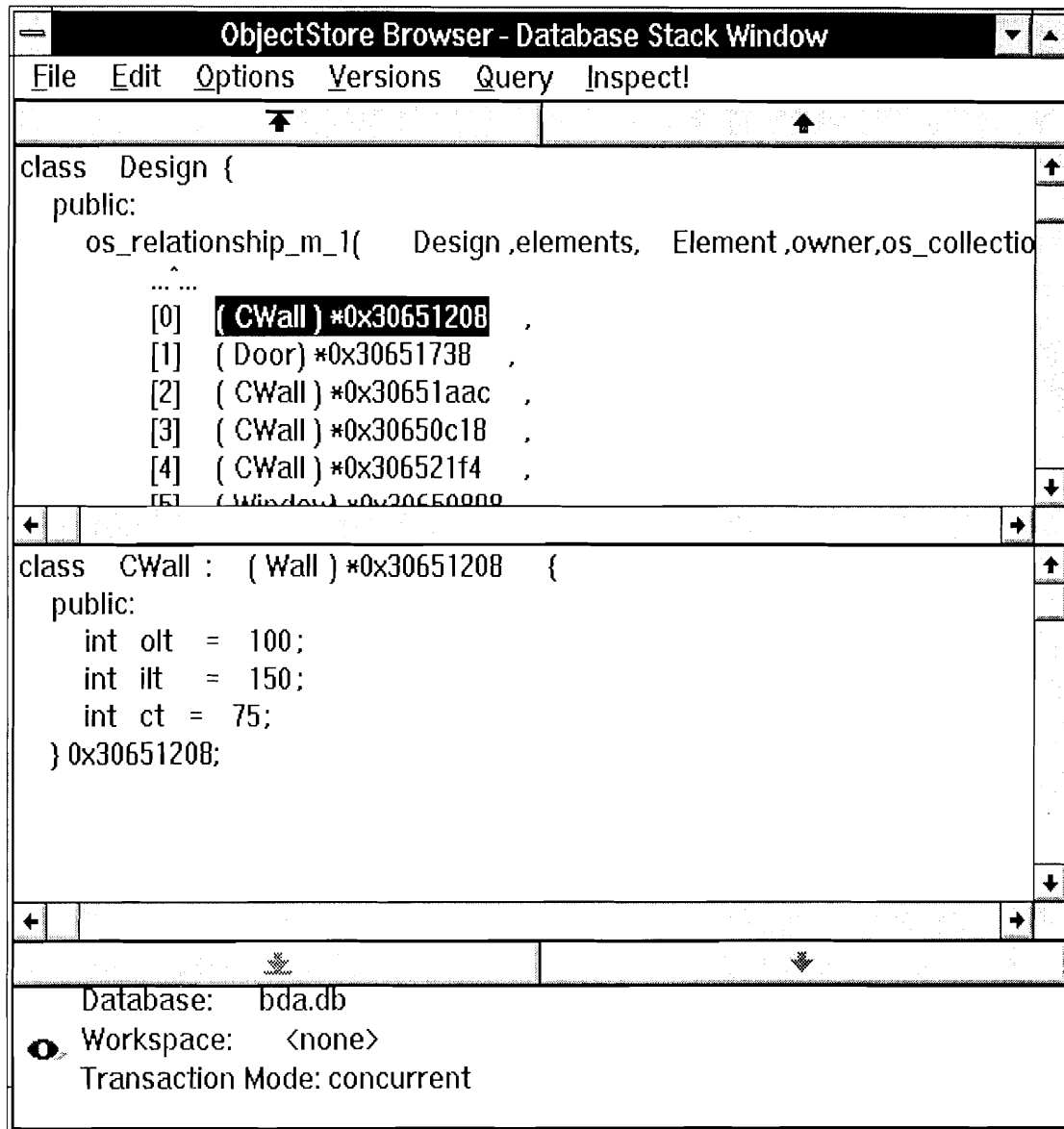


Figure 6 The ObjectStore browser (Design view)

3.5.2 The superproject demonstrator

An interface between the Superproject project planning package and ObjectStore was implemented. The user of Superproject uses facilities provided within this package in order to schedule and update the project plan. However, information about duration, etc is stored in the object oriented database. Any changes to design parameters which will affect activities durations will be recorded in the object oriented database. This ensure that information in the project plan is consistent.

CA-SuperProject was chosen as an example of an existing project planning package which could be used via a translator program to access information from the database. The information is held in the Object Store database as instances of the classes from the Construction Planning Perspective in the ICON models. SuperProject can import and export its data in text file format. Thus the translator in this case is fairly simple. To transfer data from the database into SuperProject the translator program simply needs write the data from the objects in the database to a text file which SuperProject can import, and to transfer data from SuperProject to the database the translator program need to parse a project file exported from SuperProject and create or update the objects in the database. Figure 7 shows the OSCON planning application.

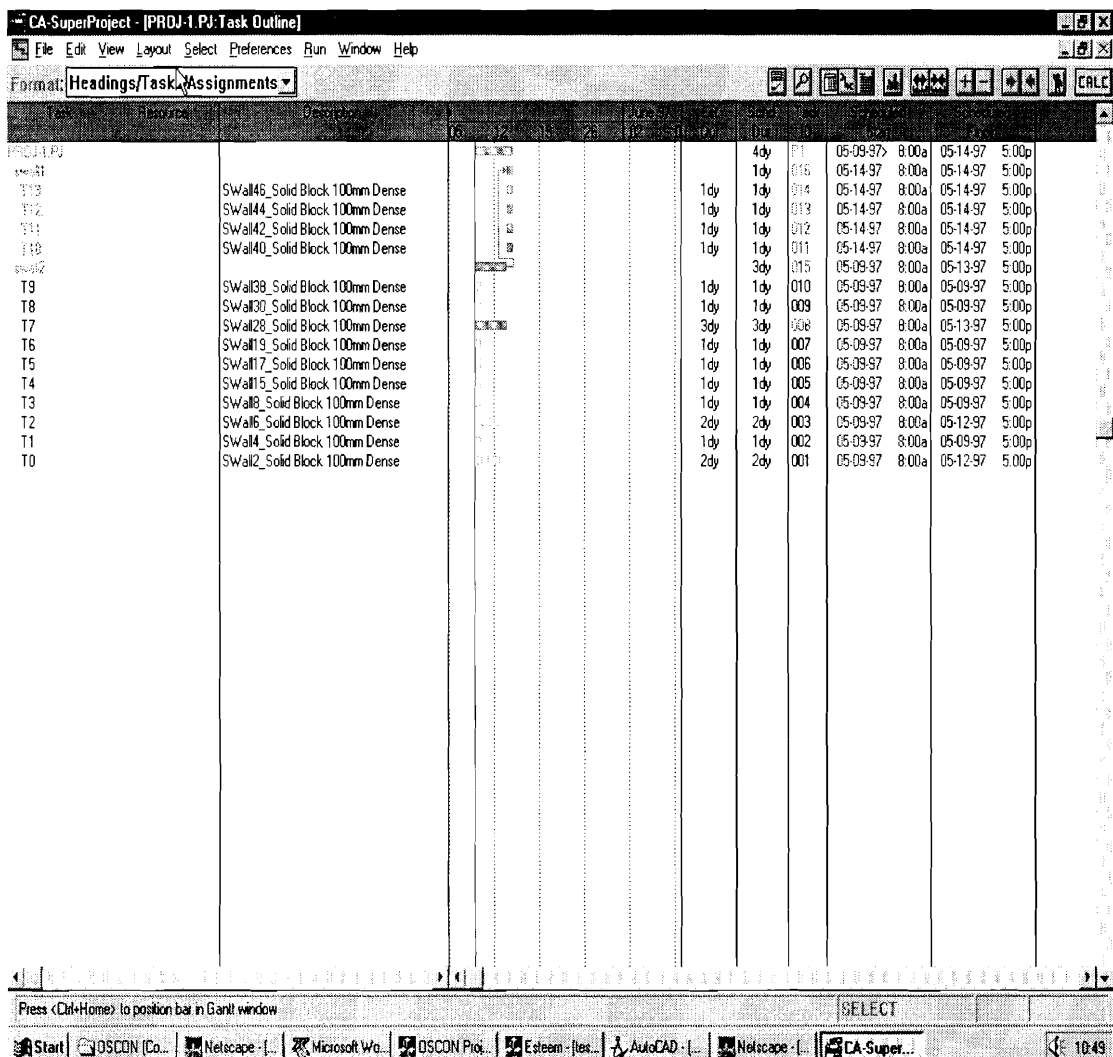


Figure 7 OSCON planning application

3.5.3 The Estimator

The OSCON team have developed a resource-based estimating application (Figure 8). The application looks like a spreadsheet which is easy to use. The estimating application can be used as a stand-alone

application or integrated with the CAD model. A library of standard work items and standard resources which can be company specific is used to identify work items and resources for a project. The user can start a new project and copy this library into the new project and use the most appropriate work items. He/she can change the quantity, rate, etc. and see the cost implications. Alternatively, the user can generate the work items and quantity take-offs from the design model. The work items will then pull the appropriate resources associated with them. The user can experiment with the design model and see the cost changes within the estimating package.

Item	Description	Quantity	Units	Rate	Extension
1	BRICKWORK AND BLOCKWORK				
2	BLOCKWORK				
3	Precast Concrete Blocks, BS 6073, natural				
4	Skins of hollow walls:				
5	Dense Solid Blocks, thickness:				
6	100mm	118.50	m2	13.51	1601.38
13120	Solid Block 100mm Dense	1.00	m2	13.51	
1042	Skin Size 100mm SF	1.00	m2	4.10	
340	Mortar 1:3	0.01	m3	52.00	
320	Convey	0.00	Tonnes	84.22	
5	UNLOADING MATERIALS	1.37	hours	6.99	
322	Hand General Building	1.23	Tonnes	6.17	
322	Rebar 0.21 Litre/50kg	2.05	litre	0.10	
210	Mixer 3/2	2.05	Hours	6.99	
391	Pump 1 day	2.04	Days	0.00	
150	REINFORCER	0.95	Hours	6.99	
15	BLINDING	0.90	Hours	6.99	
7	WOODWORK				
8	COMPOSITE ITEMS				
9	Softwood Windows (Boulton & Paul)				
10	Range: Sovereign				
11	???? x ???mm; Code: ?????	7.00	No	114.78	803.45
3271	Window A	1.00	No	75.00	
26	SITE JOINER	2.63	Hours	6.99	
7000	General Materials #	1.89	#	1.00	
6020	Non-Setting Glazing Compound	1.26	Kg	1.50	
26	SITE JOINER	2.52	Hours	6.99	
12	WOODWORK				
13	COMPOSITE ITEMS				
14	Internal Doors (Boulton & Paul)				
15	Range: Blackland, Hardwood				
16	914 x 1981 x 35mm	2.00	No	87.23	174.46
3161	Internal Door A	1.00	No	75.00	
26	SITE JOINER	1.75	Hours	6.99	
	TOTAL ESTIMATED COST=2573.30				

Figure 8 OSCON Estimating Application

3.5.4 The Virtual Reality Utility

The VR application reads information about the design produced in AutoCAD from the database and displays it in a virtual reality environment. This provides better visualisation using the web-based

VRML (Virtual Reality Modelling Language). This utility shown in Figure 9, will be used as a means of interrogating the integrated database remotely over the Internet in order to allow practitioners within the construction industry better access to the OSCON integrated database.

The potentials of using virtual reality as an interface for an integrated project database using the World Wide Web is of crucial importance. VRML is one of the newest open technologies on the web. It allows the creation of 3D views and worlds which can be explored in real time. The need for remote accessing of information within an integrated environment could no longer be ignored. For instance, site engineers can query the database from their sites if they have access to a modem and the Internet. Technologies are now available which can be used to this end. The Internet and its facilities should be exploited for the benefits of better management and retrieval of construction information.

Virtual Reality has always been looked at as a visualisation tool. However, OSCON has used VR as a user interface. For instance, the user should interact with a 3D column in VR rather than a column in traditional database environment. This will allow the construction practitioners better access to information which will motivate them to use integrated databases.

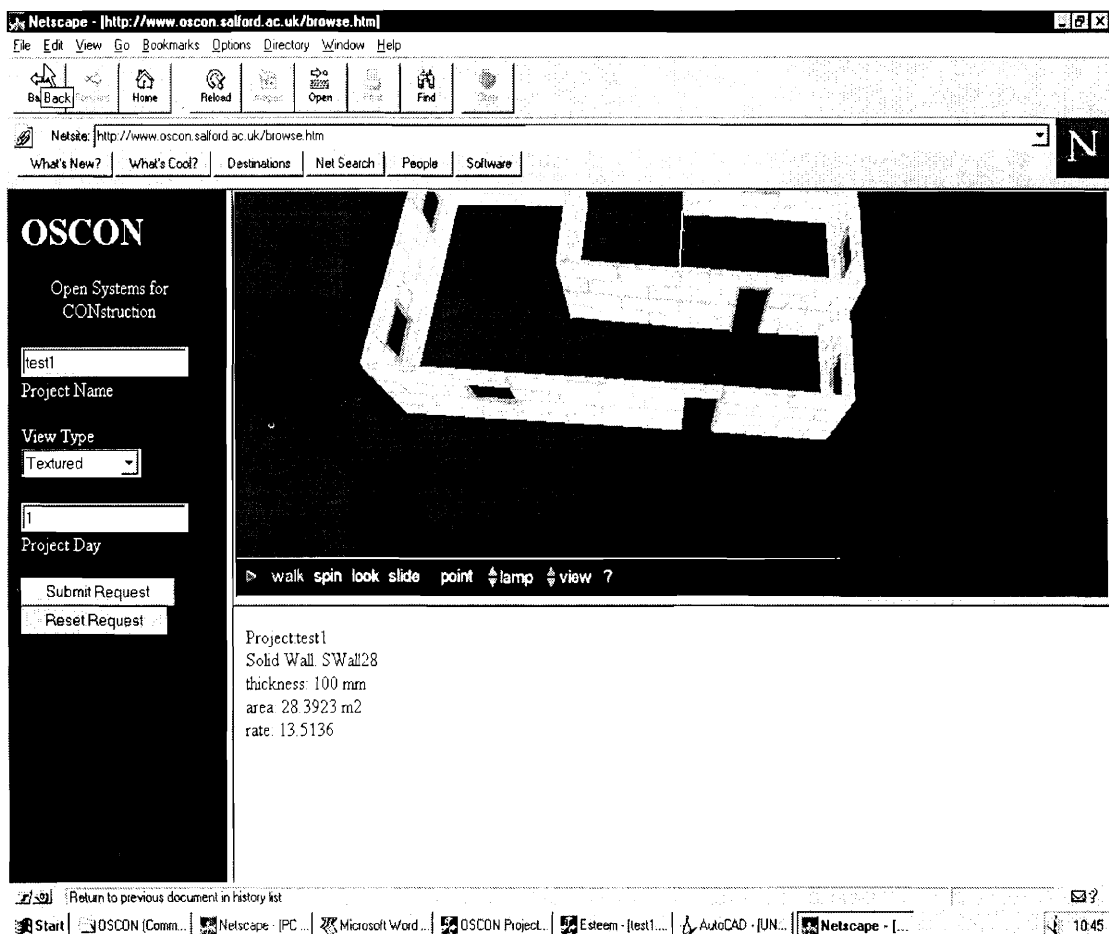


Figure 9 OSCON VR utility.

3.5.5 Project Manager Utility

Design fixity and other process issues are becoming very important within the construction sector. In addition, projects in the construction industry are increasingly characterised by large numbers of actors working concurrently at different locations and using heterogeneous technologies. OSCON is designed to support this kind of collaboration by developing an integrated construction database that can be accessed by any of the actors. To ensure the success of a given construction project and prevent any problem that may arise, the actors involved in such collaboration should be continually informed and asked to limit their actions within the project requirements and aims. It is also useful to record the action taken by any actors during the life cycle of the project. The Project Manager utility shown in Figure 10 developed within OSCON project aims to address practically these issues by allowing the participant in charge of the construction project to manage communications between the different actors and to monitor the progress of each task of the project. As an example of use of this utility is to limit access and manipulation of a given project design to only participants which are involved in this process. It can also be used to freeze or unfreeze a design depending on the client requirements who might be happy with a version of design and therefore needs not to be altered. This can be applied to project costing, planning and virtual reality interface. This also, will be helpful in locking results of the different applications once they are completed.

The screenshot displays the 'Project Manager Board' interface. At the top, there are four tabs: 'Send Message', 'Project Report', 'Project Details (I)', and 'Coming Messages (D)'. Below these, there are four sub-tabs: 'Previous Projects', 'Project Description (I)', 'Project Info', and 'Process Allocation'. The main area is divided into two sections. The left section, titled 'Registration Process', contains input fields for 'Process ID', 'Processor ID', 'Password', and 'Descriptor'. The 'Descriptor' field has a list of options: 'Altering Process', 'Freezing Process', 'Freezing Process', 'UnFreezing Process', and 'Viewing Process'. Below these fields are 'Allocate' and 'Cancel' buttons. The right section contains three groups of buttons: 'Process' with 'Add Process', 'Del Process', 'Freeze Process', and 'Unfreeze Process'; 'Descriptors' with 'Add Descriptor' and 'Del Descriptor'; and 'Processor' with 'Add Processor' and 'Remove Processor'. At the bottom of the window are 'OK', 'Cancel', and 'Apply' buttons.

Figure 10 OSCON Project Manager

3.5.6 The overall applications put together

The following diagram illustrates how the applications can be put together in an integrated environment through a case study. A case study provided by an industrial firm has been implemented within the system. The case study consisted of a four room bungalow together with time and cost plans. The AutoCAD design interface was used to generate the design layout of the building. In reality, the design information was instantiated in the integrated object oriented database and displayed in AutoCAD. The design information was then used in generating quantities which are used by the time and cost planning prototype software. Durations and rates of various construction activities were produced by the system. The VRML application was used to show the building in 3D and to retrieve information about specific objects in terms of cost and time.

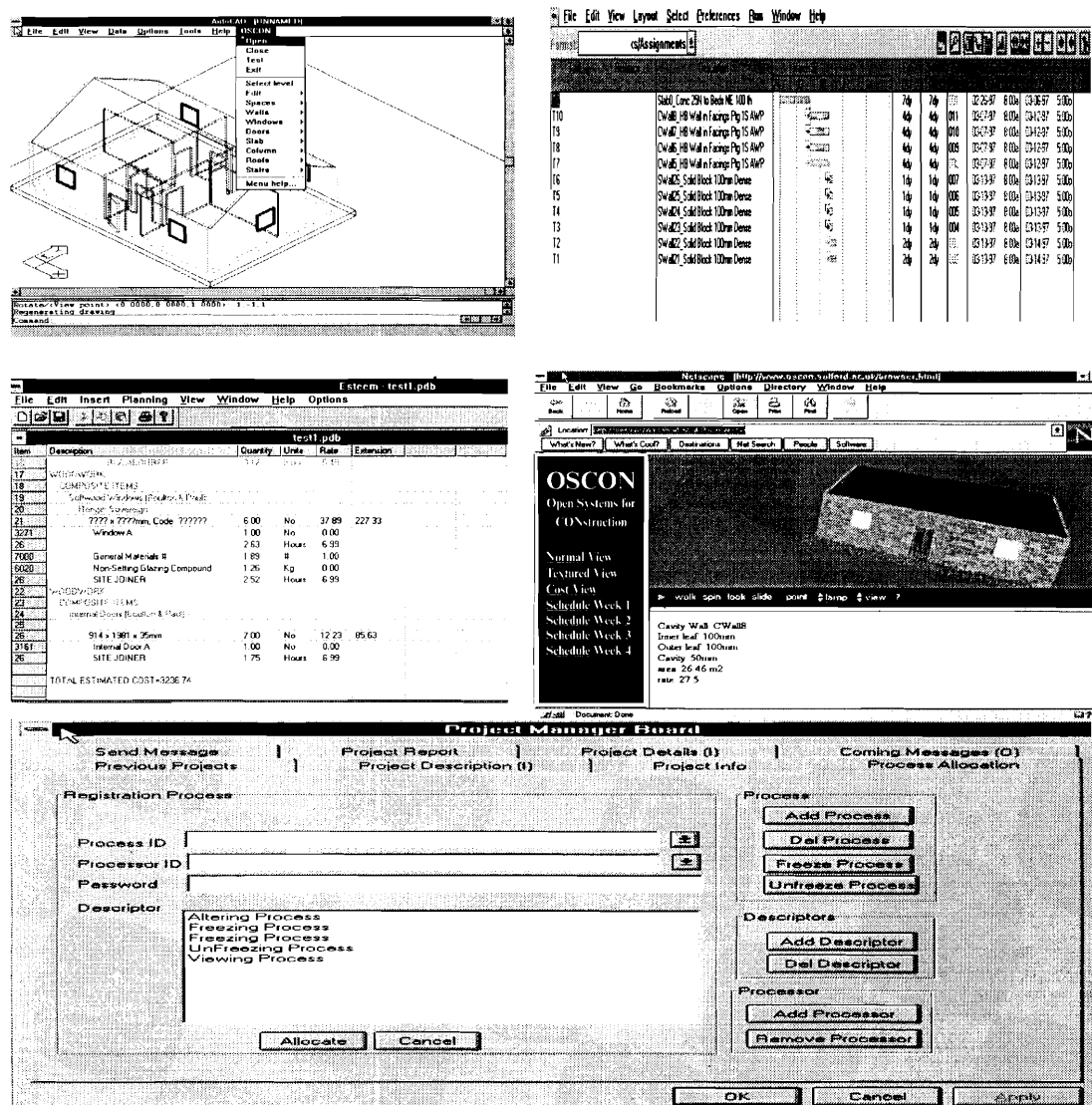


Figure 11 The OSCON overall applications

4. Methodology for Implementation (Prototyping experiences)

The application programs and the shared database have been developed side by side. By building prototype applications, the developers (researchers) were able to identify the needs of the practitioners. The practitioners were not *directly* involved in the task of modelling the shared database. Rather, they assumed the role of clients for the applications being developed. The researchers demonstrated the software and interviewed practitioners on an individual basis. From these interviews the researchers gained the knowledge necessary to improve both the applications and the shared database model. As more functionality was added to each of the applications the database model grew 'organically'.

To support this iterative development approach the researchers focused on so called 'use-cases'. A use-case is a specific, well-understood procedure which the software is required to support. An example of a use-case is the requirement of a Quantity Surveyor to be able to calculate the total glazing area of a building. To support a use-case such as this the QS application will be enhanced, which will in turn lead to further modification of the shared database.

It is believed that this prototyping approach was very helpful and led to a useful end product. This approach allows better management of the applications and speeds the development process

4.1 Implementation options (experiences)

The software development was carried out on IBM PCs running the Microsoft Windows graphical environment. For application development there were two strategies which could be adopted:

1. Programs could be written for the purpose of linking existing Windows applications to the central database.
2. An entirely new set of applications could be developed.

The advantages of the first approach are that existing applications will already contain a large amount of functionality, and practitioners may already be using such packages. The disadvantage is that such applications are primarily designed for stand alone use, and thus may not provide the facilities necessary for sharing information via an external database (especially in real-time). Also, the costs of purchasing copies of these applications needed to be considered.

The advantages of the second approach are that the new applications could be written with integration in mind, and could be made to interact with each other in real-time. We would not be limiting

ourselves to any particular types of application, or to the products of any specific manufacturer. If we were to develop our own applications we could distribute them at a nominal cost, without requiring that the users also buy copies of other commercial applications. Also, we would not ourselves have to purchase any third party software. From an IT research perspective, this approach provides more scope for creative solutions. If this approach were to be taken we could use a visual programming environment such as Visual Basic or Visual C++ for rapid prototyping.

In the end we decided to use a mixture of the above two scenarios. In particular, it seems inevitable that we will have to use a proprietary CAD environment such as AutoCAD.

For the shared database there were also two choices:

1. Use an object-oriented database system such as ObjectStore.
2. Use a well-established Windows database such as Microsoft Access.

The first approach would require the researchers to implement the database using C++ code. This would be very time consuming, and lack flexibility. However, it was possible to purchase a CASE tool (OEWS). This has allowed us to model and document the database (Schema generation).

The second approach would provide us with a quicker route to a prototype. Many application development environments such as Borland C++ and Visual Basic provide libraries for communicating with Access databases. Microsoft Access is also increasingly being shipped as bundled software with high-end PCs. The disadvantage of the Microsoft Access route is that it would produce a database which is not object oriented. The final decision what to choose the object oriented database.

5. Conclusions & Recommendations

This paper emphasised the importance of establishing a framework into which models from different domains can fit. This paper also demonstrated how contextual and conceptual modelling can facilitate the development of prototype applications. The adoption of an implementation methodology has also proven to be helpful. This paper has also described the concepts behind the ICON and OSCON integrated databases projects being undertaken at the University of Salford. It is concluded that ICON/OSCON have a lot of potentials which can offer to the UK construction industry. ICON/OSCON have highlighted how applications can be developed and integrated into an environment which will allow for better information management and integration resulting in improved productivity and quality.

This paper has demonstrated the feasibility of developing models and prototype applications within an integrated object oriented environment. The industry can significantly benefit from the development through the potential capabilities the system can offer. The following recommendations are therefore derived:

- The industry is now in a much better position to start experimenting with integrated applications. The ultimate aim is to make these applications of commercial values once enough confidence is gained by the industry of the potentials of these applications.
- Object technology needs to be considered by the industry because of the many benefits it can offer.
- Virtual reality as an interface and communication technology, in addition to its visualisation capabilities should be considered by the industry. For instance, VRML which is freely available on the web can be used remotely to interrogate an object oriented database.
- The potentials of ICON/OSCON can only be realised through more case studies which can be implemented within the system. It is therefore recommended that further improvement of the prototypes can be achieved through information provided by the industry.

6. Acknowledgements

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THE “TELEBUILD” PROJECT: INFORMATION TECHNOLOGY FOR BUILDING SITES IN TRANSACTION COST PERSPECTIVE¹

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This paper describes an ongoing collaborative research project, “TeleBuild”, for implementation of information technology (IT) on Danish building sites. Technical solutions encompassing telecommunication of sound and pictures have been developed on the basis of problems frequently experienced on building sites. The technical solutions are described along with the plans for their testing and implementation via participation by selected (lead) users. A theoretical approach, transaction cost economics, is introduced and its applicability to the field and problems in question are discussed. Basic transaction cost reasoning is then applied to the project set up in order to identify possible problems and potentials in the implementation of the technical solutions presented. Finally, some conclusions are drawn with regards to the design of a framework for the testing and implementation stage of the research project.

1. Project background and status

The TeleBuild project takes its starting point in an apparent paradox. In spite of the rapid developments in telecommunications and other information technologies it seems that the firms in the building sector have had difficulties in exploiting the progress in information technology on the building sites. A few observations help to substantiate our assertion:

- the activities in the construction phase have the greatest economic impact on a building project.
- many changes are negotiated during the building construction phase due to incomplete planning and design and due to mistakes and changes made during construction.

¹ The “TeleBuild” project is organised by TeleDanmark (TD) and the Danish Building Research Institute (SBI). The project (SBI ref. F5-196) is sponsored by the “Project Renovation” programme of the Danish Ministry of Housing and Building (the “Bjælderbæk” and “Victoriagade” building projects) and by the PPU Consortium which is supported by the “Process and Product Development in Building” initiative of the Danish Agency for Development of Trade and Industry (the “Skelbækvej” building project).

- very little R&D effort has been devoted to introducing IT solutions aimed at meeting the particular needs of building sites.

The main focus of the TeleBuild project is to exploit new technologies within tele-based transmission of sound and pictures to improve performance on building sites. Hence, the project is from the beginning aimed at communication of non-programmed information but may at a later stage be extended to encompass some kinds of programmed information.

Accordingly, the research strategy of the TeleBuild project is to begin with the problems and needs faced by firms on building sites. From there, key areas are identified which are likely to improve the results of the building process. On the basis of the key areas identified new technical solutions are proposed primarily by combining and application of existing technologies. Through application the technical solutions are then tested and refined on building sites in cooperation with a limited number of (lead) users. Two of the building sites are housing renovation projects and one is construction of new housing units.

To facilitate the exploitation of information technologies by firms on building sites two organisers have joined forces and initiated the TeleBuild project with the support of other public and private organisations. One of the organisers, *TeleDanmark*, is the leading supplier of telecom services in Denmark and holds considerable experience in both research and commercial exploitation of information technologies. The other organiser, the *Danish Building Research Institute*, is a sectoral research institution with expertise in the fields of productivity studies, building organisation and building technology. The project receives financial support from the Ministry of Housing and Building and the Danish Agency for Development of Trade and Industry.

So far, a range of problems have been identified by visits to a number of building sites and a number of key areas for improvement of the building process have been put forward. Currently, the search for new technical solutions is being finalised and the technical solutions are being prepared for testing. The next step, thus, is to introduce the technical solutions to the users on building sites. Testing and refinement will take place in cooperation with users on the three separate building sites over a period of approx. twelve months starting Summer 1997. In this paper the main focus is on the two building projects for which implementation and testing are to begin first - the renovation project "Bjælderbæk" and the new housing project "Skelbækvej".

2. Identification of main problems and key areas for improvement

Among the problem areas that were identified as particularly important with regards to building site productivity were design mistakes, supplier mistakes, construction mistakes, supervision and activities regarding documentation/liability.

By analysing the main problem areas identified it was possible to identify four key areas for improvement:

- remote diagnosis
- remote supervision
- document exchange
- conference.

The need for remote diagnosis can be either real-time or delayed (with a time lag). In the case of real-time diagnosis communication of pictures follows immediately after recording. In case of delayed diagnosis recording takes place first and only at a later stage are pictures communicated. In the first case recording of pictures can be continuously directed by the receiver to ensure their appropriateness - the receiver may be a technical expert or another decision maker. In the second case facilities for editing, storage, organisation and manipulation of pictures are more important.

Remote diagnosis and remote supervision requires transmission of sound (discussion) and picture (of the problem being discussed) whereas document exchange demands storage facilities. Conference facilities furthermore require that two or more participants are able to follow the same pictures simultaneously.

3. Presentation of technical solutions

The technical solutions proposed on the basis of the key areas for improvement encompass two basic parts. The first is a so-called “hardware” solution which is used for recording and transmission of digital pictures from the building site. The second is a “software” solution which makes it possible to store, communicate and manipulate the digital pictures recorded.² The system is flexible in use. Transmission of pictures can take place using either a mobile (GSM) phone connection or ISDN telephone lines. The “hardware” part of the system can be used independently of the “software” part. Only if the additional features offered by the “software” part are wanted is it utilised. All receivers must have a modern PC with the necessary Intranet connections and picture dialogue board in place.

The “hardware” part includes the following components:

- video camera capable of recording digital still pictures (includes monitor and zoom facilities)
- frame grabber
- picture transmitter

² “Hardware” encompasses the activities of recording and transmission; “software” encompasses storage and communication.

- GSM tele terminal
- battery
- a case for transport.

This equipment makes possible recording and transmission of still pictures from the building site. The camera may be used separate (recording on video tape) or for mobile transmission with the camera attached to the other components in the transportation case.

The “software” part includes the following components:

- central Intranet server (“web hotel”)
- archive tree structure so that every picture can be placed under a problem name
- conference facilities with facilities for indication, drawing, writing etc. on the same picture by different persons.

For each building site an Intranet structure is established. The system makes possible storage, organisation and manipulation of digital pictures and related information. With this system several persons may access the same pictures simultaneously. For a building project none of the individual firms involved need to undertake investments in server facilities nor do they need to be involved in setting up the system, maintenance, security, backup etc. The operator of the server (TD) simply charges a fee for using the Intranet system. Since Intranet solutions are set up on a project basis the building industry practice of working with changing parties does not hinder implementation.

The key areas for improvements that were identified can be interpreted as three main problem solving concepts:

1. Real time problem solving or observation of progress - transmission of sound and pictures.
2. Delayed problem solving - pictures and related information are stored for later discussion.
3. Documentation - storage of pictures and related information of more permanent value, e. g. for quality insurance, building operation etc.

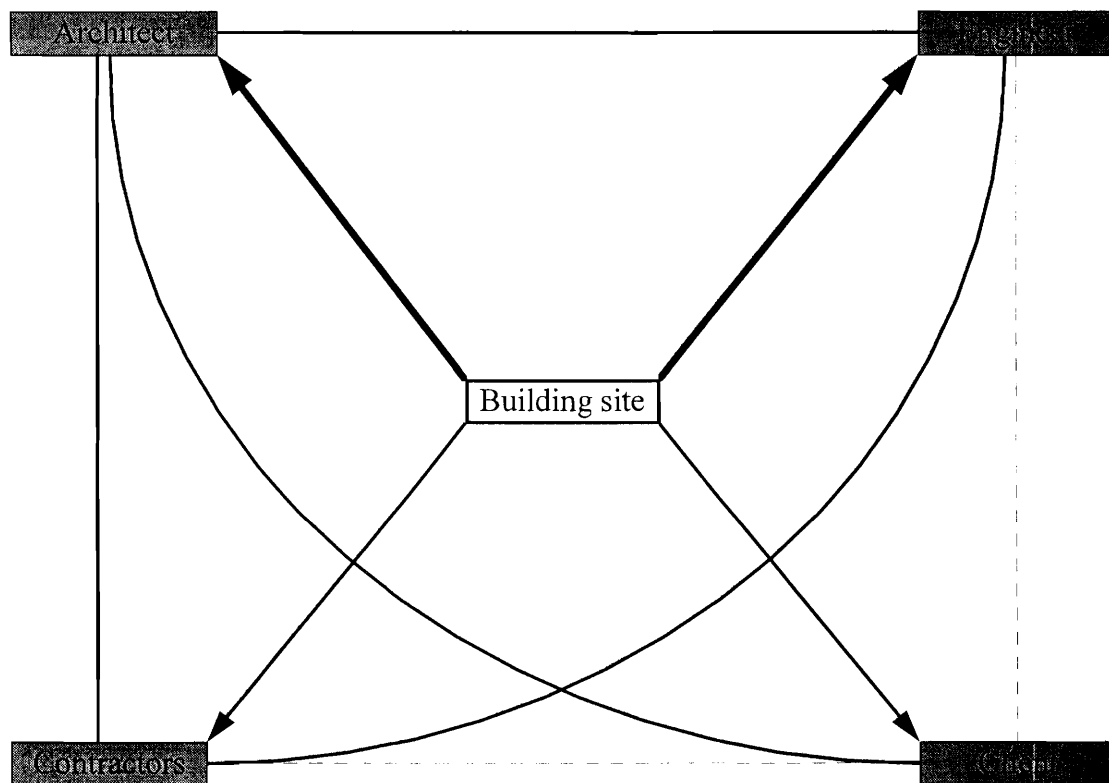
The interdependence between problem solving concepts and the underlying technical features can be illustrated as follows:

Table 1: Problems solving concepts and underlying technical features

Problem solving concepts	Technical functionalities	System utilisation
1. Real time problem solving	Direct transmission of pictures to receiver's PC	Primarily "hardware"
2. Delayed problem solving	Recording, transmission and storage of pictures with possibility of using conference facilities	"Hardware" and "software"
3. Documentation	Storage and organisation of pictures for later use	Primarily "Software"

An example of a possible setup (for the renovation project "Bjælderbæk") is provided in the following figure:

Figure 1: Information exchange for the renovation project "Bjælderbæk"



The thickness of the lines in figure 1 can be used to illustrate the expected traffic intensity between the different parties to the project. The camera facilities on the building site are used primarily by the architect and a number of contractors - whereas the use of conference facilities is likely to be limited to a few key decision makers.

4. Project objectives and research design

The overall objective of the project can be formulated as follows:

Through implementation and testing of IT concepts to document that productivity gains are substantial enough to warrant the adoption of the technical solutions because of the economic advantages to the organisations involved.

Other more detailed objectives may be:

- reduction of waiting time - i.e. working hours lost, time spent on problem solving etc.
- reduction of the number of defects - i.e. waste of materials, expenses for reparation and rectifying etc.
- increased quality of construction - increased client satisfaction
- documentation of final building - for operations management and repair
- increased understanding of other parties' problems - for long term gains.

Naturally, the objectives stated serve as important parameters for collecting information from the project participants on the results of the efforts. Through testing and evaluation of how the concepts are used on building sites we are able to continuously refine them. Furthermore, the observations will be substantiated by productivity data - as documentation for the improvements that the concepts present for the firms.

The practical realisation of the implementation and testing part encompasses the following steps:

- briefing of participants
- instruction in use of technical solutions
- frequent reporting from participants
- follow up interviews - changes in research design and/or utilisation of solutions
- observation of selected situations of utilisation
- cross-project comparisons
- follow up meetings regarding problems, opportunities and perspectives.

For data collection the starting point is the actual usage of the problem solving concepts. The participants are expected to report on each utilisation which is also recorded by the system itself. This material forms the base for follow up interviews and evaluations of actual use. Frequent analysis of data is necessary to ensure that the objectives of refinement (in use and technically) and documentation are met. Thus, a number of working papers will be produced and serve also as the basis for the final report.

Among the further perspectives in this project is the potential broadening of the use of technical solutions (and their commercialisation). Furthermore, in a longer term perspective the Intranet system may be extended as a structure through which site managers, design consultants etc. can access total project information at any time via a PC in the form of project data bank common for all parties to the project.

5. Transaction cost economics as a theoretical perspective

Transaction cost economics, which is part of what has been termed “New Institutional Economics”, is concerned with issues of organisation, economics and law (Langlois 1986, Williamson 1985). Transaction cost economics is based on an insight by Nobel Laureate Ronald Coase (1937) who explained the existence of firms by pointing to the costs of transacting through market relations (in addition to the costs of production). The theoretical problem has also been formulated as a choice between hierarchies and markets (a “make or buy” decision) in organising economic activities (Williamson 1975, 1985).

A transaction occurs when a good is transferred across an interface where one stage of activity ends and another begins. According to this definition transactions may take place both between and within firms (in the latter case the costs of transacting are often referred to as *administration costs*). Transactions are important because they are costly, indeed, transaction costs could be seen as the economic equivalent of friction in physical systems (Williamson 1985). Accordingly, transaction costs are the costs of running the economic system. With the friction analogy in mind, in the TeleBuild project introduction of information technology on the building sites could be viewed as utilising “roll bearings” to improve efficiency. The aim is to lower the costs of transactions by improving cooperation between firms participating in building projects through facilitating of communication between the parties. Consequently, we attempt in the following to analyse how the TeleBuild project can contribute to lowering the costs of transacting for the firms involved and for the building construction sector more generally.

Three main categories of transaction costs can be identified:

- *contact costs* associated with market research and the search for and screening of suppliers.
- *contract costs* associated with specifying the detailed contract between the parties.
- *control costs* associated with enforcing the contract after it has been entered.³

Especially contract and control costs are likely to be of interest with regards to the TeleBuild project. In building projects, and particularly in renovation projects, it is often impossible to define in any great

³ Milgrom and Roberts (1992) emphasise the activities of *coordination* and *motivation* when commenting on how transaction costs arise.

detail the work to be carried out in advance. Rather, specification of the work to be carried out is an ongoing problem solving and negotiation process. Also control of the work that has been carried out is likely to require some attention from the parties to the building project. Indeed, the project's key areas of *remote diagnosis* and *remote supervision* seem to be particularly promising. Among the main problem areas *design mistakes*, *supplier mistakes* and *construction mistakes* are likely to cause renegotiation of the details of the contract (contract costs) whereas *supervision* and *activities regarding documentation/liability* are more aimed at enforcing contractual obligations (control costs).

Modern transaction cost economics is based on two behavioural assumptions as explained by Williamson (1985). Decision makers are assumed to be boundedly rational and opportunistic. *Bounded rationality* implies that decision makers will not be able to foresee all the contractual changes that may be necessary in the course of a contractual relationship, that is, comprehensive planning is not possible. *Opportunism* implies that a decision maker cannot always be trusted to fulfill his contractual obligations, that is, promises are not always kept.

In addition to the behavioural assumptions transaction cost analysis relies on three variable dimensions - asset specificity, uncertainty and frequency - which are used to characterise different kinds of transactions or contractual situations.⁴ *Asset specificity* is considered the most important of the three dimensions. It is defined as the degree to which investments are incurred in support of particular transactions.⁵ Asset specificity is important as a result of the existence of human opportunism, which can lead to hold up problems in ongoing transactions because the value of investments are lower in best alternative use. Consequently, the parties to a transaction matter and resources will be spent on contractual and organisational safeguards to protect transactions from potential hold up problems (Williamson 1985, pp 52-56). For instance, transaction specific investments in human assets are frequently undertaken during contract execution in the form of specialised training and learning-by-doing economies. Also, familiarity between contract parties permits communication economies to be realised on the basis of trust relations.

The *uncertainty* dimension specifies the extent to which disturbances are likely to arise. Uncertainty is thus a measure of the need for adaptation to change, which makes enforcement of contracts difficult. The *frequency* dimension describes how often similar transactions occur between the same parties, which is important in relation to the undertaking of investments to protect transactions. With more frequent transactions (greater intensity in interaction) the relation may be valued highly enough to warrant investments in more specialised forms of governance.

⁴ Other dimensions have been suggested, e.g. by Milgrom & Roberts (1992) who specify five different transaction attributes: (1) asset specificity, (2) frequency and duration, (3) uncertainty and complexity, (4) difficulty of performance measurement and (5) connectedness to other transactions.

⁵ Six different types of asset specificity have been identified (Williamson 1989): (1) site specificity, (2) physical specificity, (3) human specificity, (4) dedicated assets, (5) trade mark specificity and (6) temporal specificity.

Transaction cost economics has been particularly useful in analysing different contractual problems in order to come up with an appropriate organisational solution. Generally, a comparative institutional perspective is relied on in which different organisational structures are evaluated in terms of economic efficiency, i.e. cost minimisation. It should be remembered, though, that what is compared is the total of transaction, administration and transaction costs for each alternative.

The closest we in building construction get to examples of pure market modes, where transaction costs are negligible, are in purchasing of highly standardised components or basic materials such as timber, bricks, gravel and cement.⁶ Such market transactions are usefully contrasted with hierarchical organisation in firms, where transactions are generally more specific, more uncertain and more frequent. In addition to the extremes of pure market and pure hierarchical modes of organisation a number of other, intermediate organisational solutions to contractual problems have been identified. Examples are trilateral governance (neoclassical contracting) and bilateral governance (relational contracting). In both cases contracts are more long term than in the pure market mode. In the first case third party arbitrators are involved in administration of the contract between the parties. In the second case transactions are more frequent and consequently the arbitrator is not needed because the parties are engaged in a continuous contractual relationship. In conclusion, a number of various contractual relations exist in the continuum between the extremes of pure market and pure hierarchy.

6. Interpretation of building projects and the building site.

There are good reasons why transaction cost economics can be usefully applied to the problems of building construction and the building site. A number of basic characteristics of building construction can be mentioned:

- site specificity - construction activity takes place *in situ*.
- made to specification - construction is not mass production.
- made by a coalition of different firms - the different parties are organised via contracts.
- a process of long duration - building projects and contracts are typically long lasting.

By definition a large proportion of building construction takes place on site, that is, where the buildings are to be permanently situated and used. Consequently, buildings are also constructed to fit the particular environment in which they are located, e.g. particular soil conditions, function and architecture. Generally, building construction is also made to specifications so that the construction of each individual building is in fact equal to producing a prototype. These special features have implications for the asset specificity of the transactions involved in building construction. Several aspects contribute to a high level

⁶ More generally, close approximations to pure market modes can be observed in trading of highly standardised commodities on spot markets (or in currency exchange markets).

of asset specificity, most notably high levels of site specificity, physical specificity and temporal specificity.

Construction of buildings is usually undertaken by a coalition of firms organised via contracts. This makes the roles of different parties to the contracts particularly interesting to analyse using a transaction cost perspective. Indeed, a number of studies have been conducted of the organisation of construction activity using transaction cost economics (Eccles 1981a & 1981b, Reve & Levitt 1984, Stinchcombe 1985, Casson 1987 and Winch 1989 to name some of the most important). Among other things the papers have focused on determinants of subcontracting, the role of design consultants, the organisation of construction projects and institutional features of the construction sector. For instance, it has been suggested that governance of subcontracting is usually between relational and neoclassical contracting modes (Eccles 1981b) and that design consultants frequently assume the role of arbitrators in the relation between construction clients and contractors (Winch 1989).

Because of the long duration of building projects, with different firms working sequentially on complex structures, construction contracts are typically long term and subject to uncertainty and changes during execution. Prior to entering a contract the client typically has a choice between several firms, but once the contract has been signed he is locked into one specific relation. This applies similarly for the subcontracting decisions by contractors. In transaction cost terms this is referred to as a “fundamental transformation” by which flexibility is lost because the competitive situation changes from a large numbers to a small numbers interaction. Contract execution changes the competitive situation if durable investments in transaction specific assets are incurred, and this has implications for renegotiations of existing contracts, where the incumbent supplier often enjoys special advantages over competitors. As a consequence, stable (bilateral and trilateral) relations are most often observed for the duration of the project, even when considerable changes have to be negotiated in relation to the original contract.

7. Discussion of the “Bjælderbæk” and “Skelbækvej” building projects

In order to analyse the contractual implications of the TeleBuild project we consider the organisational and contractual set up for one renovation and one new building project. As already indicated a building project consists of a number of contracts to be executed on the building site with numerous transactions occurring for each contract. Indeed, many of the technological interfaces which define transactions can be observed on the building site. Most adjustments and changes made in relation to contractual specifications are consequently based on decisions and communication regarding building site problems.

The renovation project “Bjælderbæk” (see figure 1) is organised as a separate trades contract with the architect playing the main role with respect to preparations for tender and supervision of construction. Indeed, the architect is acting as the representative of the client and is involved in the administration of

the client's contracts with specialist and trade contractors. Furthermore, the architect coordinates his decisions with the consulting engineer. The architect may in some respects act as an arbitrator in a trilateral relation between the client and each of the contractors. In the project the consulting engineer functions mostly as a subcontractor to the architectural firm.

12-13 specialist and trade contractors are expected to take part in the building project. For the architect this means a considerable load on limited decision making resources (i.e. bounded rationality). Time spent by the architect on coordinating and renegotiating individual contracts is likely to be the limiting factor. Consequently, the main focus of the implementation and testing of the technical solutions is on the role of the architect.

In a transaction cost perspective the idiosyncratic nature of renovation work adds to the asset specificity of transactions, since most work must be performed on site (site and physical specificity) according to the problems encountered. Also, familiarity with the peculiarities of the project participants in question (human asset specificity) and the coordination of different activities and actors (temporal specificity) are likely to add to asset specificity for the individual contracts. Uncertainty is quite high due to the high likelihood of encountering problems in the old building that were not anticipated. Furthermore, the frequency of each type of transaction is quite low due to the large number of contracts and firms, although some repetition is likely in terms of similar flats with similar types of work. Only for a couple of the largest contracts will the TeleBuild technical solutions be implemented among the contractors - for the smaller contracts the volume of transactions is probably too small to warrant the investment.

If we assume that the architect spends the same amount of time on the project as he would without the technical solutions of the TeleBuild project he would be able to spend more time on problem solving and negotiating of changes to each individual contract. Consequently, the client would get a better deal either in terms of cost savings (less spent on "extras") or in terms of a better final product. There is a risk, however, that the contractors will resist the implementation of the TeleBuild technical solutions because they feel threatened by the improved bargaining position of the architect as the client's representative. With regards to implementation it is therefore important to place some emphasis on the potential cost savings for contractors in terms of less time spent on coordination (and site visits) by foremen (and managers).

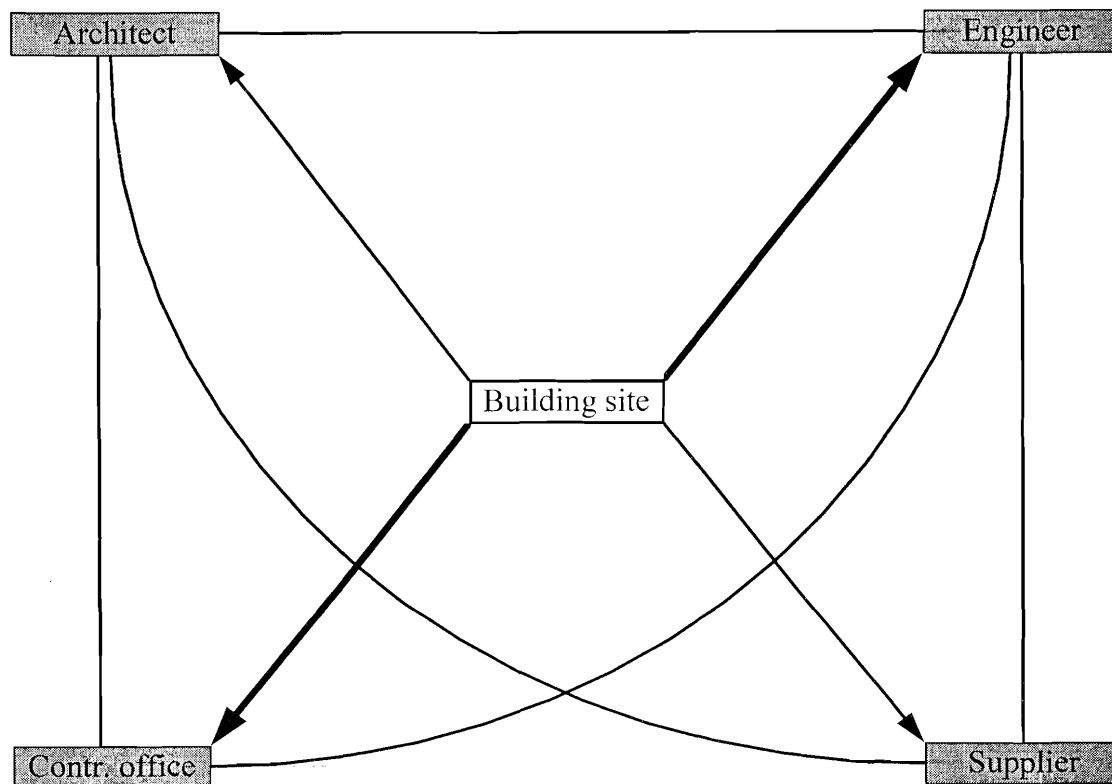
In a more dynamic perspective improved planning and coordination by the architect may not be reflected in reduction of transaction costs. Rather, the same resources spent in terms of transaction costs may result in improvements "spilling over" into reduced production costs and improvements in product quality etc. This may be problematic because the gains from investing in the use of TeleBuild technical solutions may be reaped by firms not taking an active part in implementation. It is therefore important to document such gains so that the results in future projects can be used to establish appropriate price levels for various

types of firms and work. In the long term - with improved knowledge of the redistributive consequences - such problems are likely to diminish.

The new building project “Skelbækvej” (see figure 2) is organised as a design and build contract between the client and a consortium consisting of a large contractor, an architectural firm and an engineering consultant. As already mentioned the consortium is part of an experimental programme for product and process development in building. The same consortium is therefore building a number of projects in order to realise some of the gains of continuous cooperation between the parties. In addition to the consortium partners a supplier of prefabricated construction elements will be involved in the implementation and testing of the TeleBuild technical solutions.

A preliminary illustration of the possible setup for the new building project “Skelbækvej” is provided in figure 2 (with thickness of the lines used to illustrate expected communication intensity):

Figure 2: Information exchange for the new building project “Skelbækvej”



The relation to the client is much clearer in this case because there is only one main contract - the one between the client and the consortium. The design consultants do not play the role of arbitrators and consequently the contractual relation is bilateral (relational) rather than trilateral (neoclassical). On the other hand, it is assumed in this kind of contract that client involvement in decision making with regards

to the execution of the contract is quite limited. Accordingly, the client organisation is not part of the organisational set up for implementing and testing of the TeleBuild technical solutions.

The primary actor in the project is the large contracting firm. The contractor manages activities on the site including the administration of contracts to subcontractors and suppliers. The site manager of the contractor is also responsible for discussion and implementation of design decisions with the architectural and engineering firm. In addition to decision making with regards to subcontractors, suppliers and design consultants the site manager also needs to be in close contact with the contractor home office both for supplies and work handled by the contractor as well as for decisions which require advice or authorisation from the contractor organisation. The largest decision making pressure is on the contractor's site manager in terms of both coordination and renegotiation of contracts. Consequently, the site manager is the main focus in the implementation and testing of technical solutions.

In a transaction cost perspective the asset specificity of transactions is likely to be slightly lower than in the case of renovation because more activity can be undertaken off site via prefabrication (lower site and physical specificity). Improved prospects for planning of activities should work to reduce uncertainty. On the other hand increased scale and complexity of the project may offset part of the reduction. The frequency of each type of transaction is likely to be higher for a new building project. Therefore, the prospects for undertaking investments supporting the governance of these transactions are better - also for implementation of TeleBuild technical solutions. As a result, implementation of the TeleBuild technical solutions should be possible for a number of the largest subcontractors and suppliers. In the "Skelbækvej" project one of the large suppliers will take part in implementation and testing.

The site manager of the contractor will be active in negotiating changes with subcontractors and suppliers (involving also the design consultants). Any savings in the costs of communicating can be interpreted as reduced administration costs for the contractor. The site manager will be responsible for coordinating changes with the production units of his own organisation. In the first case improvements are in the form of transaction cost savings. In the second, where transactions are between two units of the same firm, improvements are in the form of administration cost savings. This difference is important because in implementation it matters who receives the benefits from the improvements. Basically, we should expect the sharing of benefits between two units of the same firm to be less problematic than between two separate firms. Again, it is particularly important for successful implementation to make sure that contractors and suppliers are also presented for the potential advantages of adoption.

Also in the case of renovation there may be problems of resources spent on improved communication benefiting parties that do not take an active part in the implementation and testing of the TeleBuild project. This may be in the form of reduced production costs or increased product quality. Because the consortium has a longer term perspective than what is the norm for building project organisations it is

likely that it has better prospects for benefiting from these other more “dynamic effects” than what is normally the case. Moreover, using the TeleBuild technical solutions to improve communication may well further the objectives of increasing cooperation/efficiency among the consortium partners. These effects should also be documented as part of the implementation and testing of the TeleBuild project.

8. Conclusions regarding approaches to implementation and testing

We now conclude with respect to the usefulness of the transaction cost perspective in identifying appropriate approaches to implementation and testing of the TeleBuild technical solutions. Our preliminary analysis has shown that transaction cost economics is indeed a useful framework for establishing to an understanding of the organisational and contractual structures of building projects and how they affect activities on building sites.

Basic transaction cost economics can be used as a theoretical framework for structuring and analysing the process of implementation and testing of technical solutions. Especially when investigating the results of implementation relative to the detailed objectives of the TeleBuild project (reduction of waiting time, reduction of the number of defects, increased quality of construction, etc.) does this particular theoretical perspective seem promising. Indeed, when collecting and interpreting data the basic logic of separating cost savings into transaction, administration and production components is a powerful analytical approach that enables a much more detailed understanding of the basic cost accounting. It should be remembered, though, that improvements need not be direct cost savings - improvements in quality may also result from implementation of the TeleBuild solutions. The transaction cost efficiency perspective does not take this into explicit consideration. In conclusion, the data collection process and format should reflect this more detailed understanding of the underlying factors of productivity improvements.

Another important aspect which has been uncovered using transaction cost reasoning is the fact that redistribution of productivity gains between the different parties to a building project may in effect hinder the implementation of TeleBuild solutions by creating incentive problems. It is therefore necessary to focus on the redistributive consequences of TeleBuild implementation for the key participants. In that respect, analysis of contractual relations using basic transaction cost reasoning is useful. On the basis of such analysis it may be necessary to provide special incentives - for instance for subcontractors - in order to ensure successful implementation.

Finally, it should be mentioned that in addition to immediate cost savings the TeleBuild project may also contribute to changing the relative costs of different organisational solutions. Consequently, implementation of technical solutions may require adjustments or changes to organisational and contractual structures. Transaction cost savings may well translate into structural change for building projects - following a transaction cost logic.

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THE UK CONSTRUCT IT CENTRE OF EXCELLENCE

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MANAGEMENT BOARD

Abstract

The Construct IT Centre of Excellence in the UK is an industry-led, government-endorsed, network. Its members are drawn from leading companies from construction and associated industries, a number of leading UK Universities, and from professional institutions, trade associations and government departments. The Centre has emerged from its kick-start phase to a point where it is now very firmly established and able to offer valuable services to its members. The founding principles of the Centre are that it seeks to inform the IT investments of its member companies, and ensure that these investments remain well informed within the context of national strategies to realise the full potential of IT within the industry. It seeks to do this by a range of activities concerned with sharing experiences in research and innovation in construction IT. These activities include: showcasing technological innovation, developing and implementing national IT strategy; devising long-term research strategies; benchmarking current IT applications; conducting a strategic IT health check of the way IT is managed, measuring the value and benefits of IT investment, helping the industry prepare for the millennium date change problem, undertaking advanced collaborative industrial training; communications activities in support of an innovation network; and international links.

The presentation at the meeting will outline: the background to the formation of the Centre; its involvement with UK government strategy formation; and its use of a process road-map as a framework to achieve research coordination.

1. Introduction

The UK Construct IT Centre of Excellence grew out of a long period of successful applied research carried out within IT in Construction at the University of Salford between the mid 1980's and the present. This was typically based on major research projects from funders such as Science and Engineering Research Council, the Alvey programme and the Royal Institution of Chartered Surveyors. Projects were typically steered by industrialists and usually resulted in industry oriented deliverables including software products. The University formed successful companies out of some of its projects as joint ventures with construction and IT companies and the commercial arms of professional institutions in the industry.

Based on this success, the obvious migration path was to extend the scale of this activity by involving a broader cross-section of UK university research, formalising disparate steering committees into a management board, and seeking to build a coordinated programme of research and innovation from a base of individual projects.

This coincided with a time when UK industry was going through a period of substantial change, when innovation in IT was emerging as a Board level priority, and when UK government was beginning to think more strategically about the industry's future, the place of IT within it, and the need for research funding to be strategy-driven. This combination of forces spawned the creation of the Construct IT Centre of Excellence.

From an initial kick-off meeting in February 1995, the Centre has met all the objectives that it was set for its initial two-year formation period. It has now emerged as an established, value-adding network with a rapidly expanding business plan for its activities and with its horizons increasingly moving to the international arena.

2. An Industry Lead

The Centre was chaired in its initial phase by Geoff Topping, the former chairman of Taylor Woodrow Construction Holdings. Geoff was a senior figurehead within UK industry with a keen interest in research and innovation. Geoff chaired the Management Board of the Centre which has industrial representatives from all of the major constituencies: clients, consultants, contractors, IT supply, communications, and research.. All of the major activities of the Centre are championed by an industrial member of the management board.

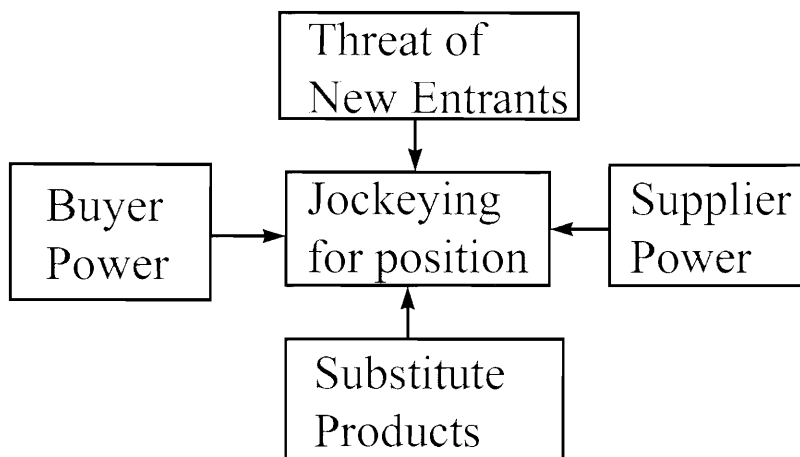
3. A Network

Whilst having a base at the University of Salford, Construct IT is a network of some 40 companies, 10 universities and research organisations, and 15 professional institutions and trade associations. The Centre's activities engage members of the network working in a virtual way in its offices, projects, meeting rooms, research groups and occasionally in attractive English country hotels.

All organisations that are part of Construct IT have their own projects, innovations, products, services, and interests that they bring to the Construct IT party in a spirit of pre-competitive collaboration.

Michael Porter's five forces model demonstrates how an individual company's strategic position is influenced by other organisations with which it relates. All organisations within a construction company's own five forces model have been incorporated into the network..

Supplier and buyer power is represented by suppliers, sub-contractors and industry clients. The threat of new entrants and substitute products are represented by other types of construction organisations, by management consultants, by associated industries and by international participants. Rivalry and jockeying for position is represented by competing construction firms participating in a pre-competitive way in the Centre's work..



4. Step Change in Industry Process Performance

The mission of the Centre is to change fundamentally the process performance of the UK construction industry through the adoption and application of innovative, integrated IT techniques. It seeks to do this by looking to IT as an enabling technology. As such, Construct IT is at the centre of UK innovation activities resulting from the Latham review and actively participates within Construction Research and Innovation Strategy Panel (CRISP) activities concerned with process and IT. CRISP is an initiative by the UK Government to create an industry-led panel to promote and steer research and innovation in construction.

The focus for the Centre's work is not to develop technology for technology's sake but to innovate with IT as an enabler to facilitate step change in industry process performance.

5. Aims and Objectives

In its founding principles, the Centre adopted four key objectives:

- to inform the IT investments of construction organisations
- to ensure IT investments remain well informed
- to showcase leading edge IT and communications technologies
- to promote coordinated construction IT research

It carries out a series of activities that seek to realise these objectives as follows:

- producing an IT toolkit
- showcasing technological innovation,
- developing and implementing national IT strategy;
- devising long-term research work plans and strategies;
- benchmarking current IT applications;

- conducting a strategic IT health check of the way IT is managed,
- measuring the value and benefits of IT investment,
- helping the industry prepare for the millennium date change problem,
- undertaking advanced collaborative industrial training;
- communications activities in support of an innovation network;
- developing an industry leading WWW site,
- and international links.

6. Progress to date

The following projects are at an advanced stage of progress:

- ✓ best practice benchmarking
- ✓ host international practice and theory conferences
- ✓ conduct postgraduate and continuing education
- ✓ develop a national IT strategy and research work plan
- ✓ research database

Progress with these will be described in outline before describing more recent progress with new activities that have developed within the two-year formation period. The most successful element of the Centre's work has been in its best practice benchmarking of current IT support to mission-critical business processes. This has been more fully described in other parts of this document.. The Centre has also worked with Strathclyde University, Association of Consulting Engineers, Royal Institution of Chartered Surveyors, the European Intelligent Building Group, Chartered Institute of Building Services Engineers, and others in holding practice and theory conferences on the work of its various members.

The postgraduate and continuing education work of the Centre is mainly conducted through a part-time modular masters, Management of IT programme at Salford University. Its development is funded by the Innovative Manufacturing Initiative as part of its Integrated Graduate Development Scheme programme. This supports collaborative management education development in new technologies in arrangements where consortia of industrial companies work with an academic institution in designing, developing and delivering training programmes that are sufficiently industrially relevant that the companies are prepared to delegate their senior managers of the future to benefit from the shared, high quality, pre-competitive training that results. The programme is entering the end of its second year and has successfully recruited senior delegates from UK industry who are gaining knowledge that is leading to them becoming change agents within their organisations in their ability to manage IT for the benefit of the business.

The Centre has been a major contributor to the UK Government Department of Environment commissioning the drafting of a national IT strategy for construction. The strategy, and its subsequent feasibility studies and implementation plans, were prepared with extensive assistance from members of the Centre and have been extensively reported through the Centre's communications activities.

The *Construct IT: Bridging the Gap* report specified a technological vision towards which a series of implementation efforts are currently being directed. The central elements of the vision are of an integrated project database and an industry knowledge-base. These are depicted in Figures 1 and 2.

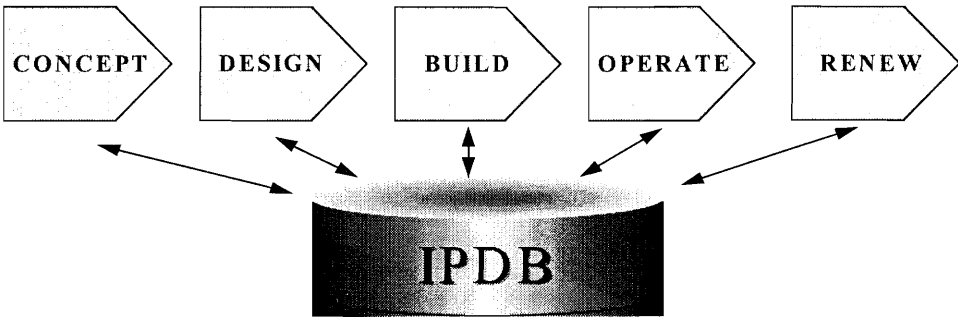


Fig. 1. The Integrated Project Database

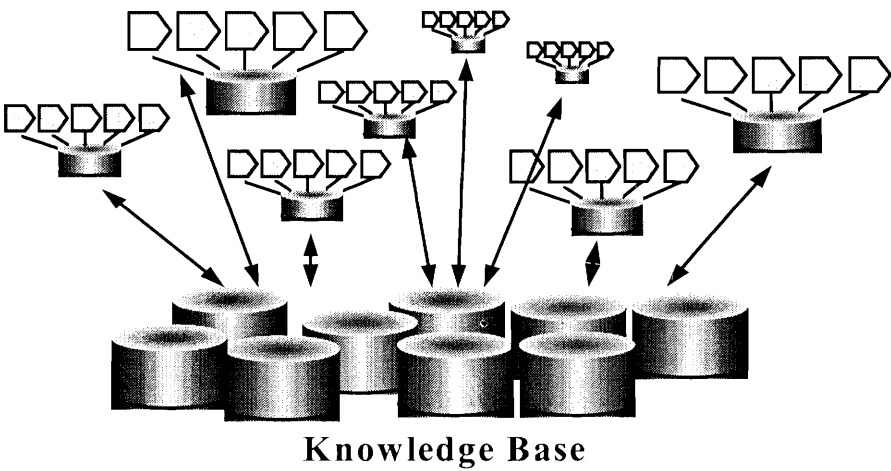


Fig. 2. The Industry Knowledge Base

The Centre has also undertaken two major studies to derive a research work plan by which research and innovation can be collaboratively coordinated. The first study was a process-based analysis of major obstacles to efficient industry performance and of how IT research and innovation could overcome these. The second is the development of a consensus view of UK construction IT academics of what long-term IT research is required to address the main industry challenges that have been identified.

The final element of progress against founding principles has been to develop a research database of major IT research projects underway in the UK positioned in relation to each other by being positioned within a generic construction industry process roadmap. This roadmap has become a unifying feature or framework for the Centre's overall activities.

Much of the current thinking in management generally, and construction specifically, involves the adoption of the process paradigm. Process thinking, and more specifically process redesign, are widely applicable to the construction enterprise. The application of process thinking to construction projects is becoming increasingly common in theory and practice.

A significant example of industrial innovation to define a project process for construction has been undertaken by the British Airports Authority (BAA) in the UK. BAA have devoted considerable resources to defining a project process which as a leading construction client they wish to apply to their portfolio of construction activities. Their motivation for doing so is to obtain substantial improvements in the productivity of their project process as part of their broader aim to become a world class company. Their project process has been documented as a wall chart, a video and a project handbook. The latter is issued to all of their staff, and representatives of their preferred suppliers, who complete an extensive training programme. BAA are also using their project process as a basis for exploring the innovative potential of IT.

BAA are one of a number of major players within the Construct IT Centre of Excellence. Their project process has been adopted by the Centre as a basis for part of its work in attempting to identify and encourage cohesion in Construction IT research. Their continuing work with Alfred McAlpine and Salford University in developing a fully generic process protocol will become the road map for research collaboration in the future in the same way that it has been adopted by the CRISP group and the design management group within IAI. Figure 3 illustrates this in principle by showing how a process road map could allow current and future research to be navigated.

This form of input from a major corporate player within the Centre is typical of the way the Centre works as a network of major organisations combining their work in IT innovation. Other major corporate players within the Centre are represented in other contributors to these papers and other participants at this meeting.

By identifying parts of the project process, as executed at different stages, where existing research and innovation is being undertaken, overlap and synergy can be identified. Gaps in current research and innovation can also be seen and prioritised on the basis of the extent of process improvement that are possible.

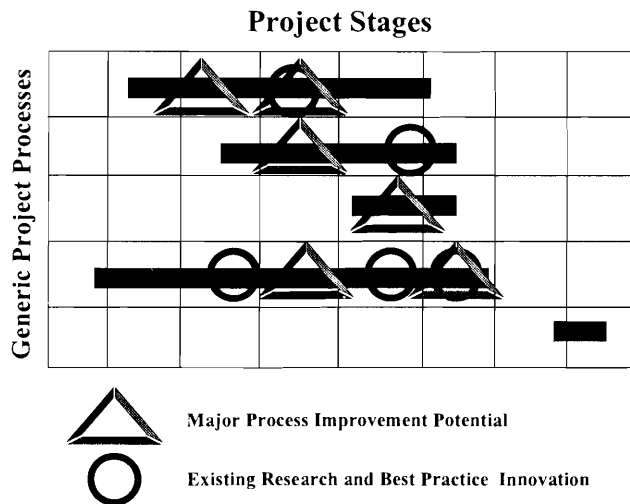


Fig. 3. The Process Road Map

6. More Recent Activities

The Centre's more recent activities also relate to this roadmap in the following way:

- showcasing technological innovation, a stream of activity is being developed whereby leading currently available IT systems that relate to the need for process improvement, will be made available at a physical demonstration centre, through a series of mobile technology showcases, and through a WWW site.
- conducting a strategic IT health check of the way IT is managed, as a result of major case studies of the way IT is being managed in UK and international companies, distilling principles of good practice from the cases, and producing a set of key questions that organisations should ask of themselves to assess how they measure up to leading industry practice. This is closely linked to our benchmarking activity.
- measuring the value and benefits of IT investment, by reviewing methodologies currently in use in construction and other industries from best academic and consulting experience, applying this to major investments being made in IT in the UK at present, and deriving a practical methodology from these experiences.

- helping the industry prepare for the millennium date change problem, by promoting the need for this issue to be taken seriously and outlining a methodology by which construction companies can manage the problem.
- developing an industry leading WWW site, that allows the Centre's work to be made accessible to the wider industry, allows self-benchmarking and self health-checking, allows research and current technology to be showcased, and demonstrates the application of the Internet.
- producing an IT toolkit, by capturing the outputs of all the other activities of the Centre and packaging them as a series of usable tools by which construction companies can help move themselves towards a future best practice of effective IT support to effective construction processes.
- communications activities in support of the Government strategy and the innovation network; that enable the Centre's work and its toolkit to be brought to the attention of the wider construction industry
- and international links.

A national IT strategy can be justified on a theoretical basis. Michael Porter has made a series of studies showing how and why certain clusters of companies in sectors in different parts of the world were outperforming others in international competition. He derived his diamond model to explain superior performance by international clusters of companies. The elements extend beyond a simple model of comparative advantage based on internal factors of production to embrace external issues of customer demands and links with associated industries. An industry getting together to create a strategy is necessary beyond leaving performance of companies to chance. This can be depicted as in Figure 4.

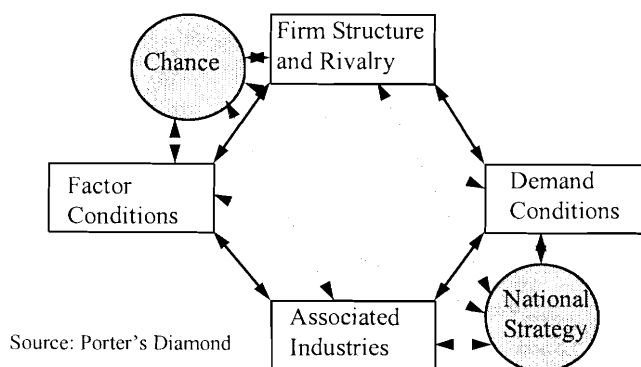


Fig. 4 - The Need for National Strategy

All of the activities of the Centre can be related to Michael Porter's diamond model in the following way:

- producing an IT toolkit to improve factor conditions,

- showcasing technological innovation, as a means of involving associated industries,
- developing and implementing national IT strategy; to polish all of the diamond's rough edges,
- devising long-term research work plans and strategies; to involve associated industries and to improve factor conditions,
- benchmarking current IT applications; to improve demand conditions and improve the firm rivalry,
- conducting a strategic IT health check of the way IT is managed, to improve factor conditions,
- measuring the value and benefits of IT investment, to improve firm structure and strategy,
- helping the industry prepare for the millennium date change problem, to improve factor and demand conditions
- undertaking advanced collaborative industrial training; to improve factor conditions and firm structure in the long-term,
- communications activities in support of an innovation network; to improve firm rivalry, demand conditions and links with associated industries,
- developing an industry leading WWW site, to improve factor conditions,
- and international links.

This framework of project processes has been used within Construct IT as basis for analysing ongoing Construction IT research. Currently more than 200 ongoing research projects have been collected in a web based research database. It is being led by Dr Eddie Finch of Reading University and can be visited at <http://www.constructit.reading.ac.uk/IT.html>.

An earlier sample of almost fifty of these projects were subject to preliminary analysis using the project process as in Figure 5.

Process Road Map - Existing IT Research - Processes and Project Stages

Process	A. INCEPTION	B. FEASIBILITY	C. CONCEPT DESIGN	D. CO-ORDINATED DESIGN	E. PROD. INFO	F. CONSTRUCTION	G. OPP. & MAIN
1	40	14, 40	14, 40				
2		14, 10	14, 10				
3	11, 29, 48	7, 11, 12, 14, 15, 21, 24, 33, 41, 45, 48	6, 7, 11, 14, 15, 21, 23, 24, 33, 41, 45, 48	6, 7, 11, 15, 21, 22, 23, 24, 33, 35, 41, 45, 48	11, 15, 24, 33, 41, 42, 45, 48	11, 13, 15, 24, 33, 41, 42, 45, 48	11, 33
4		15, 24, 32	15, 24, 32	15, 24, 27, 32	15, 24, 42	13, 15, 24, 42	
5	39, 47, 48	39, 45, 47, 48	39, 45, 47, 48	27, 39, 45, 47, 48	39, 42, 45, 48	3A, 13, 38, 39, 42, 45, 48	39
6						13	
7	48	24, 41, 45, 48	24, 41, 45, 48	24, 41, 45, 48	24, 34, 41, 42, 45, 48	3B, 13, 20, 24, 28, 34, 38, 41, 42, 45, 48	
8						13	8, 17, 25, 26

Fig 5. The BAA Project Process

8. The Centre in an International Context

It is increasingly coming to our attention that the nature of IT and innovation is such that to operate nationally rather than globally is futile. Within the Centre we have always had very close links with leading international groups. We had begun to formalise these through EU funding within the SCENIC network of Construction IT Centres throughout Europe. The opportunity and need are increasingly urgent for global collaboration. The UK Construct IT Centre would like to play an active role within a global network. Our close international links clearly indicate to us that many other leading international groups share such an ambition for global collaboration.

9. The Future

The Centre has clearly established itself as the authoritative source of information on construction IT innovation in the UK. It is a successful model that is beginning to be followed in other countries. The work to be done is clearly wide enough to allow pre-competitive collaboration on a global scale. The future for the Centre lies in the leadership of a global network of such activities in major countries around the world.

MAINTENANCE PROBLEMS IN THE REPUBLIC OF CROATIA

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Abstract

The problem of maintenance has been considered in the European and international scientific circles for a long time, due to the fact that economic development and advances in business in a country induce structural changes in investments. The level of investment in the construction of new structural projects is continuously decreasing, while, at the same time, the amount of assets invested in the maintenance of existing structures is on the rise. Indicators of this trends exist in the Republic of Croatia. With the high age of the existing real estate and its exceptionally poor maintenance history, it is realistic to expect the intensification of this problem. The reinstatement of private ownership of real estate will surely lead to increased care given to proper maintenance of buildings. Usage, maintenance and reconstruction costs far outweigh the cost of initial construction.

The paper purposes principles on which management and maintenance of buildings in the Republic of Croatia should be based. A complete information system for total monitoring and control of all activities related to maintenance of buildings is proposed. Also presented is an approach to concise determination of priorities in building maintenance, especially customised to Croatian conditions.

Key word: information system, building maintenance, priorities in building maintenance.

1. Introduction

The European and international scientific circles have been aware of the problem of maintenance of buildings for a long time, since the economic development and industrial advances in a country change the structure of investments. The level of investments in new construction is continuously decreasing, while, at the same, the

amount of assets invested in the maintenance of existing structures is increasing. These trends are fully present in the Republic of Croatia as one of the consequences of the socialist management system. Considering the age of the existing real estate stock and its poor maintenance history, it is realistic to expect intensification of this problem.

Before 1945, the housing building stock in the Republic of Croatia was predominantly privately owned. After World War II, Communists came to power in Yugoslavia and enforce the nationalisation of all private property. Owners of a larger number of apartments or houses were left only one larger (5-6 room) or two smaller (1-2 room) apartments and the remaining were given to new users, the so-called "apartment right users". All other property became state owned.

After 1991 and the disintegration of Yugoslavia, new social and economic relations were established in Croatia. The so-called socially owned apartments were sold to their users at very acceptable prices and thus were again transformed to private property. This resulted in an increased willingness of new owners to better maintain now privately owned buildings and apartments. However, the restoration costs of the facade of a three-storey building in Zagreb built in 1930 are approximately 300,000 DM (cca 100,000 £S). Due to a poor financial situation which is mainly the result of the war and war destruction, but also due to the transition in the economy, the middle class has become poor and incapable to finance the refurbishment of deteriorated facades of buildings in which they own apartments.

To date, no systematic research in the area of building maintenance has been undertaken in the Republic of Croatia. The Department for Construction Organisation at the Faculty of Civil Engineering in Zagreb has submitted to the Ministry of Science of the Republic of Croatia a scientific project titled "Problems in buildings maintenance in the Republic of Croatia". The financing of the project has been approved and this paper represents the first systematic approach to the research into the problem of building maintenance in our country. A systematic approach to rational building maintenance is essential for the identification of priorities in the renewal and maintenance of buildings and also for the definition of ways to include the municipal and statal institutions in this process. The old urban core zones are a historical heritage belonging to each resident.

2. Existing Condition

Building maintenance in the former system was disordered and non-systematic, with the main difference between the maintenance of apartment buildings and public buildings (theaters, schools, hospitals, office buildings, etc.). Therefore, it is possible to classify the buildings into two main groups:

- a) public purpose buildings.
- b) housing buildings.

Public purpose buildings were the direct responsibility of individual ministries, and there was always a shortage of money for their maintenance. Repairs were carried out only when it became indispensable, and partial or complete reconstruction of a building would be undertaken only when the condition of the building became alarming.

The housing buildings stock was divided between the actual apartment owners and the so-called 'apartment right users', who had the same rights as the actual apartment owners although their apartments were owned by the state or their company. The institute of 'apartment right users' was a specialty of the socialist system in Yugoslavia, and had a significant impact on the condition and maintenance of housing buildings. This will be detailed hereinafter.

The following table shows the structure of state investments in the maintenance of all buildings. There are different categories: regular maintenance, reconstruction, and repairs, including urgent interventions.

Table 1: Costs of building maintenance in the Republic of Croatia

Year	Regular maintenance %	Reconstructions %	Repairs %
1985	18	71	11
1986	12	81	7
1987	11	66	23
1988	16	70	15
1989	15	65	20
1990	8	84	8
1991	16	69	15
1992	25	53	21
1993	11	71	18
1994	57	32	11
1995	10	62	28

Source: State Statistics Institute

What is interesting is that before 1991 regular maintenance was represented with 8% to 16%, repairs with the same proportion, but reconstructions represented 65% to 84% of the total costs. This represents US\$ 97,500,000 for 1995.

Table 2. Maintenance costs for public buildings (schools, dispensaries, out-patient departments, hospitals, retirement homes, sports halls, municipality buildings, etc.)

Year	Regular maintenance %	Reconstructions %	Repairs %
1985	4	85	11
1986	3	88	9
1987	4	85	11
1988	8	79	13
1989	6	73	21
1990	1	93	5
1991	3	84	13
1992	3	76	21
1993	2	80	18
1994	2	83	15
1995	5	81	14

Source: State Statistics Institute

When analysed, the investments into public buildings are divided as follows: regular maintenance 2-4% of the total funds, repairs between 10% and 20%, and funds invested in reconstruction between 73% and 93% of the total funds available for maintenance in the Republic of Croatia. This amounts to US\$ 34,350,000 for 1994.

The attitude towards the city and housing buildings in Croatia shows improvement after 1985. as a result of changed political relationships in Yugoslavia. More funds are being invested in regular maintenance, although investments in reconstruction are still a large item due to long period of deterioration, especially in Zagreb. For 1995 this amounts to US\$ 53,395,000.

Table 3. Structure of maintenance costs for housing buildings stock in the Republic of Croatia

Year	Regular maintenance %	Reconstructions %	Repairs %
1985	44	46	10
1986	38	59	3
1987	20	40	40
1988	33	50	18
1989	36	47	17
1990	37	48	16
1991	29	53	18
1992	50	29	22
1993	28	52	19
1994	78	13	9
1995	16	39	44

Source: State Statistics Institute

Many years of poor maintenance of the old urban core areas, particularly pronounced in Zagreb, have caused serious deterioration of the once beautiful fronts of buildings built at the turn of the century due to lack of basic maintenance.

The age structure of housing buildings stock in Croatia shows a high proportion of over 36% of the stock being before 1960. Here a difference should be noted between buildings constructed before 1945 (23%) and buildings constructed immediately after World War II. The quality of buildings constructed during the first fifteen years after World War II is significantly inferior, which creates additional maintenance problems.

Table 4. Age structure of housing buildings stock in the Republic of Croatia

Year of construction	Number of apartments	%
before 1918	223,004	14.2
1919-1945	147,769	9.5
1946-1960	199,697	12.7
1961-1970	329,937	20.9
1971-1980	379,876	24.3
1981-1985	156,630	9.9
after 1985	132,812	8.5
Total	1,569,725	100

Source: 1996 Statistic Yearbook of the Republic of Croatia

As shown in the above Table, over 63% of total number of housing buildings in the Republic of Croatia had been constructed during the last 35 years. It was customary in the socialist system that the state would built new housing blocks in newly developed districts, while the existing stock consisting of old pre-war "patrician" buildings was being systematically neglected and left to deteriorate because "there was no money" for their maintenance. Those buildings were mainly occupied by actual owners of the apartments and the so-called 'apartment right users', and the apartments were maintained depending on personal needs, preferences or financial capacity of the tenants, but without any obligations to do so.

Because of all stated above, the need arose to reconsider the problem of buildings maintenance in its entirety as integral maintenance management.

3. Buildings Management and Maintenance Principles in the Republic of Croatia

To gain complete perspective of the buildings maintenance problem in the Republic of Croatia, it a number of preparatory activities are required in order to establish the principles of buildings management and maintenance throughout the country. It is also essential to establish the methodology that will result in the development of the information system for the support of buildings management and maintenance.

Firstly, it is necessary to research into the phenomenon of maintenance, refurbishment, reconstruction and real estate management in the Republic of Croatia regarding the regulations, market conditions, past practice, financial possibilities and traditions. Secondly, several types of buildings within the Croatian buildings stock are selected based on their number and problems related to technical and financial aspects of their usage and

maintenance. Then follows the determination of the structure of the main structural and non-structural elements of selected buildings and the definition of maintenance works for these buildings. This is followed by the research of the durability of the above elements and entire buildings and the possibility and requirement for their maintenance, refurbishment or technical replacement. Regarding the technical possibilities to carry out refurbishment works, the current trends are to treat the problem from the aspect of technical resources used in the maintenance, the technological systems and materials applied, the durability of individual construction materials and application of new construction materials.

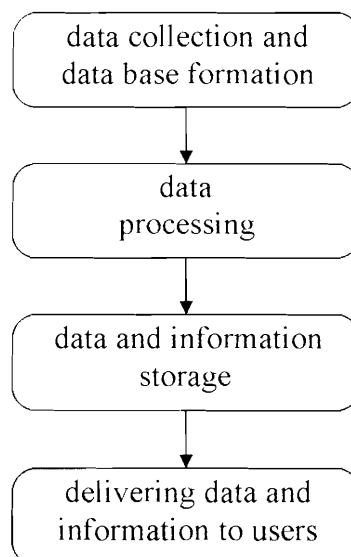
When the essential structural and non-structural building elements are defined and the possibilities for their refurbishment or reconstruction investigated, the priorities in maintenance are to be defined. The impact of the elements on the safety, accommodation, external appearance, location, esthetics etc. is considered.

After the priorities are set, the following items are to be costed: maintenance, refurbishment, and replacement costs, their structure, magnitude, frequency and similar - and the model for forecasting building maintenance costs is formulated. Relationships between the funds invested in maintenance, refurbishment and reconstruction of buildings are then established, taking into account their usability, durability and value.

Efficient maintenance is practically impossible without the build-up of the information system linking all the above listed activities.

4. Information System as Support to Decision Making

Basically, the information system executes four sequential functions which can be shown in the flow chart:



The sources used by the system, the origin of data, as well as the preparation, collection and data input are to be defined. Collected data are processed according to the user's needs. That includes calculations, regrouping, sorting, compression and analysis. Collected and processed data are stored for later use or are delivered to users for decision making purposes.

Two Zagreb districts, Downtown and New Zagreb, will be used as basis for the implementation of the complete information system of buildings management and maintenance in the Republic of Croatia.

The archive of the Municipal Housing and Communal Management Department of the City of Zagreb is used as the source of information. The archive comprises information on all building elements subject to maintenance in the mentioned districts and the amount of funds spent so far for maintenance and refurbishment of those elements.

Records on maintenance works for each particular building are extraced from the databas:.

water supply installations
electrical installations
roof structure
carpentry
facade
floors
...

In order to define the priorities in maintenance of individual building elements, criteria are defined, based on which individual works are evaluated and the decision is made. Each criterion weighs each maintenance element and the collective assessment defines the priorities. These criteria differ from country to country and are the object of continuous scientific research. A large number of criteria and consistency in their evaluation lead to a better assessment of maintenance priorities.

Some of the criteria applicable in our region are:

structural safety
quality of accommodation
external appearance
building durability
environmental impact
price
...

A sort of ranking list of elements to be maintained is defined by interconnecting the database of maintainable elements and the maintenance criteria database. The goal of the information system is also to show that the evaluation of the criteria has been consistent. The total maintenance costs are then estimated and relationships between the funds invested in maintenance and the increased usability, durability and value are established.

Applying the analysis on several buildings, a database is created consisting of buildings and already set maintenance priorities, as well as the costs involved. Thus, a realistic picture of the resources required for the maintenance of buildings in one district is created.

The database will expand to cover the entire Zagreb area and eventually the Republic of Croatia, which will give a realistic assessment of how large funds should be allocated from the budget for a quality management of the housing buildings stock.

Thus, both the researchers, which are continuously upgrading the information system, and the City Authority, in charge of budgeting the maintenance of buildings, become the users of the new database.

5. Conclusion

This report presents the basis for a complete information system for the monitoring and control of all activities related with buildings maintenance, especially designed to accommodate the conditions prevailing in the Republic of Croatia.

Numerous researches conducted in many developed countries had contributed, from various aspects, in throwing more light on the real estate maintenance problem. Thus, particularly studied are buildings maintenance management, real estate maintenance and management economics, management and execution of works on maintenance and refurbishment, refurbishment and protection of buildings, sociological problems related to maintenance and modernisation, education and training for participation in real estate maintenance and management, monitoring and control methods, maintenance technology, computerisation in maintenance, and legal issues in the field of maintenance.

So far, there was no scientific research into buildings management and maintenance carried out in Croatia. Foreign experiences in this area cannot be directly applied because each country has its own specifics which are the result of differing problems to be solved in the maintenance process. These problems are: age of the buildings, their original quality, used construction technology and materials, climate, type of ownership, financial state of the country etc. It is, therefore, impossible to apply the available knowledge on maintenance management on the 'Croatian case', and is necessary to adjust existing knowledge and capabilities to our needs and conditions.

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THE INTERNATIONAL BENCHMARKING OF VALUE MANAGEMENT

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Summary

This paper is based on a project entitled “International Benchmarking of Value Management” funded under the EPSRC IMI programme. The paper outlines the prime objectives of the project which is to benchmark the performance of the value management methodologies described in the textbook “Value Management in Design and Construction: 2nd edition” by Kelly and Male against those practised in the UK and overseas, in order to arrive at a conclusion of best practice.

The paper supports the view that benchmarking in the construction industry is in its infancy with the majority of hard techniques being geared towards producing databases of site costs and duration of construction activity. The paper describes the first case study based exercise in determining what to measure and concludes that hard metrics are not appropriate for a subject such as value management and that soft metrics are required. Following the development of a benchmarking method using soft metrics extensive benchmarking was undertaken with value management practitioners in UK, Australia and USA. Further benchmarking is planned for Europe and Japan.

1. Introduction

The paper describes the formation of a method of benchmarking which involves distinguishing from literature those techniques which are considered “hard” as opposed to “information grazing” or “industrial tourism”. The techniques were formalised into strategies for action and bearing in mind these strategies four case studies were undertaken. This paper addresses a number of issues raised by the literature, defines the critical success factors of value management, assesses the outcome of the case study work, defines a soft metrics approach to benchmarking, and describes the extensive benchmarking undertaken with value management practitioners in UK, Australia and USA. The paper concludes with a definition of a soft metrics approach to benchmarking with an example based upon the pre-workshop activities. The paper concludes with a statement of the way forward in continually improving the value management service.

2. Benchmarking

For a definition of benchmarking Camp firstly quotes David T Kearns, Chief Executive Officer, Xerox Corporation; benchmarking is “the continuous process of measuring products, services and practices against the toughest competitors or those companies recognised as industry leaders”. Camp secondly adapts this definition to “Benchmarking is the search for industry best practices that lead to superior performance”. [Camp, 1989]

Benchmarking can be undertaken either with or without the co-operation, consent or even knowledge of the parties involved. Benchmarking products, for example computers, is an example of benchmarking which can take place without the knowledge of the party whose products are being benchmarked. In the context of benchmarking with co-operation, consent or knowledge there are three types:

- Competitive benchmarking where information is sought from a hostile competitor. This is generally considered the most difficult type of benchmarking.
- Co-operative benchmarking where knowledge is exchanged with the benchmarking partner. In this case it is generally observed that the initiator usually receives more information than they give.
- Collaborative benchmarking where there is full knowledge exchange between the parties.

In the context of value management it is anticipated that benchmarking will be either co-operative or collaborative. In selecting benchmarking partners four groups of organisation could be considered [Camp, 1989]:

- Current direct industry competitors.
- Latent competitors, including those in the same industry but not currently in your market.
- Best-in-class groups from within your own organisation.
- Best-in-class companies from other industries.

In addition to the above listed by Camp there are also:

- Best-in-class groups from within the same industry who may or may not be direct or current competitors.

This gives a useful framework within which to operate. Those relevant to this study are value management consultancies and in-house organisations operating in the construction, process and manufacturing fields. Latent competitors are not relevant immediately to this study.

Boxwell describes six basic steps to benchmarking [Boxwell, 1994]

1. Deciding what to benchmark.
2. Planning the benchmarking project.
3. Understanding your own performance.
4. Studying others.
5. Learning from the data.
6. Using the findings.

These steps will be adopted for the methodology of benchmarking value management.

Robert Camp identifies ten success indicators which will ensure that a benchmarking exercise will run smoothly [Camp, 1989]:

- An active commitment to benchmarking from management.
- A clear and comprehensive understanding of how one's own work is conducted as a basis for comparison to industry best practices.
- A willingness to change and adapt based on benchmark findings.
- A realisation that competition is constantly changing and there is a need to 'shoot ahead of the duck'.
- A willingness to share information with benchmark partners.
- A focus on benchmarking first on industry best practices and second, on performance metrics.
- The concentration of leading companies in the industry or other functionally best operations that are recognised as leaders.
- Adherence to the benchmarking process.
- An openness to new ideas, being creative and innovative in the application of new procedures to existing processes.
- The institutionalisation of benchmarking.

It has been shown that there is a tendency to get carried away when benchmarking, it is realised that there is a limit to how much information can be collected and assimilated at one time. The whole exercise must be properly time-tabled with clear goals and deadlines, the identification of what is crucial, especially when benchmarking 'customer satisfaction'.

Watson [1993] defines a code of conduct which generally highlights the do's and don'ts of benchmarking and can be summarised as follows:

- There is a real need to make sure that all information gathering is within legal limits.
- Information is fully shared with benchmarking partners and information received is kept confidential if asked to do so.
- The expectations of the exercise are to be fully understood, both within the research team and when in contact with external parties.

Honesty towards potential partners is most important.

3. Benchmarking in the Construction Industry

The growing body of management literature dedicated to benchmarking deals with good practice procedures and a generic process model that can be used as a framework for carrying out benchmarking exercises. To date, UK managers have had little experience of the technique in practice [Lema, 1995]. This position is changing with an increased awareness of the technique, though there is still a general lack of awareness of what benchmarking actually means.

Literature supports the view that there are currently a lack of benchmarking standards for construction internationally, though industry and academia have recently turned their attention to developing them. One reason put forward for this [Lema, 1995], is that the concept and principles of benchmarking are more difficult to apply to essentially project based activities and “one-off” products. In the USA the absence of any identifiable benchmarked data has stimulated researchers to compile initial data of construction activities for use by the industry [Fisher, 1995].

A common feature of the construction activities that Fisher describes as being benchmarked is their ability to be measured in terms of cost and time, therefore, fulfilling a primary requirement of objective comparability. This type of data includes, for example, actual versus authorised project cost, actual versus target schedule, actual versus estimated labour etc., all data which can be given classic statistical treatment.

4. Benchmarking Value Management

An examination of the work of Fisher above leads to the conclusion that it is not realistic to expect that meaningful external benchmarking of value management activities can be derived from this type of “hard” analysis. On the other hand the ultimate in “soft” analysis, i.e. unstructured comparisons, could be criticised as being “information grazing” or “industrial tourism” from which few firm conclusions could be drawn.

The way forward appeared, in the first instance, to lie in the stripping down of value management into its critical success factors and then examining the hard techniques which lie within each factor. The hard techniques could be realised through an examination of case studies.

Value management is defined as:

a proactive, creative, problem solving service, using a multi-disciplinary team orientated approach to make explicit the client’s value system using functional analysis to expose the relationship between time, cost and quality. Strategic and tactical decisions are audited

against the client's value system at targeted stages through the development of a project or the life of a facility. [Kelly & Male, 1993]

The critical success factors can be summarised as:

- Structuring the project information
- The structured approach through the "job plan"
- The skill of the facilitator
- The team structure, skills and working relationship
- The attitude of stakeholders

The above reflects a philosophical rather than a technical approach. If this can be presented as a series of commonly used techniques then it is thought that true benchmarking can take place. An examination of case studies was thought to enable:

- the identification of discrete techniques displaying time and performance characteristics
- the measurement of factors such as identified activity/hour e.g. ideas/hour, ideas/£, ideas generated/ideas implemented, savings/cost of exercise, people involved/idea recommended, facilitator efficiency in gathering material, client satisfaction on a proved scale.

5. Benchmarking value management case studies

The following case studies are based upon an examination of completed value management reports of studies undertaken using the Kelly and Male methodology by the authors as value management consultancy projects. The aim of the case study investigation was to determine the extent to which value management studies could be the subject of benchmarking. The commonality of the authorship of the method, the facilitation of the value management workshops and the authorship of the workshop reports is a useful means of ensuring commonality of data for an initial trial bearing in mind the following:

- the workshop reports were contemporary with the workshop and were not written to facilitate benchmarking.
- the workshop reports were of a similar style to those of other consultants undertaking similar work.
- workshop reports are the prime source of inert data for benchmarking.

Kelly & Male [1993] have described their approach to value management with reference to levels of decision in the project life cycle associated with different stages of the RIBA Plan of Work (extended to include a pre-brief stage) reproduced here as figure 1.

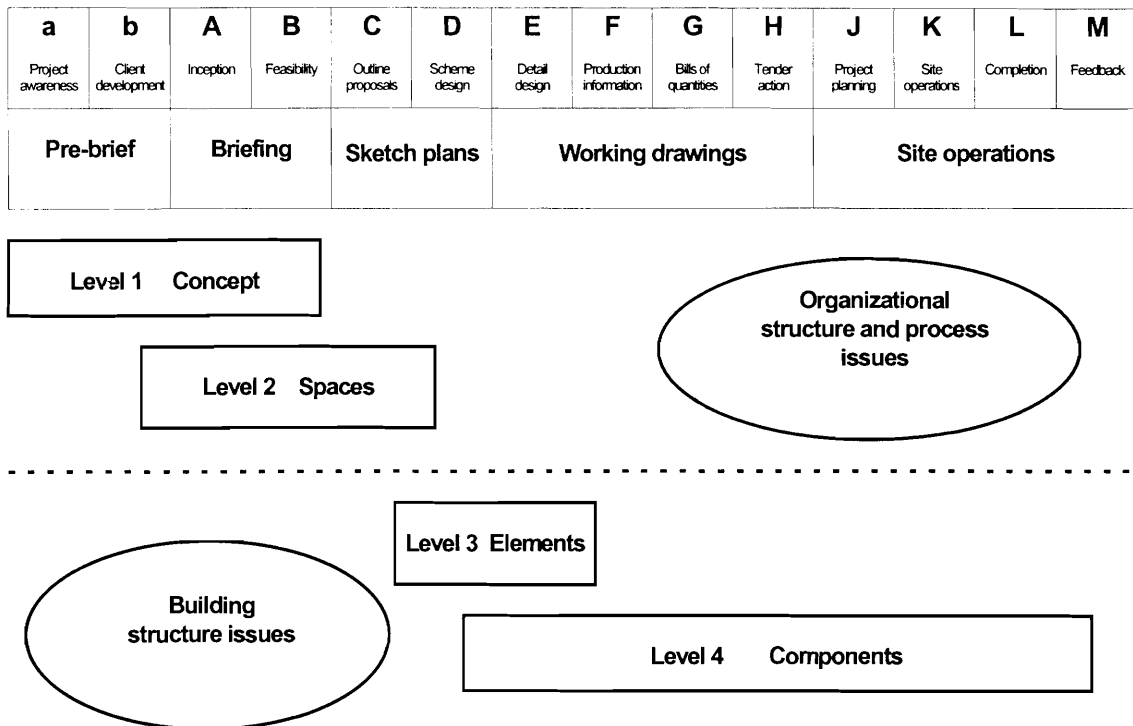


Figure 1 Level of decision in the project life cycle

The case studies chosen to represent value management studies at different stages in the project life cycle are as follows:

- Project 1: Pro-forma briefing document for a Sheriff Courthouse
- Project 2: Design-build project at pre bid stage for an industrial works upgrade
- Project 3: Pharmaceutical clinical trials unit at outline sketch design stage
- Project 4: Crown court at final sketch design.

The techniques used are summarised in table 1 below:

Table 1: Analysis of case studies

	Project 1 Sheriff Courthouse	Project 2 Works Upgrade	Project 3 Clinical Trials Unit	Project 4 Crown Court
Pre workshop				
Post Occupancy Evaluation of existing building	•			
Document analysis	•			•
Facility walk through	•	•		•
Interviews	•	•		•
Workshop				
Project context analysis	•	•	•	•
Function analysis		•	•	•
Function diagram	•			•
Time/cost/quality	•	•	•	•
User flows	•		•	•
Adjacency matrix	•			•
REDReSS	•		•	•
Brainstorming (ideas generated)	not recorded	392	205	90
Judgement	•	•	•	•
Development	•		•	•
Procurement choice	•		•	
Presentation	•			•
Workshop time (hours)	30	12	24	40

The table supports no specific conclusions. There is no correlation between ideas generated and the time spent at the workshop; time preparing pre-workshop and ideas generated nor between tasks undertaken and ideas generated. There is some correlation between the number of techniques used and workshop time and possibly between time taken, the number of techniques used and overall workshop quality although this can not be judged from the reports.

In judging the workshops, Project 4, the Crown Court, could be said to be the closest to a textbook interpretation of a value management study aided perhaps by a previous study at outline sketch design stage. Project 3, the clinical trials unit, a study undertaken at outline sketch design stage highlighted a number of logical concerns of a strategic nature mainly related to time and cost certainty coupled with a risk averse client. These issues should strictly have been addressed earlier in the project life cycle. Project 2, commissioned by the design/build contractor with the co-operation of the client, was concerned with generating as many ideas as possible and getting client feedback. The other tendering contractor was also given the opportunity of undertaking a value management exercise. Project 1, the Sheriff Courthouse, was an exercise at producing a generic brief and as such had no specific project applicability. A part of the information stage was undertaken as a Post Occupancy Evaluation of an existing Sheriff Courthouse.

6. Findings of the first stage study

The literature on benchmarking has raised a number of issues of which the following are seen to be dominant:

- identifying the critical success factors and determining which of these to benchmark
- establishing quantifiable performance metrics (defined as measurable outcomes that indicate a degree of success in achieving some value management objective).

In terms of value management the critical success factors have been established as:

- Structuring the project information
- The structured approach through the “job plan”
- The skill of the facilitator
- The team structure, skills and working relationship
- The attitude of stakeholders

However, “what to measure?” posed a dilemma. The case studies support the intermediate conclusion that the analysis of a complete value management study is unlikely to yield any benefit. This led to the speculation that the answer to this dilemma lies in the value management toolbox, in the tools and techniques themselves. Performance metrics may be determined in two ways:

1. to analyse each tool in turn to determine a characteristic time taken to achieve a pre-determined objective. This could be carried out by experimentation and yield a measurable efficiency rating.
2. to build a series of example case situations to be presented to those practising value management with a request that they chose the appropriate tool to facilitate the solution to the problem.

Both of these methods had their own attraction and formed the focus of the next stage of this study.

7. A Case Vignette Approach

A vignette is a brief but clear verbal description. A case vignette in the context of this study is a brief written description of a construction situation conducive to value management. MacPherson (1994) used a case vignette approach in his study of decision making in the design of building services systems. The proposal was made that if a number of case vignettes were developed to represent various construction project situations then these could be used with benchmarking partners to explore best value management practice.

A number of case vignettes were developed from a matrix describing projects under headings of:

- Public or privately funded
- Owner occupier or speculative (which in the latter case required a surrogate user)
- Complex- high value, complex- low value, straightforward- high value, straightforward-low value.
- High quality, low quality
- Tight time constraints, no major time constraints
- Procurement route i.e. design/build, traditional, management contract, construction management.
- The stage in the project at which the value management study was to be held.

A seminar was held to test the case vignettes involving the research team and a client representative. After extensive trials and discussion the consensus was reached that the factors which were important from a value management stand point were:

- whether or not the client and/or user were to be present at the study and
- the stage in the project at which the study was to be undertaken:

All other factors were addressed within the value management study but did not impact the style of study. The extensive development of case vignettes was therefore abandoned in favour of two direct preliminary questions.

8. Development of a Benchmarking Methodology for Value Management

An extensive review of the benchmarking literature summarised earlier identified the following attributes of benchmarking which distinguished it from subjective comparisons, industrial tourism or information grazing:

- the identification of best in class value management practitioners and the attempt to arrange benchmarking exercises with these.
- the frank, honest and open sharing of information.
- the focusing first on industry best practice and then on performance metrics
- the respecting of confidentiality.

This is further reinforced by McGeorge and Palmer (1997) who summarise the stages of benchmarking as being:

- The analysis of own systems and methods of working and make any necessary improvements
- Look at own industry to learn the best methods and try to achieve the best practice
- Look outside of own industry to learn the best methods and try to achieve those best practices also.

The benchmarking methodology adopted for value management is based upon a soft metrics approach and synthesised from the above as follows:

Stage 1	Make explicit the value management method derived from research and used by Kelly and Male in consultancy activity.
Stage 2	Identify performance metrics
Stage 3	Identify best in class value management practitioners and make contact with these with the aim of organising a benchmarking activity.
Stage 4	Undertake benchmarking
Stage 5	Revise Kelly and Male methodology in order to reflect benefits from the benchmarking exercise. The final document becomes a best practice manual which is tested at expert seminars.

9. Application of a Benchmarking Methodology

Stage 1 - Make explicit the Kelly and Male methodology

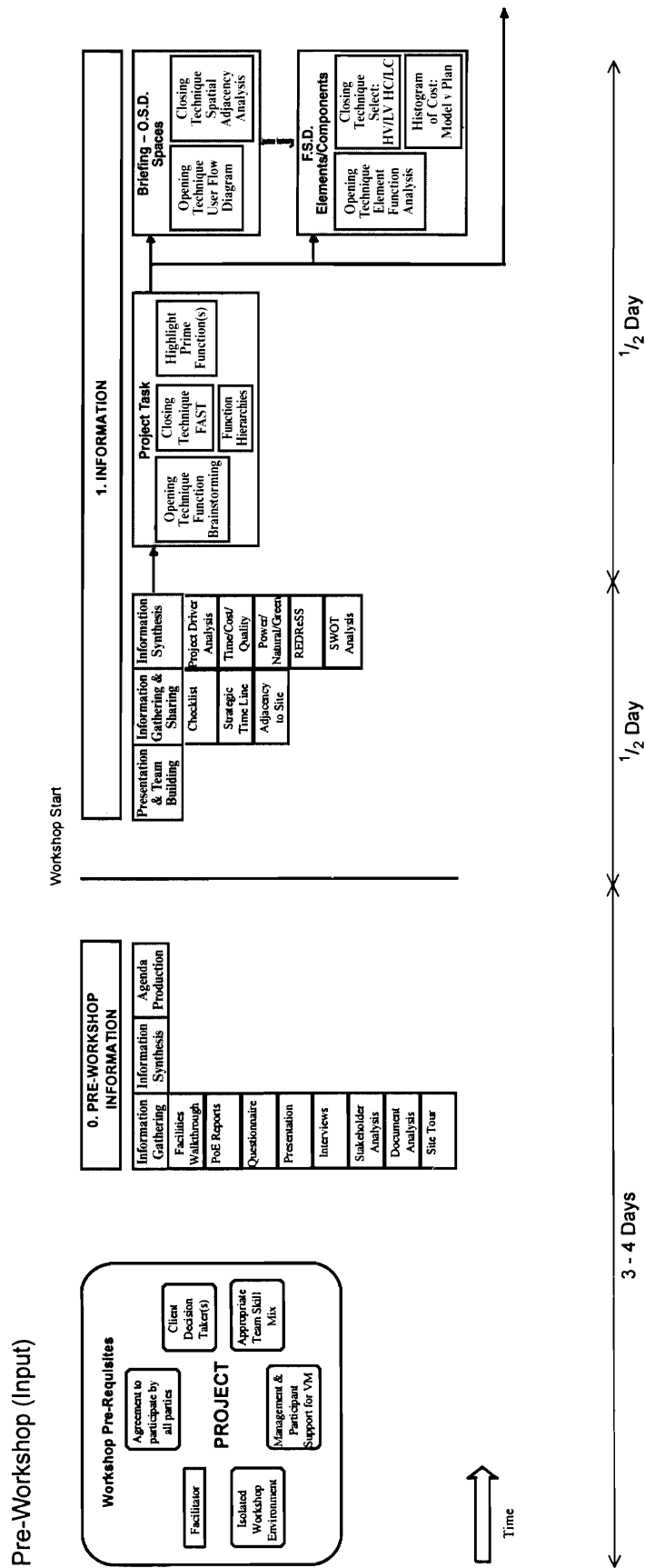
The Kelly and Male methodology was reduced to the diagram as shown in figures 2 and 3. The diagram embodies the stages of the value management process and the techniques used by Kelly and Male in value management consultancy.

Stage 2 - Identify performance metrics

The diagram therefore provides a breakdown of the value management process into discrete performance metrics. These metrics are characterised by their capability of being described in terms of activity and an approximate time associated with the activity.

Stage 3 - Identify best in class value management practitioners

The RICS Geographic Directory identifies 78 surveying organisations which offer a value management service. From information gleaned primarily from clients of value management services, best in class organisations



Note: O.S.D. = Outline Sketch Design stage in the project life cycle.
F.S.D. = Final Sketch Design

Figure 2 Pre-workshop and first day

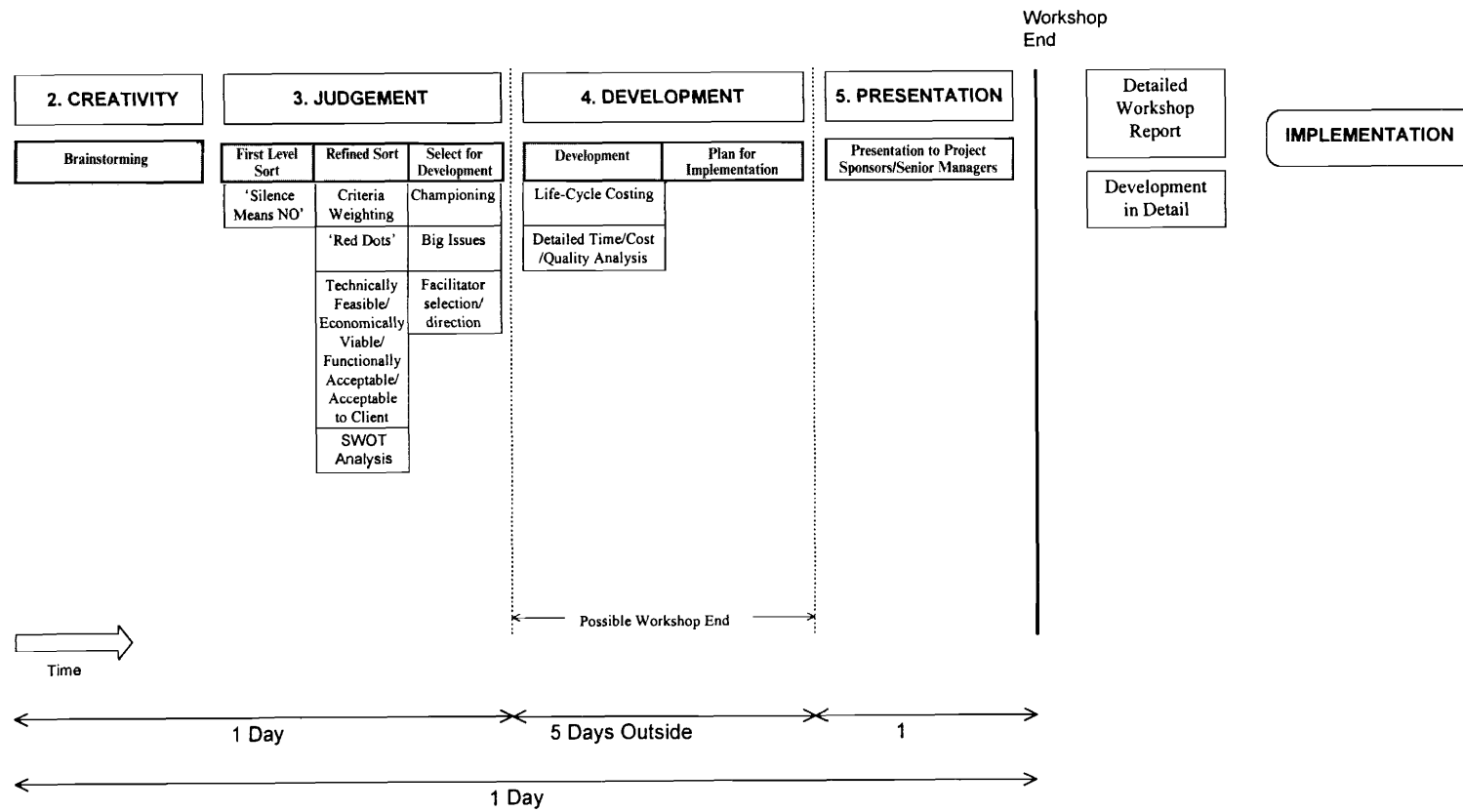


Figure 3 Workshop day 2 (or alternative if development outside workshop)

were identified as being two contractor based organisations and seven value management consultancies of which six were either Quantity Surveying practices or wholly owned subsidiaries of Quantity Surveying practices. Arrangements were made to undertake benchmarking in the early part of 1997.

At the same time contacts were being made in Australia, Japan, USA and Europe with the intention of identifying best in class. In the case of Australia a start was made by making reference to the New South Wales, Public Works Department's list of approved value management practitioners and a number of benchmarking sessions were arranged before travelling to Australia. On arrival in Australia Kelly and Male made a presentation to the Institute of Value Management Australia and subsequently took advice on best in class and sought these practitioners where they were not on the original list.

A similar approach was used for the USA with the SAVE International conference in Seattle being the focus and site of 18 benchmarking exercises.

Stage 4 Benchmarking

In the UK two client interviews gave focus and direction towards 11 benchmarking studies of which 2 were undertaken with manufacturers. In Australia 10 studies were undertaken including 2 with national and state government representatives which also provided focus. In the USA 12 construction and 6 manufacturing benchmarking studies were undertaken. Some work has been done in Europe which presents a patchy picture of the application of value management generally and some work has been undertaken in making contacts in Japan although to date no benchmarking studies have been arranged.

Stage 5 Application of Results

The sorting of data gained is currently being undertaken, it is hoped to complete stage 5 before the end of 1997.

10. Illustration of Preliminary Results

The following is an illustration of the preliminary results from Benchmarking the metric pre-workshop information gathering. The Kelly and Male methodology requires structured information gathering by the value management facilitator(s) comprising:

- Facilities walk through, in situations where the client is proposing a building of a similar corporate style to an existing facility.
- PoE reports, the study of any post occupancy report data.
- Questionnaire, the studying of any user satisfaction surveys as appropriate.
- Stakeholder analysis, the discovery, usually in discussion with the client, of all those who will have a stake in the completed project.

- Document analysis, the study of client files to map a history of the project, primarily to gain an insight into the brief which would also be studied.
- Interviews, with key people who may or may not attend the value management workshop e.g. client's project sponsor, the architect and project manager.
- Presentation of the information at a pre workshop meeting which would be held on the evening before the first day of the workshop.

The Kelly and Male methodology requires the use of two facilitators during the workshop which is generally of two or three days duration. However, normally information gathering would fall to one facilitator.

Benchmarking highlighted different approaches to this stage as follows:

- Pre-workshop meeting of the full value management team to highlight the main issues was used by three facilitators in Australia, two in the USA and four in the UK. This meeting could precede the main workshop by up to three weeks. This meeting prompted an information pack prepared by the facilitator in two cases in Australia and one case in the UK. In the USA it was common for a meeting to be held between the facilitator and the client only and/or a further meeting with the facilitator and a cost consultant. The issuing of information packs prior to the workshop was a common feature of value management studies in the USA.
- No pre-workshop activity was the preferred situation for three facilitators in Australia, three in the USA and one in the UK. The cost of such an activity in a competitive commercial environment was the most common reason for it not being undertaken.
- Some variant of the Kelly and Male approach was used by one facilitator in Australia (also nominated as best in class by other facilitators), four in the USA of which two were manufacturers and four in the UK of which one was a manufacturer and another construction organisation was considered best in class by the majority of those surveyed.

The issue of fee bidding was mentioned by the majority of facilitators with those who undertook up to three man days on pre-workshop activity stating that they could not compete on price and relied on repeat commissions.

It was noted that the Kelly and Male methodology at the pre-workshop stage was used in some form by two best in class practitioners, one in Australia and one in UK. However, the Kelly and Male methodology focused on briefing the facilitator only whereas others used the information gained to form the basis of an information pack which was circulated to the team prior to the workshop. This it was argued was an efficiency gain and allowed the team a faster entry into the workshop. The extent of the efficiency gain will be measured and if it is considered appropriate the Kelly and Male methodology will be modified.

11. Conclusion

A considerable amount of research in this project has been devoted to identifying and defining soft metrics and realising a method of their measurement. At the time of preparing this paper a Microsoft Access based data base is being compiled with all of the results of the benchmarking exercises. From this database it is expected to draw a meaningful correlation between individual items of data. As a part of the benchmarking procedure complete confidentiality has been maintained, with the benchmarking partners gaining the most through an anonymous version of the full database. It is confidently anticipated that a best practice manual for value management will be available during the early part of 1998. The realisation of soft metrics and a method of benchmarking will promote continuous improvement in value management services.

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RESEARCH INFORMATION IN CONSTRUCTION
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Abstract

The research addresses the problems associated with the gap which exists in the provision and dissemination of construction research and other relevant information and the need to improve the accessibility to the sources of information.

To this end, the work investigates the major sources of research information in the UK and abroad. The sources have been categorised under commercial and institutional databases. These are collated under On-line, CD-Rom and Hard Copy prints out formats. The areas covered primarily relate to the disciplines within construction management and economics. But the report also covers other disciplines within construction.

The report demonstrates that there is no shortage of relevant information in the fields of construction and the amount of research information is indeed significant. The sources of information may be varied and sometimes very expensive, but they are structured and they are accessible for use and for interrogation. However, it seems that there is a very low level of awareness, amongst both academics and the industry, about the existence of these sources.

Keywords: Construction, Research, Database, Information

1 Introduction

The success of a research project is to a large extent dependent on the availability of information relevant to the area under investigation. The knowledge about the past work lays the foundation for the conduct of the relevant ongoing and future works. Similarly, for the industry to be able to take advantage of the research activities, it must have access and have up-to-date knowledge about other research activities. The same applies to the professional institutions and bodies. This is particularly true for the Construction Industry in the UK which has a less than satisfactory record of R&D. The construction data/information consumers tend to spend a good proportion of their research time searching for the right information.

Often a completed research work finds its home in a bookshelf amongst other works, which would have otherwise had the potential to be converted into a form exploitable by the industry. Even the subsequent publications arising from the research works in the refereed academic and trade journals, or the proceedings of conferences, do not present themselves exploitable by the industry.

With the significant advancement of the tools and methods of communication and information technology, the discussion about the location of information needs to be addressed. The dominating trend that prevailed during the 80s advocated a centralised approach to data storage. On the other hand, the advent of the Internet and the enhancement of the tools of communication, during the past few years, has promoted a completely opposite course of action: centralised information bases have, to a large extent, given way to individual web pages.

However, the problem with the distributed approach to location of information is its total reliance on the effort of the individual be it a person or organisation. The dynamic nature of the Internet has facilitated its expansion into the world's largest source of information. However, this dynamic nature and the anarchical approach to information storage have a downside that information can alter or disappear or, the quality, origin and authenticity of the information can be compromised. Nevertheless, much of the problems with the use of the Internet are the problems of growth, though the development and expansion of the Web may result in the growth of new problems such as extensive copy rights infringements, but the technology has the potential to deal with these problems.

At present the main problems facing the research community is that much of the information, on the net, has not yet been shared widely. Certainly, in the field of construction, the information about the vast amount of research works have not been made available to the interested parties and there is no evidence of it moving in that direction. Therefore, it appears that despite the advancements of the tools of communication which bring individuals closer together, there still is a need for the availability of centralised sources of research information: identifiable points of reference can shorten the often tedious and timely process of literature searches and the dissemination of research information to the industry. This is the direction which the large companies are currently exploiting: the development of Meta-Data, Data Warehouses and Data Marts has proved to be the way forward. This is a highly centralised approach to data storage and processing that enables the use of information also in a distributed manner but with a greater degree of control and processing efficiency.

Nevertheless, as it stands both, the centralised and distributed forms will continue their development separately and in combination, and their interdependence will not hinder their independence.

This paper is based on the identification of the need for access to research information by the academics, industry and the institutions, and the problems of the dissemination of research information. The work is to a large extent a survey of the sources of research data in the UK and abroad. These sources are categorised under Commercial databases and Institutionalised databases. These categories are subdivided into on-line, CD-Rom and hard copy print out. The areas covered primarily relate to the areas relating to construction management and economics. But the report also covers other disciplines within construction.

2 Background

This research is the extension of the work that was originally commissioned by the Chartered Institute Of Building

and Association of Researchers in Construction management. The work addresses the problems associated with the gap which exists in the provision and dissemination of information and the need to improve the accessibility to the sources of information. The result was a report titled "Construction Research Database" identifying the major sources of research information in the UK and abroad.

3 Research Databases

The databases are grouped in terms of their form: they consist of On-line, CD-Rom and those available on Hard-copy format. They are categorised under Construction, Management, Biographical, Conferences and Events, and Research information. The categories are as such due to the core emphasis of the databases. However, the categories often contain databases, which cover a variety of subjects, hence, there may be overlap of the subjects in different categories. These subjects were broadly divided into classes: Construction Management, Building Economics, Architecture, Civil Engineering, Structural Engineering, Town Planning and Environment. However, the extent of the coverage of the databases required these classes to be expanded.

3.1 On-Line Databases

The information which have been used to describe the characteristics of the on-line databases consist of the following fields.

The database name

The producer of database

The country of origin

The hosts providing the database (may be available on more than one host)

A description of the content of the database

The period of coverage

The estimated number of records contained

The sources from which the information is taken

The frequency with which it is updated

The type of data (bibliographic, biographic, directory etc)

The cost, where available.

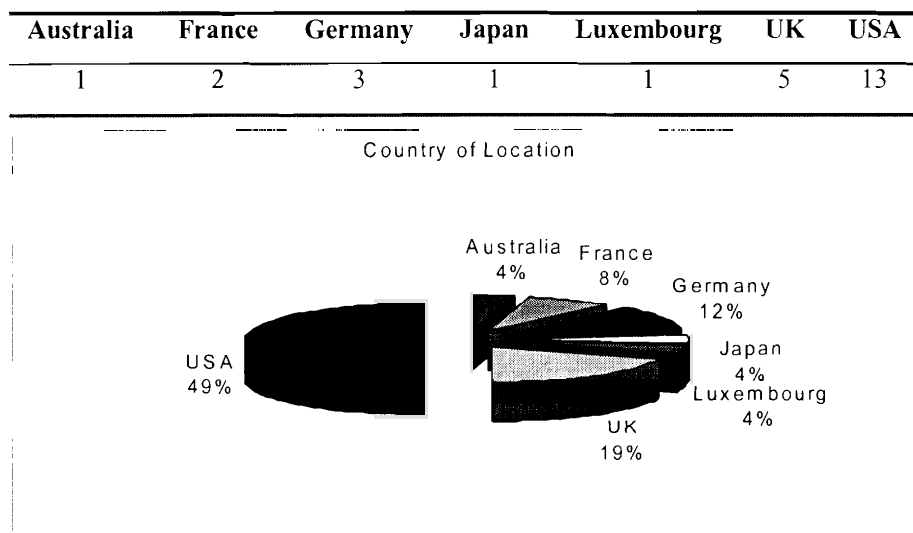
Where necessary, these fields are categorised and coded. In Table 1, the basic detail relating to the on-line databases is provided.

DATABASE	COVERAGE	SIZE	UPDATED	TYPE	Connection price/min	Rent monthly
Architecture	1978 to date	100000	Monthly	Biblio.	\$1.20	
ARIANE	1913 to date		Weekly	Full Text		
Australian Arch. Database		7500	Bi-monthly	Biblio.		
Avery Index (Architecture)	1979 to date	10000	Semiann.	Biblio.	\$1.10	\$6.00
ABI/INFORM	1971 to date	763000	Weekly	Biblio.	\$2.20	\$13.00
Bowker Biographical Dir.		123000	Bi/triennial	Biblio.	\$1.60	
Dissertat'n Abstracts Online	1861 to date	1000000	Quarterly	Biblio.	\$1.60	\$9.95
Ei Compendex Plus	1970 to date	3100000	Monthly	Biblio.	\$2.00	\$12.00

Federal Research in progress	Current eds		Monthly	Biblio.	\$1.40	
NTIS	1964 to date	1640000	Biweekly	Biblio.	\$1.40	\$10.95
PASCAL	1973 to date	10000000	Monthly	Biblio.	\$1.00	\$12.00
Research Centres\Services	Current eds	17000	Semiann.	Directory		
Scisearch	1974 to date		Weekly	Biblio.	\$2.70	\$21.00
Civil Engineering Database	1975 to date	63600	Bimonthly	Biblio.		
CONF	1976 to date	96200	Weekly	Directory		
CONFSCI	1973 to date	1300000	Bimonthly	Biblio.		
FTN	1976 to date	63600	Bimonthly	Directory		
ICONDA	1976 to date	350000	Monthly	Biblio.		
N	Current eds.	36500	Annual	Directory		
ISMEC	1973 to date	258100	Bimonthly	Biblio.		
Current Contents Search			Weekly	T.O.C.		
Acompline	1974 to date	258000	Monthly	Biblio.		
Urbaline	1974 to date	258000	Monthly			
Resline			Annually	Biblio.		
CORDIS						
Government Research Dir.	Current eds.	3700		Directory		
L	Average	972410				

Table 1. List and Information on On-Line Databases

It is evident from Table1 and Figure 1 that USA and UK hold the majority of the databases, however, lack of information about databases in other countries makes this judgment somewhat invalid.



The sources of the databases within each category are identified in Table 2: information about conferences and journals are rather significant and popular amongst the hosts. Also, there are interests in books and reports including government publications.

	SOURCES	construction	Management	Events	Researc
A	Abstracts			1	1
B	Books, Booklets	5		1	
C	Business publications				
D	Conferences	6		1	
E	Education		1		1
F	Exhibition catalogues	1			
	Government publications	4			5
	Journals	8		1	
I	Laboratories	1			
J	Monographs	1			
	Patents	1			
L	Periodicals	2			
	Phamphlets	1			
N	Press:magazines&newsletters	3		1	
	Reports	4			1
P	Research centres	1		1	1
	Technical literatures, Manuals	3			
R	Theses	1			1

Table 2. Sources of Information for On-line Databases

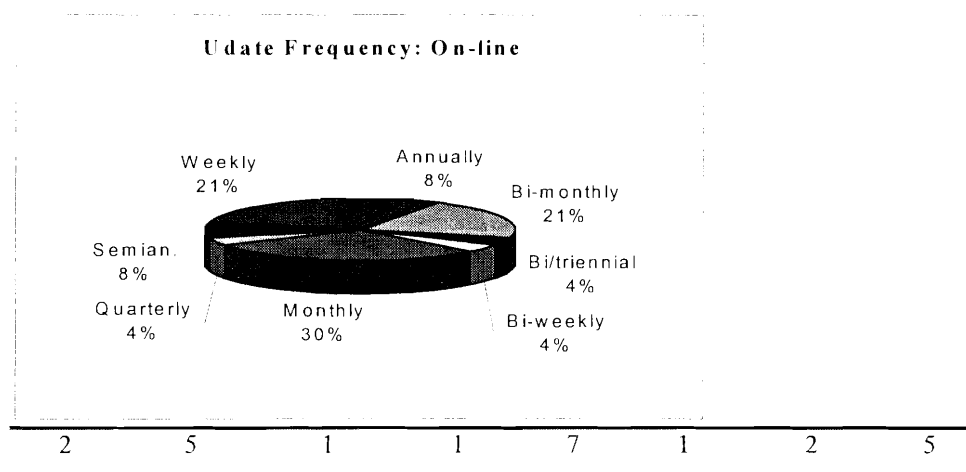
In Table 3, the producers and the institutions hosting the on-line databases are introduced. It is shown that a database can be hosted by more than one host-company. It is interesting to note that while there are many sources producing the on-line databases, there only a handful of hosts covering all databases.

DATABASE	PRODUCER	host1	host2	host3	host4
Architecture	British Architectural Library, RIBA	DIS			
ARIANE	Institut Technique du Batiment;travaux	self			
Australian Architecture	Stanton Library, New South Wales	ACI			
Avery Index (	Avery Library, Columbia University,	DIS			
ABI/INFORM	University Microfilms	DIS	STN		
Bowker Biographical	R.R. Bowker	DIS			
Dissertation Abstracts	University Microfilms International	DIS			
Ei Compendex Plus	Ei, Engineering Information, Inc.	DIS	ESA-	Data-	Orbit
Federal Research in	National Technical Information	DIS			
NTIS	National Technical Information	DIS	ESA-		
PASCAL	Institut de l'Information Scientifique et	DIS	Questel	ESA-	
Research	Gale Research Inc.	DIS			
Scisearch	Institute for Scientific Information	DIS	DIMDI	Data-	
Civil Engineering	American Society of Civil Engineers	STN			
CONF	FIZ Karlsruhe	STN			
CONFSCI	Cambridge Scientific Abstracts	STN			
FTN	FIZ Karlsruhe	STN			
ICONDA	Fraunhofer Society	STN			
N	Japan Information Centre of Science	STN			
ISMEC	Cambridge Scientific Abstracts	STN			
Current Contents Search	Institute for Scientific Information	Dialog	BRS	Data-	
Acompline	London Research Centre	ESA-			
Urbaline	London Research Centre	ESA-			
Resline	Library of the DoE &Transport	LRC			
CORDIS	Commission of the European	ECHO			
Government Research	Gale Research International Ltd	Dialog			

DIS:Dialog Information Services

Table 3. Producers and Providers of On-line Databases

Annual Bimonthly Bi/triennial Bi-weekly Monthly Quarterly Semi-annual Weekly



These on-line databases are updated on a regular basis. Figure 2 demonstrates the distribution of the frequency of update of the databases. While the 'monthly' is the most frequent update, the bimonthly and weekly updates are also popular.

As far as the subject matters of the databases are concerned, these are divided into thirteen main subjects. These subjects have their corresponding constituent sub-divisions. These are listed in Table 4 and the frequency of their occurrence is cross-tabulated against the categories of the databases. The table shows no lack of information relating to construction, engineering, & science, various aspects of planning and transportation, as well as research matters.

	Sub-elements	const'n	mgt	Biog	conf	research
A Design	Architecture, art, interior design	3				
B Const'n/Build	bld. Technology, regs, restoration,	5				
C Economics	Economic development, finance	4				1
D Education	Education	1				
E Eng.& Science	civil, physical&life sciences, mechanical,	6		1		1
F Environment	Environmental issues, preservation &	2				1
Funding	Research, facilities, foundations, bodies					2
History	Architectural, building	2				
I Management	admin, business, management	2	1			
J Mats&Produc	Materials& products, manufacturing, material	3				
Politics	EC, social policies,	5				2
L Planning	Economic, housing, land scaping&use, regional,	6				1
Projects	Leisure&recreation	2				
N Research	Conferences, theses, institutes, journals, projects	5			2	6
Transportatio	Transportation	4				1

Table 4. Constituent Subjects of On-line Databases

Abstracts	Bibliographic	Directory	Full Text	Numeric	Tables of contents
1	17	5	2	1	1

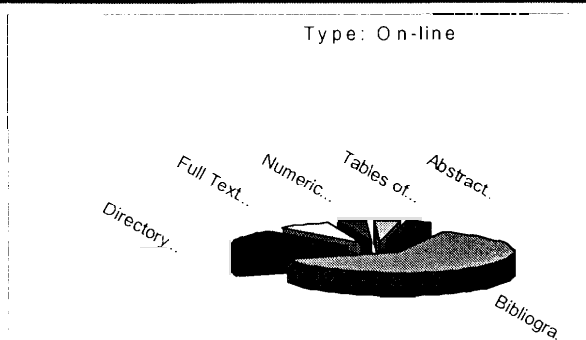


Figure 3 shows that the majority of the on-line databases are of bibliographical type. But, there can be different types within one source.

Figure 3. Types of On-line databases

3.2 CD-ROM Databases

Similar fields are used to describe the features of the databases on CD-Roms. These features are highlighted in the following Tables. Table 5 provides the general information about the CD-Rom databases: as well as a considerable price variation, the databases also vary in terms of the coverage and the frequency of update.

Table 6 lists the subject areas covered by the databases and their sub-divisions. Here, in comparison with the on-line, IT areas are added but other subject areas have been removed.

Table 7 shows the distribution of the sources of information and Table 8 introduces the producers and the providers.

DATABASE	COVERAGE	SIZE	UPDATE	TYPE	price/ann	disc no
ABI/Inform	as online					
Applied Science & Tech. Index	1983 to date	624,000 +	Monthly	Biblio.	\$1030	1
Buld Expertise in Science &	Current			Biblio.		
Business Periodicals Index	1982 to date	822,000 +	Monthly	Biblio.	\$398	1
Citis	1972 to date		Semiann.	Biblio.		
Concise Engineering and Tech.						
CTI PLUS	1981 to date	215,000	Quarterly		£850/qrt	
Current Research in Britain	Current			Directory	\$130	
Directory of American Research	Current				\$250	
Dissertation Abstracts	as online	as online	Quarterly	Biblio.		
Ei Civildisc	1984 to date	600,000	Quarterly	Biblio.	\$2,495	
Ei Compendex Plus	1989 to date		Quarterly	Biblio.	\$2,460	2 or 5
Ei Page One		600,000		Biblio.	\$710	
European R&D Database Plus	Current	120,000			\$995	
Findex	1980 to date		Quarterly	Full Text		1
Grants Database	Current		Bimonthl		\$607	1
ICONDA	as online	as online	Quarterly	Biblio.	\$757	1
IBSSA:Building Science &	1972 to date		Semiann.	Biblio.		1
Market Studies Library on CD	1990 to date	200 +	Quarterly	Full Text		1
NTIS	1980 to date		Quarterly		\$2,571	2 or 3
R & D in Russia	1989 to date		Semiann.	Biblio.+	\$543	
RIBA.ti			1/3 ann.	Full Text		
SCI/Tech Reference Plus				Biblio.+		
Science Citation Index (SCI)	1945 to date		Quarterly	Biblio.		
UK Reference on Research	Current		Annually	Directory	\$975	
Urbadisc						
Who's Who in Science and Eng.	Current	22,000		Bio.	\$190	
World Research Database	Current		Annually	Bio. +	\$2,400	

Table 5. Information on CD-Rom-based Databases

	Sub-elements	const'	biographical	research
A Design	architecture, art, interior design	1		
B Const'n/Build.	bld. technology, regs, restoration, specifications	4		
C Economics	economic development, finance	1		
D Education	education	1	1	2
E Eng. & Science	civil, physical&life sciences, mechanical,	8	1	
F Environment	environmental issues, preservation &	2		
Funding	research, facilities, foundations, bodies	1		1
IT	IT, AI	2		
L Planning	economic, housing, land scaping&use, regional,	3		
N Research	conferences, theses, institutes, journals, projects	1		7
Transportation	transportation	2		

Table 6. Constituent Subjects of CD-Rom Databases

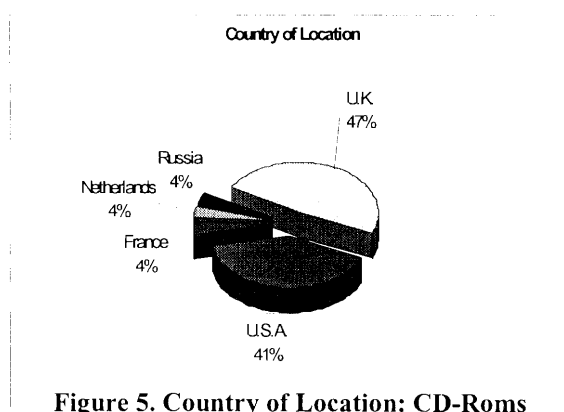
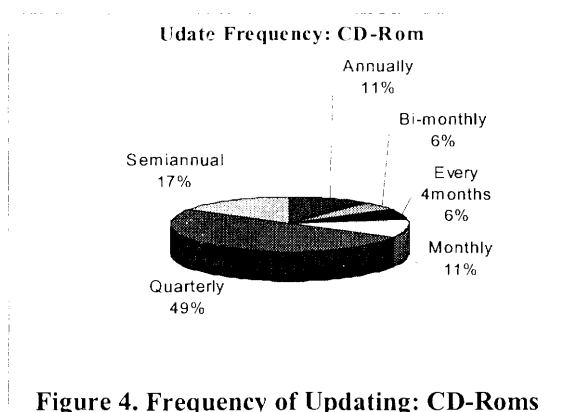
SOURCES	score	SOURCES	score
A Books, Booklets	2	E Journals	6
B Business publications	2	F Periodicals	2
C Conferences	2	G Reports	2
D Government publications	2	H Theses	1

Table 7. The Sources of information for CD-Rom Databases

DATABASE	PRODUCER	host1
ABI/Inform	UMI	Microinfo
Applied Science & Tech. Index	H.M.Wilson	Wilsondisc
Buld Expertise in Science &	Longman Cartermill	Longman Cartermill
Business Periodicals Index	H.M.Wilson	H.M.Wilson
Citis	Citis	Citis
Concise Engineering and Tech.	Microinfo	Microinfo
CTI PLUS	Bowker Saur, Reed Ref. Publishing	Bowker Saur
Current Research in Britain	LongmanCartermill	Longman Cartermill
Directory of American	Bowker Saur, Reed Ref. Publishing	Bowker Saur
Dissertation Abstracts	UMI	CD Plus Tech.
Ei Civildisc	Engineering Information Inc	Engineering Info Inc
Ei Compendex Plus	Engineering Information Inc.	Engineering Info Inc
Ei Page One	Engineering Information Inc.	Engineering Info Inc
European R&D Database Plus	Bowker Saur, Reed Ref. Publishing	Bowker Saur
Findex	Cambridge Scientific Abstracts	Silver Platter
Grants Database		Dialog
ICONDA	IRB	Microinfo
IBSSA:Building Science &	Citis	Citis
Market Studies Library on CD	FIND/SVP	Silver Platter
NTIS	(NTIS), U.S. Dept. of Commerce	Dialog
R & D in Russia	Scientific&Tech. Info	Microinfo
RIBA.ti	Technical Indexes	Technical Indexes
SCI/TECH REFERENCE	Bowker Saur, Reed Ref. Publishing	Bowker Saur
Science Citation Index (SCI)	Institute for Scientific Information	Institute for Scientific Info.
UK Reference on Research	Microinfo	Microinfo
Urbadisc	Reseau Urbamet and Questel	London Research Centre
Who's Who in Science and	Bowker Saur, Reed Ref. Publishing	Bowker Saur
World Research Database	Longman/Microinfo	Longman/Microinfo

Table 8. The Producers and Providers of CD-Rom Databases

Unlike on-line databases, the CD-Roms are produced by many and hosted by many companies. The information relating to the frequency of update and the country of location are provided in Figure 4 and Figure 5. Again UK and USA dominate the figures. It seems that the CD-Roms have a slower pace for updating than the on-line.



3.3 Databases of the Institutions

Some 400 institutions were investigated worldwide and a list of 29 institution with some sort of a database was collected. These sources cover a variety of subjects – listed in Table 9.

	Sub-elements	scores
A Design	architecture, art, interior design	2
B Const'n/Build.	tech., regs, restoration,	10
C Economics	economic development, finance	2
E Eng. & Science	civil, physical&life sciences, mechanical,	5
F Environment	environmental issues, preservation &	2
Funding	research, facilities, foundations, bodies	1
IT	IT, AI, Software	1
I Management	admin, business, management	2
J Mats&Product	materials& products, manufacturing, material	2
L Planning	economic, housing, land scaping&use, regional,	8
N Research	conferences, theses, institutes, journals, projects	6
Transportation	Transportation	1

Table 9. Constituent subjects of the Institution Databases

Table 10. provides the listing of the services or databases that are provided by some building research institutions worldwide. The list is by no means definitive. But, most of those providing relevant information on construction research are included. The great majority of these are provided as lists or registers of research in print format, and access to them is merely a matter of approaching the institutions involved.

Institution	Country	Type	Updating
ASEAN Association for Planning and Housing	Philippines		
Association of Researchers in Construction Management	UK	Bibliographic	
Building Research Establishment	UK	Bibli+abstract	Annually
Building Research Institute (Japan)	Japan		
Building Research Station	UK		Annually
Building Services Research Unit ; Hospital Engineering	UK		
Building Services Research and Information Association	UK		
Centre Scientifique et Technique de la Construction	Belgium	Bibliographic	Annually
Centre for International Co-operation Activities	Netherlands		Annually
Construction Industry Authority of the Philippines	Philippines		
Department of the Environment	UK	Bibliographic	Biannually
IRB Verlag Information Centre for Fraunhofer Society	Germany		
Institut de Sciences et des techniques de 'equipement	France	Bibliographic	
Institut de Technologica de la Construccio de Catalunya	Spain		
Institut technique de Batiment – Building Research Institute	Poland		
Instituto Colombiano de Productores de Cemento	Columbia		Annually
National Council of Building Materials Producers	UK		3per year
Science and Engineering Research Council	UK	Abstracted	Annually
Science and Engineering Research Council	UK	Abstracted	Annually
Swedish Institute of Building Documentation	Sweden	Bibliographic	Fortnightly
The Commonwealth Scientific and Industrial Research Org.	Australia		Biannually
The Department of the Environment; Construction Sponsorship	UK		
The Department of the Environment; Construction Sponsorship	UK		Annually

The Royal Institution of Chartered Surveyors	UK		Annually
The Steel Construction Institute	UK		
The Swedish Institute for Wood Technology Research	Sweden		Annually
US Department of Housing and Urban Development	USA	Bibliographic	Quarterly
Union Internationale des Centres du Batimen	Netherlands		
University of Reading, Dept of Construction Management and	UK		

Table 10. Institution Databases

3.4 Hard copy reports

Only a few sources have been identified that provide hard copy report of research information. These vary significantly in terms of their nature, size and price. These are described below.

Index to Theses: Consisting of several volumes, this is provided by the Association for Information Management (ASLIB). It is a comprehensive register of theses arising from research in British institutions.

Building Construction Architecture Databases: Again, provided by ASLIB, this is a register of existing databases in construction. It does not contain information on construction research but can be used as a source document.

Ei Civil and Structural Engineering: The print version of Ei Civil disc is provided by the Engineering Information Inc. at the price of £435.

Applied Science & Technology Index: By H.M.Wilson

Current Contents: It is the print version of Current Contents Search Online provided by the Institute for Scientific Information with the price tag of £442. It covers Engineering, Technology and Applied Sciences.

Science Citation Index: The print version of the index at the price of £11,650.

Current Research in Britain: By Longman Cartemill

National Technical Information Service: At the price of £60, it consist of a Directory of Scientific and Technical Research Programs in the U.S. Government. It provides an overview of Federal agencies' responsibilities in disseminating scientific and technical information (STI) originating with Federal R&D Programmes. It lists the major agencies involved and is a guide to comprehending the scope and relationship of Federal STI programmes.

Science and Technology Resources in U.S. Industry: At a lower price of £54, the National Technical Information Service provides a summary of American industrial science and technology resources in terms of R&D activity,

employment and use of scientists, engineers and technicians.

European R & D Database Plus: Produced by Bowker-Saur - Reed Reference Publishing, this is the print format of the CD-ROM edition, including the Directory of European Research and Development and Who's Who in European Research and Development. It costs £995

Directory of American Research and Technology: The same provider - Reed Reference Publishing - produces a print format of the CD-ROM version charging £250.

European Regional Incentives: For £69, Reed Reference Publishing provides a current and comprehensive review of all regional grants and other aid offered to industry and business in each of the 12 EC countries and Sweden. There is also an expanded section on the European Commission.

Annual Register of Grant Support: Again, Reed Reference Publishing gives a guide to over 3,000 programmes offering billions of dollars in non-repayable support shows how to access the funding potential of these sources. There are 11 major subject areas, 61 specific areas. All types of funding included: educational, unions, corporate, private and public. The price is £145.

Who's Who in Science and Engineering: The same publisher provides the print format of the CD-ROM version for £190.

Information Sources in Engineering: This contains reports, standards, patents, journals, conferences, theses, product information, abstracting and indexing services, bibliographies and reviews, computerised information services, standard reference sources and much more, for a mere £65.

Current Technology Index: This is the print version of CTI, but costs £595.

Sources of Construction Information: A report is produced by the University of Strathclyde: Department of Civil engineering providing an extensive list and description of general sources of information and statistical data relating to the field of construction.

4 Conclusion

It has been noted that the success of any research depends on the ability to build on the relevant work carried out previously. Similarly, the success of any organisation hinges on its ability to have access to various types of information. In this respect, construction academics and practitioners are no exception.

To this end, it has been demonstrated that there is a significant volume of construction research and other information available in organised and structured ways. These sources empower researchers with the knowledge of relevant information. However, these are often at a notable price making them available to larger organisations and institutions only.

The work has unleashed the information relating to various disciplines within construction, stored in various forms by several organisations, in different countries and in different formats. Undoubtedly, it will not be long before these databases will be made available on the Internet with greater efficiency of access - the price changes can not be assessed at this stage.

The analysis of the databases revealed that they vary in terms of their size, frequency of update, price, coverage period, format, country of location, sources of data and content. Some of the databases focus on a specific discipline and other are broad encompassing various areas within construction fields and those peripheral to them

5 Future Work

Although the databases outlined in the work are comprehensive and structured, nevertheless, they are scattered in different locations, they have varied structures and they can be very expensive. Therefore, the establishment of a centre funded through a grant or by an institution(s) can help to bring all these databases under one roof. The centre can coordinate the acquisition of the data/information and administer its dissemination. The establishment of such a centre will undoubtedly enhance the quality of research in construction.

Obviously, the boundaries of the functions and services of the centre can expand over the years and so will the underlying technology that will support the whole process.

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BUILDING ECONOMICS - THE STORY AND THE RESULTS OF A VIABLE HYBRID IN BUILDING RESEARCH

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Abstract

Based on the story of CIB W55 Commission on Building Economics since its start in 1969 the lines of building economics will be described. The three present objectives and the scope of work will be traced back to their introduction in the W55 Commission. This includes the development of research in resource management in construction; evaluation in design and construction planning, and the information systems applied in the assessment of buildings, construction and the environment. The development of the hybrid characteristic of research in building economics will be discussed considering the various research interests. In this research field activities currently range from research in global construction strategy to research in budgeting the working hours for maintenance of a building. The paper also includes a complete list of publications issued in collaboration with the W55 since its start. Also some persons of the Commission will be mentioned briefly or referred to.

1. A turbulent start

The Commission W55 on Building Economics was initiated by the CIB Board in 1969. Originally the Commission was established to promote the application of economic assessment methods in the professions due to the recognised gap between everyday practice and the state of the art of economic assessment and evaluation. Two major interests were presented from the beginning. One was the need for relevant and comparable methods to assess the economic assumptions and consequences in relation to the planning and design of buildings and the construction process. The

other was the need for measuring and comparing productivity in the construction sector nationally and internationally to promote construction development. To find a balanced fit for international collaboration in the CIB has not been an easy task.

After the CIB Congress in Paris 1972 the board appointed Klara Szöke, from Hungary, as the coordinator of W55. She became the first permanent coordinator following three temporary coordinators. She continued as coordinator until her reassignment in 1991, whereupon I was appointed. That is the story about coordinator ship of the W55 Commission until this year when I resign and a new coordinator is to be appointed.



The collaboration in CIB W55 was excellent between the coordinator 1973-1991 Klara Szöke, Hungary, and the coordinator 1991-1997 Dan Ove Pedersen, Denmark, since their first meeting in 1970 (photo) at the Research Institute for Building and Architecture, Prague.

The Commission with the newly appointed coordinator then started to become more goal directed by preparing its first international symposium, convened in Dublin, Ireland during 1974. The subject matter was "Assessing the Economics of Buildings". Disputes about the terms of work continued however at many subsequent annual meetings. Still the Commission managed to get work done mainly directed towards preparing the research programmes for the triennial International Symposia on Building Economics. Seven triennial symposium have been convened. Two were joint with the CIB W65 Commission on Organisation and Management of Construction. One in Canada 1984 /9/ and the other in Australia 1990/7/. The symposium in Portugal 1996 /4/ was joint with the CIB W95 Commission on Urban Infrastructure. The symposium in Denmark 1987 /8/ was joint with CIB W82 Commission on Futures Studies in Construction. Other symposia were organised by W55 in Ireland 1974 /11/, in Switzerland 1980/10/ and in Croatia 1996/1/.

Membership of the Commission was from the start restricted to invited researchers from the member institutes. At the meeting in 1970 we were ten members. After the first International Symposium in 1974 many participants expressed a keen interest in membership of the Commission and many were invited to join in. During the 1970s and 1980s membership increased to approximately 100 representing about 35 countries taking part in the symposia and about 25 participating at the annual meetings /Szöke 1987 in 8. Keynotes/. To day the Commission has 130 members from about 40 countries.

The present scope of work is to collect, study, evaluate, disseminate, exchange and discuss the objectives of the Commission. In practice, however, the Commission works by meetings and by contributions to meetings. It is expected that members - at least every third year to the international symposia on building economics - participate and contribute with research work.

2. What is Building Economics?

The present text of objectives of work for W55 (annex 1) along with new requirements for standards and procedures for the reviewing of papers (to be presented at Commission meetings and Symposia) was decided at the annual meeting in 1994 which was held in Hong Kong . The research themes that the Commission agreed upon will be reviewed in the following by tracing back the development in the objectives and the results of the work in the W55 Commission on Building Economics. The research work is delimited to the economic aspects of the following: Resource management of the construction sector on macro and micro level; Evaluation in design and construction planning; Information systems applied in the assessment of buildings and the built environment.

The concept of Building Economics used as a heading for these work objectives does not appear in the acknowledged classification systems of economics as for example the one from the American Economic Association. Instead the various concepts studied in W55 are classified in numerous categories which makes it hard to identify and define the research field that we name Building Economics. Within the Commission discussion on this issue is raised at intervals. In /5/ G.Dandri made a constructive proposal in that he subdivided the term economics into the three areas: Economic policy, Economic science and Economic techniques. Each of these parts of economic theory and practice were then classed within the various fields of practice: Projects; Real Estate; Land; Infrastructure; Design; Construction; Housing; Energy, etc. In this way it is straightforward to identify in a well-arranged system all the concepts of the W55's objectives of work without offending the pure economic research environment.

The debate on research work organised according to industrial sector instead of to category of economic problems has always influenced the research world. As can be read in the following the W55 Commission has endeavoured to work with any type of economic problems that may now and again be applied in the real world of construction and the built environment.

3. Economic aspects of resource management in the construction sector

3.1 Internationalisation of construction and civil works

Construction is still mainly a local based traditional activity with only a small share traded internationally. The tendency, however, is clear. Today, technological development drives the internationalisation of most industrial business and business services that contribute to the wealth and welfare of nations. This force in the international development follows a period with reduction of financial barriers in many regions of the world due to the liberalisation of trade barriers in the 1950s and 1960s.

The building materials industry is, today, oriented towards internationalisation just as most other major industries. It works typically as global companies linked together by capital investments or as networking between companies and supply chains of products, equipment and raw material. The important features of this international development are that the ideas of logistic planning, performance specification and quality management are encouraged and create flexibility in production and customised design. This then reduces cost in production and in transactions.

The Commission W55 does create some information about international building market development and, from time to time, reports on comparative conditions concerning financing and cost for construction and housing in various countries. In recent years the Commission has been presented for the ECERU Survey /Bon 1996 in 1. Vol.II/. This provides an opinion based survey of future trends in the global construction market by ranking attractiveness for countries and for cities with one and five years perspectives. The annual questionnaire is answered by approximately 125 expert respondents.

3.2 Global development in construction

The model behind the questionnaire is based on the findings that the construction outputs for a specific country vary through time and with increases in GDP per inhabitant. Developing countries experience a relatively fast increasing construction activity. The next group, the new industrialised countries, do gradually experience a period of mature construction market. In the group of advanced industrialised countries the construction output tends to decrease to a more stable but higher level of GDP than originally. The share of repair and modernisation increases during time and in some advanced industrialised countries amount to more than half the total construction output.

The reasons for these long-term cyclical movements in construction output are that the combination of demand for housing, business buildings and infrastructure is increasing relatively faster than the GDP; but also the technology of construction itself makes it almost impossible to enlarge the supply capacity concurrently with the excessive demand. Gradual adjustments of the construction capacity to the demand fluctuations are not an easy task in national economic policy or resource management. Many research papers of the W55 have dealt with these types of problems. Just to mention some headings: The role of economic assessment in decision-making /Szöke 1974 in 11/; Government policy towards the construction industry /Buyks 1990 in 7. Vol.1/; Building Cycles - A Focus on the Supply Chain /Flanagan 1996 in 1. Vol.II/.

3.3 Construction and economic transition problems

The research in national and global construction activities has created the need for information like the ECERU Survey. The effort to elaborate a world wide econometric model for the construction activities has not been successful. Some research work has been done for comparison between countries during time; most notably presented in 1990 in /7, Vol.1/. The macro economic analysis of the construction sector in the national and international economy was first presented in two keynote papers by Bon and Urien in 1987 /in 8. Keynotes/. This followed the Commissions' decision in 1985 to include the study of national/regional building markets in the programme of work.

The intention with macro economic research in the W55 was to study methods for the control and avoidance of cyclical fluctuations in construction. Such type of economic development causes much trouble, not only for the firms in the sector, but also for the authorities concerned with economic policy and productivity. Much work was done on forecasting and on sector policy issues for construction activities. Later the focus turned from the efforts to control and remove the cyclical movements to finding means by which firms can adapt to the realities of cyclical demand in construction which tend to be more severe than in many other industries. Not only were the cyclical movements studied but during the 1990s the important issues of transition problems in formerly planned economies and in developing countries came into focus. The seminar in Moscow 1995 was devoted to this specific issue /2/. Two other typical references are: The cost management of construction in Shenzhen special economic Zones /K.Y.Chen 1994 in 3/; Management of construction in transition economics /Oltean-Dumbrava 1996 in 1. Vol. 2/.

3.4 Business cycles and construction

Private commercial construction market's volatility and growth cycles bear a close relationship to structural changes in the economy in most countries. This observation and the consequences for the industry and for the companies has been widely studied. See for example /Akintoye 1996 in 1. Vol. 1./ and /Hindle 1993 in 4. Vol.2/. The research efforts are to a high degree devoted to developing the means by which firms or authorities can reduce the uncertainty imposed by market fluctuations. Forecasting of the building market or segments hereof was taken into

the terms of work for W55 in the 1970s. This also includes study of means to control subsidised housing and other construction activities suitable for long-term planning so that the effects of business cycles in construction may be counterbalanced. Another way to tackle this type of problem is for companies to have efficient means of foreseeing their own business opportunities regardless of the economic cycles. This of course includes research in the field of price indexes and cost assessment and the models and data bases related to this purpose. The companies' way of acting on the market is equally important and many papers have been presented about bidding behaviour and tendering practice just to mention Skitmore's paper on The Raftery Curve /1996 in 1.Vol.I./.

3.5 *The economics of innovation*

The research into strategy and planning for the construction sector may have immense influence on the building markets and the construction companies in some countries. Fortunately this issue of research seems of equal or even more importance in the economic regime today of competitive advantage compared with the former regime of economic planning of construction. Along with the term competitiveness, the terms technical progress and innovation also become more important as they are the headlines for growth in the companies and in the societies. For the Commission such issues have always been in the focus of the research. See for example /Pedersen 1996 in 1. Vol.II/. It was very clearly manifested at the last International Symposium in Zagreb 1996 and its proceeding that has the title: Economic Management of Innovation, Productivity and Quality in Construction /1/. This line of work is, I think, important for the future work of W55. Innovation has a crucial role in international economic development. It stimulates growth and contributes to the wealth of nations. Construction activities are very sensitive to economic growth, but at the same time they create and promote income and employment opportunities better than many others. The construction industry, however, is lagging behind most other fields in taking advantage of new technologies and innovation. This may be a challenge for the W55 Commission's work to pave the way for economic evaluation and utilisation of building research in practice. The research programme should include economic analysis of construction activities world wide combined with professionals evaluation of the characteristics of construction activities in various regions.

4. Economic evaluation in design and construction planning

The objective that has attracted most contributions to the W55 work is the evaluation in design and cost planning. The research focuses on economic evaluation methods, VE/VA methods, design optimisation and productivity studies. These themes are of relevance for many researchers and professionals in universities, planning institutes and in companies. The building communities need technically correct, but practical, methods and guidelines for evaluating the economic performance of other building technologies and projects in a consistent manner.

4.1 *Economic evaluation methods and cost modelling*

The economic evaluation methods studied and recommended in the W55 are the traditional methods for analysing capital investment. They include life-cycle costing, benefit-to-cost ratio, internal rate of return, payback, total cost estimates, etc. Certainly also, the issues of uncertainty in the application of the methods has been dealt with. Many case studies were prepared (and several reports distributed to W55 by Marshall, NIST, USA) especially concerning energy conservation, safety and environmental regulations. Also models for evaluation of building codes have been presented. The Commission actually came to a fine end with this type of work in that H.E.Marshall wrote a hand-book on Economic Methods and Risk Analysis Techniques for Evaluating Building Investment - A Survey /1991, 6/. It is the only monograph issued by the CIB W55. Some of these methods especially life-cycle-costing are today also applied extensively in the field of environmental protection for example in 'cradle to grave' types of analysis. The application of this type of economic analysis ought to be an integrated part of the evaluation of any building project that gives a multitude of choices. This may be during the process or in the selection of one among several design proposals. In the assessment of consequences of change in technologies or in building standards the analysis should be essential due to its widespread implications. It is however not simple to do this because, projects are not only about cost and measurable benefit, as energy conservation often is. Typically the benefits are not easy to measure or agree on because, they normally include non measurable values of performance and quality, cost in use, risks due to difficult construction conditions, institutional obstacles, etc.

4.2 Value Engineering and Value Analysis

The Commission made quite an effort to study and distribute Value Engineering (VE) and Value Analysis (VA) techniques /Diepeveen in 10. Vol.V./ The essential feature of VE/VA is that it sets out from the performances of products or buildings that they have to fulfil and generates alternatives to this end. By means of analysing the functions of the product it facilitates the importance of the functions according to the weights (values) allocated to them. It then examines the costs of these functions with the aim of selecting the most valuable set of functions according to a value/cost comparison. Actually it may be done in a way that the results come out with 'shadow prices' for the selected qualities /Pedersen 1980 in 10.Vol.II./. These methods are mainly used between contractor and suppliers while innovating products. Through VE the contracting parties set targets for expected prices and costs for a new product. The direct production costs are identified in view of the product specifications as to quality, durability and design. The detailed cost information needed in the process has also become known as Open Book Accounting. This has proved to be an efficient method to achieve cost reductions and quality improvements simultaneously.

The VA method is different in that it does not create a process over time but is a method to assess performance/cost ratios for projects and by that give a means to award a project among several proposals. The W55 Commission carried out an international survey on the application of VE/VA in construction practice in the seventies /Szöke and Dandri 1980 in 10. Vol.II./. The study revealed that these methods were not applied often in the building sector.

Serious obstacles mainly caused by the fragmented structure of the building sector hindered the distribution of the methods in practice. The study also revealed that in house application of the method was common in some countries as Canada, USA and Japan /see Baba 1987 in 8. Vol.A/. Looking back with our present knowledge the Commission should have carried on with encouraging the application of the methods in the building sector because VE/VA today are regarded as powerful wheels in the innovation process in industries and in assessment of bids in international tendering.

4.3 Economic evaluation in design

The economic assessment of design has attracted much interest in the W55. The first International Symposium had the title “Assessing the Economics of Buildings” /11/. The papers included analysis of the basic cost factors in design such as cost/function indexes, area/function ratios, geometric cost ratio, cost per functional-area or gross-floor-area for various types of measurable functions or buildings, use-value-index, efficiency index, etc. The idea of total cost was also in focus in the presentations including the effects of change in prices and in interest rate. The use of cost assessment was, and still is, to give the client, the designers and the contractors' possibilities to assess the cost of design proposals as early in the process as possible and eventually offer some comparative or optimising features.

The research in the field went on with more refined methods on cost assessment and computer programmes to handle cost assessment. Many cost accounting models and programmes were developed at this stage. Typically they were founded on a detailed break down of all parts of building to which it was possible to attach cost. That can be done in many ways according to the building model applied and the types of bills of quantities and quantity surveying is widely applied in the construction process, often as the only cost assessment method needed. The disadvantages of bills of quantities are that a scheme design is needed to account for the quantities and no optimisation or even comparisons between more design proposals are performed. Furthermore costs, prices and values are not well defined units in competitive building markets. The need to develop new methods and models was obvious. The efforts were directed towards more precise assessment of cost at an early stage in the design process, and to optimise the design in the briefing stage, for the outline proposal and for the detail design. The cost models may be classified in four types: Bills of quantities; simulating models; statistical based models; knowledge based models (that include values based on opinions).

'Building design optimisation' was actually the same title of keynote papers to both the 4th and 5th international symposia /Alan Wilson 1987 in 8. Keynote//J.R.Kelly 1990 in 7. Vol. 2/. The conclusions in the 1987 Keynote are however not optimistic. The question is not how to optimise but what to optimise. Thus, although an optimum solution based upon a specified economic optimality criterion can be obtained, how can one ever prove that some greater benefit has not been forgone elsewhere? An optimal building is an unrealistic ideal! Fortunately the conclusion from the 1990 symposium was a bit more optimistic. It says that optimal design is achieved when the

client receives a building that is visually sympathetic in terms of internal and external environment, suits the intended function and is economical in terms of its demands for costly resources. It is hypothesised that this subjective criterium can be achieved in a sub-optimal context by measuring the extent to which an idea can be improved upon.

To interpret the various views on optimality I think it is necessary to understand that economics is a relative science in that it cannot give absolute answers. By making comparisons - sometimes very sublimely carried out indeed - it may be possible to find feasible solutions for sorting out uneconomic proposals by the criteria that either you can get better or more for the same cost, or you can get the same thing for less cost. To select the best design solution among more feasible ones can only be done if you can specify your utility values in a manageable way. Most designers will run into difficulties with such a requirement especially concerning future values, but still the process may help you to reach optimal design and satisfaction. Notice that values are relative as well. Values do change during time. To be a bit philosophical I think that changing values may be the driving wheel for economic development. For now however building and design economics may save you money and give you better performance of buildings.

4.4 Productivity and efficiency in construction

An important experience from other industries is that improvement in productivity and quality simultaneously is an efficient way to promote business opportunities. Productivity is a widely used and not always well defined term. Productivity is a measure of the value of output (quantity units multiplied by price) related to the amount of labour and capital applied in the production and in the process. In construction, however, the actors often prefer the broader term efficiency of the production and the process. It differs by not including the valuation but only the quantity of construction output, and that more emphasis is laid on the use of man hour per quantity of construction. Fortunately for the building economists the value and quality of construction works are normally closely related. Consequently quality management is an important means to attain the attractive combination of improving productivity and quality simultaneously and continuously, a feature that has been a leading star in the best innovative and competitive industries for several decades.

One means to improve productivity and quality is cost and performance bench marking that is a major subject for this seminar. The term is often used to set defined targets for a firm concerning competitiveness and comparing these with others. It may be benchmarks for international or interindustrial comparisons, it may be comparisons with special selected competitors or internal comparisons between identical processes. To day the effort to improve construction is focusing on the organisation of the construction process not at least in the planning and design stages and in stressing the obstacles due to the fragmented structure of the industry. The need is pressing, however, for information systems for detailed benchmarks, yardsticks, bills of quantities, open book accounting, etc. to do

relevant comparisons at all levels in the construction process where optimising and comparison may be an opportunity.

This line of research has been in the centre of the research work in W55 since its start. For examples see /Lemessany, Urien, 1980, in 10.Vol.V./. The research object has had many titles and it includes hundreds of concepts and definitions that may together be termed productivity and efficiency. One requirement for application in practice is however that one must have something to measure and to compare. Most of us have the experience that in construction it is not a simple matter to keep apart the concepts and registration of cost, price, value and quality irrespective of we are working in an economic regime in construction of market or of regulated economy. Another requirement is that useful information system must be available.

5. Information systems applied in the assessment of buildings and the built environment

The construction process and thus building economics is a subject area which has been useful for exploiting the advances in information systems and information technology IT. The number and complexity of products, the fragmented structure of the industry and the increasing demand for documentation makes IT attractive in construction and project design and for building economists. The heart of building economy is estimating and forecasting, not only at the design and project level, but also at the company and industry level as mentioned above. From the start of W55 the IT systems for bills of quantities, forecasting and simulation have been presented at all international symposia and annual meetings.

Some titles of presented papers at W55 Symposia and meetings may illustrate the development in computerised models in building economics starting with the still viable: The CBC System and Sub-systems /Bindslev 1974 in 11/. Life Cycle Planning and Budgeting Model (LCPBM)

/Orshan 1980 in 10. Vol.I/. SYRE - A System of Building Economics /Söderberg 1984 in 9. Vol.3/. A rate data bank for the cost estimating of a building /Gosselin 1987 in 8. Vol.B/. Expert systems after the hype is over /Brandon 1990 in 7. Vol 2/. Economic selection in building /Salokangas in 5/. Cost Lab for Building Economics and Management /Kiiras 1993 in 4.Vol.6/. The Selection of Building Price Forecasting Models /Fortune and Hinks 1996 in 1. Vol. II/.

5.1 Knowledge based information systems

Still however, compared with other industries in society, information technology is not used very extensively in the building sector. IT largely exists today in isolated areas within the company as CAD, accounting, etc. Although huge efforts have been made to produce comprehensive IT systems for construction firms, such IT systems inclusive integration of processes, knowledge and information management are only implemented to a limited degree. Most

notable, concerning application in the industry, is in my view, the knowledge based systems supported by the RICS, UK, as reported in /Brandon 1993 in 4. Vol.7/.

The breakthrough for IT or more advanced AI (artificial intelligence) systems has really not yet come to Construction. In other industries the application of computer aided or integrated design and manufacturing has been a requisite for survival but it is not yet so in construction. One economic reason may be similar to the causes for the slow penetration and low degree of industrialisation of construction components. It is because it has not been shown to be competitive for one or a few buildings but that companies must rely on rather stable and long term marketing possibilities which is not the typical conditions for the building market.

5.2 Computer integrated construction

The challenge for researchers may be to design a computer integrated construction (CIC) platform. However the many aspects of building do mean different things to various partners in a building process so the long term strategy for an integrated information platform also challenges the traditional division of work and in this way may be a threat for many actors of the present generation in the industry. Therefore, the perspective for building economics and research should be to establish a framework for a building model. It should be coordinated with development in other sectors and especially with international achievements to make common means and standards to generate electronic data exchange. Within such a framework each company can establish its own models simplified to their needs. The contributions from W55 to such an achievement could be to provide for adequate estimations, forecasts and evaluation of cost and environmental consequences of resource management /see Yashiro 1993 in 4.Vol.4/.

5.3 Information technology and the organisation of construction

The on-going development in information systems is of vital interest for the assessment of building cost and qualities, and for the management of planning and construction projects. The W55 promotes data-support knowledge-based systems, computer-aided cost and quality assessment and the development of data bases for environmental and economic assessment. These research activities are expected to improve continuously the productivity and quality of professional work, and not least to give firms improved knowledge and means for strategic planning for the future. It is the combination of integrated information systems with the organisational structure and a way of collaboration that is the serious problem to be dealt with in the effort to improve construction by means of IT.

6. The platform for the future work of W55

6.1 *The foundation is the members of the Commission*

The members of W55 represent several fields of science. Some have an education as economists and some are architects by education. Most members I think have a background in technical research covering either construction or information technology. The interdisciplinary composition of the members education has influenced the work in the Commission considerably in the way that when selecting the objectives of work these have had to be attractive for most members. The Commission has become rather global since 1970s. To day the members of the Commission are representing about 90 university institutes, 30 other research and information institutions and about 10 companies. To agree on objectives of work has always been a delicate balance between many varied interests. The Commission works however by the contribution of its members. The programme for the international symposia and the annual meetings that in the 1990's were extended to workshops are typically composed of the research work that members have in preparation and are ready to introduce or publish. Formerly the requirements for papers and presentations were rather informal but today the Commission has adopted procedures for accepting and presenting papers at the meetings. The results of this restricted procedure is that the papers presented to the Commission are of improved research quality and that the hosts for the meetings are able to publish a reviewed proceeding from the annual meetings.

6.2 *Perspectives*

In its future work I shall recommend the Commission to develop and refine the present combination of research. That is research both in: The perspectives for the construction industry world wide; the research in planning and design assessment methods for projects and buildings as well as research in the data and information systems that support the strategic and planning issues of construction. I know quite well that this composite of building research may be considered as sophisticated and mainly of interest for the professional organisations. However the community and organisations also need correct, relevant, truthful, sober and critical research in this composite research area between technical and economic science and architecture in the construction industry. Furthermore international collaboration in this field produces benefits due to the efficient information on international development in construction and the easy access to a world wide network of researcher working in the specialised field of building economics. The present and future research needs of the Commission W55 may be formulated as follows.

6.3 *Future research objectives*

The international development in construction activities worldwide should be dealt with by including economic analysis of construction activities world wide combined with professionals evaluation of the characteristics of construction activities in various regions.

Assessment methods for investment, productivity, innovation and environmental effects need to be refined and made suitable for international comparison for the practice to judge the opportunities for improvement and development. Publishing of reports and recommendations on best practice regarding economic assessment and evaluation methods of buildings and the built environment should be aimed at.

Research is also needed to refine assessment methods for qualities and values for international application based on costumers response and relative values for various properties of buildings and the environment.

Data support and information systems for building economics and management is recommended as a research area. Results of research in many specialised fields may be known to and applied more intensive by practice when included in data-support systems that are easily accessible for practice and that are continuously upgraded.

It is stressed however that it is the research works of the members that make up the objectives of work and do fill the programme for the meetings and international symposium of CIB W55 in the coming years.

ANNEX 1.

7. Objectives and scope for the CIB W55 on Building Economics

To collect, study, evaluate, disseminate, exchange and discuss the following issues and related items:

7.1 * Economic aspects of resource management and competitiveness, financing, innovation and development of the construction sector at the international, macro and micro levels

- concerning the design and construction process, the construction activities, renewal and use of buildings, the built environment, the international building markets, and comparative conditions regarding financing, subsidizing schemes and user cost regulations.

7.2 * Economic evaluation in design and construction planning

- including quality, productivity and efficiency assessment, design optimization and methods applied in the construction field such as cost-benefit, risk analysis, life-cycle costing, value engineering, cost and price indexes, comparative studies and forecasting methods.

7.3 * Information systems applied in the assessment of buildings, construction and the environment

- considering knowledge based systems, computer-aided cost modelling systems for monitoring cost, quality and risk factors, and the development of economic data bases.

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ECONOMIC FEASIBILITY OF AUTOMATION IN BUILDING CONSTRUCTION

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ABSTRACT

The paper presents an economic model for the feasibility analysis of robots employment on building sites. The parameters of the model depend on the nature of the robot, the nature of the robotized task, the nature of the typical building project and the mode of employment of the robot. Four generic types of building robots are analyzed with the aid of the model using data published by developers and users of building robots to date. General conclusions are presented with respect to the feasibility of employment of four types of robots on building sites: (1) exterior facades finishing robots, (2) floor finishing robots, (3) multipurpose interior finishing robots, and (4) crane-based assembling-handling robots.

Keywords: Building Economics, Construction, Automation, Robotics

1. Introduction

The economic feasibility of robotizing construction work depends on the associated costs and benefits, when compared with conventional construction methods (Warszawski, 1990). It can be examined at different levels - macro and micro - from various perspectives, e.g. that of the national economy, the construction industry, the individual contractor, the owner, or the end-user. The focus of this paper is mainly on the direct

costs and benefits to the constructor, who has to make the decision whether to invest in a specific robotic system to replace a conventional method.

The objective of the paper is to present a methodology and an economic model for analyzing the feasibility of robots employment in building construction, and to draw some general conclusions with respect to the major robot types, that have been developed and tested to date in building construction.

Conclusions are drawn with respect to four types of robots, in order to indicate the feasibility range of their application.

2. Basic Components of the Model

The model takes into account almost all cost and benefit components vis-a-vis conventional construction methods. The parameters of the model are dependent on:

- the nature of the robot
- the nature of its task
- the nature of the building project
- the mode of employment

The robot parameters include the cost of capital investments in its purchase, the operating expenses, the maintenance expenses, the costs of transfers between building sites, between locations on site, and between work stations.

The task parameters include the productivity (units of output per hour) of the robot and of its human operators for the particular task, the energy cost for operating the robot, the difference (plus or minus) in the cost of materials, and the cost of auxiliary labor per work unit.

The project parameters include the quantity of work on an average site, on a typical floor level and at an average work station.

The employment parameters involve, on the one hand, the rate of utilization of the robot in terms of working hours per year, and - on the other hand - the cost of labor - skilled and non-skilled - that it saves during its operating hours.

The benefit side of robotized construction includes "tangible" benefits and "intangible" benefits. The tangible benefits are primarily the cost of labor saved due to the robot's employment, and can be readily

evaluated in direct money terms. The "intangible" benefits are more difficult to measure objectively in money terms, and can be mainly used to augment the conclusions of the objective numerical analysis.

Various studies [e.g. (Arai, 1993), (Everett, 1995), (Rosenfeld, 1995), (Shintani and Yamamoto, 1993), (Tanijiri et al., 1996), (Warszawski, 1990), (Warszawski and Navon, 1996)] reveal that expectations from robot employment - both in manufacturing and in construction - include such aspects as improved work environment, faster completion of the task, better quality of product, elimination of dangerous jobs, and raising the morale of employees.

Although these factors cannot be readily measured in economic terms in a similar manner to labor savings, their indirect economic and managerial implications are very important. These implications and their effect on decision-makers in construction have not been included in this study.

The model is presented first in its general form, and subsequently it is simplified by introducing some practical assumptions pertaining to the nature of the building projects in which the robot is employed. Numerical data are applied with respect to four major robot types: exterior facade finishers, horizontal slab finishers, multitask building interior finishers, and large handling-assembling robots. The analysis is based on data obtained from actual development and application cases.

3. The Cost of Robotized Work Per Unit of Output

The total cost (for the constructor) of robotizing a specific task, is composed of the direct cost of the robotized work as well as indirect costs such as: the capital cost of the robotized system, the cost of maintenance of the robot and the cost of the robot's setup and transfers. The total cost of robotized work per unit, c_r , can be calculated from:

$$(1) \quad c_r = C_{rs}/(H*Q_h) + C_d/Q_h + c_t + C_M/(H*Q_h)$$

with:

C_{rs} - capital cost of the robotized system, per year, as calculated with eq. (2).

Q_h - output of the robotized system, per hour.

H - number of hours the robot is employed per year.

C_d - direct cost of the robot per hour - as calculated with eq. (3).

c_t - cost of transfers per unit - as calculated with eq. (4).

C_M - annual maintenance cost, which is often calculated as a percentage of the initial investment. It is composed of both routine - daily, weekly, etc. - maintenance of the robot, as well as the cost of its malfunction and repairs. The latter also includes indirect losses of income during these periods.

These partial costs will be further detailed in the following sections.

3.1 The equivalent annual capital cost of the robot

The annual capital cost, C_{rs} , of the robotic system includes the depreciation of the robot and the interest on the investment in its purchase and/or development. The first component of eq. (2) distributes the net investment in the robotic system (purchase and development minus its terminal value) over n years of its economic life. The second component of eq. (2) reflects the annual loss of interest on L .

$$(2) \quad C_{rs} = (P - L) \cdot \text{pr}(i, n) + L \cdot i$$

with:

P - investment in the robotized system (the robot and its peripheral devices).

L - terminal value of the system at the end of its economic life.

n - the economic life span of the robot (in years)

$\text{pr}(i, n) = (1+i)^n / [(1+i)^n - 1]$ - capital recovery factor over a period of n years with annual interest rate i .

3.2 The direct cost per hour of operation

The direct cost, C_d , varying directly with the number of work hours, includes the cost of the robot's operator, the expenses of the operation of the robot, the difference (plus or minus) in the cost of materials, and the cost of auxiliary labor necessary to assist the robotized work. The auxiliary labor may be needed for

materials handling or for complementing the robotic work in places which are inaccessible to the robot, or in partial tasks that are ill-structured for robotic work.

The direct cost of robotized work per hour, C_d , can be calculated from:

$$(3) \quad C_d = C_o + C_e + c_{mt} * Q_h + c_x * Q_h$$

with:

C_o - the cost of an operator (or a skilled worker) per hour. It depends on the mode of control of the robot: whether an operator is needed continuously for each robot or whether the operator can perform simultaneously additional tasks, such as auxiliary work or overseeing the work of other robots. In the latter case this cost component should be reduced accordingly.

C_e - the cost, per hour, of electricity, fuel, or other resources, needed for the operation of the robot.

c_{mt} - the difference (plus or minus) in the cost of materials, per work unit.

c_x - the cost of auxiliary labor per work unit. The auxiliary labor may be needed to handle materials or complement the robot's work.

3.3 The transfer and setup costs per unit of output

The cost of setup and transfers includes the setup on site, the transfer of the robot between different locations (floors, buildings) and - in the case of a robot employed from temporary workstations - the traveling of the robot between stations at each location. The setup cost of a robot on site includes the hauling of the robot to and from the site, its installation on site, and the cost of all organizational adaptations that are needed to enable robotized work on site.

The setup and transfer cost of the robot per work unit, c_t , can be calculated from these components as follows:

$$(4) \quad c_t = C_s/Q_s + C_l/Q_l + C_w/Q_w$$

C_s - the average setup cost of the robot on site (allocated to the particular work).

Q_s - the number of work units of the robot on an average site.

C_1 - the average transfer cost of the robot between locations (floors and/or buildings) on site.

Q_l - the average number of work units for the robot per location.

C_w - the average traveling cost of the robot between workstations. This cost component applies only to robots that operate from temporary workstations.

Q_w - the average number of work units per workstation.

3.4 Summary of the cost components

The systematic formulation of the various cost components highlights the fact that the cost of robotized construction depends on four types of parameters:

a. Parameters dependent on the nature of the robotized system:

These include the initial investment, the operation and the maintenance costs of the robot, and its setup and transfer costs on site. A "user friendly" robotized system is inexpensive to operate, easy to maintain, and - most important - can, due to its versatility, be employed for many hours per year. High versatility, means - adaptability of the robot to different works and to different configurations of buildings.

b. Parameters dependent on the nature of task to be done:

These include the robot's productivity (in terms of the number of work units produced per hour), the technological adaptations necessary for robotized performance of the task, and the auxiliary work needed. The more "robot friendly" is the task, the higher will be its productivity (output per hour) in the performance of the task, and the lower will be the cost of adaptation and auxiliary labor.

c. Parameters dependent on the nature of the construction projects:

These include the amount of work on site that is suitable to robotized construction, and the dispersion of work among different locations and work stations. The latter may largely depend on the accessibility of

spaces within the building to the robot. A "robot friendly" project is characterized by large amount of work suitable for the robot, few and easy transfers and minimal adaptation cost on site.

d. Parameters dependent on employment characteristics of the robot.

This last parameter is very important, considering the high fixed cost of the robot, which has to be distributed over the expected number of its work hours, and thence - of its output units. A "robot friendly" construction market is one that can consume many robot-hours per year, thus efficiently utilizing the capital investment and save labor costs on more units of work.

The cost of robotized construction, calculated in this manner, has to be evaluated in light of the benefits of robotized construction.

4. Cost-Benefit Break-even Calculations

In order to draw some general conclusions, and make the analysis applicable to different types of robots and different types of building sites, some simplifications can be introduced. It was found that in most cases the highest transfer cost component (see eq. 4) is the transfer cost between sites, while the costs of transfer between locations on the same site and between workstations are less significant, and can actually be included in the calculations of the robot's output per hour. The transfer cost was therefore assumed here, for simplicity, as directly proportional to the number of transfers between sites. Also for simplicity (without changing significantly the results of the calculations) the salvage value of the robot, L , was assumed to be zero, and an average labor wage rate for all types of workers was assumed.

These assumptions enable to calculate, fairly conveniently, the approximate maximum feasible investment in a robot under different circumstances pertaining to: average labor wages, the number of the robot's work hours per year, the size of an average project and the cost per transfer of the robot. The maximum feasible investment is calculated by eq. (5), as a break-even value, V , of the investment for which the benefits, B , from the use of the robot cover its cost, C :

$$(5) \quad C = V \cdot \text{pr}(i,n) + C_M + (H/h) \cdot C_t + H \cdot C_e = H \cdot k \cdot C_L + L = B$$

with :

V - the break-even value of the robot, i.e. the maximum economically feasible investment in the robot.

$\text{pr}(i,n)$ - the capital recovery factor of the investment over a period of n years with interest rate i .

C_M - cost of maintenance per year.

H - total number of working hours of the robot per year.

h - average number of the robot's working hours per site.

C_t - average setup and transfer cost per site (all types of transfers).

C_e - operating cost of the robot per hour.

k - number of labor hours saved per each hour of robotized work.

C_L - average labor cost per hour.

I - intangible gains of robotized work per year.

The feasibility of investment in robotized systems, will be determined in the next section, considering (initially) only the tangible benefits of labor savings.

The major variables that determine the economic feasibility of the employment of a given robot can be seen from eq. (5). They are: savings in labor cost due to the robot's work (the number of manual work hours saved per each robot's hour multiplied by the workers' average wage per hour), the number of robot's employment hours per year, and the transfer cost of the robot (number of sites per year multiplied by the average transfer cost per site).

The maximum feasible investment, V (the break-even value of the robot), calculated with eq. (5) for different values of these variables, are shown in Table 1, assuming the following parameter values:

$C_t = \$500$ per site.

$C_e = \$2$ (for energy) per hour

$C_M = 0.1V + 0.06H \cdot C_L$ (i.e. the annual expenses for labor, parts and downtime during repairs are estimated at 10% of the initial investment, while the routine maintenance is assumed to be equivalent to the cost of 6% of the working hours of the robot per year).

$i = 7\%$ per year

$n = 5$ years

$C_L = \$25$ per hour.

The values in Table 1 are conservative: they do not take into account the intangible benefits of robotization.

Table 1: Tangible value of the robot to the user for different labor savings.

H (hr./yr.)	k	H/h	$V(\$)$	k	H/h	$V(\$)$	k	H/h	$V(\$)$	k	H/h	$V(\$)$
500	1	5	24,000	1.5	5	42,181	2	5	60,362	3	5	96,724
500	1	10	16,727	1.5	10	34,908	2	10	53,089	3	10	89,452
500	1	20	2182	1.5	20	20,363	2	20	38,544	3	20	74,907
500	1	40	-26,908	1.5	40	-8,727	2	40	9,454	3	40	45,817
1000	1	5	55,271	1.5	5	91,634	2	5	127,996	3	5	200,721
1000	1	10	47,998	1.5	10	84,361	2	10	120,724	3	10	193,449
1000	1	20	33,454	1.5	20	69,816	2	20	106,179	3	20	178,904
1000	1	40	4,364	1.5	40	40,726	2	40	77,089	3	40	149,814
1500	1	5	86,543	1.5	5	141,087	2	5	195,630	3	5	304,718
1500	1	10	79,270	1.5	10	133,614	2	10	188,358	3	10	297,445
1500	1	20	64,725	1.5	20	119,269	2	20	173,813	3	20	282,900
1500	1	40	35,635	1.5	40	90,179	2	40	144,723	3	40	253,810

5. Application of the Model to Four Generic Types of Robots

The model will now be applied to examine the economic feasibility of four generic types of robots for building construction: the vertical (exterior wall painting), the horizontal (floor leveling), the interior finishing (multipurpose) and the assembling/handling robotic systems.

The productivity data for the first two types of robots were taken from information supplied by their developers. The information about productivity and cost of the interior finishing robot and the assembling-handling robot has been primarily accumulated during their development by the authors, and supplemented by other related sources.

5.1 Exterior finishing robots

The reported average output of a vertical finisher is c. 45-50 m² per hour (70-150 m² per hour per coat) and it saves 2-3 workers [(Dailey et al., 1993), (Tokioka et al., 1989)]. Let us assume that an average building in which it will be employed is 8 stories high, has a floor area of 1,000 m² per story, and its gross facade area is c. 3,200 m² (40% of the floor area). Let us further assume that such a building requires 3 coats of paint at an average rate of 130-150 m² per hour per coat, that will add-up to 64-74 robot hours per building. To be employed 1,500 work hours per year, the robot must paint each year about 20-24 buildings of this size. If such magnitude of work can be assured to the robot over its life-cycle, its worth to the user (see Table 1), at labor cost of \$25 per hour, is about \$174, 000 (for saving 2 workers).

Assuming only one third of this utilization - i.e. 500 hours per year on 6-10 buildings - it still worth \$55,000 - \$60,000 to the user. One must, however, take into account that a supply of 10 buildings of this size per year - suitable for robot employment - may not be easy, unless appropriate building methods, that will make them "robot friendly", are adopted.

We will now proceed to examine the sensitivity of the robot's value to changes in the transfer cost and the labor rate: Should the transfer cost amount to \$1,000 per transfer (instead of \$500 as assumed), the value of the robot for 1,500 hours of work per year (and 20-25 transfers) will drop to \$145,000, and in the case of 500 hours (and 5-10 transfers) - to \$45,000 - \$50,000. This is still within the economic feasibility range

The feasible investment is even more sensitive to the cost of labor: For average labor rate of \$12.5 per hour (instead of \$25) the value of the robot at 1,500 hours of utilization and 20-25 transfers will be \$68,000, and at 500 hours and 6-10 transfers - only \$20,000. If the robot can be improved to replace more workers, as envisioned [(Dailey et al., 1993), (Gokyu et al., 1996), (Miyajima et al., 1996), (Terauchi et al., 1996)], then its economic feasibility will substantially improve, even with low labor rates. According to one detailed report (Takeno et al., 1989), one robot plus 3 workers should be able to perform equally to a team of 8 men.

5.2 Horizontal finishing robots

The output of advanced models of horizontal finishers is c. 500 m² per hour, and one robot can save the labor of 3 workers [e.g. (Kobayashi et al., 1996), (Neil et al., 1993)]. Let us assume again that an average building in which it will be employed is, as in the former case, 8 stories high with a gross area of 8,000 m². Such a building can utilize only 16 robot hours. In order to accumulate 1,500 working hours, the robot will have to complete 90 such buildings per year, which will probably be too much, considering the transfer and setup time needed (the robot will have to be brought to the site for each floor separately). It is, perhaps, more conceivable that the robot will be employed 500 hours and complete 20-40 buildings per year (which will still require 150-300 transfers). In this case it will worth to the user - assuming at least \$1,000 per site for 8 transfers - merely \$10,000 to \$30,000, which will make it certainly non-feasible.

The situation will improve if the robot is employed in very large buildings with daily casts of large floor segments, or where the pace of progress of floor casting is one per 1-2 working days. In such cases the robot can be left on site between castings, and assuming then an average transfer cost per site of \$500, its value will increase to \$50,000 - \$60,000, which is within the feasibility range. However, a stable supply of 250,000 m² of work for the robot in such buildings per year will still require prodigious marketing and logistic efforts. It results that the employment of this robot type will be feasible in buildings (or other concrete structures) with very large floor areas - in the range of 5,000 - 10,000 m² each.

The employment of the robot will certainly be non-feasible if the cost of labor is \$12.5 per hour.

5.3 Interior Finishing Robots

The development of TAMIR - Technion Autonomous Multipurpose Interior Robot [(Rosenfeld et al., 1993), (Warszawski and Rosenfeld, 1993), (Warszawski and Rosenfeld, 1994)] demonstrated that a variety of interior finishing tasks, such as building of walls, setting tiles, painting and plastering can be performed by the same robot, by changing its end-effectors and peripheral systems. The firsthand experience of the authors with this development from concept to a full-size prototype, and the intensive technological, organizational and economic research that accompanied it, led them to the conclusion that it will be more advantageous under the prevailing conditions to have the robot act under close human supervision, with fairly frequent interventions for assisting the robot in transfers, calibrations, materials supply etc.. Nevertheless, despite the constant presence of an operator, the robot can still save the wages of 2 - 4 additional workers. Moreover, it will have sufficient work to do for more than an entire year in even one single building of the aforementioned size (total floor area of 8,000 m². Each square-meter of the building interior may consume on average 0.2 to 0.5 robot-hours, depending on a number of variables (the sophistication level of the robotic system, the complexity of the building, the nature of the applications, the adaptability of the materials to robotized work, etc.). Thus, the previously used model-building, with its 8,000 m² of floor area, may utilize 1,600 to 4,000 robot-hours per year; namely - it can employ at least one "full-time-robot", and perhaps - more than one, and/or more than for a single shift per day.

For the multipurpose interior robot, the authors can estimate that its value to the user (see Table 1) will be at the minimum c. \$100,000, if it will be employed only 1,000 hours per year and save the wages of 1.5 workers, to over \$300,000 if it will be employed for 1,500 hours per year and save the wages of 3 workers. Both estimates used \$25 per hour as labor cost.

For lower labor cost, however, the value of the robot to the user decreases almost proportionally. The purchase price of a commercial robot, like TAMIR, (with tools and peripheral systems) is estimated by the authors within the range of \$100,000 - \$150,000. Hence from the user's perspective, it is already economically feasible in countries with high wages, and will gradually become more-and-more feasible in countries with lower wages, as its efficiency and reliability improve, and its cost - reduced. The multipurpose (versus the single-purpose) approach has gained strength in recent R&D efforts by many teams [e.g. (Berlin, 1994), (Bock and Leyh, 1995), (Drees et al., 1991), (Miyama et al., 1994), (Pritchow et al., 1994)].

One must, however, take into account that the efficient employment of an interior finishing robot, with the envisioned economic benefits, requires considerable adaptations of the building design to the constraints of robotized work. This requires, among other measures, due attention to small work spaces, to entries and passages of sufficient width, proper sequencing of the construction activities and carefully planned supply of work materials.

5.4 Assembling-handling robot

A special case in this respect is the handling - assembling robot. Unlike the other robot types - this one does not replace manual labor but actually improves the performance of a conventional mechanized crane by introducing automated control systems, and stabilizing devices (Rosenfeld and Berkovitz, 1989). The usual work-cycle of such robot/crane system will consist of picking the load at its origin, moving it to its designated location, discharging it, and - moving back to the same, or to a different origin to pick-up a new load. The first feature assists the robot/crane in bringing the load to its precise location and saves the usual "trial and error" movements of the operator. The other, saves the swinging of the load at the location before its actual deposition as required. Both types of savings are repeated twice for each work cycle - at the origin and the destination.

Each feature - the automated system and the stabilizing device has its own particular cost and its own economic contribution in shortening the robot/crane's work cycle. The cost of each device can be assessed once its technological nature is determined. The benefit is more difficult to assess: At the minimum - when the continuous work of the robot/crane is not critical to the work progress - the value of the time saved is merely the direct cost of the wages of the operator and of the energy. At the maximum - when the pace of the robot/crane is critical for work progress on site - the savings may amount to the total cost of the system - the costs of capital, interest, maintenance, wages of the teams served by the crane etc., as explained before. Based on measurements (Rosenfeld, 1995), the total time savings may amount to 30% of the work cycle, and save the wages of 1-5 workers during its operating time.

The direct value of the automatic feature, according to these estimates, varies between a minimum of \$24,000 for a non-busy crane with 500 operating hours per year, that saves the wage of a single worker; through medium savings of c. \$128,000 for a crane that operates 1,000 hours per year, and saves the wages of 2 workers; up to c. \$300,000 for a busy crane that operates 1,500 hours per year, and saves the wages of 5 workers. In all these cases - 5 transfers per year were assumed. In the two latter - the added indirect (yet quantifiable in money terms) value may become very substantial due to considerable shortening of the total project duration.

6. Conclusions

The paper presented a model for the micro-economic analysis of robots employment on building sites, and applied it to four types of building robots, using the available productivity data, which have been published to-date by their developers and users. The analysis referred to the cost of robot employment versus the economic benefit of the improved productivity in the particular tasks performed by the robot. The indirect - non-quantifiable benefits were not considered.

The conclusions, drawn from the analysis, are as follows:

a. Exterior wall finishing robots: It appears that the employment of an exterior painting robot will be economically feasible, provided that it will be employed at least 30% - 50% of its time (500 - 750 hours per year) on buildings of appropriate size and configuration. The supply of appropriate buildings may pose difficulties unless the robot is employed by a very large contractor or within a very efficient subcontracted exterior finishing service.

b. Horizontal floor finishing robots: It appears that a robot in this category will be feasible only if it will be employed, continuously (allowing for the transfer down-time), in buildings erected at a very fast pace, or buildings with exceptionally large floor area on each level..

c. Multipurpose interior finishing robots: This type of robot can be economically feasible if it will be employed about 60%-70% of its time. Its extent of employment can be attained more easily than with the other robot types, due to its capacity to perform different types of building tasks. On the other hand, it requires buildings with carefully adapted design and construction planning.

d. Assembling - handling robots: This type of robots - if they are based on automated control of existing mechanized equipment - has potentially the highest additional benefit/cost ratio. This is because of the comparatively low investment in the additional feature of automated or semi-automated control, which results, in turn, in considerable productivity savings.

The analysis also revealed that the first three robot types have economic viability only at considerably high wage rates, that prevail in developed countries. They will not be economic at considerably lower wage rates. On the other hand - the automation of existing handling equipment, which is at the heart of the last robot type will be justified at almost any wage rate.

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INFORMATION ON THE CONSTRUCTION INDUSTRY: AN INTERNATIONAL MACROECONOMIC PERSPECTIVE

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1. Introduction

In a seminal paper presented at the *1990 CIB Conference on Building Economics*, Ranko Bon wrote of the need for better data on the construction sector for those researchers concerned with construction economics on a global scale and expressed the view that: “The state of our knowledge about the construction sector is deplorable in light of its role in national and world economies. The data on construction activity is poor and erratic. This is true at both national and international levels. Among the economic sectors, it is least studied and understood.” (Bon, 1990).

His attempt to take an overview of of global trends in construction activities identified two major problems in dealing with international statistics:

- The tremendous variety of statistical definitions and accounting procedures.
- The problem of coverage.

The problems encountered in international comparisons of the construction sector are well-documented and the large discrepancies between the data values of the published statistics published by different bodies are still apparent today.

This paper has three main objectives:

- a. To determine whether there has been much improvement in recent years in the usefulness of published statistical information available to construction macroeconomists at an international level.
- b. To explain how data from primary and secondary sources have been used in one particular research project to produce a viable study of the relationship between the construction sector and the macroeconomy in specific countries.
- c. To consider recent trends and projections in European construction globally, using available macroeconomic statistics.

These objectives are discussed, in turn, in ensuing sections.

2. National Accounts - A basic database for the macroeconomist

The National Accounts are the accounts of the nation's economy. In the U.K. they are compiled by the Office for National Statistics (ONS) according to international standards and record and describe economic activity in the U.K.. As such they are used to support the formulation and monitoring of economic policies.

2.1 The framework of the national accounts and gross domestic product

The great wealth of data contained within the accounts represents a comprehensive national accounting framework. An understanding of this framework is crucial in any analysis of the figures. It helps to understand what information is available and how it has been put together, and in doing so reveals the different perspectives from which the figures can be viewed.

However, before going on to describe the framework it is useful to consider briefly the economy as a whole and the measurement of total domestic activity, or gross domestic product (GDP).

2.1.1 Economic activity: What production is included?

As GDP is defined as the sum of all economic activity taking place in UK territory it is important to be clear about what is defined as economic activity. In its widest sense it could cover all activities resulting in the production of goods or services and so encompass some activities which are very difficult to measure (for example, minor building and repair work performed around the house by the householder).

In practice, a production boundary - determined by international convention - is defined, inside which are all the economic activities taken to contribute to economic performance. These activities range from agriculture, construction and production through service producing activities, to the provision of health, education, public administration and defence.

In this approach the decision whether to include a particular activity takes into account the following:

- does the activity produce a useful output?
- is the product of the activity marketable and so have a market value?
- if the product does not have a meaningful market value, can a meaningful market value be assigned?
- would exclusion (or inclusion) of the product of the activity make comparisons between countries or over time more meaningful?

Some activities, not directly exchanged for money, but for which a market price can be estimated or imputed include; the provision of owner occupied housing (by the owner for their own use) and the non trading use of fixed assets owned by the government and by private non profit making bodies (for example, school buildings). For the record, the productive "domestic" activities of households are not included in GDP as estimation is so difficult; moreover inclusion by the U.K. alone would not help international comparisons.

2.1.2 Measurement of GDP: The output approach

The output approach looks at the contribution to production of each economic unit; that is the value of production less the value of the inputs used up in the production process. The sum of this *value added*, for all producers, is GDP.

GDP measured by this approach is presented in seasonally adjusted index number form at *constant* prices.

Although the input-output balance compilation allows the calculation of this measure at *current* prices, this information is only available for those years for which the balances are produced.

In theory, value added at constant prices should be estimated by deflating separately the gross inputs and the gross outputs of each economic unit and then subtracting one from the other. But, because it is hard to get reliable information from companies which can make this calculation possible on a timely basis, a simple assumption is made: value added is assumed to be proportional to the output produced.

As a result it is possible to say, broadly, if the volume of output increases by say 10 per cent, then inputs will increase by the same percentage and hence value added will also increase by 10 per cent. With this approach, which is valid in the short term, the data required is on the volume of output. This is often approximated (or proxied) by deflating the turnover or value of production. The commonly used proxies include the quantity of goods and services provided or employment (with adjustments made for production. The output indicators obtained for each industry are then expressed in index number form with base year (currently 1990) equal to 100.

These output indicators are then combined (or weighed together) using the value added of each industrial sector in the base list established from the input-output balance.

2.1.3 European Community definition of gross national product

The Statistical Office of the European Community (EUROSTAT) uses a slightly different definition of GDP from that mentioned. EUROSTAT publications use the definition of GDP at market prices based on the European system of integrated accounts (ESA). This definition is also used for statistical returns to the United Nations (UN) and to the Organisation for Economic Cooperation and Development (OECD).

2.2 Definitions of Construction Activity

The United Nations in its Annual Yearbook of National Accounts draws concepts and definitions from the International Recommendations for Construction Statistics. Unfortunately, there are sometimes differences in underlying concepts and definitions for different countries.

2.2.1 Scope and coverage

Generally, the whole of construction activity consists of the following:

- Construction industry proper: contract construction by general builders, civil engineers and special trade contractors;
- Contract construction carried out for others by establishments or organisations classified to industries other than construction;
- Own-account construction carried out by independent units of enterprises or other organisations not classified to the construction industry proper;
- Own-account construction carried out by establishments or other organisations not classified to the construction industry, with no independent construction unit;
- Own-account construction carried out by individuals.

Data on construction authorized and completed cover, in principle, all construction activities in urban and rural areas and are derived from information collected by municipalities or other local authorities during the exercise of regulatory or controlling functions. In some cases, coverage is restricted to urban areas or major cities; in other instances, only to construction by private sector. Construction of a temporary nature is excluded from all series.

2.3 Introduction of the new international system of accounts

As in many other countries, the ONS is preparing for the introduction of the latest internationally agreed system of national accounts. The 1998 National Accounts (or Blue Book) will be the first edition to incorporate the recommendations of the UN System of National Accounts 1993 (SNA93) and the requirements of the European System of Accounts 1995 (ESA95), which is consistent with the SNA 93. Following the 1997 Blue Book, an ESA95 version of the accounts will be published in Autumn 1997, reworked to show as far as possible what the accounts would look like on the new basis and in the new format. This will enable users to familiarise themselves with the changes in the systems and to contribute to consultations with the ONS on the changes.

2.3.1 Improvements in SNA

A major revision of the United Nations System of National Accounts (SNA) in 1993 had taken almost two decades, beginning in 1975 as an updating, clarification and harmonisation of the 1968 SNA with other

international statistical systems. There were quite major changes in some areas but some of the inadequacies of the previous SNA were perpetuated.

On the positive side, the question of consistency with the data collected by other international agencies was actively accepted.

With respect to the question of whether the SNA will provide an adequate framework for analytic uses for data about the economy, it should be recognised that the SNA is both conceptually and statistically a set of aggregate accounts designed to be presented as tabulations. In a sense, the SNA is a prisoner of the printed page and punch card mentality; it reflects both data needs and data technology characteristic of the past 50 years. The revision has not been designed to take advantage of the recent development and anticipated future changes in both data needs and data technology.

Considering the present analytical needs for detailed information about the economic system and the capabilities of modern computers, the national accounts should be constructed in a manner capable of integrating and accessing microdata bases derived from administrative sources and large samples. If the national accounts cannot provide efficient access to such detailed data, both business and governments will increasingly come to depend on private proprietary data bases, and the advantages of an overall integrated system will be lost.

However, if a set of core accounts are used to record the transactions of enterprises, governments and households in the national accounts could be directly related to a wide variety of microdata bases referring to such entities and their transactions. Harmonisation of concepts used for the national accounts and microdata sources would be required, and the familiar problems of data reconciliation would need to be resolved.

The SNA should be built around the task of integrating macro aggregates with the underlying microdata. From an analytical point of view such integration is essential if computational techniques such as microsimulation modeling utilising longitudinal data are to be related to macroeconomic analysis.

3. A Study of the Relationship between the Construction Sector and the General Economy in Developing Countries

Little published work appears to have been undertaken on the role of the construction sector in lesser developed countries, in which consistent economic growth has not been a feature. A recent project, undertaken at the University of Salford, was undertaken with the aim of analysing the the relationship between the construction sector and the general economy. The project has been concerned with the Sub-Saharan countries of Africa, particularly with two countries, Angola and Mozambique, with a turbulent political (and consequently economic) recent history. Results of the study are published elsewhere, but concern here is only with data sources and data usage.(Ruddock and Lopes. 1996).

One aim of the research was to collect and coordinate data on Angola's and Mozambique's construction sectors. It has already been mentioned that data on the construction sector, though they appear twice in national accounts statistics (in terms of value-added and as a component of gross fixed capital formation),

are less reliable compared to those of other sectors. Regarding developing countries, the situation tends to get worse in terms of the accuracy of data.

3.1 Statistical Sources for the study

The main statistical sources used in the analysis were the *Yearbook of National Account Statistics* from the United Nations (1988 and 1994), *World Development Report* (World Bank. 1991 and 1995), *African Development Indicators*. Additional sources were drawn from secondary data collected in the fieldwork carried out in Angola and Mozambique.

As data were drawn from various sources, there was not necessarily any great consistency between data, or their desegregation. It should also be noted that the United Nations is forbidden by protocol to revise data provided by the Statistical Offices of its member states, unlike the World Bank which is more free to make adjustments. Yet, the U.N. is the only one that publishes these data in a comparative format for all its members and according to the SNA conventions.

The production approach of the SNA presents data on value-added of different sectors that make up a country's GDP, and the expenditure approach shows data on the components of GDP by expenditure.

The indicators of the construction industry activity used for this analysis were construction value added (CVA) and gross fixed capital formation in construction (GFCFC). CVA is calculated the same way as in any other sector, but includes only the activities of the construction activity proper (for example it excludes the building materials industry which is accounted in the manufacturing sector). GFCFC is a component of a country's gross capital formation. It measures growth output in construction excluding maintenance and repair construction works which are accounted as current expenditures. The main indicator of economic activity used in this study is GDP per capita. It adjusts the growth in the economy with the growth in population. It is a better indicator of a country's welfare particularly in developing nations where the growth rate of population has been

since the World War II twice as high as in developed economies. Thus, a country is experiencing a *sustained* economic growth in a given period when GDP per capita at the end of the period (measured in constant prices) does not fall back to the level of the beginning of the period. Of course, this does not take in account annual fluctuations which characterise the development pattern of many developing economies.

3.2 Method of Analysis

The analysis employed was that of a comparative analysis of national time series. The fact that this method was used instead of a cross-sectional study deserves a special note. Cross-sectional studies were popular in the seventies and early eighties, when time series data were scarce and less reliable, particularly in less developed countries. Countries were arranged according to their level of income per

capita in U.S dollars as of a particular year, and GDP per capita or GNP per capita were used as independent variables to explore differences in the pattern of the indicators of construction industry activity. However, conversion of national currencies to \$U.S. equivalents do not reveal the distortions of a country's economy nor the comparative levels of prices in non-tradable goods and services (as are the case of most construction services). Further, cross-section analysis at a single point in time cannot reproduce the richness of events over time. It cannot answer such questions as why some countries grow faster than others, nor can illuminate the qualitative changes in political and economic institutions that typically accompany economic growth.

The justification for using construction value added (CVA) as the main indicator of the construction industry activity rather than gross fixed capital formation in construction (GFCFC) or gross construction output (GCO) is twofold:

Firstly, the production approach (value added components) has been utilised by international bodies as a more reliable way to compound a country's national aggregate.

Secondly, as far as this sample of countries is concerned (and for the period of reference analysed), data on construction value added are more consistent than on the other indicators of the construction industry, let alone data on construction employment.

With regard to GFCFC, it is, as already mentioned, a component of a country's gross capital formation. The gross output of repair and maintenance in construction works is not accounted for in GFCFC and obviously not in gross capital formation. Often, it is difficult to distinguish a minor from a major rehabilitation work. Then bias can occur looking at the rough figures of a country's national accounts tables. It is, also, worth noting that maintenance and repair construction works may concern inputs from all sectors of the economy. Thus, it appears to be less difficult to discover the aggregate value added component in this sub-sector of the construction industry (work done, mostly, by construction enterprises) than the aggregate gross output of construction repair and maintenance by other sectors of the economy, which may account either as investment or current expenditure of this sectors.

4. Recent Trends in European Construction Activity

As the last publication of the U.N. *Construction Statistics Yearbook* was in 1989 (showing 1985 data) and the recently (April 1997) published *National Accounts: Main Aggregates and Detailed Tables* deals with data up to 1993, it is necessary to investigate other sources in order to examine more current state of the industry across countries, in order to gauge the general pattern.

The Organisation for Economic Cooperation and Development (OECD) publication *Economic Outlook* compiles various macroeconomic statistical measures for member countries and provides a periodic assessment of economic trends that includes short-term projections of GDP and GFCF.

Table 1 shows the projections for the annual % change in real GDP for 1997 and 1998 in several countries. In addition to the U.S.A. and Canada (included for comparative purposes), the countries are chosen to exemplify both Western and Central/Eastern Europe (CEE).

Table 1: Percentage change in real GDP (over previous period)

	1997	1998
United States	2.2	2.0
Canada	3.3	3.3
Germany	2.2	2.6
France	2.5	2.6
Italy	1.2	2.1
United Kingdom	3.3	3.0
Hungary	1.7	3.2
Poland	5.0	5.0
EU	2.4	2.7

One particularly notable aspect here, is the consistently higher growth rate for the CEE countries than for the EU.

The *Annual Bulletin of Housing and Building Statistics* of the United Nations aims to provide basic annual data in the field of housing and building in European countries, Canada and the U.S.A.. The statistics are provided for fifty-five countries and use commonly agreed definitions worked out under the auspices of the Confederation of European Statisticians.

The data compiled, covers:

- Dwelling stock.
- Number of buildings constructed.
- Value of construction (completed construction work by category).
- Building firms (number of firms, output, employment).
- Building materials (including production and *apparent use* of cement).
- Prices, costs and rents (wholesale price indices of materials, input and output price indices for housing construction).

(One complication with trying to make comparisons is the fact that many countries [particularly those in Eastern Europe] have, until relatively recently, been producing national accounts under the MPS system and this has complicated comparisons between these countries and those using the SNA system, particularly in the area of capital formation. This has been especially important for the construction sector.)

The *Annual Bulletin* (1989-96 editions) provide information on annual GFCFC and, using a regression equation for GFCFC and GDP based on ten years' data, I have made extrapolations to show projected growth in GFCFC for 1997 and 1998. This is illustrated in Table 2.

(As already mentioned in section 3.2, there may be better indicators of construction activity [particularly CVA], but with the limited availability of easily accessible macroeconomic data, GFCFC is used here.)

Table 2: Projected growth in GFCF Construction (over previous period)

	1997	1998
United States	2.3	1.9
Canada	3.4	3.2
Germany	2.3	2.8
France	2.6	2.5
Italy	1.3	2.0
United Kingdom	3.4	2.8
Hungary	1.8	3.3
Poland	5.1	5.3
EU	2.5	2.9

There is notable divergence between countries, especially EU members, but again the greater growth is apparent for CEE nations.

There are data in the *Annual Bulletins* to permit comparison on employment change in the industry since 1980. Table 3 shows employment for three chosen years for a selection of two EU and three CEE countries.

Table 3: Number of employees in the building industry

	1980	1990	1994
Ireland	103 000	76 000	79 000
United Kingdom	964 000	773 000	561 438
Estonia	50 200	51 800	39 000
Hungary	327 000	213 000	99 123
Poland	1 028 000	638 600	642 901

Whilst the size of relative decline is apparent from Table 3, the overall picture for the twenty-two countries for which a series of data is available is shown in Table 4. Of those countries, only four showed a rise in construction employment, whereas eighteen showed a fall.

Table 4: Comparison of employment in construction (number of workers) between 1980 and 1994

Employment down				Employment up
Austria	Estonia	Norway	Slovenia	Cyprus
Belgium	Germany (W&E)	Poland	Sweden	Finland
Bulgaria	Hungary	Moldova	U.K.	Luxembourg
Croatia	Iceland	Romania		Portugal
Denmark	Ireland	Slovakia		

This is not particularly surprising, given the recessionary state of European economies in recent years, but it is certainly worth comparing this with Bon's 1990 study, when the employment figures (up to 1985) were showing considerable falls in numbers in the selected European countries. The decline in employment numbers has continued, with all the major European economies showing a similar trend.

Use of the data on GDP, GFCF and GFCFC from the 1997 Annual Bulletin enables the calculation of GFCFC as a %age of GDP for 1994. For the twenty-two countries, for which these data are available, it is interesting to consider the variation in this %age. Table 5 shows the *league table* of countries, indicating that at the extremes, whilst GFCFC has a value of over 15% of GDP in Switzerland, the Finnish economy shows a comparable figure of only 6.4%. This massive variation is worthy of more in-depth study. This is, itself, the subject of a current research project but the scope of this paper is merely to concern itself with an investigation into the availability of data and to point out its more interesting features.

Table 5: GFCFC as a %age of GDP

	1994
Switzerland	15.2
Cyprus	14.7
Austria	14.3
Germany	14.2
Spain	13.4
Canada	12.3
France	10.5
Belgium	10.0
Hungary	9.9
Kyrgyzstan	9.0

Greece	9.0
Romania	8.9
Slovenia	8.8
Italy	8.8
Ireland	8.5
Malta	8.0
Iceland	7.8
Netherlands	7.7
Denmark	7.6
U.K.	7.1
U.S.A.	6.7
Finland	6.4

5. Conclusion

This paper represents an attempt to investigate the usefulness of principal macroeconomic data sources on the construction sector, available to the researcher concerned with international comparisons. For much research work, dealing with only a small number of countries, recourse to an individual country's national accounts, supported by groundwork in that country, may be appropriate. Yet this would be impossible for wider international comparisons. Good opinion surveys, such as those of Bon's (1996), certainly provide important and interesting information, to complement 'official' information sources but 'improved' official data is essential.

The recent revamp of the SNA in an attempt to provide further standardisation of national accounting procedures, and the move away from the MPS by countries, have certainly been moves in the right direction. Yet the most disappointing features of data availability are still the lack of availability of a regular, complete set of U.N. statistics on the industry and the inevitable degree of under-reporting in many countries, which still leads to the questionable reliability of data.

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THE DEVELOPMENT AND IMPLEMENTATION OF KNOWLEDGE MODULES FOR AUTOMATED STRUCTURAL DESIGN

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This paper presents an automated system for building design for rectangular shaped buildings of one or more stories, built using any kind of construction technology. The system is based on an object-oriented building Project Module that has been designed to support the information needs of the system throughout the project life cycle. Distinct knowledge module's process project information through predefined stages of the design and construction planning process. The knowledge modules have direct access to external data bases containing up-to-date information regarding the physical and business environment of the project. They also query the user whenever necessary. The Building Project Model and structural design knowledge modules have been developed and implemented in a computerised system. This paper describes the use of the Project Model and the functioning of the system and its structural design knowledge modules. The automated system can produce designs of high quality as it uses up-to-date data (defining materials, technologies and costs), and also enables the user to explore and compare numerous design alternatives in depth. The economic advantages of such automation lie in the direct savings in design costs, in shortening of the project duration, and in the potential savings in construction costs which result from higher quality design.

1.0 Introduction

The quantity of information generated and use for the average modern construction project is vast. This is due to the complexity of the building product, the multitude of organisations involved and the fact that the majority of construction projects are prototypical. While computers are currently used to perform diverse design and management tasks, the construction industry has yet to adapt its work practices to the Information Age. Fully computer integrated construction (CIC) will fundamentally change the ways in which project participants perform and communicate (Teicholz & Fischer 1994).

The aim of an Automated, Computer Integrated Building Realization System (ABS) is to automatically generate all of the information required for the design, planning and execution of a building project (Warzawski 90).

Sacks and Warszawski (97) have detailed an ABS intended for the design of multi-storey buildings with rectangular uniform floor plans. This conforms to the approach that systems should be limited in scope in order to be feasible (Karhu 97). The proposed ABS functions in a step by step manner through distinct predefined stages; the user can respond and intervene at each stage to approve or reject the results presented. The user can also change the project data directly, and, if necessary, instruct the system to repeat the previous step. The system can produce, on demand, any of the project documents required by the user (such as plans, costings, textual reports, specification's etc.,

The ABS used knowledge based modules to generate and manipulate the project information, and has direct access to various construction databases. Each of the knowledge modules incorporates procedural knowledge of its domain, such as structural design, floor layout, electrical system design, HVAC etc.,. The discussion in this paper highlights the structural knowledge modules of such a system.

The generalised structural design process has been formally described as consisting of four distinct and consecutive activities: Formulation of functional requirements, Conceptual design, Optimization and Detailing (Kirsch 93). The first three steps are usually repeated (Bakkeren 94) as the design is refined. While computerisation of evaluation and detailing is reasonably commonplace in structural design offices, the first activities (formulation of requirements and syntheses of new solutions for evaluation) have remained the domain of human designers. This is clearly the most complex part of the design process to computerise, as it is 'creative' in nature. The structural knowledge modules of ABS address all four steps.

2.0 Building Project Data Model

While other aspects of the proposed ABS, such as Design of Prefabricated Buildings (Retik and Warszawski 94), Construction Planning (Shaked and Warszawski 95), have been investigated at the Israel National Building Research Institute (NBRI), this module is the first to be based on a common building Project Data Model (BPDM) designed and implemented specifically for the ABS.

The current data model covers the design process from the statement of the owner /developer's requirements through to the start of construction scheduling, and demonstrates the ability of the project model to support representation of the project information through the project life-cycle. The model schema accounts not only for the varied data requirements of different system modules, but also for the different ways in which they require that the data be structured. This is a daunting challenge for the case of a generic building model (Bjork 92); the BPDM is tailored specifically for rectangular shaped, multi-storey buildings whose floors are of consistent shape through the height of the building.

The project model utilises object-oriented technology to structure the generation and storage of the information describing the building project. The object classes organise the information around three key axes (this

building's spaces, its physical systems and their parts, and the activities and resources required for its construction. Each axis is divided into three main levels of detail. The relationships which are possible between the object classes are detailed in a model schema, which also includes classification hierarchies for each of the classes in the main schema.

The project model is described in detail in (Sacks and Warszawski 97).

3.0 Processing Stages and Knowledge Modules

The overall design and planning process of an Automated Building system for rectangular multi-storey buildings have been defined as being composed of different stages (Sacks & Warszawski 1997). These are:

1. Brief Generation
2. Conceptual Design (building shape and height),
3. General Design I (structural scheme and floor layouts),
4. General Design II (selection and layout of Work Assemblies),
5. Detailed Design (analysis of the work Assemblies and detailing of each of their Elements),
6. Scheduling and Purchase Planning.

Each of the knowledge modules required for the system has also been detailed with respect to the stage at which it functions, the data input it requires, and the building g information it generates. Structural design is not limited to any stage in the design process; different parts of the structural system are designed and detailed at various levels of detail through each stage, by different knowledge modules. It is therefore necessary to conceive of ABS structural design knowledge modules as parts of the overall knowledge modules for each stage. Three Specific sub-modules are defined:

3.1 Core and Structure Knowledge Module, which is part of the General Design Knowledge Module (GDKM). The structural design of a building is closely entwined with its spatial design, particularly in the layout phase. At this time a solution type must be decided upon resisting the horizontal forces which act on the structure, and the positions of the columns that carry the vertical loads must be set. Both of these design issues must not only account for structural functional requirements, but must also enable the building spaces to fulfil their required services functions. The building core may contain elevators, stairwells, service shafts, public bathrooms, etc., as well as providing the primary stiffening element for resistance of earthquake and wind loads. The positioning of the columns and their spacing in each direction must allow subdivision of the floors in a way compatible with their function, whilst at the same time allowing for design of a cost-effective slab system. Therefore, the set of rules and methods in this section includes both structural and architectural knowledge.

The module develops candidate solutions for the core and structure whose parameters include the column spacings in each direction, the type of horizontal load resisting system, and the type of foundation system. The parameters are fixed on the basis of a detailed comparison of the estimated direct and indirect costs of each possible solution. In the present implementation, solution costs include direct slab costs for the building g's floors, the costs of columns and core walls, and the costs of finishes associated with the slab type. It is recognised that additional factors such as the cost of the foundation system, the economic impact of construction duration, and the impact of the column spacings on the value of the resulting building space, should be considered in a full scale commercial system. Figure 1 shows a user interface screen on which different alternative solutions are presented.

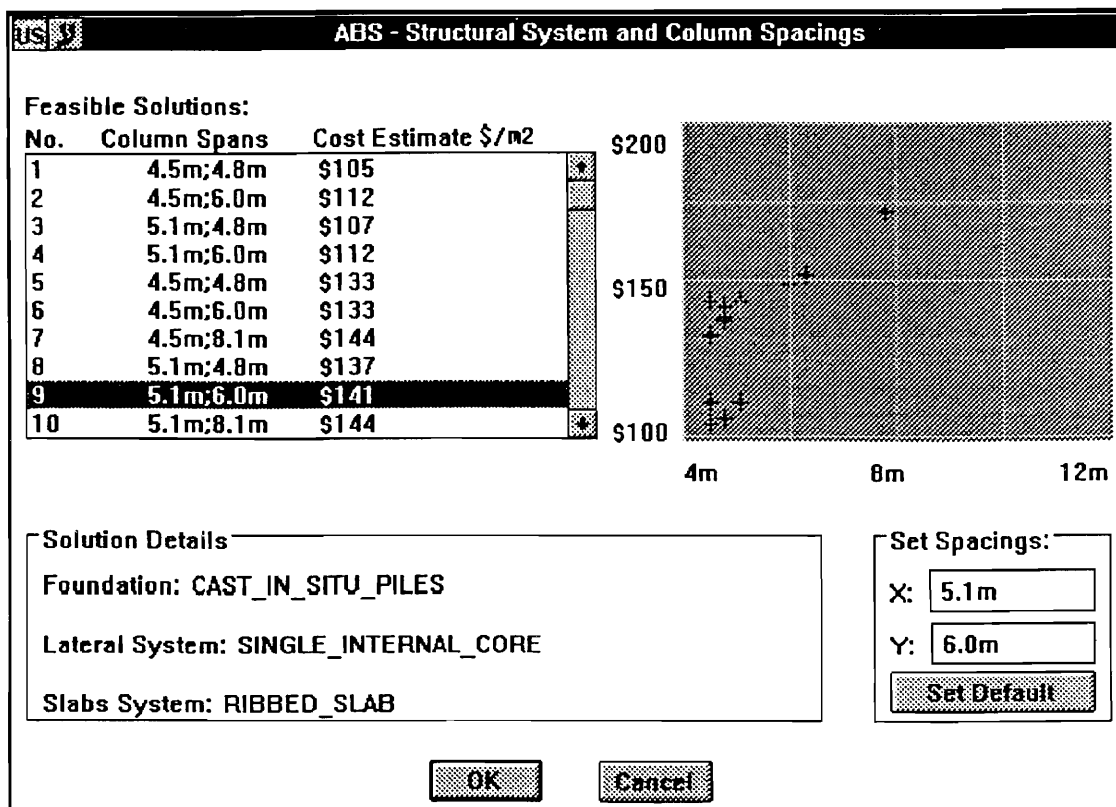


Figure 1: ABS user interface screen showing feasible structural solutions.

3.2 General Structural Design Knowledge Module, one of the functional System Knowledge Modules (FSKM). At the outset, functional system requirements are detailed for supporting the service loads on each

floor, on the basis of the proposed function of the floor (e.g. office space, housing, education, etc.,), and stored in the project model. for each functional system requirement instance, selection rules are processed for each feasible slab solution. The slab solutions are implemented in the form on Intelligent Parametric Templates (IPT) (Sacks & Warszawski 97), which are templates of complete solutions for different functional systems of the building (Warszawski & Sacks 95). the IPT's encapsulate the physical definition of the system and its parts, together with knowledge-based rules, algorithms and data base and user queries required for their evaluation, selection, layout and detailing.

At this stage the level of detail is greater than that at the previous stage. The column positions, and therefore the spans, have already been fixed (Figure 2), as have the locations and sizes of the building's cores. thus, more accurate evaluation of each feasible slab configuration is possible. The most economical slab solution can therefore be selected. The methods and rules of the selected slab solution are then processed to la out its elements. Figure 3 shows part of a drawing of a joist slab, after design by the joist slab IPT's lay methods and its set layout rules.

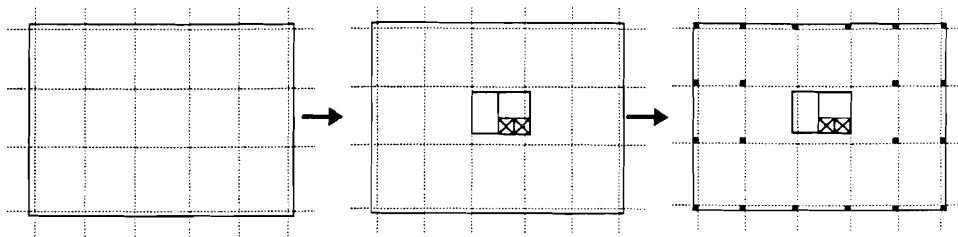


Figure 2: Setting of core size and location and column positions for buildings where the core can be designed to fit the column grid.

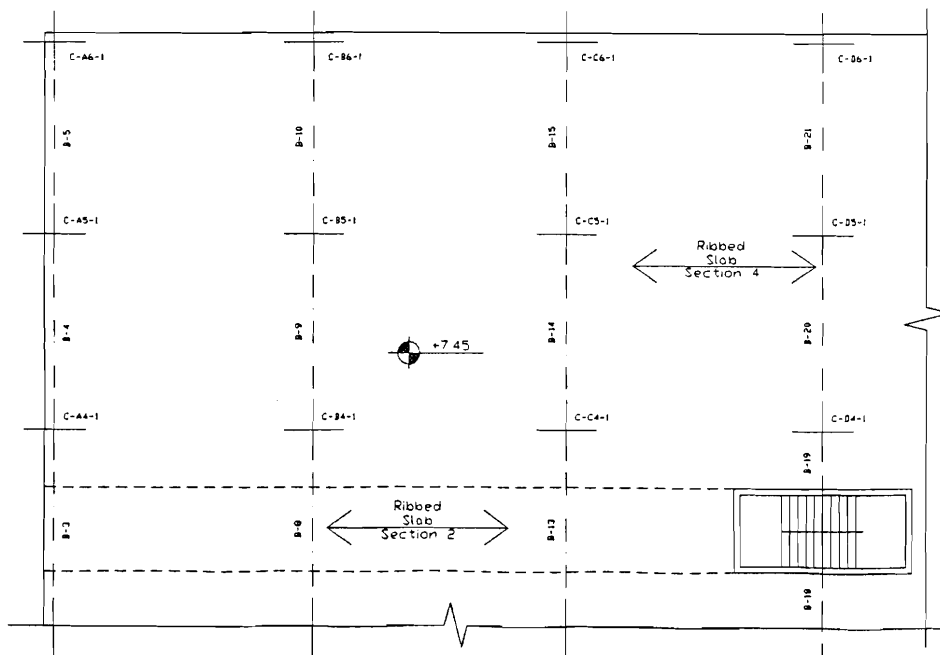


Figure 3: General Layout Drawing of a Ribbed (Joist) Slab.

3.1 Detailed Structural Design Knowledge Modules, which are in fact individual. Work Assembly Knowledge Modules (WAKMs). In the final step of the design process, the ‘detailed _ design’ method of the IPT is called for each work assembly; in effect, each work assembly details itself. Detailing of structural work assemblies includes structural analysis and element design (either selection of standard sections or reinforcement detailing). Much of the knowledge at this stage is procedural in nature, and is therefore, implemented mostly as object methods, and less in the form of heuristic rule sets.

4.0 Implementation

A Prototype systems has been implemented using the autoLISP++ object-oriented development tool¹. Only the user interface and the structural knowledge modules been fully implemented, while other components function as demonstration modules only.

The user can request that the system produce drawings and reports at each stage. Figure 3 shows the structural layout of a joist slab with hidden beams at the end of the general design stage. figure 4 shows a detailed layout drawing of the same slab, plotted after the detailed design stage. One advantage of storing the project information in a building project model rather than a conventional set of drawings, is that designers and builders can each view the building in ways appropriate to their immediate needs. For example, a steel fixer could examine a column head reinforcement detail (Figure 5). Reports, such as the rebar quantity take-off report shown in figure 6, are also produced automatically.

¹ Developed for this purpose using AutoCAD® 13 (Autodesk Inc.) on a PC 486 computer.

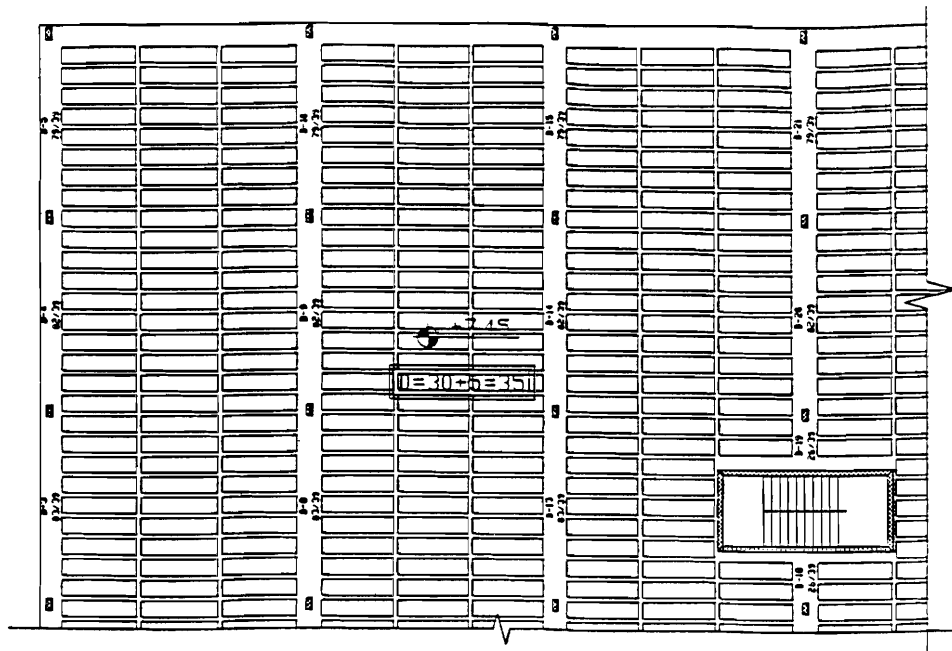


Figure 4: Detailed Layout Drawing of a Ribbed (Joist) Slab with Hidden Beams.

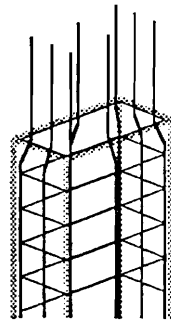


Figure 5: Column head reinforcing detail.

Reinforcing Bars				
Bar Id	Bar Definition	Quantity	Weight(kg)	Total Weight(kg)
1	Φ 10 L=5450	40	3.4	135
2	Φ 10 L=6300	56	3.9	219
3	Φ 10 L=6700	96	4.2	399
.....				

Figure 6: Section of a rebar quantity take-off report.

5.0 Conclusions

An automated building system has been defined for rectangular shaped multi-storey buildings. the Building Project Model of the system has been implemented and tested, and structural design knowledge modules have been developed, using an Intelligent Parametric Template design strategy.

The envisaged benefits of use of an automated system are numerous. The direct costs of design are significantly less than the labour-intensive process common today (in limited testing, the system was able to produce complete structural drawings for a six storey building in just four hours). As a result, the designers can also consider more design alternatives more thoroughly than previously, thus increasing the likelihood of achieving an optimal design. The system can produce design information of high quality (ISO 8402-86), thus reducing construction costs associated with inconsistencies and errors in design drawings. Also, the fact that the information is computerised and accessible at all stages enables the use of automated production systems without requiring additional labour inputs for information processing (Navon *et al* 94).

While concept has been demonstrated on rectangular shaped buildings only, it is proposed that the system could be extended to include buildings whose shape is composed of basic rectangles, without restriction on buildings types and construction technologies. In this way, the system concept could be applied to a majority of all buildings.

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INTERNAL RATE OF RETURN AND ANNUAL COST CALCULATION IN PROPERTY INVESTMENT DECISION MAKING

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Abstract

Professional property investment decisions usually are based on the irr concerning a period in which one or more upgrading investments are included. As a result the selling value is very speculative. To have a better basis for decision making the planning period should be shortened to a rental period in which the supply of facilities is constant. As a result the costs of the facilities can be compared with the market rent. When annual costs are calculated it will be possible as well to calculate the residual value at a moment of upgrading and at the end of the investment period. The Residual value is the basis for an upgrading decision, since the total investment depends on the market rent to be expected after upgrading, the decision maker should be aware of the fact that the residual value should be based on actual prices and not on the historical investment. Undervaluation of the residual value may result in a too high upgrading investment. Changes in value of the land will be substantial and have to be taken into account in investment and upgrading decisions; they are in fact the only speculative factor. Decision making based on costs instead of cash flows needs more data than available now. They concern maintenance, economical life span and disposal costs in upgrading situations.

Keyword: irr, annual cost, upgrading, residual value.

1.0 Introduction

Professional property investors usually base their investment decisions on the internal rate of return over an investment period of about twenty years. In this way the balance between supply and demand is neglected, as well as the level of upgrading within the investment period. This balance can only be found over a shorter (usually rental) period in which the quantity and quality of the flow of facilities is constant. Over such a period the average annual costs have to be calculated to compare them with the market rent. On the basis of

this cost calculation (including depreciation) the residual value of the building at the end of a rental period may be found as an output as well.

In this article will be discussed which planning period has to be chosen, which financial parameter should be used for decision making and which information is needed for the calculation.

2.0 Speculative return on investment.

The goal of a property investment is to generate an income. In the case of an investor-user the income is generated indirectly by using the property as a durable means of production in his primary process and by selling the property after the period in which it has been usable for this particular process. Professional investors invest to generate a direct return on the investment, over a well defined investment period by getting a rental income and a more speculative, but very important high selling value.

The return over the investment period is uncertain, since changing market demand influences the market rent and the selling value of the property. The value of the land hardly can be influenced by the investor, while the value of the building depends partly on the initial investment, but as well - substantially - on the additional, upgrading investments within the investment period. These additional investments can hardly be predicted at the moment of the initial investment, since the change in demand is not clear over the investment period. The possibilities for an investment in upgrading depends on the expected market rent and the residual value at the moment of decision making, which usually is not determined at all. A calculation method has to be chosen to generate reliable data on which investment decision (initial or upgrading) can be based.

3.0 Irr and cash flow

The irr is meant to determine the average annual return over the investment period, to be used as a basis for the investment decision. Obviously it does not concern a cost calculation, but it concerns the transformation of (incoming and outgoing) cash flows into a net percentage of the initial investment, but including the interest cost of the investment, (Figure). Since the cash flows can only be estimated in a global way over such a long period, it creates a speculative basis to the output and as a consequence can be used just as an indicator of the attractiveness of the investment.

The most speculative input to be predicted is the selling value of the property. It would be better to calculate this value as an output of a cost calculation.. To make this possible, we may have to switch to shorter planning periods in such a way that the cost calculation will concern a period with a flow of facilities constant in quality and in quantity. Over such a period rent and costs should be clear to decide about the best balance between them.

First out attention will be focused on the period with could serve as a good basis for cost calculation, after which will be focused on the period which could serve as a good basis for cost calculation, after which can be decided the type of cost parameter which could serve for out goal to value the building at each decision moment.

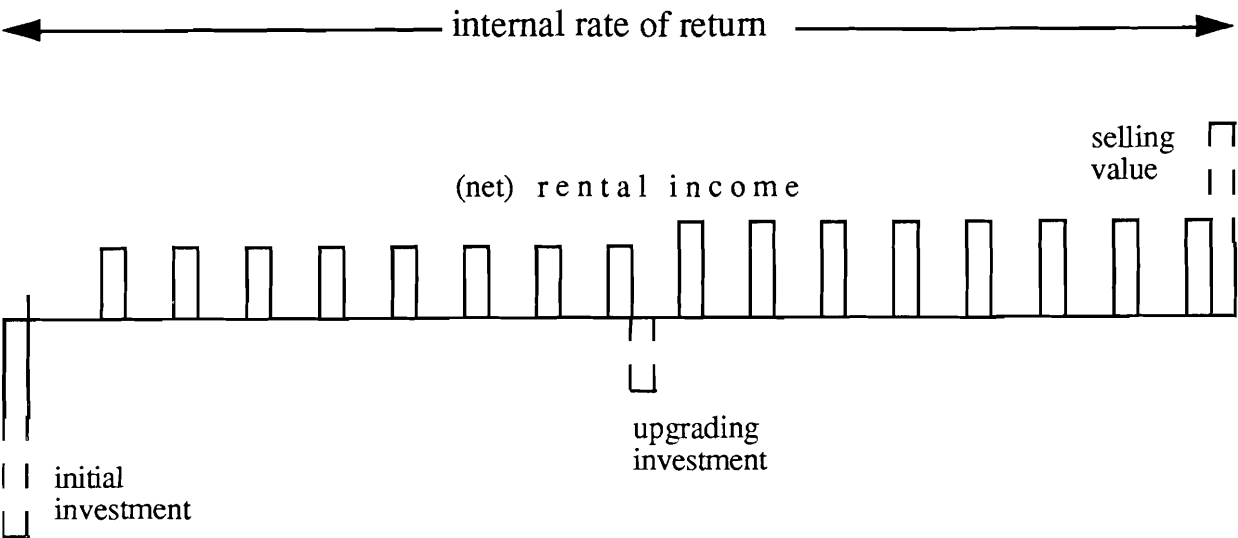


fig. 1. Internal rate of return to be calculated over the investment period and based on cash flows.

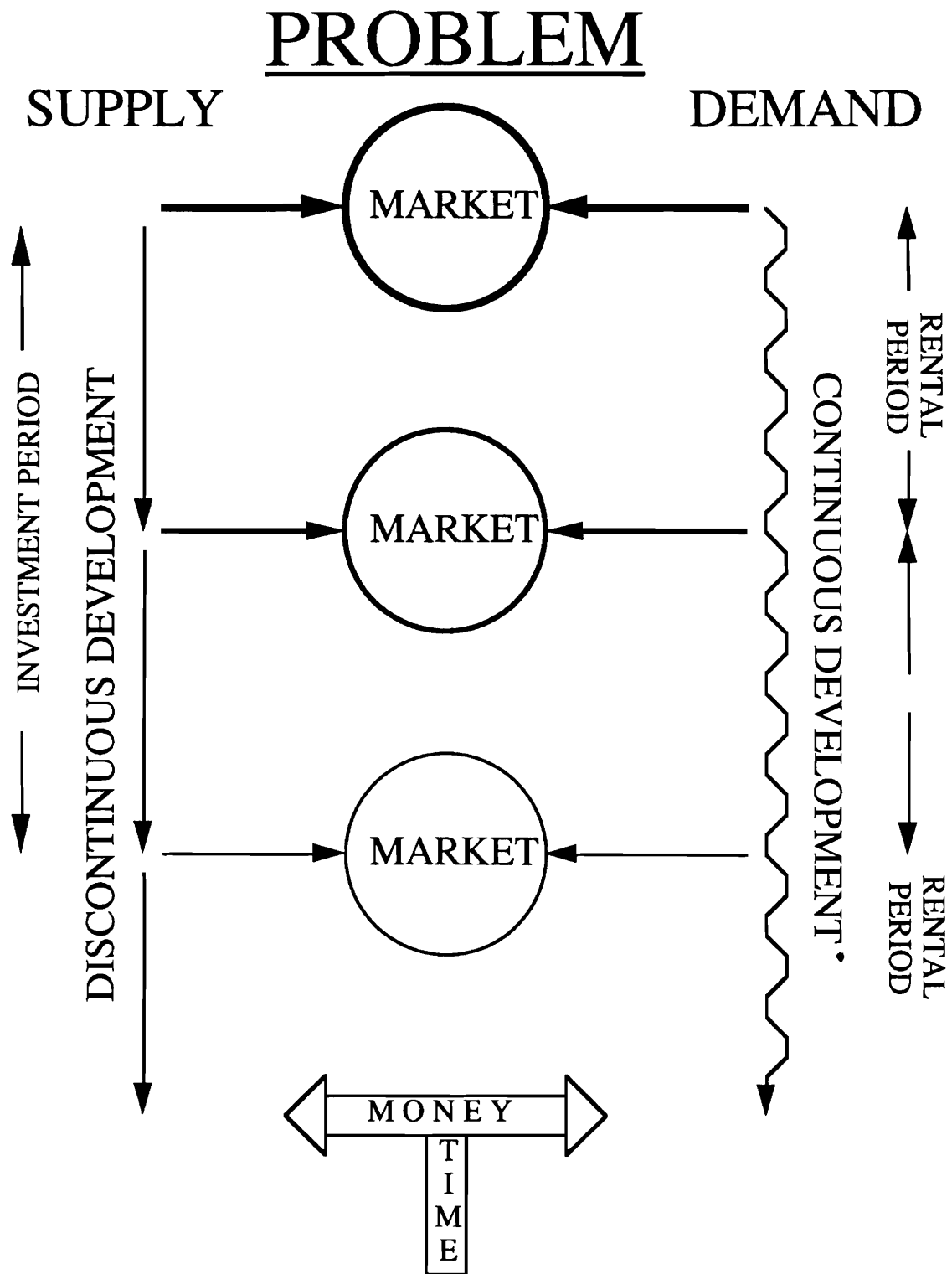


fig. 2. Two planning periods:
investment period and rental period

4.0 Planning periods

The static building supplies a constant flow of facilities to a continuously changing market until the moment when the building may be adapted to fulfil new market demands again. As has been visualised in figure 2, we may recognise (during the investment period) several rental periods with a constant flow of facilities, which are separated by adaptation activities. After such an adaptation the quantity and/or the quality of the facilities will have changed as well as the costs and the market rent.

About the initial investment will be decided over a planning period which equals the investment period, while about adaptation (upgrading investments will be decided over a planning period which usually equals a rental period. The tenant does not take the risk of a misfit between supply and demand, resulting a short rental period, while the investor takes the risk to decide over a longer period with a lack of information about additional investments and rental income. It would be better to base decisions on rental periods.

Since rental periods are (from the point of view of the investment decision maker) connected by the residual values, which are partly responsible for the future (total) investment, we have to focus on this value now.

5.0 Importance of the property value.

The property values at the beginning and at the end of a planning period are important factors in the cost calculation. At the beginning of the investment period the value is determined by

- the construction cost and the price of the land, in the case of new construction
- the purchase price and the construction cost of adaptation, in the case of a building to be adapted.

At the moment of upgrading within an investment period the value of the building to be adapted is as important as at the initial moment of investment.. In both cases the expected rental income should be compared with the annual costs resulting from the total investment. The rent to be expected over the rental period after adaptation depends partly on the components which remain in situ and partly on the components which will be added to the 'old' components in the upgrading activity. To find the investment concerning the components to be added will cause no problems, but the value of the untouched components is less easy to find. It is really very important to know this value, because it determines the maximum the additional investment within the total investment after upgrading of which the annual costs have to be covered by the market rent.

At the end of the investment period the property will be sold,. The value of the land is difficult to predict, but the change of value of the building over the investment period can be calculated in the same way as in preceding calculations. This residual value should be calculated as an output as (*Janssen, 1997*).

6.0 Property value at constant prices.

Usually, the value of a property (land and building) is determined by the actual market rent and by the gross initial annual return which is considered to be normal for such an investment. As long as these factors do not change, the value of the property (determined in this way) will no change over the rental period (Figure 3).

However, the property obviously has lost value, when at the end of a rental period the building has to be upgraded in order to find a tenant who will pay a reasonable rent in the future. the investment may be split into two parts:

- an investment which would be needed to bring the building in such a condition that the production of the initially meant flow of facilities can be continued, which means a replacement investment concerning components of which the life span has expired.
- the upgrading of the facilities to fulfil the present demand, which means an addition to the replacement investment.

As a consequence, we should accept that a building will (at constant prices) lose value during a rental period. This loss gives the possibility to replace (when a fund has been created based on depreciation and without a rise of the annual costs) and to add (which results in higher annual total cost and higher rent) components. To find the value of the building, depreciation should take place based on the initial investment over the economical life span which can be expected: sometimes equal to the rental period, sometimes even longer than the investment period.

We would be aware of the fact that the additional investment could be financed out of profit made previously on this investment. Endowments to a fund to finance additional investments should (however) not be considered as costs and should not influence the investment decision. This decision just depends on the market rent to be expected after upgrading and the value of the property before upgrading.

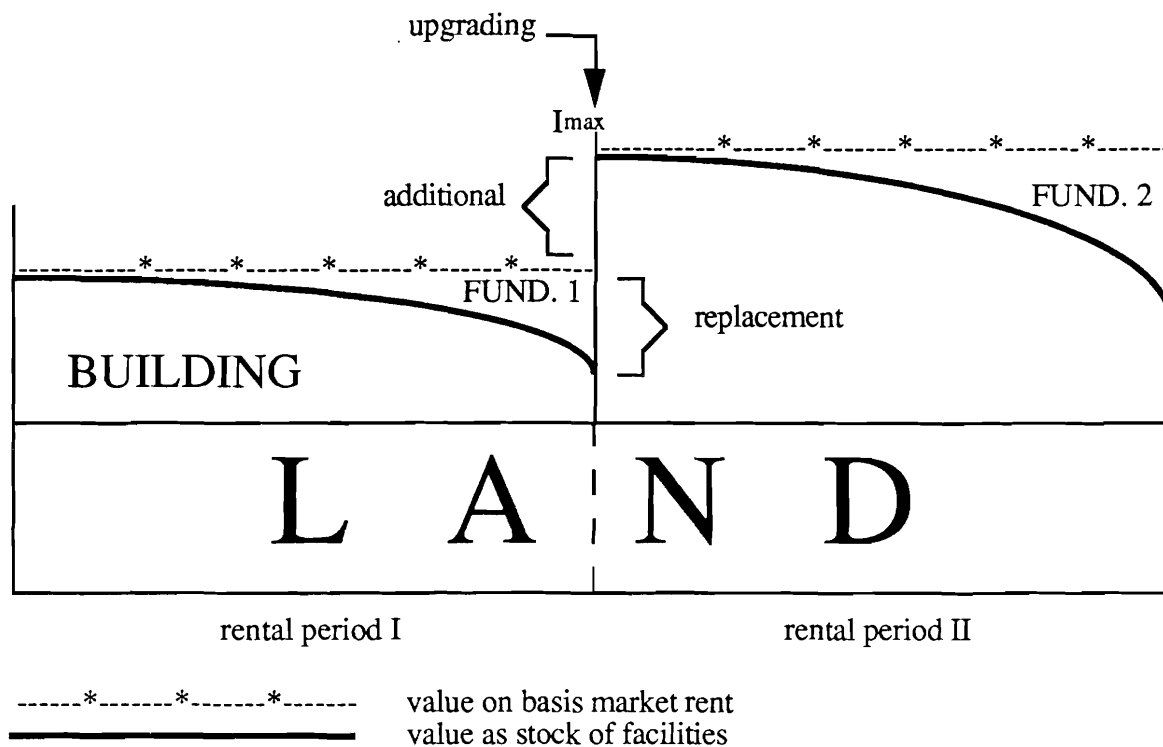


fig. 3. Property value in two rental periods

7.0 Consequence of price changes.

The loss of value because of the use of a building (reflected in depreciation cost) should be distinguished from a rise in value of the property because of changing construction prices and the rise in value of the land. However, both types of changes should be taken into account at the moment of an upgrading decision. In the case of a sharp rise in the value of the land, the initial property has been taken into account. This rise in value may diminish the initially expected financial possibilities of upgrading.

As has been visualised in Figure 4, the maximum total investment (I_{max}) is determined by the market rent to be expected in the sector focused on. This rent will be paid for the combination of facilities; partly depending on the old components, and partly depending on the newly installed components. The higher the value and as a consequence the costs of the old component, the less can be invested in new components which will be required to supply the market. When the initial (historical) investment is taken into account seems that much

8.0 Cost calculation and residual value

Costs have to be calculated in such a way that they can be compared with the rental income over a period within two investments decisions (Figure 5). the cost calculation should be connected to the investment at the beginning as well as at the end of the period. As has been argued, the initial investment is an input, whilst the residual value of the building should be an output of the calculation.

Since the loss of the value of the building (as a part of the total investment which includes the land as well) should be considered as a cost factor, depreciation should be introduced implicitly resulting in the determination of the residual or resale value -based on components which still have a future using value. This value depends on the expected economical life span and the depreciation pattern.

In the costs of the facilities - supplied on an annual basis within the rental period - should be incorporated the capital costs (interest and depreciation), maintenance and disposal of the components at the end of their life span. (See: Tempelmans Plat 1995). To make comparisons with the expected market rent possible and easy, average annual cost will be the best choice for decision making. (Ruokolainen and Tempelmans Plat, 1997).

The consequence of this choice for the residual value at the moment of upgrading is that depreciation will be based on the annuity calculation of the average annual capital cost. So at each point in time the value of each component can be calculated. This value should be adapted for a maintenance fund and a disposal fund (Tempelmans Plat, 1996) .

9.0 Total investment after upgrading

The total investment after upgrading depends on (Figure 4)

- the value of the land
- the value of the old component
- the value of the newly assembled components

The value of the new components are calculated on the basis of the construction costs. The value of the old components is the result of the cost calculation concerning the preceding rental period, but taking into account the construction price level at the moment of upgrading. Rents concerning properties at attractive locations will increase (much) faster than construction prices. As a consequence, the value of the property will rise according to the change in rent (adapted for depreciation). Since the value of the building can (in economical

sense, not as a monument) not be higher than the replacement value in a stable market situation, the major change in value will concern the land., which is nearly always scarce. The higher the value of the land (depending on the use with the highest return) the less are the possibilities to upgrade a building designed some rental periods ago in different circumstances,

Only on the basis of a good valuation of the land and the residual value of the building a good upgrading decision can be made or to be decided to destroy the building. The influence of the market is reflected by the actual value of the land, which remains a speculative factor.

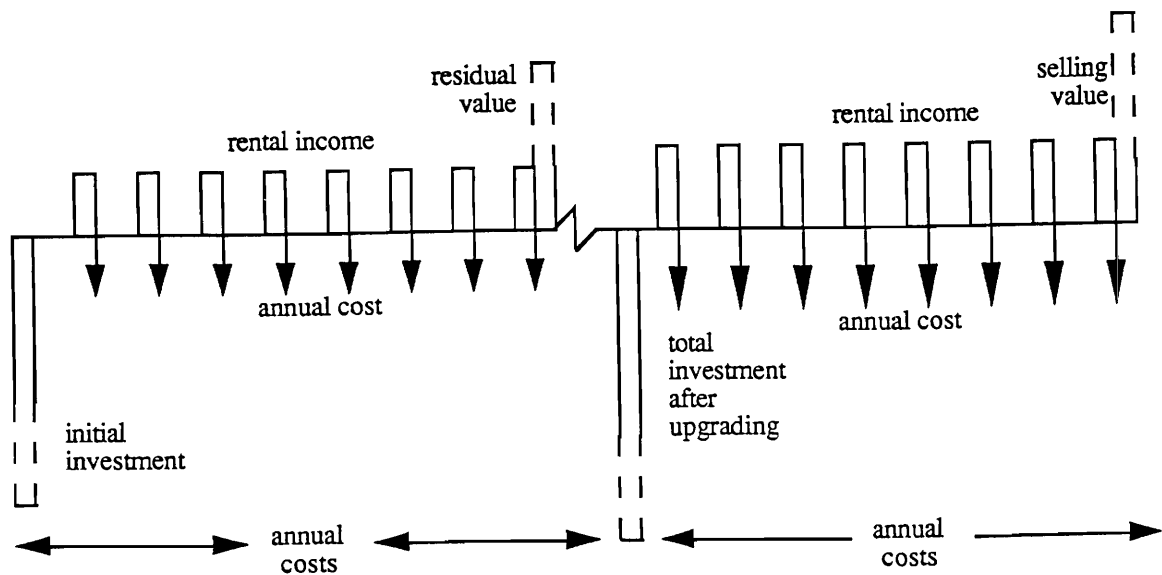


fig. 5. Average annual cost calculation over the rental period and based on interest cost and depreciation
(N.B. maintenance and other expenditures PM)

10.0 Data base

One can expect that data are available about construction costs, maintenance and technical life spans. However, more detailed information is needed for property investment decisions concerning existing buildings.

Information about maintenance on the level of the total building and about installations is available. However, it is necessary to have information on the building component level, to be able to balance investment and maintenance in order to minimise annual costs within (mostly) the rental period.

Information about economical life spans is needed to calculate capital costs, including depreciation and to calculate the residual value of a building at the end of the rental or investment period. This cannot be a general data base, but should be connected to the types of buildings, to the types of users and to the location (Jannsen, 1997).

Important as well are - and will be more in the future - the disposal costs. The costs of the destruction in upgrading circumstance are not easy to calculate. It depends on the connecting components and the possibility to reuse components, or to recycle material

11.0 Conclusion

Professional investors should not consider building just as a sum of money, which should generate an acceptable return, like shares or bonds. The important difference concerns the additional investment which usually has to be done to upgrade a building. As a consequence, this cash flow has to be predicted to calculate the irr over the intended investment period. However, the additional investment (and in fact the initial investment as well) has to be considered in relation with the expected rental income over a (short) rental period. This needs a detailed (annual cost calculation in which depreciation costs are incorporated, while the depreciation to fulfil demand in the next rental period.

By connecting annual cost calculation and valuation of building (both as a basis for investment decisions) construction management and property management decisions will be closely connected.

12.0 Definitions

Internal rate of return : method with which the return on the initially invested capital will be calculated over the investment period on the basis of cash flows to be predicted.

Average annual costs: price per year of a constant flow of facilities produced by a building as a continuous process.

Residual value: value of a building based on the value and the period over which facilities can be produced.

Selling value: residual value of which reservations made for maintenance and for disposal expenditures are deducted.

Replacement investment: investment in a building to bring it back in the condition to supply the facilities as meant at the moment of new construction.

Additional investment: investment which is needed in addition to the replacement investment to bring the facilities to be supplied on a higher quantitative and / or qualitative level.

Upgrading investment: sum of replacement investment and additional investment.

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CAIRN: CASE-BASED INFORMATION RETRIEVAL

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Abstract

This paper describes a document retrieval system called CAIRN that uses case-based reasoning to retrieve documents based on natural language queries. CAIRN parses a document set using a large lexicon to automatically generate a case index to that document set. The index is used by a case-based retrieval engine to find documents. The retrieval engine is tolerant of noisy natural language queries. CAIRN also supports failure-driven learning of important concepts during its use and thus can significantly improve its retrieval accuracy over time. The limitations of this system are discussed.

1. Introduction

The problem of obtaining timely and relevant information from digital information sources (e.g., CD's & the Internet) is becoming daily more acute, as there is an ever increasing variety of sources and volume of information available. This problem is compounded when end-users are not familiar with search techniques. Current information retrieval (IR) systems use keyword, free-text, context-based search, hypertext structures and statistical IR techniques. These techniques are either laborious for the information publisher, since keywords and hypertext structures must be defined before publication, computationally inefficient (e.g., a free-text search of megabytes of text) or unsuitable to novice users (because of a vocabulary mismatch between how a user expresses a query and the available indexes). This paper presents initial results from the CAIRN project, which is investigating a case-based document indexing and retrieval system that can be both efficient for the content publisher and intuitive to the user.

Case-based reasoning (CBR) has recently been shown, most notably in the US electronics industry, to be a powerful and flexible retrieval technology [Kitano et al., 1992; Kitano & Shimazu, 1996], that is being increasingly used for information retrieval [Anick & Simoudis, 1993; Smail, 1993; Cunningham et al., 1995]. CBR is an improvement over some retrieval methods because it combines the friendliness of context-based searches with flexible means of indexing the information. Using case-based retrieval users can ask for information in their own words. The CBR system then asks the user for more information as required, to focus a search if too many or too few documents are returned. This dialogue between the system and the user is an intuitive way of retrieving information that lets the user remain in control.

However, most current case-based retrieval systems are manually created by a laborious process. The CAIRN project uses an *automated* indexing process, thereby greatly reducing the effort for the publisher. This

approach is supported by a recent report commissioned by the Department of Education and Employment from ICL, in which they explicitly recognise the need for AI support of the user and the librarian [Yapp, 1995, p.9].

2. System Requirements

At the start of the CAIRN project a set of requirements was formulated that the CAIRN tool would need to satisfy. These were divided into two categories: requirements from the users view point and requirements from the content publishers view point. Those from the users` view point were as follows:

- The tool should run on relatively low cost hardware (i.e., PCs) and be network friendly.
- It should allow users to enter free-form natural language (NL) text as a search query; e.g., a user can ask for “*advice on paints and breathing*”;
- It should be tolerant of spelling mistakes and typographical errors.
- It should be reasonably quick (i.e., a second or two for retrieval).
- It should be able to infer that *thinners* and *solvent* may be synonymous.
- It should be able to ask the user questions to focus the search such as: “*Are you interested in A) solvents in confined spaces, B) safe application of spray paints C) breathing apparatus?*”.

From the publishers` view point the requirements were:

- The tool should run on relatively low cost hardware (i.e., PCs) and be network friendly.
- It should generate the case-index automatically without human intervention.
- It should be able to deal with megabytes of content.
- It should be customisable to improve retrieval accuracy.
- It should interface with existing retrieval software.
- It should have a customisable user interface.

Although there are many case-retrieval systems on the market that satisfy many of these criteria (e.g., ReMind, ReCall, and CBR3 [Watson, 1997]) generating cases by hand for all of them is very labour intensive (just as creating keywords, document summaries or hypertext links are). A recent study by the applicant showed that an experienced developer can index between 20 and 40 documents per day depending on their complexity [Watson & Abdullah, 94]. Thus, developing an index by hand for 10,000 documents could take 500 days. CAIRN automates this process and can process thousands of files per hour.

3. System Architecture

The CAIRN system uses the same primary software components as the Swiss Bank Corporation`s Know How Project [Block & Poynter, 1996], namely Inference Corporation`s CBR3 Generator and CasePoint tools. The two principle components are described below.

CAIRN reads text files (ASCII text, HTML, Microsoft Word files, and RTF files) and builds a case index to

the document library. In order to understand the content of a text file CAIRN uses a lexicon containing an alphabetical list of approximately 50,000, mainly English, words identified by part of speech and by the word's *polysemy index*¹. In addition, content publishers can add specific technical terms, abbreviations, jargon and acronyms to the lexicon.

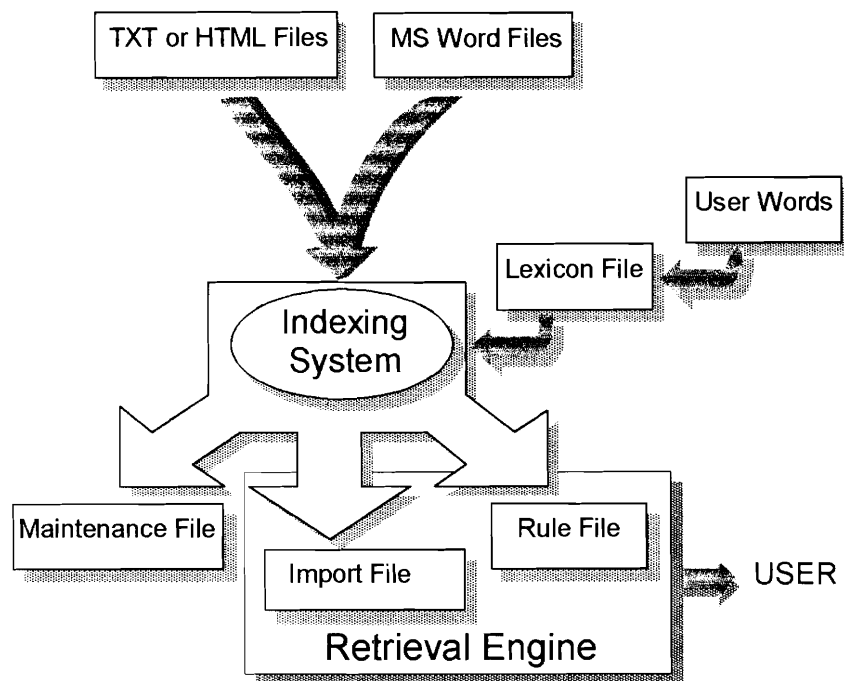


Figure 1. The CAIRN Architecture

CAIRN parses each text file using the lexicon to decide the subjects of the file (i.e., the case index). It produces a short textual summary of the file that is used in the first phase of document retrieval. It also constructs a set of questions that further discriminates between files and thus focuses the search using knowledge guided retrieval. This is an important distinction from conventional IR systems which expect to receive a *well-formed* query. In CAIRN a query is refined in an iterative process of questioning and researching.

CAIRN outputs three files:

1. an indexed Import File that is in a format that can be imported into the case-based retrieval tool.
2. a Rule File that can be used by the CBR tool to ask questions and focus document retrieval.
3. a Maintenance File that will be used to maintain the case index when files in the library are added, removed or modified.

¹ The *polysemy index* of a word is a measure of the number of meanings the word can take. For example, the word *watch* is both a noun and a verb with several different meanings. This means that *watch* might be ambiguous as an indicator of document content. Conversely, the word *asbestos*, is a noun with a single meaning. Documents that contain the word *asbestos* are certainly in some way concerned with *asbestos*.

4. Indexing

One of the CAIRN project's collaborators is Chapman & Hall Publishers (<http://www.chaphall.com/chaphall.html>). They are a major multinational publishing firm with a wide range of periodicals, and technical publications. Increasingly they are using digital media to publish, including CD-ROMS and the Internet. Their Electronic Publishing Division provided the CAIRN project with data from a database of European Health and Safety Legislation. This data is currently retailed on a CD-ROM using a conventional keyword retrieval system. An sample abstract (ref. # 212880-1) is shown in Figure 2.

```
<newdocument>
<uid>212880-1</uid>
<tit>Electrical Equipment for Explosives Atmospheres (Certification) (Amendment) Regulations
(Northern Ireland) 1995</tit>
<sht>Explosive Atmospheres Regulations 1995</sht>
<lan>English</lan>
<amd>Electrical Equipment for Explosive Atmospheres (Certification) (Amendment) Regulations
(Northern Ireland) 1991 SR 1991 No. 339<xuid>213973-3</xuid></amd>
<sub>Equipment, Workplaces and Operations</sub>
<sub>Fire, Explosions</sub>
<sub>Industries</sub>
<des>Approval</des>
<des>Electrical Equipment</des>
<des>Explosive Atmospheres</des>
<des>Mining Industries</des>
<rel>European Communities Act 1972 <xuid>240390-7</xuid></rel>
<non>Council Directive 79/196/EEC concerning electrical equipment for use in potentially
explosive atmospheres employing certain types of protection<xuid>241784-6</xuid></non>
<abs>These Regulations amend the Electrical Equipment for Explosive Atmospheres (Certification)
Regulations (Northern Ireland) 1990. Regulation 3(3) substitutes a new Regulation 12 which now
states that a manufacturer of electrical equipment who applies for a certificate of conformity will be
able to have that equipment certified by reference to the harmonised standards in the unamended
regulations. Where an application for a certificate of conformity or review is made before the coming
into force of these regulations such application shall continue to be dealt with under the unamended
regulations. Certificates of conformity will not be issued in respect of electrical equipment to which
the Framework Directive applies after 29 February 1996 or to which the Gassy Mines Directive
applies after 31 December 1996. Certificates of conformity issued on or before these dates shall be
regarded as in force as regards the use of a distinctive Community Mark until 30 June 2003.</abs>
```

Figure 2. Sample Abstract from Health & Safety Data Set

As you can see the text is quite noisy, with a lot of formatting tags in it. The most important fields in the sample are the Subject <sub> and Description <des>. These were defined manually by Chapman and Hall and include the following terms: *Equipment, Workplaces, Operations, Fire, Explosions, Industries, Approval, Electrical Equipment, Explosive Atmospheres, Mining Industries*. These are the keywords that a user would search on to retrieve this piece of legislation. CAIRN automatically produced the case shown in Figure 3 to index this file.

The case is divided into four main areas. The *Title* and *Description* fields are what are matched against the user's NL-query. The questions are used to confirm or reject this case (i.e., to discriminate this case from other similar cases). The attachments will open the appropriate document (i.e., the file 212880-1.TXT).

Case: C4 Status: Active ☐ F1 Cases

Title: Iframework, framework directive, certain type, kingdom, I council, explosive, explosive atmosphere, ...

Description: apply, European, application, interpretation, interpretation act, I conformity, august, continue, EEC, reference, deal, substitute, I mark, electrical equipment, mining industry, unamended regulation, I 1995 tit, fire, coming, directive, manufacturer, atmosphere, I atmosphere regulation, mining, amend, ...

☐ Inherited ☒ Learned

Information: ...

Comments: ...

Cost: 0 Accepted: 0 Rejected: 0

Questions	Answers	1/2	100	100	%	Source
Q19 Are you interested in certificate?	Used	10	0	11%		
Q35 Are you interested in directive?	Used	10	0	11%		
Q56 Are you interested in amendment?	Used	10	0	11%		
Q94 Are you interested in Mines?	Used	10	0	11%		
Q100 Are you interested in explosive?	Used	10	0	11%		

☐ Actions ☒ Attachments

T4 Open C:\CAIRN\212880-1.TXT

Ready

Figure 3. An Automatically Generated Case

One way of assessing the utility of the automatic case index generation is to determine if CAIRN accurately identifies the same keywords as the publishers did manually. Thus, one would expect CAIRN's title and description to contain the publisher's keywords. A comparison is shown in Table 1.

Of these terms only *workplaces* is not present. The singular of explosions, atmospheres and industries are all present, and since CAIRN is not adversely effected by the differences between singular and plural terms these can be read as the same. However, more strikingly is the fact that of the five confirming questions that CAIRN generated two are about *mines* and *explosives*. This confirms that CAIRN has correctly inferred that this piece of legislation is a directive about mines and explosions. A study of 5000 cases showed that in 95% of cases, 90% or more of the publisher defined keywords were contained in the automatically generated case title, description or questions. This confirms that CAIRN is accurately indexing the text files.

Publisher's keywords	CAIRN's title & description keywords
Equipment, Workplaces, Operations, Fire, Explosions, Industries, Approval, Electrical Equipment, Explosive Atmospheres, Mining Industries	framework, framework directive, certain type, kingdom, council, explosive, explosive atmosphere, non council, firedamp, commission, commission directive, explosion, explosion sub, february, certificate, certification, date, standard, potential, apply, European, application, interpretation, interpretation act, conformity, august, continue, EEC, reference, deal, substitute, mark, electrical equipment, mining industry, unamended regulation, 1995, fire, coming, directive, manufacturer, atmosphere, atmosphere regulation, mining, amend

Table 1. Manual vs. Automatically Generated Keywords

5. Retrieval

Once the case-index has been generated Inference's CBR3 CasePoint retrieval engine is used. A user can enter a NL-query into the description field and CAIRN will search the case-index for cases whose titles and descriptions are similar to the NL-query. Using the same text file as our target (i.e., 212880-1.TXT concerning explosives and mines) a user could type in the simple query "*explosives*". This is shown in Figure 4.

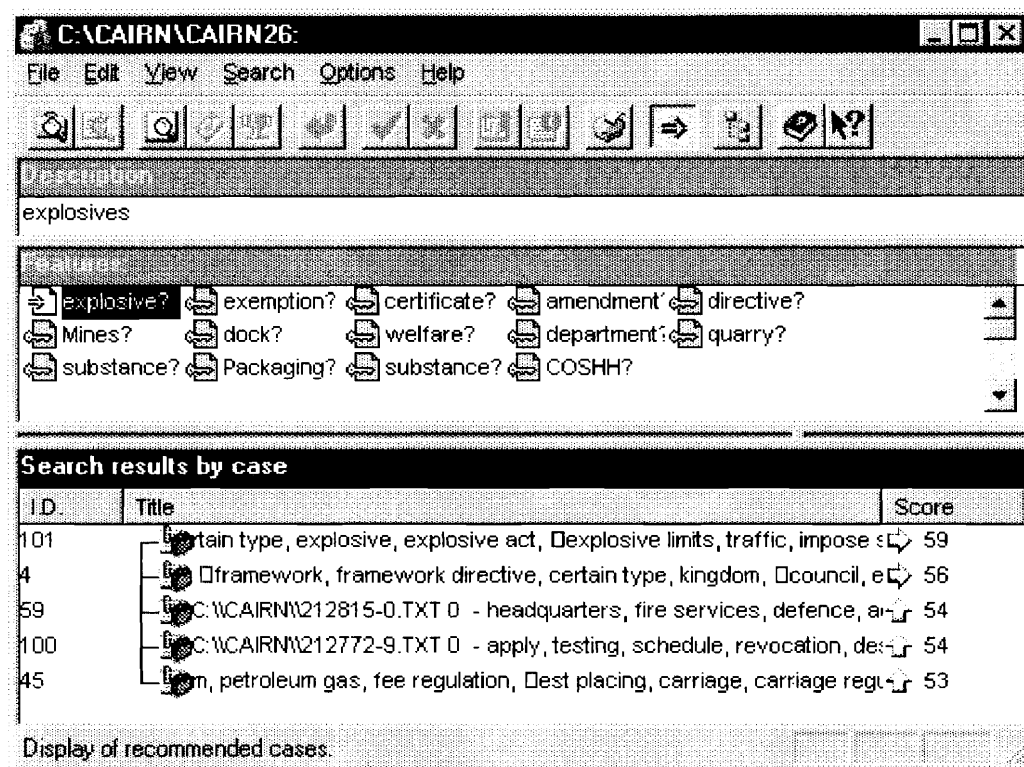


Figure 4. Retrieval Using a Simple Query

At the bottom of the CAIRN screen is a list of cases ranked in order of similarity. In the middle are a set of features that help discriminate between the cases. The text we are looking for is indexed by case id. 4. If the user clicks the mouse on *Mines?* in the feature panel the similarity score for case id. 4 increases from 58 to 67. This is shown in Figure 5.

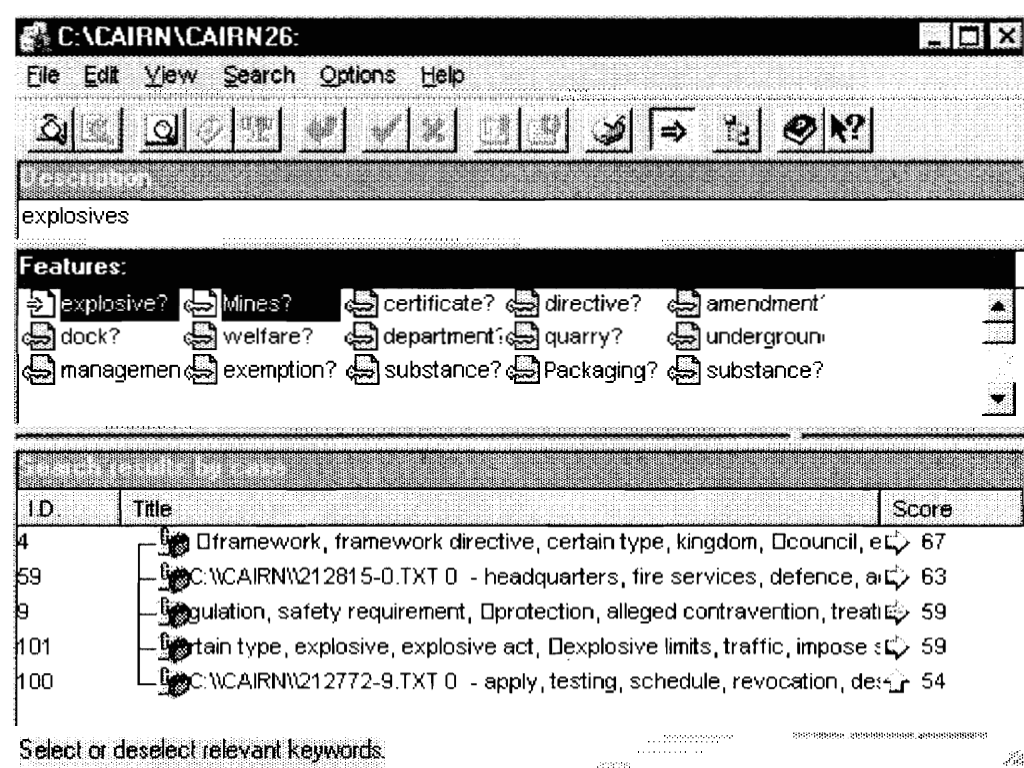


Figure 5. Interactive Retrieval

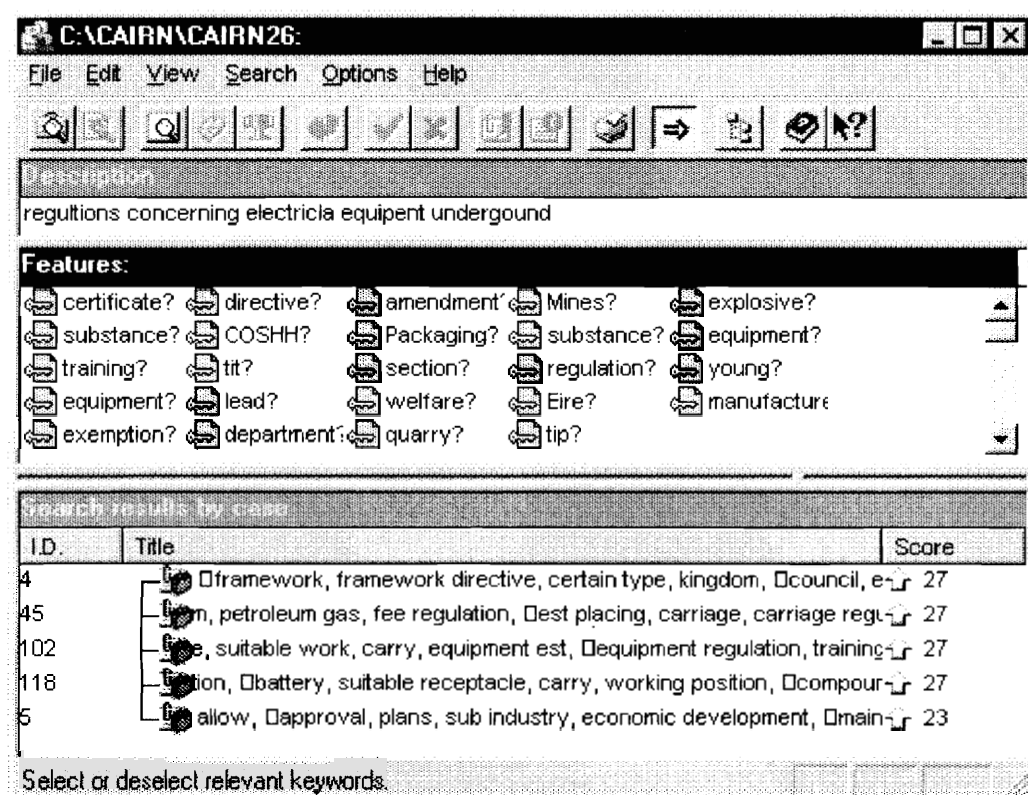


Figure 6. Retrieval Using a Noisy Query

Thus, CAIRN has correctly found the target document. Let us now try a more difficult and noisy query such as "regulations concerning electricla equipent underground" (the spelling mistake are intentional in this query).

Given this query CAIRN performs well as is shown below.

CAIRN has successfully ranked case id. 4 at the top of the similar cases despite the incorrect spelling of many terms in the query. Finally, if CAIRN is given a precise and accurate query such as might be provided by someone who was familiar with the data source (e.g., “*directives about electrical equipment in explosive atmospheres in mines*”). It performs very well as shown in Figure 7.

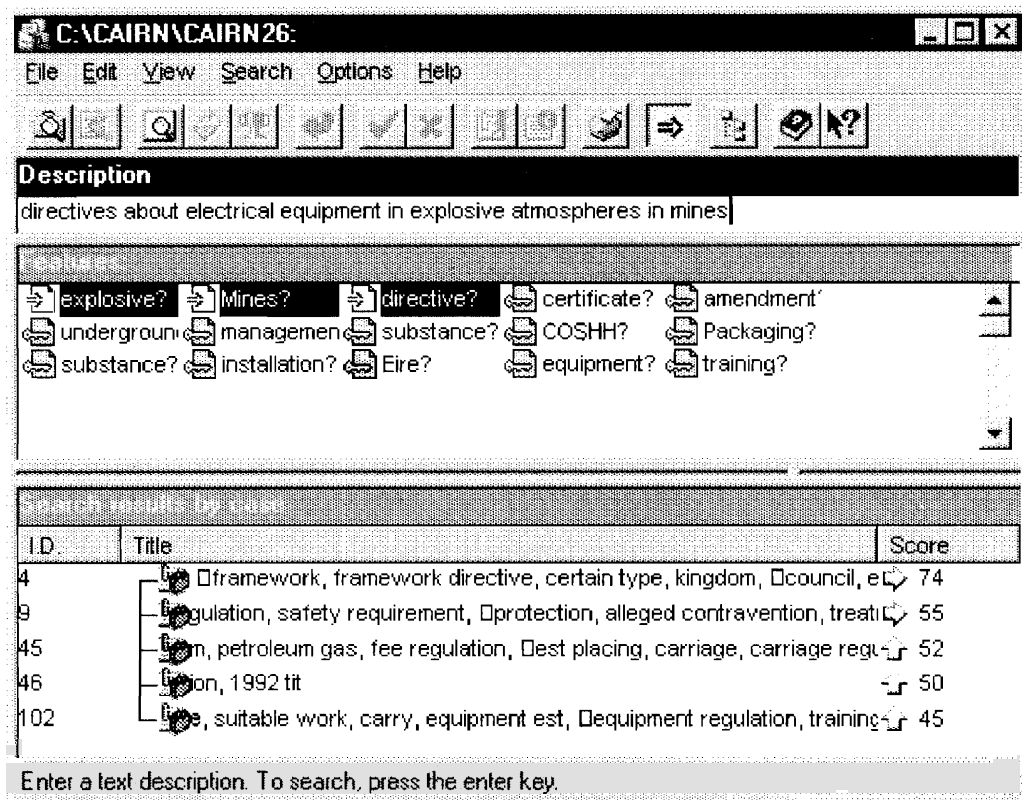


Figure 7. Retrieval Using a Complex Precise Query

6. Failure-driven learning

CAIRN has one other useful feature, that of failure-driven learning. A document retrieval system will probably never perform at 100% accuracy, thus it is useful if a retrieval system can learn from its failures. This is a characteristic of CBR, which is called failure-driven learning [Schank, 1982; Leake 1996]. If CAIRN fails to correctly retrieve a document, the user can resort to using another search technique (e.g., an exhaustive word search of the document set, such as that provided by the Windows 95™ “Find” utility or by using other search engines such as Verity). If a document is successfully retrieved (i.e., one that matches the initial NL-query), CAIRN records the concepts in the original NL-query and adds these to the “Learned” field of the case index (shown in Figure 10). These *learned concepts* can then be used by CAIRN as part of the case index. Thus, over time, the performance of the retrieval engine will improve.

Failure-driven learning was tested on a document set of abstracts on aerodynamics. The set of 1400 abstracts was obtained from the IDOMENEUS technology transfer server in the Department of Computing Science at the University of Glasgow (<http://www.dcs.gla.ac.uk/idom/>). The Cranfield test collection, comes with

standard NL-queries and list of documents that are relevant to each query. Thus it was possible to compare CAIRN's performance against that of the test set. These abstracts are of a highly technical nature with many terms that are not in CAIRN's lexicon. Moreover, many of the documents are similar making it difficult for a search engine to differentiate between them.

periodic temperature distribution in a two-layer composite slab.
w. f. campbell
national aeronautical establishment, ottawa, ont., canada
in a recent contribution to the reader's forum, under the above title, stonecypher outlined a method for finding the periodic temperature distribution in a two-layer composite slab, one exposed surface of the slab being insulated and the other subject to a sinusoidal temperature variation. perfect thermal contact between the two layers, and constant thermal properties were assumed. two years ago i drew attention in these pages to a method for determining the transient temperature in such a two-layer slab resulting from a triangular heat-input pulse . i should like to point out that this same method also is applicable to the case where one external face is given a sinusoidal temperature variation with time. the method is based on the analogy between one-dimensional heat flow and the flow of an electric current in a simple transmission line having only series resistance and parallel capacitance.

Figure 8. Sample Abstract from the Cranfield Data Set

Consequently, at first, CAIRN's performance was poor (an average 20% accuracy rate). Over successive generations (i.e., running the queries and manually retrieving the correct documents, if necessary so CAIRN could learn new concepts) CAIRN's performance improved to almost a 60% accuracy. These results are shown in Figure 9. The slow start to concept learning is explainable. As CAIRN learns new concepts, it initially does not give them much credence until it has seen the same concept appearing several times in the NL-query. This is a user definable threshold that was set to 3 (i.e., don't give a new concept much importance in retrieval until the new concept has occurred at least three times in unsuccessful searches). It is also predictable that concept learning would plateau since a limited number of NL-queries were being used. It was perhaps disappointing that the plateau was not higher than 60%.

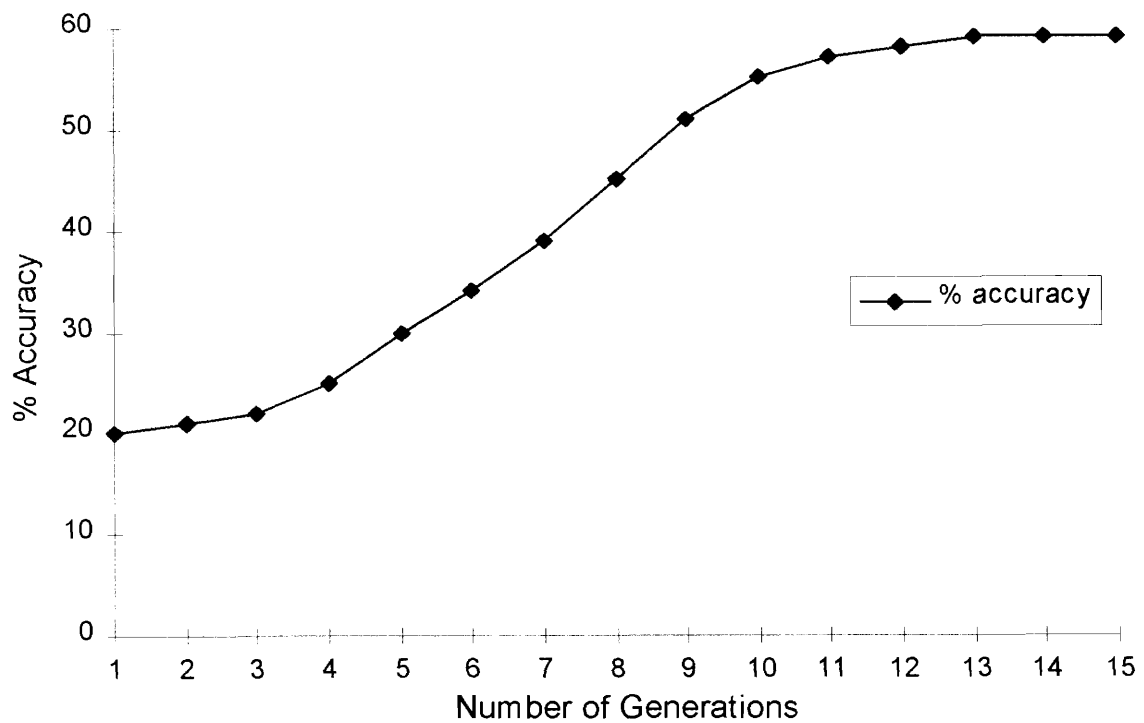


Figure 9. Graph of Concept Learning Indicated by % Accuracy

Thus, it is clear that to achieve a higher success rate it would be necessary to add many technical terms to CAIRN's lexicon at the outset (i.e., before the automatic generation of the case index). Concept learning certainly helps but for this data set it was not enough. This is the next phase of the project. Figure 10 shows the concepts that CAIRN learned from the queries for the abstract shown in Figure 8.

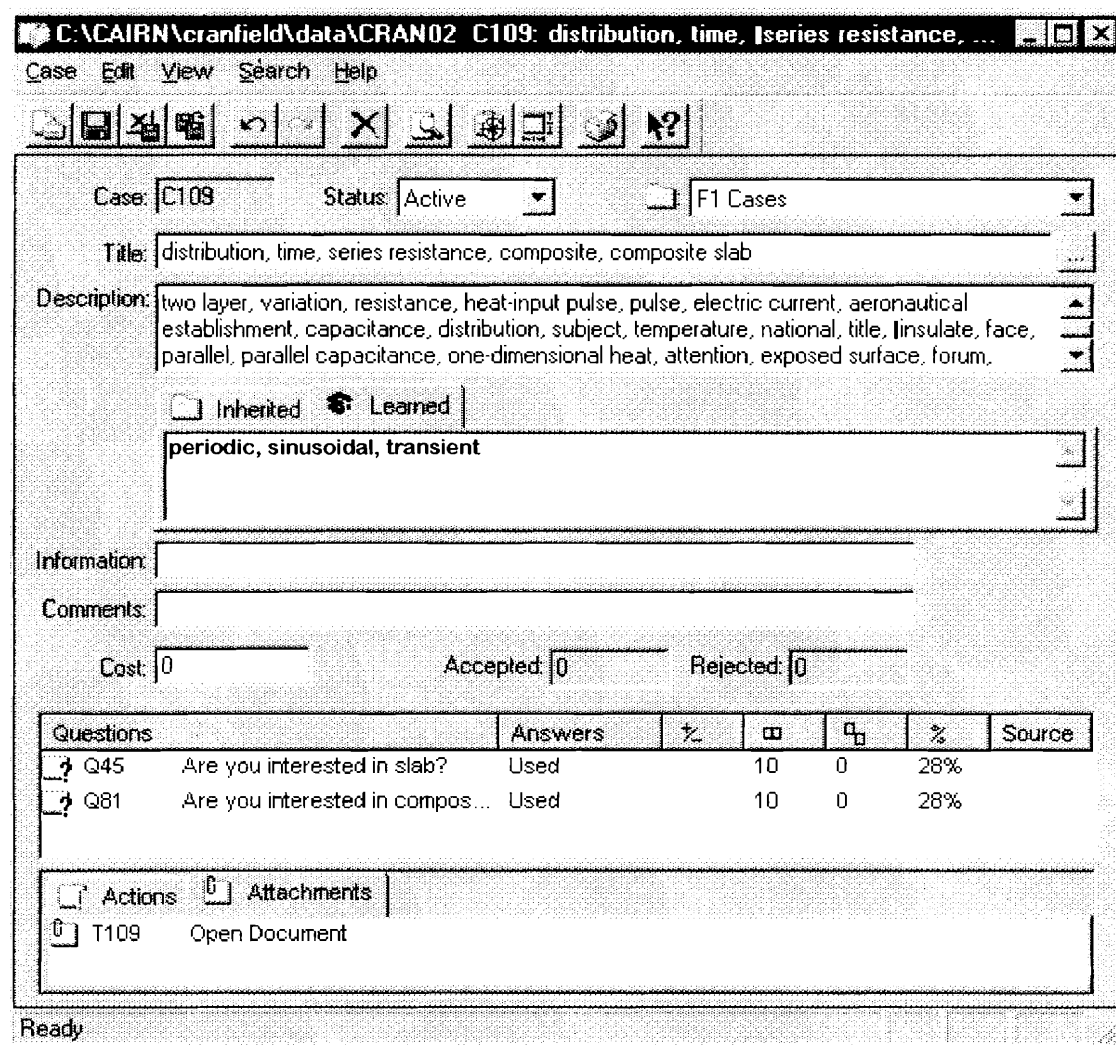


Figure 10. The Case Editor Showing Learned Concepts

7. Conclusions

Our initial evaluation of CAIRN has shown that it immediately performs well on document sets such as the Health & Safety legislation data set provided by Chapman & Hall Publishers, despite the presence of noise in the documents. Its tolerance of noise is not surprising, since when CAIRN parses a document it ignores anything it does not recognise as a word in its lexicon. More problems were met on highly technical data sets such as the Cranfield aerodynamics data set. Initially, CAIRN's performance was poor. Even after allowing a significant time for failure-driven learning its accuracy was only at best tolerable. This clearly indicates that for highly technical documents CAIRN's lexicon needs to be added to, for its performance to be acceptable. Whilst it can learn new index concepts and improve its performance through failure-driven learning, it is doubtful if users would continue using a search engine that performed so poorly at first. Another significant limitation encountered is the size of the data set that CAIRN can feasibly index. Although we have not performed a rigorous study, our empirical evidence would suggest that as the data set approaches 5000 documents the time taken to index the documents becomes unacceptable. When CAIRN produces the case to reference the document it seeks to differentiate the new case from others in its index. Thus, as the size of the

case index increases the time taken to complete this task would appear to increase at least geometrically. However, despite these limitations the approach demonstrated here does show good results with appropriate data sets and has met all of our initial requirements, except the ability to handle many megabytes of data. We shall continue to experiment with case-based information retrieval.

8. Acknowledgements

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THE EVALUATION OF A CASE-BASED ESTIMATING SYSTEM

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Abstract

This paper presents a case-based estimating system using a hierarchical case representation and a context guided retrieval method. The performance of this method is compared to that of a simple flat file representation using standard nearest neighbour retrieval. The estimation of the construction costs of light industrial warehouse buildings is used as the test domain. Each case in the system comprises approximately 400 features. These are structured into a hierarchical case representation that holds more general contextual features at its top and specific building elements at its leaves. A modified nearest neighbour retrieval algorithm is used that is guided by contextual similarity. Problems are decomposed into sub-problems and solutions recomposed into a final solution. The comparative results show that the context guided retrieval method using the hierarchical case representation outperforms the simple flat file representation and standard nearest neighbour retrieval.

Keywords. Case-Based Reasoning, Context Guided Retrieval, Hierarchical Case-Representation

1. Introduction

Representing cases as a set of constituent pieces [Barletta & Mark, 1988; Macedo et al., 1996], *snippets* [Kolodner, 1988; Redmond, 1990; Sycara & Navinchandra, 1991] or *footprints* [Veloso, 1992; Bento et al., 1994], instead of as a single large entity, has long been proposed as a way of improving the effectiveness of a CBR system. These parts, when represented as separate structured cases, can be represented, retrieved and recomposed separately to create new solutions [Flemming, 1994; Maher & Balchandran, 1994; Bartsch-Sporl, 1995; Hunt & Miles, 1995]. Some systems, for example, CADSYN, explicitly take into account the context of a snippet or sub-problem to reduced constraint problems when recomposing solutions [Maher & Zhang, 1991].

Many successful CBR systems use relatively simple case representations of attribute-value pairs stored in flat files or record structures similar to those of a conventional database. There are good reasons for this. A primary one is, that for many commercial applications, the knowledge engineering effort required to create case-bases must be kept to a minimum. These case representations may be characterised as being

knowledge-poor. That is they do not contain many (or any) structures that describe the relationships or constraints between case features. However, these case representations usually describe relatively simple cases with few indexed features, perhaps in the order of ten to twenty indexed features.

As the number of indexed case features increases (i.e., the number of features that are predictive of a case's solution or outcome) the utility of this knowledge-poor approach reduces. As the problem space increases, from say a 20 dimensional space to a 200 dimensional space it becomes statistically less likely that a close matching case will exist. Thus, a retrieve and propose CBR system (i.e., one without adaptation) may be proposing a relatively distant solution. If adaptation is used, the adaptation effort or distance will increase correspondingly, possibly reducing the accuracy or utility of the solution. This is illustrated in the two figures below, after Leake [p8, 1996]. Figure 1, shows, on the left, a relatively small problem space and assumes a similar sized solution space. Notice that the retrieval distance (the arrow labelled R) and the adaptation distance (the arrow labelled A) are both quite short. As the size of the problem space increases (shown on the right) the retrieval and adaptation distances may increase, as shown by the lengths of the arrows.

Moreover, as has been reported by Maher et al. [1995] there is often an inverse relationship between the number of cases in a case-base and the number of indexed features in the cases. This is because it often harder to collect a few large cases than it is to collect hundreds of small cases. Thus, case coverage is often likely to be lower in a large problem space than in a small problem space. This may cause the case-base to return a mediocre match that will require considerable adaptation, resulting in poorer solutions.

A potential solution to this problem is the *divide and conquer* approach. This suggests that, where suitable, a large problem is divided into several smaller sub-problems, each of which can be solved separately using CBR. The sub-solutions can then be combined to produce an accurate solution to the entire problem [Maher & Zhang, 1991]. A key assumption for this approach is that the sub-problems are not highly constrained one upon the other, so that they can be solved independently (i.e., that the problem can be sensibly decomposed and the solution recomposed). This approach may be visualised as in Figure 2.

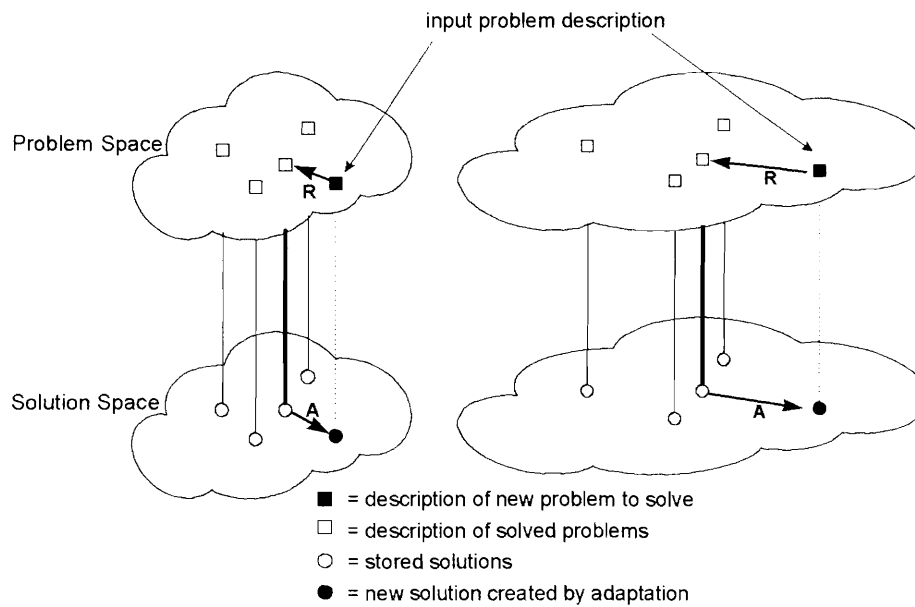


Figure 1. Small and Large Problem & Solution Spaces, after Leake [p.8, 1996]

The advantage of this approach is that each individual sub-problem is represented by a case-base that is significantly smaller (in terms of problem and solution space size) than if the

whole problem were represented by a single case-base. Because each sub-problem space has fewer case features, the theory predicts, that each individual sub-case retrieval distance will be shorter than for the undecomposed problem. Therefore, the adaptation distance will be shorter and a better sub-solution will be generated. Assuming there are no conflicting constraints, the recomposition of sub-solutions will produce a better solution than would have been obtained by using a single large case-base. One way that has been suggested to reduce constraint problems with solution recombination is to use contextual information to guide retrieval [Hammond, 1986; Hennessy & Hinkle, 1992; Kolodner, 1993; Maher et al., 1995; Marir & Watson, 1995; Ram & Francis, 1996]. The argument being, that if cases share similar contexts, this will reduce constraint problems during solution recombination.

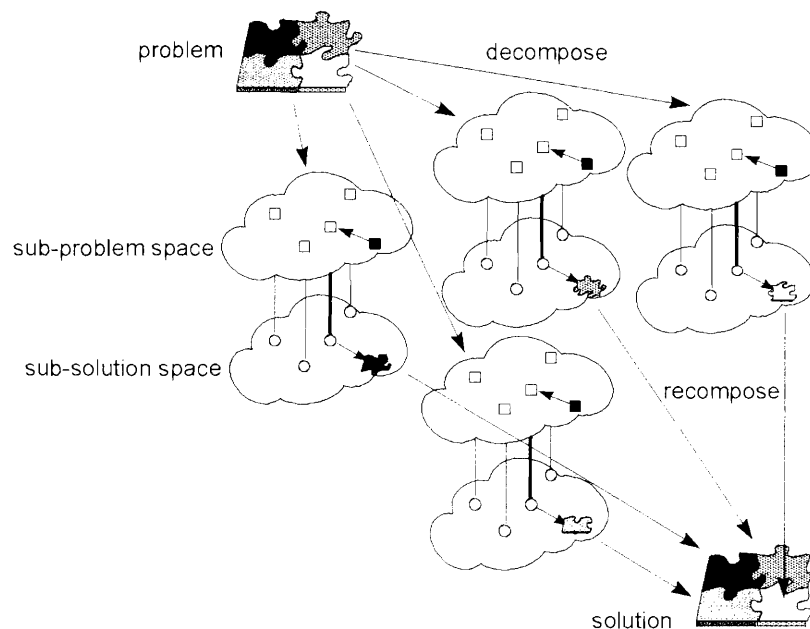


Figure 2. Problem Decomposition and Solution Recomposition

The purpose of the study presented in this paper was to quantitatively assess the accuracy of a CBR system that uses a hierarchical case representation and context-guided retrieval to decompose a complex problem and recompose a solution. The accuracy of this complex case representation and retrieval technique is compared to that of a simple flat record of attribute-value pairs using a standard nearest neighbour retrieval algorithm. The evaluation will show that the more complex representation and retrieval method outperforms the simpler representation, thereby justifying the knowledge engineering and programming effort put into it.

2. The Problem Domain

For this study we selected the estimation of the construction costs of light industrial warehousing as a suitable domain. These buildings are used as storage and distribution warehouses, as low cost retail buildings, and as light industrial factory units. They were suitable for this study for the following reasons:

- Warehouses are strictly functional buildings with aesthetic issues being very secondary (i.e., they rarely win design prizes). Consequently, cost is a more important issue than for most other building types.
- They are constructed using steel frames that are produced in standard sizes along with many other components (e.g., roofing sheets) that are also produced in standard sizes.
- The buildings are structurally fairly simple and consequently the constraints between different building elements are small. This therefore suggested that divided and conquer would be appropriate.
- The cost of a building is derived directly from the cost of its sub-assemblies. Thus, the problem decomposes naturally. This is supported by the way that cost estimators usually work. They calculate the cost of each sub-assembly and sum them to obtain a total cost.
- Finally, we had access to a cost estimating computer system for this building type. This has significant methodological importance and will be discussed later.

3. The Case Representation

The system, called NIRMANI, was implemented in ART*Enterprise, from BrightWare, on Windows 95 [Watson & Perera, 1995]. The environment provides an object-oriented knowledge-based development environment, that supports objects, rules (a forward chaining Rete algorithm), a procedural programming environment, case-based reasoning (nearest neighbour), a GUI builder, and an ODBC database interface [Watson, 1997]. Representing cases hierarchically is a popular approach to the use and reuse of sub-cases (e.g., Redmond, 1990; Goel, 1994; Aha & Branting, 1995). A building in NIRMANI is a meta-case, consisting of a hierarchy of cases and sub-cases. At the top of the hierarchy is the *Project Context* case. The second level contains *Architectural Context* and *Estimating Context* cases representing the perspectives (or views) of architects and cost estimators. A third level decomposes the design into functional spaces and aesthetic requirements hierarchies and the estimating problem into an industry standard elemental classification hierarchy [Perera & Watson 1996].

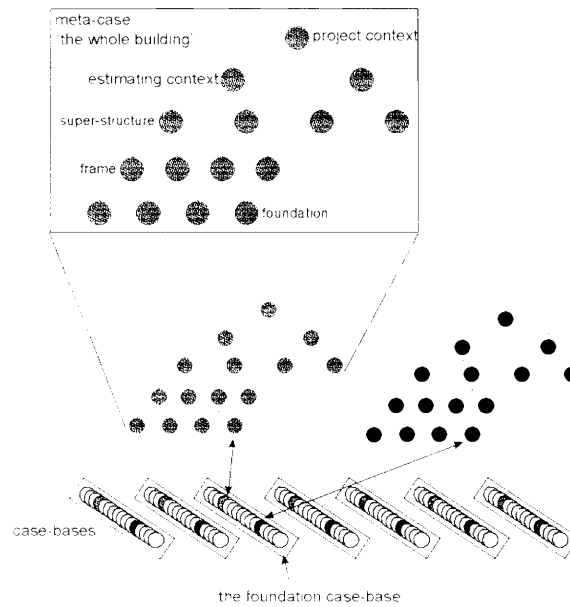


Figure 3. Schematic of the Hierarchical Case Representation

Each node in the hierarchy is stored in a separate case-base. The cases are stored as records in a relational database external to the system since this has the benefit of allowing a design organisation to keep their case data in their existing databases [Brown et al., 1995]. An object hierarchy within the system maps to the tables in the database and cases are presented (when required) as instances. Cases contain attribute-value pairs as case features.

A *Project Context* case describes the environment within which the project was carried out (features such as the type of building, its intended function, gross internal floor area (GIFA), the site conditions, and other features common to the project context). The second level cases (architectural and estimating) describe the context of the sub-problems. The system prefers to retrieve sub-cases with similar contexts (i.e., with similar parents in the hierarchy) in order to reduce problems of case adaptation and solution recomposition due to contextual dissimilarity.

	Attribute	Value(s)	Data Type
1.	Case_No	Value per project	cat:nir.capitols
2.	Number-key	Unique integer value per case per case-base	cat:integer-or-nil
3.	Source_cases	List of cases	default
4.	Name_of_Project	Text	default
5.	Site_Address	Text	default
6.	Site_Post_Code	Text	default
7.	Client	Text	default
8.	Client_Address	Text	default
9.	Client_Post_Code	Text	default
10.	Type_of_warehouse	Storage Distribution Retail	catnl:wh-type

	Attribute	Value(s)	Data Type
11.	Type_of_occupier	Owner occupier Tenant occupier Developer	catnl:occupier
12.	Use	Basic materials Completed - goods Perishable - goods Equipment Retail goods Electronic - Components Re-distribution- Goods	catnl:use
13.	Storage_Category	Flammable Non-flammable Chemical Flammable Chemical Non-flammable	catnl:st-cat
14.	Region	List of regions (BCIS)	catnl:regions
15.	Construction_period	Months	cat:float-or-nil
16.	Project_duration	Months	cat:float-or-nil
17.	Project_Cost_limit	£	cat:integer-or-nil
18.	Tender_Month	List of Months	catnl:months
19.	Tender_Year	1983-1998	cat:nir:year1983-1998
20.	Actual_project_cost	£	cat:integer-or-nil
21.	Total_variations	£	cat:integer-or-nil
22.	Completed_duration	Months	cat:float-or-nil
23.	Completed_date	Text	default
24.	Type_of_contract	List of Contract Types	catnl:contract
25.	Gross_Floor_Area	m ²	cat:integer-or-nil
26.	Gross_office_area	m ²	cat:integer-or-nil
27.	Type_of_Structure	Portal Frame Propped Portal- Frame Steel Frame & Joists Clear Span - Frame Structural Steel - Frame Timber Frame	catnl:struct-type
...	...	...	...
66.	Structural_Engineer	Text	default
67.	Services_Engineer	Text	default
68.	Other_Consultants	Text	default
69.	Contractor	Text	default
70.	Contractor_Address	Text	default

Table 1. A Selection of Attributes from the Project Context Case Definition

The interface of NIRMANI allows cases to be viewed as attribute-value pairs along with CAD drawings and other multimedia elements. It supports case comparison using a tabulated form (similar to a spreadsheet).

4. Retrieval

NIRMANI provides a variety of retrieval methods, of which only two are compared in this paper. Full details of these retrieval methods can be found in Perera & Watson [1996]. ART*Enterprise uses a nearest neighbour algorithm with weighted features. Its programming environment gives the developer considerable control of the algorithm making it a good environment to explore different retrieval strategies. The two strategies compared in this paper are described below.

4.1 Default Retrieval

This is essentially standard nearest neighbour retrieval. The user is allowed to select which features are indexed. These will usually be the majority of the features in the *Project Context* case (except the construction cost) plus some other significant features from other aspects of the building. For example, the user may want a glazed curtain wall on the front elevation of the building but have no definite views or wishes as to the roofing type. The user may set weights on features reflecting their relative importance to them.

In default retrieval an index is prepared dynamically at run-time for those case features entered by the user. Feature comparison is carried out as in normal nearest neighbour retrieval. A normalised match score for each entire meta-case is calculated and the highest ranking cases are then presented to the user. Only an entire meta-case can then be selected for adaptation.

4.2 Context Guided Retrieval

Context guided retrieval proceeds in series of recursive steps down the hierarchy of the case representation. In the first step, the features of the *Project Context* case (at the top of the hierarchy) are used to retrieve similar *Project Context* cases from the *Project Context* case-base. This is done using ART*E's standard nearest neighbour algorithm. In the second step, retrieval of cases from the *estimating* or *architectural* case-bases (the next nodes down the hierarchy) is restricted to those cases that are the children of the cases found similar in the first retrieval step. That is, retrieval is limited to those sub-cases that share similar project contexts (i.e., similar parents). This process is repeated all the way down the hierarchy. Retrieval at each level is restricted to those cases in a case-base that have similar parents.

This process reduces the search space by enforcing contextual similarity. However, if a close enough match cannot be found at any level (this is more likely to occur at leaf nodes since the number of cases included in the search may reduce at each level) then the contextual guiding can be relaxed. This relaxation is achieved by back tracking up the hierarchy and reducing the threshold at which similarity is judged acceptable for the parent case. This will increase the number of cases allowed into the children's retrieval process. This relaxation can proceed all the way to zero, if necessary, allowing retrieval from all cases in a child's case-base, thus removing the context guidance completely.

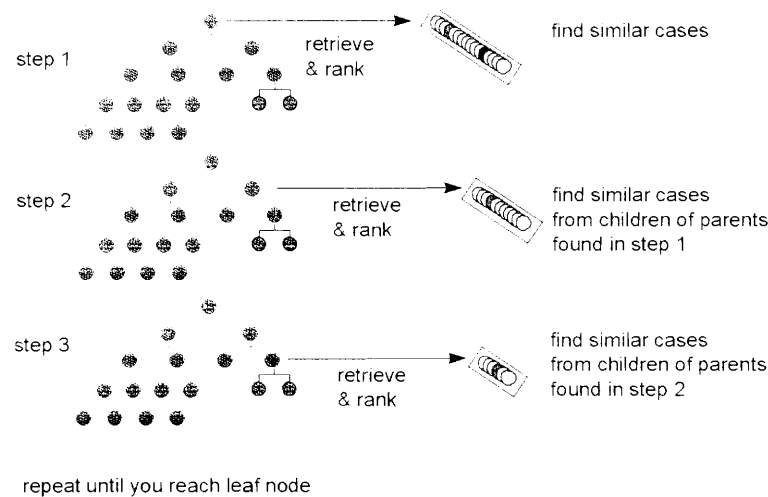


Figure 4. Context Guided Retrieval

5. Adaptation

Cases are ranked and presented to the user. Users are allowed to select cases and case features for adaptation. Note that using the default retrieval method only sub-cases from one meta-case can be used for adaptation. Whereas, for context guided retrieval, sub-cases from different meta-cases with a similar context can be used. Moreover, using context guided retrieval adaptation can occur at the elemental unit level of detail, whereas for the default retrieval adaptation occurs at the level of the project context case (i.e., only the total estimated construction cost is adapted). A modification knowledge-base, containing a set of rules, functions and procedures provides the adaptation. In general, adaptation is in the form of parameter adjustment through interpolation. For example, if a retrieved case has the feature “*floor finishes*” at a cost of “£12,000” with a GIFA of “2000m²”, then the adaptation function will calculate a *rate* for floor finishes of “£6 per m²”. This rate can then be applied to a new case with a different GIFA but a similar specification for floor finishes.

6. Methodology

In the 1980s and early 1990s Salford University, in collaboration with the Royal Institution of Chartered Surveyors (the RICS is the professional institution for cost estimators in the UK), developed several knowledge-based construction cost estimation systems. The first of these, a rule-based system called ELSIE, could estimate the construction costs of commercial office developments [Brandon et al., 1988]. In a subsequent development another rule-based system, called ELI, was developed for estimating the construction costs of light industrial warehouse units. These systems are sold commercially, by a joint venture company, and have sold over a thousand copies world-wide.

The RICS commissioned a study to check the accuracy of the systems [Castell et al., 1992], which found that their estimates are within plus or minus 5% of eventual construction costs. This is well within acceptable error and is as good as the most experienced cost estimators [Skitmore, 1990]. For our study we used ELI as both a case generator (i.e., to produce projects to populate our case-base) and as an evaluator (i.e., to test the accuracy of the CBR systems).

6.1 Case Acquisition

Details of thirty construction projects were obtained from the Building Construction Cost Information Service (BCIS), an information service for the UK construction industry. ELI was used to generate a further twelve hypothetical construction projects. These projects were carefully designed to fill in the gaps between the thirty real projects from the BCIS. These were then entered into a database that NIRMANI used for its case data. The projects generated by ELI were carefully designed so as to create a case-base with an even case distribution. Thus, projects were created which had a variety of functions (e.g., dry goods distribution warehouses, cold storage warehouses, flammable goods storage and distribution, retail warehouses, etc.). The projects varied in size consistently in graduations of approximately 100 m², from 1,500 m² to 3,500 m². In addition, a range of construction complexity with additional features, such as office space, were included. We recognise that this case-base is artificial. We felt that a well distributed case-base should be analysed before attempting a randomly distributed one.

6.2 Evaluation

Evaluation of the accuracy of NIRMANI using the two retrieval techniques described above was done in three ways.

1. Cases with a known construction cost that were in NIRMANI's case-base were removed and used as target cases (i.e., as a new problem to solve). This would remove a known case from the well-distributed case-base and force NIRMANI to solve the problem using neighbouring cases. This test was performed five times.
2. New projects (i.e., ones that NIRMANI had never seen) were developed by ELI and hence we new ELI's estimation of their construction cost. These were then presented to NIRMANI as new problems for it to estimate. This test was performed ten times.
3. Finally, as a test of both ELI's and NIRMANI's accuracy, real projects (with known costs) were obtained from the Building Cost Information Service and given to ELI and NIRMANI to solve. This acted as an independent check on the accuracy of both systems.

These evaluation methods are shown schematically in Figure 5.

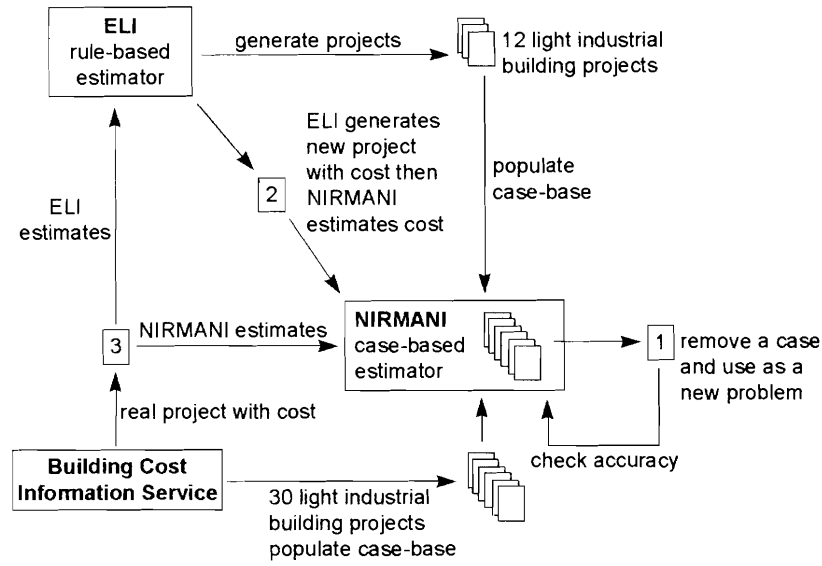


Figure 5. The Case Generation & Evaluation Methodology

The results from the evaluation tests were statistically analysed using the coefficient of variation method. This technique is widely used as the most common criteria for the determination of the accuracy of an estimating method or model [McCaffer, 1975]. CV is defined as:

$$CV = \frac{\text{Standard Deviation of Residuals } (S_r)}{\text{Mean Cost of All Schemes} - \text{Actual } (M_a)}$$

Thus, CV can be termed as the estimating error where:

$$\text{accuracy} = 1 - \% \text{ estimating error}$$

and therefore:

$$\text{accuracy} = 100 - CV$$

7. Results

A summary of the tests is given below and shown in Figure 6. Exactly the same feature weightings were used for both the NN retrieval and the context guided retrieval.

7.1 Test 1

For test 1 a case was removed from NIRMANI's case-base and used a target case. The results of the five tests are summarised in Table 2.

Test No	Data				NN Retrieval		Context Guided NN	
	GIFA m ²	Office Area m ²	Building Use	Actual Cost £	Estimate £	% Diff.	Estimate £	% Diff
T1	2325	111	Storage	500,562	525,314	4.94	499,539	-0.20
T2	2138	244	Retail	648,500	468,750	-27.72	603,825	-6.89
T3	2000	100	Storage	660,100	678,628	2.81	663,129	0.46
T4	2590	250	Storage	593,697	657,029	10.67	592,075	-0.27
T5	1500	0	Storage	399,506	294,636	-26.25	421,566	5.52

Table 2. Results of Test 1

Two major studies on the accuracy of estimation in the construction industry revealed that an accuracy ranging from $\pm 15\%$ to $\pm 20\%$ [Ashworth & Skitmore, 1983] and $\pm 8\%$ to $\pm 15\%$ [Skitmore et. al., 1990] are acceptable for early stage estimating of construction costs. Therefore, all the estimates using context guided retrieval were well within acceptable error. However, the flat representation using standard nearest neighbour failed in tests T2 and T5 (with context guided retrieval the percentage difference was also considerably greater for these two). This was because the cases in these two tests do not have close nearest neighbours within NIRMANI's case-base. The accuracy of the context guided retrieval is increased because it can find nearest neighbours for individual elements of buildings, whereas the other technique cannot find a whole building that matches well enough. A detailed examination of these two tests revealed that the poor estimate was caused by a poor match for the substructure, for test T2, and for external works for test T5.

Test No	Nearest Neighbour		Context Guided NN	
	% Diff.	Contributor	% Diff.	Contributing Cases
T1	4.94	WHS_A3	-0.20	<u>WHS_A2*3</u> , WHS_A3*2
T2	-27.72	WHS_A3	-6.89	<u>WHS_T1</u> , WHD_GG1, WHS_A4, WHS_A1*2, WHS_A2
T3	2.81	WHS_T2	0.46	<u>WHS_T2*5</u>
T4	10.67	WHS_C2	-0.27	<u>WHS_C2*3</u> , WHS_C3*2
T5	-26.25	WHS_A4	5.52	<u>WHS_E1</u> , WHS_A4, WHS_A2, WHS_T2, WHS_G1, WHD_K1,

Table 3. Cases Contributing to a Solution for Test 1

For the standard nearest neighbour retrieval only one entire meta-case can contribute to the solution. For context guided retrieval parts of different meta-cases can contribute. In Table 3, the case reference number that is underlined and in italics contributed most to the solution.

7.2 Test 2

For test 2, ELI was used to generate ten new projects and to estimate their construction costs. NIRMANI

was then given the same projects to estimate.

Test No.	Data			ELI	Nearest Neighbour		Context Guided NN	
	GIFA m ²	Office Area m ²	Building Use	Estimate £s	Estimate £s	% Diff.	Estimate £s	% Diff.
CS1	1,500	75	Storage	329,600	320,773	-2.68	322,177	-2.25
CS2	1,750	100	Storage	388,500	430,783	10.88	391,598	0.80
CS3	2,000	125	Storage	486,600	477,114	-1.95	488,709	0.43
CS4	2,000	200	Retail	575,600	614,457	6.75	581,639	1.05
CS5	2,250	175	Storage	607,400	474,812	-21.83	606,749	-0.11
CS6	2,500	200	Storage	663,200	602,832	-9.10	661,294	-0.29
CS7	2,750	200	Storage	1,221,100	809,090	-33.74	1,233,125	0.98
CS8	3,000	250	Retail	825,100	903,321	9.48	809,475	-1.89
CS9	3,250	300	Retail	898,400	970,686	8.05	910,048	1.30
CS10	1,250	50	Distribution	363,700	326,330	-10.27	369,652	1.64

Table 4 Results of Test 2

This test gave consistently similar estimates with a maximum percentage difference of -2.25% for context guided retrieval. However, the standard nearest neighbour retrieval was more inconsistent, ranging from 10.88% to -33.74%.

Test No.	Nearest Neighbour		Context Guided NN	
	% Diff.	Contributor	% Diff.	Contributors
CS1	-2.68	WHS_A4	-2.25	WHS_A4*5, WHS_F1, WHS_W1
CS2	10.88	WHS_T2	0.80	WHS_A4*4, WHS_T2*3, WHS_D1*2
CS3	-1.95	WHS_T1	0.43	WHS_T1*3, WHS_T2, WHR_B1, WHS_A3*2, WHR_BB1*2
CS4	6.75	WHR_BB1	1.05	WHR_BB1*4, WHR_M1, WHS_A4, WHS_A3
CS5	-21.83	WHS_A3	-0.11	WHS_X1*3, WHS_A1, WHS_A3, WHS_T3
CS6	-9.10	WHS_T4	-0.29	WHS_T4*3, WHS_C1, WHS_C5, WHS_D1
CS7	-33.74	WHS_C2	0.98	WHS_AA1*2, WHS_C2*4, WHR_BB1, WHS_W1
CS8	9.48	WHR_N1	-1.89	WHR_N1*3, WHR_Q1*2, WHR_FF1, WHR_V1
CS9	8.05	WHR_N1	1.30	WHR_N1*2, WHR_Z1, WHR_M1, WHS_AA1, WHS_W1
CS10	-10.27	WHD_HH1	1.64	WHD_HH1*3, WHR_V1, WHS_W1*2, WHS_T2*2

Table 5. Cases Contributing to a Solution For Test 2

7.3 Statistical Analysis

The results from test 1 and 2 were combined (i.e., $n = 15$) and are summarised in Table 6.

Statistic	<u>BCIS or ELI</u>	<u>Nearest Neighbour</u>			<u>Context Guided NN</u>		
	<u>Cost/m²</u>	<u>Cost/m²</u>	<u>Diff Absolute</u>	<u>% Diff. Absolute</u>	<u>Cost/m²</u>	<u>Diff. Absolute</u>	<u>% Diff. Absolute</u>
Mean	275.92	256.51	37.58	12.47	276.02	4.53	1.61
Standard Deviation (Population)	55.09806	40.93379	37.559007	10.008	56.080815	7.192149	1.993
Coefficient of Variation (CV)			14.090187			2.095961	
T Test		0.282962			0.9958138		
Co-relation coefficient		0.502196			0.9917861		
Estimating Accuracy			85.909813			97.904034	

Table 6. Summary of Results from Tests 1 & 2

Since the sample size was less than 30 (i.e., $n = 15$), the Students' t Test was used for statistical analysis. Three tests were carried out. All were carried out initially for 95% confidence limits, which is accepted as providing statistically significant results.

1. *Hypothesis Test 1 (HT 1)*

The context guided retrieval achieves a mean accuracy of 98% (i.e. 2% error in estimating). In statistical terms this means hypothesising a population mean of 2% ($\mu = 2$ null hypothesis. The statistical aim of the test is to prove that $\mu = 2$ is not possible. H_0 has to be accepted, because the hypothesis $\mu = 2$, or estimating accuracy $EA_N = 98\%$, cannot be disapproved at a 95% level of confidence.

2. *Hypothesis Test 2 (HT 2)*

The same test as HT 1 was carried out to check if the standard nearest neighbour retrieval could achieve a mean accuracy of 86% (i.e. 14% error in estimating). The test hypothesis was, $H_0: \mu = 14$ Null hypothesis. H_0 has to be accepted, because the hypothesis $\mu = 14$ or estimating accuracy $EA_F = 86\%$ cannot be disapproved at a 95% level of confidence.

3. *Hypothesis Test 3 (HT 3)*

The aim of this test is to determine whether the results obtained for the standard nearest neighbour and context guided retrieval represent significantly different approaches. In statistical terms this involve testing whether the test samples could be from the same population. In order to achieve

these results a “Paired Sample Student’ t Test” was carried out. The test hypothesis was as follows: $H_0: \mu = 0$ (The mean of the difference between the two techniques is zero). The test was repeated for the differences in estimated values (absolute) obtained from Table 6. T-Tests were carried out as for HT 1 for a 95% level of confidence. This found that H_0 could not be rejected at 95% confidence levels. However, at 90% confidence levels H_0 could be rejected.

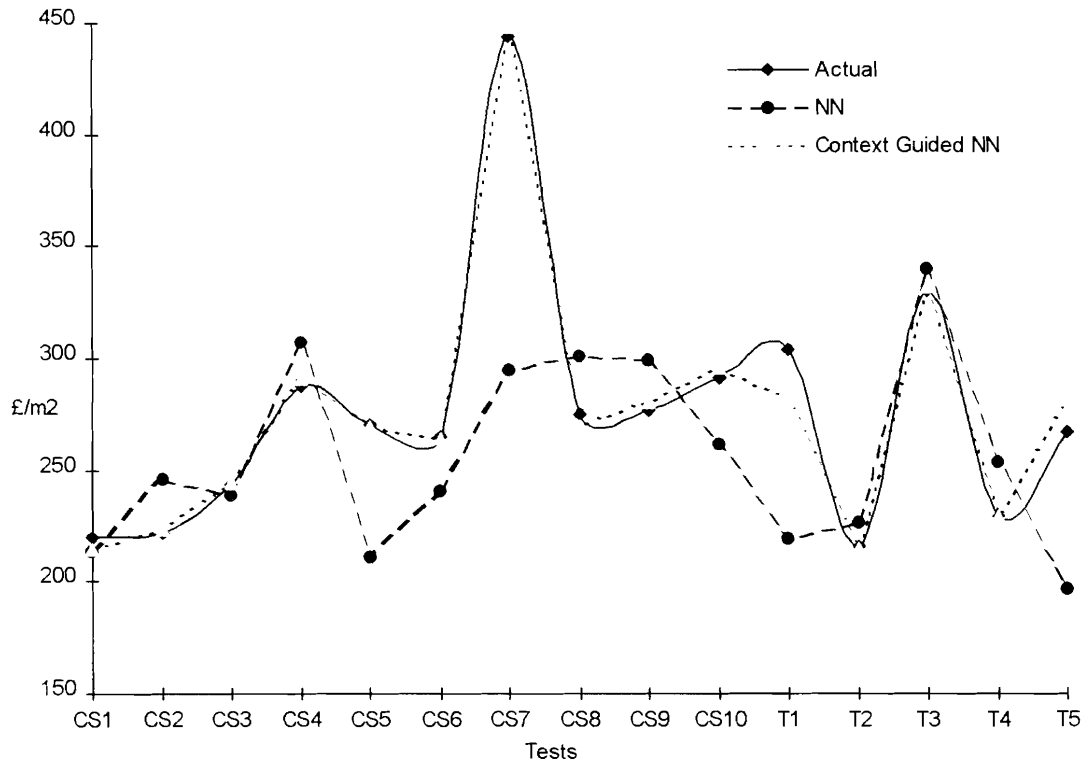


Figure 6. Summary of Test Results

8. Conclusion

The systematic evaluation of a CBR system is very difficult because such systems are typically very complex with many interacting components [Santamaria & Ram, 1996]. Consequently, this study has simplified the performance of our system down to a single quantifiable measure - estimating accuracy. We accept that this measure is a simplification of the performance of our system. Nonetheless, the evaluation demonstrates that the context guided retrieval method out performs that of the simpler flat-file nearest neighbour method. The only times that the simpler technique performed acceptably were when a problem happened to find a close near neighbour within the case-base. When the simpler technique performed badly it was because it was unable to find a complete matching case and was forced to use the closest case that matched on a subset of features. Conversely, when the context guided retrieval method significantly out performs the simpler technique it is because it has composed a solution from many cases. Thus, when a close near neighbour cannot be found the divide and conquer approach, using context guided retrieval, performs better as the theory predicts. It is interesting to note that that the simpler technique usually recognises which case can contribute most to solution, but, by being unable to use snippets from other cases

as well, its accuracy is reduced.

We recognise that this has been a fairly limited study, with a small sample size. We have shown that for our tests the context guided retrieval (HT 1) was accurate. However, there was only a 90% confidence that this technique was statistically different from standard nearest neighbour retrieval (HT 3). Because of the size of each meta-case (i.e., approx. 400 case features) each single evaluation test took one day to perform. Consequently, the number of tests was limited and therefore it would be unwise to rely too heavily on the simple statistical analysis performed here. However, the results are indicative and support the view that divide and conquer, through problem decomposition and solution recomposition, is an effective method of solving problems with large complex cases. The context guided retrieval method evaluated here may also be a useful way of reducing the problems of conflicting constraints between parts of the solution. The fact that the case-base was populated with an evenly distributed set of cases may have skewed our results. Although from the results it would appear that this should skew the results in favour of the simpler method. Since it performs better when a close good match can be found, one would expect it to perform more erratically with a more unevenly distributed case-base. Finally, it was interesting to see that the case-based estimator performed as well as the rule-based estimation system, with a mean error of 2%. The rule-based estimator took over three person years to implement, whilst the case-based estimator took less than half that time. This further supports the many findings that show that CBR systems can be implemented quicker than their rule-based counterparts [Simoudis & Miller, 1991; Mark et al., 1996].

9. References

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INFORMATION AND STUDENT EXCHANGE IN THE EU. THE EXPERIENCE OF THE 'COMBEE' GROUP OF EUROPEAN UNIVERSITIES

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1. Introduction

This paper will:

- introduce the COMBEE group. describing its membership, objectives and historical background.
- describe the information and student exchange achieved to date.
- outline the development proposals. using computer conferencing and Internet facilities.

2. The COMBEE group

CONSTRUCTION MANAGEMENT & BUILDING ECONOMICS IN EUROPE

bringing a pan-European perspective to Construction studies

COMBEE is a group of European universities sharing a common interest in the study and development of Construction Management and Building Economics in Europe.

2.1 The collaborating universities

The group comprises:

RTC Limerick, Ireland

University of the West of England, Bristol, UK

Universidade do Porto, Portugal

Horsens Polytechnic, Denmark

Chalmers University of Technology, Göteborg, Sweden

Technical University of Trondheim, Norway

Université de Nantes, France

Technische Universität München, Germany

Fachhochschule Potsdam, Germany

Rheinische-Westfälische Technische Hochschule Aachen, Germany

Aristotle University of Thessaloniki, Greece

Hogeschool 's-Hertogenbosch, Netherlands

Universitat de Girona, Spain

Universidad de Oviedo, Spain

Seinäjoki Institute of Technology

Technical University of Budapest

Technical University of Istanbul

2.2 Objectives

The key objective of the COMBEE group is to:

- promote and develop a strong European dimension to the study and research of the subjects of Construction Management and Building Economics in the universities of Europe

Derived from this key objective, the COMBEE group aims to:

- facilitate university degree students to experience, and prepare dissertations, theses and project reports on, European construction issues;
- raise the awareness of and access to pan-European construction information and research for lecturers;
- develop a Masters level programme with course content specifically focused on European construction management & economics.

2.3 *Historical development*

Early 1989 saw another recession looming in the UK construction industry and uncertain opportunities with the impending Single European Market to be implemented in 1992. Good reliable information was in short supply.

Three quantity surveying lecturers at the then Bristol Polytechnic successfully applied for Study Visit Grants from the Erasmus Bureau of the European Commission (EC) and began a two-year programme of visits to European universities to find out how their professional equivalents, construction economists, were being educated, being trained and were practising in Europe.

The Royal Institution of Chartered Surveyors and the European Committee of Construction Economists (Comité Européen des Economistes de la Construction - CEEC) helped with contacts and the London-based quantity surveying practice of Gardiner & Theobald provided further sponsorship to extend the number of countries visited.

For the purposes of the study, the term *construction economist* was taken to mean a person whose primary role or interest is in the management of costs and maximisation of value for money of building and engineering construction projects derived from a definition by Michael Hartmann, Vice President of CEEC at the time. It was used in its widest sense to include the study of economic, legal and managerial issues in the product and process of construction projects from conception to completion, together with an appreciation of the effect of those issues on a project's life cycle through to obsolescence.

One interesting observation was that construction economists were rarely associated with faculties of Architecture and were most frequently associated with faculties of Civil Engineering.

Funding from the Erasmus Bureau encouraged the formation of a group of universities collaborating in an Inter-university Cooperation Programme (ICP) to facilitate the exchange of students and teaching staff, to promote joint curriculum development and intensive study programmes.

UWE called a conference with Scandinavian universities in September 1993 and met with other universities in the European Construction Economists Consortium, coordinated by the University of Reading.

Discussions between potential partners took place at conferences at the University of Reading, UWE and CIB W55 in Lisbon during 1993, resulting in two ICP applications going forward to the Erasmus Bureau in November 1993: one in the subject area of Construction Economics and another taking the broader church of Construction Management and Building Economics.

Both applications were successful, but only the latter group has continued beyond the first year and has established itself under the title of the COMBEE group. The group continues to grow and has this year welcomed the Technical Universities of Budapest and Istanbul as associate members, in anticipation of their respective countries future incorporation into the European Union.

Conferences of the group have met in Bristol (June 1994), Porto (May 1995), Limerick (April 1996) and 's-Hertogenbosch (May 1997). The next meeting of the group is in Munich in March 1998.

The group is managed by an executive group from UWE Bristol, Limerick, Porto and 's-Hertogenbosch.

This section has given an overview of the historical development of the COMBEE group. The paper will now look at the COMBEE group's focus on student and staff exchange under the EC's Erasmus programme (now organised under the Socrates Office). It will describe the information support used to facilitate and support this, and identify some of the issues and proposals for future collaboration.

3. Information and student exchange to date

The development of a joint masters level programme in the subject area of European Construction Management and Economics has been identified as a group aim, but realistically it remains something to be worked towards in the longer term. Experience has shown that other courses, for example in Town Planning, Real Estate, and Project Management, have been easier to set on a European basis, probably because they are more easily identifiable as specialisms that offer less challenge and/or more marketable added value to existing professional roles and their associated academic courses.

The focus of the COMBEE group has therefore been to establish student and staff exchange as a learning vehicle upon which to build further collaboration. Student exchanges within the COMBEE are typically for a minimum 3 months period. A brief profile of student exchanges to date can be classified as follows:

1. Dissertation exchange. Usually the dissertation is the final semester study of a five year engineering course and for example, a student from Munich is currently at UWE completing a comparative study on early stage cost estimating techniques between UK and Germany, whilst two students from Chalmers are comparing the problems faced by subcontractors in Sweden, UK and Italy. The 4 year sandwich BSc students at UWE are able to combine 3 months of dissertation study with 9 months of work experience in Europe during their third year out, and so a UWE student is undertaking a comparative study of UK and French estimating methods. The host university provides supervision and pastoral support, whilst the home university will normally retain responsibility for the final assessment.
2. Special projects exchange. In some universities the final semester study is more like a practice project. So BSc students from Horsens have been to UWE to undertake design and compile a priced tender for a civil engineering project in UK. An MSc student from Oviedo is completing

the design for a factory in Bristol under Eurocodes. Here the assessment has been agreed by a joint panel drawn from home and host universities or delegated to the host university.

3. Taught modules exchange. These are potentially the most difficult to arrange and require a good deal of mutual trust and confidence from all parties concerned. Final semester studies may have a large element of optional modules and those will provide some flexibility in following a course of studies at another university. Thus, for example, a fourth student from Porto is about to follow a course of studies at UWE which will give exemption from her fifth year final semester studies at Porto for her MSc in Civil Engineering. UWE's change to a modular programme in 1993 with modules completed within one semester has greatly facilitated this. Students are able in one semester to follow a mix of post-graduate and final stage undergraduate modules to the equivalent of a PG certificate. As the host university retains full authority for assessment and awarding credits, it is important in this case for the partner universities to agree to adopt the European Credit Transfer System (ECTS).
4. Student Study Visits. For example, all final year Construction Management and Quantity Surveying students at UWE undertake a European Study visit linked to an integrating project module. For the last three years UWE has linked with Potsdam to organise joint lectures and local project material.
5. Collaboration on Course Development and Delivery. Developing from the above have come collaborations on:
 - Students conferencing by e mail to access information e.g. UWE students on the module European Property and Development and Construction accessing local information from students in Horsens and s'Hertogenbosch on their respective construction markets.
 - Joint teaching on courses, e.g. UWE tutors teaching on the postgraduate Project Management course at s'Hertogenbosch and providing tutorial support by e mail; one week of a five week course for the Swedish Telia group on International Project Management delivered at Bristol, managed by Chalmers.
 - Collaboration on development of teaching material, e.g. comparison of UK and German practice in cost management for delivery in a course on quantity surveying in Hungary

The use of e mail, both between staff and students has facilitated initial communication, organisation, exchange of teaching material, tutoring and feedback. Prior to e-mail, it would be fair to say the practical communication problems were frustrating at best and truly daunting at worst.

Implementing ECTS provides a good example of the additional facility provided by the Internet.

The three key demands of ECTS are:

1. the information package

2. ECTS credits

3. the learning agreement

The information package is required to be updated annually and provided in the home language and a second Community language. It should give full general information about the institution as well as course specific information, including details of content, teaching, & learning methods and modes of assessment.

Providing this for a handful of students exchanging each year was a truly daunting prospect and certainly not environmentally friendly to trees.

COMBEE has set up its own WWW home page with links to each of its member universities. Many of them now provide access to this information via the Internet. Perhaps one of the best examples is that provided by Trondheim who have detailed general and course specific information in Norwegian and English. Chalmers have more course specific detail on their home pages and now use the Internet for communicating with their International Project Management students.

Agreeing learning credits and the particular learning agreement is then easily concluded using e-mail, with the facility to bring the student into the discussions between tutors and provide continuing pastoral support.

Looking back over just three years it seems difficult to believe that originally all communication between the COMBEE members was by snail-mail and fax, but during the last year all members have come on to e-mail and this is transforming the ease of communication. It is opening up exciting possibilities in terms of future collaboration, which will be described in section 3 of this paper.

4. Development proposals

Finally, the paper presents proposals for developing and extending collaboration between European universities in the subject area of Construction Management & Building Economics, particularly by extending existing Intranet development work to the Internet and using computer conferencing to develop a network of information and teaching support.

In May of this year, four members of the group were awarded a Socrates advanced-level curriculum development grant to jointly develop modules to contribute to a potentially pan-European masters programme, using open and distance learning tools covering topics in the management of the construction process, risk, cost, and information.

A further bid to use telematics in support of open and distance learning on masters level courses has been submitted and this project tries to address several needs:

- creation of an European dimension in the COMBEE subject area

- exchange of national practices
- overcoming the costs of physical mobility
- appropriate to the busy schedules of adult students
- the internationalization within the EU of construction activities

The project aims to:

- facilitate cooperation between the participating institutions in the COMBEE area and increase the number of teachers and students involved in the European COMBEE courses
- encourage the use of ODL courses and encourage the recognition of qualifications obtained with ODL materials
- improve the quality education in the COMBEE area, whilst using the best teaching materials from the ODL package

The project aims to overcome the difficulties created by physical mobility. The *virtual* mobility pretends to overcome the high cost of travelling to another country and to eliminate the barrier of time constraint to fit the schedules of potential users. The schedule constraint is valid for adult students that want to improve their skills and for full-time students that otherwise will have difficulty in attending just a few courses in a foreign institution. Since the course are available on a wider scale it will also increase the choice and consequently the education provided.

The outcomes of the project are courses in ODL form that can be used totally or partially by any of the partners in their own teaching. These are instruction materials to be used in the WWW, in video cassettes, electronic mailing and in videoconferences. All will be accompanied by manuals enabling its use in any other institution.

The courses will be produced in three different forms according to the local possibilities. The first will be the use of videoconferencing enabling the dissemination of some sessions in a interactive way with other participants. The second will be videorecording of classes that can be used at any time and any place by other institutions. The third one is the production of teaching materials for the WWW in a written and structured form. All these types of courses will need local monitoring and learning evaluation. All communications between partners, teachers, monitors and students will be done using electronic mail.

The members have agreed to collaborate on updating for publication a study of the education, training and practice of construction economists in Europe using First Class Client conferencing to facilitate the collation and final editing of material. As well as a hard copy edition, it is proposed that individual members will take responsibility for keeping copy of their own section current on their Internet sites.

Electronic library facilities are developing in several member universities and this will provide exciting opportunities to access and exchange teaching material; for example, the second stage Inter-professional Development project at UWE is based on the Bristol 2000 Harbourside scheme and the 300+ students who take this module access the module guide and supporting background information, including cuttings from the local press and CIS information from an Intranet web site.

Software such as Acrobat is providing practical possibilities to easily make other information, such as the Potsdam redevelopment proposals, available on the Internet for easy access to home students, and for exchange and collaboration on projects between widely spread universities.

It is also proposed to apply for a LEONARDO pilot project to facilitate work placements in construction management and building economics in Europe; a benefit of a large group being the degree of flexibility that can be offered.

Currently there is no Socrates thematic network in the area of Construction Management or Building Economics. To be a credible network, it would need a group of 50 - 60 universities to participate. Computer conferencing offers the possibility to assemble and manage such a group within the funds that might be available to support it and it is proposed that an appropriate theme for such a network would be to establish an information network based on the ECTS requirements, to support student and staff mobility with a pool of teaching material and conferencing facilities accessible through the Internet using a common agreed set of protocols.

This paper invites interested parties to contact the authors.

The COMBEE is keen to expand its membership particularly amongst universities in Belgium, France and Italy and welcomes enquiries from interested parties.

DOWN-SIZED IT SUPPORT SYSTEMS FOR CONSTRUCTION: LESSONS IN JAPAN

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1. Introduction

In the past decade, parties in Japanese construction - like independent R&D firms and in-house R&D department of construction firms - have been involved in developing comprehensive and integrated IT systems for construction.

Large general contractors (GC) and innovative specialist contractors introduced the developed systems by using powerful host computers. Large GC established the division to promote the dissemination of the developed systems in the firm. Eventually, in large construction projects where intensive automated logistics and installation are applied, these developed systems are used intensively. These practices are already introduced in articles and papers written in English (Miyatake 1993).

The comprehensive and integrated IT systems are developed by the initiatives of headquarters. These systems are tried to be disseminated from headquarters to each branch and section. It is a sort of vertical (top-down) type of R&D. However, these systems are not applied in 'ordinary' projects because;

- These systems require using large scale computer machine which is not available in 'ordinary' projects.
- These systems have difficulty in customization for specific need in each project
- These systems are too particular so that these do not assure full compatibility in data exchange with various software used by other parties involved in projects.
- Not all site office staffs are well trained in operating computer.

The existence of these barriers suggests the limitation of vertical (top-down) type of R&D.

Alternatively, in Japan, it occurs the cases that IT tools developed at some project are applied at the other project through improvements and customization. It is a sort of horizontal type of R&D. The horizontal type is supposed to be another way to disseminate the IT support system for construction management.

This brief paper illustrates how project base development has the nature of promoting down-sizing of IT support systems for construction management.

2. Need for computer integrated construction management

In the site offices of Japanese contractors, the following management activities are being implemented by site resident staffs of main contractors.

- Detailed design developments including clarification of ambiguous issues relating to design-construction interface.
- Construction planning including:
 - ‘Job package’ planning (identification of all site activities and decision making on what specialist/trade contractors would do each activity).
 - Scheduling of construction procedures
 - Logistics of resources for construction
 - Scaffolding and temporary equipment design
 - Machinery arrangement
 - Site layout planning
 - Budget planning
- Management of subcontractors
- Quality control
- Safety management
- Labour management
- Environmental management
- Resources management
- Document management including permit application and official reporting to the related public authorities

The first item reflects the particular situation of design-construction interface in Japan. Contract drawings do not involve enough information for construction. The contract drawings are quite often uncertain and are quite frequently changed during construction process. It is usual that general contractors make shop drawings and production drawings. Moreover site resident staff of general contractors coordinate and integrate the design offered from specialist contractors involved in the project. This is a sort of concurrent and cooperative design development process (Minemasa, 1996 Yoon , 1996).

Contractors usually make coordination drawing called as ‘Sogo-zu’, in order to avoid contradiction between drawings made by different parties (Oka, 1996). Moreover, it is usual that original design in contract drawings is frequently changed by client or conceptual design team. Eventually detailed design development and its management are serious burden for the staffs of main contractors.

Like in other countries, site office staffs of main contractors in Japan are creating documents, graphics and data relating to the items above. They are really involved in heavy ‘paper works’. In another word, the business to generate and manage information for construction occupies the largest share in management works in site. The enormous quantity and complicated interdependency of this information are increasing the need of

computer integrated construction management.

3. Initiation of project base development toward down-sized IT tools

Tokyu Construction is one of second largest contractors in Japan. At the project to construct 28 stories' office building in Osaka, Tokyu Construction developed IT support system for construction management through the project.

Ingenious director general of site office well understood the potential of IT tools for improvement of management business in site office. There are not intensive supports by research institute and headquarters in Tokyo. Thus, independently he decided to develop IT tools to improve management business in his project. All the initiatives were vertically taken by the director general. He is in charge of allocation of budget for management under ramp-sum basis contract, though total construction budget were extremely tight. The director general had free hand for investing all the resources for developing IT tools specifically used for his project. The system he developed is based on local area networks (LAN) of personal computer.

The total system involves tools such as:

- OA tools
- CAD tools
- Databases
- Server tools
- Network tools
- Presentation tools

(Katayama, 1995)

3.1 OA tools and CAD tools

The purpose of developing OA tools is the integration and co-possession of information generated on site. In order to make all information electronically exchangeable between site staffs and subcontractors, various kinds of devices like digital cameras, video monitor cameras and personal computers are used.

CAD tools are used for efficient design data exchange between design firms, the main contractor and subcontractors (Yoon Won-ki et.al., 1996). Moreover, CAD data are used for construction management works itself. For example:

- Construction planning
Site office staffs make drawing on construction planning diagram by editing CAD data imported from design firm and imported ready made CAD graphics of machines from Osaka branch office.
- Erection procedure of steel frames
Similarly, site office staffs makes diagram of erection procedure of steel frames by edited imported data from design firm and subcontractors.
- Procedure of concrete casting
Positioning devices need for concrete casting works are expressed on the site layout drawings

expressed by CAD data.

- Report on concrete casting

In general, report on sample test of cast concrete is composed of text and tables. In this project, the report involves drawings imported from CAD drawings through copy and paste procedure

3.2 Databases

The system involves the following data base.

- Library of previously completed buildings

- Library of photography & video pictures observed from the same viewpoint (daily, monthly basis)

Construction activities and procedures are monitored and recorded by video cameras put at the fixed position in the site (most of them are birds' eyes). These graphic data are sorted by customized graphic data base editable by personal computer.

- Velocity of wind

Velocities of wind are measured in site. The measured velocities are real-timely displayed in the CRT of site office staffs. Moreover observed velocities are recorded and processed in the database.

- Monitoring Typhoon

Open data supplied by the weather forecast agency is used for monitoring storms called as Typhoon.

- Database of reinforced bars' installation

As an evidence for inspection, photographs of reinforced bars' installation are taken in Japanese construction practices. However, it is difficult to sort stocked photographic data. By customizing existing graphic data base, all the photographs of reinforced bars' installation were taken by digital cameras. All the photographs in the database can be searched by parts and places.

- Database of entered personnel into construction site

In this data base, skills, qualification, information need in casualty (blood type and so on), addresses are recorded for all site operatives and staffs.

3.3 Server function

All parties are accessible for specific folders in server exemplified as below:

- Folders for message box to/from subcontractors
- Folders for format of documents and business letters
- Common folders

Common folders are composed of the following systems.

- Document management system
- Quality management
- Achievement of concrete casting including the result of performance test of test pieces

- Achievement of steel frame erection including the record of accuracy of positioning
- Record of the finishing works
- Record of the piling works
- Scheduling
 - Total
 - Monthly
 - Weekly
 - Daily
- Construction planning document
- Construction planning drawing
- Request of machines and materials to regional branch office (logistics paper)
- Personal folders
 - Instruction document of the works to subcontractors
 - Database of visitors

3.4 Network tools

The Network tools are composed of tools as below;

- E-mail
- Management of lifts

The lift of constructed building is the critical path of vertical logistics and transportation. The networks tools provide function of reserving lifts to all parties related. In addition, actual usage of lifts is automatically recorded by sensor installed in the lift. Thus, it is possible to compare the request and the actual usage. The comparison is referred in deciding the allocation of time of lift's usage for subcontractors. Eventually, it promotes improvement of efficiency of use of lifts.

One of the subcontractors reported that the project gave the intensive motivation to introduce IT tools to their firm (Matsumoto, 1997).

3.5 Presentation

Presentation function involves home pages and animation to display how the building would be built through various construction stages.

4. Down-sizing in other more 'ordinary' project

Tools invented in the skyscraper project above gave impacts to other departments and to other regional office of the same firm. Moreover, it gave the impacts to the larger firm than Tokyu, where centralized and top-down type dissemination of IT tools were promoted more intensively.

4.1 Down sizing practice 1;

In the commercial facilities' development project in Tokyo, the different team of Tokyo modified the developed system made in Osaka skyscraper project. The total floor area of the facility has fourteen floors above the ground level and three floors under ground level. The project was smaller than Osaka. Consequently, in the process of customization to the specific need in the project, the system was down-sized.

Like Osaka project, comprehensive local networks (LAN) with one sever (one Macintosh) were installed in the site office. 18 personal computers, two monitoring video cameras, printers and faxes are connected by LAN. The data filing system used in Osaka was provided to the site management team in this project. The site management team modified and revised these data filing system.

Under the comprehensive LAN, various C/S databases were used for communication between members of construction team. Databases are composed of records. Each record represents personnel, stuff, place or activity. The record has various attributes. For instance, the database titled as 'archive of labour management' is composed of record representing the activity done by specific trade contractor on the specific date. One record has 205 attributes. These attributes are utilized to make documents such as:

- Activity reference sheet where main contractor clarifies the activity of the specific trade on the specific date
- Construction works diary
- Labour's statistics
- Safety meeting sheet

In the Osaka project, these data were utilized by different site staffs. However, quite often, the timing of entering the data is overlapped. The improvement of the overlapping problem was the motivation to apply C/S database in this project. Different site staffs are able to revise the content of the same database at the same time.

Three types of databases were used. These are:

- Reference database

All attributes of the records have fix values. These values are not changed by the progress of construction works. Basically number of records are not changeable. Reference database is used as a reference to the other databases.
- Progress archive database

All attributes of one record are input to the database by corresponding to the progress of construction works. The number of records is increased by the progress of construction work.
- Progress survey database

One record is composed of the attributes of fixed value and these with values revised corresponding to the progress of construction work. Some of the attributes are revised. Basically, the number of records is not changeable by the progress of construction works.

Table 1 shows the list of database used in this project. 26 databases are used in this project. The table indicates to which type each database belongs to. The constructor of database in the table means the way to enter values of attribute of database. ‘Single’ means one person in charge construct and revise the database. ‘Collaboration’ means that plural staffs collaborate to construct and revise the database.

Database of ‘progress of production of precast concrete panels’ has links with CAD data. CAD software has the function to send attributes data to database automatically. The function provides the benefit to reduce manpower to enter the data, because the database has about 2000 records with 101 attributes. It also provides the benefit to assure concurrence between database and CAD data (Nakano, 1996).

Table 1: The list of database used in the project (Source Katayama, 1996)

	Title of Database	Type of DB	Constructor of DB
1	Requests of attending inspection procedure (to the in-house departments)	Progress archive	Single
2	Requests of attending inspection procedure (in the other firms)	Progress archive	Single
3	Inspection scheduling	Progress archive	Single
4	The list of subcontractors participating in the project	Reference	Single
5	Request of certification of appointing subcontractors	Reference	Single
6	Report of construction activity achievement	Progress archive	Single
7	Minutes of regular meeting at site office	Progress archive	Collaboration
8	Minutes of regular meeting by all parties in construction team	Progress archive	Collaboration
9	Minutes of regular design coordination meeting	Progress archive	Collaboration
10	Minutes of regular design coordination meeting on specific phases	Progress archive	Collaboration
11	The list of submitted documents and drawings	Progress archive	Collaboration
12	Archive of achievement of concrete casting planning	Progress archive	Single
13	Archive of sent fax	Progress archive	Single
14	Archive of expended budget per each subcontractor	Progress archive	Single
15	Archive of new entries to the construction site	Reference	Single
16	Archive of equipment and machinery management	Progress archive	Collaboration
17	Archive of labour management	Progress archive	Collaboration
18	Archive of reinforced bar's arrangement and its inspection	Progress archive	Single
19	Archive of welding between reinforced bars	Progress archive	Single
20	The checklist of doors and sashes	Progress archive	Single
21	Archive of parking permission	Reference	Single
22	Archive of logistics	Progress archive	Collaboration
23	Achievement and progress of making shop drawings	Progress archive	Collaboration
24	Progress of production of precast concrete panels	Progress Survey	Collaboration
25	Progress of water proofing around pits	Reference	Single
26	Bill of quantities	Progress archive	Single

4.2 Down sizing practice 2;

Following the commercial facilities' project, the system was applied in hospital buildings' extension project. The number of site resident staffs of this project is only 10. Through the customization, they made even more smaller IT system. These are composed of following tools:

- CAD
 - Coordination Drawing (Sogo-zu)
 - Shop drawing of building fabric
 - Production drawing
 - Drawing of devices and scaffolding
 - Scheduling
 - Sketches for comparing alternative construction method
- Database
 - Minutes of the discussion
 - Daily report by subcontractors
 - Record of regular meeting
 - Record of questions and answers between involved parties
 - Measured data in site
 - Report of sample tests
 - Request of machines
 - Design management document (date and person in charge and so on)
 - Personnel entered to the site
 - Format of report to authorities and parties related to the project

The site staff of this project give up to manage the single server because there is not enough number of staffs to maintain server. Alternatively, they established the network where anyone in the office is accessible to the other staff's machine where information he/she need temporarily need is stocked. This method has the benefit to make it clear who is responsible to the specific database, though there are lower data securities.

5. Potential of communication network among construction team members

Practices and evolution of down-sizing of IT tools by Tokyu gave impact to researchers and practitioners in construction industry. Many of them gave attention to the potential of network communication among construction team members. Eventually various prototypes were proposed.

For instance, Miyabe proposed prototype using HTML (Miyabe et.al. , 1997). The management of interior finishing works is one of the difficult area to apply IT, because the activities of various specialist and trade contractors are complicatedly correlated. Miyabe experimentally invented prototype IT tools which aid concurrent and intensive communication between construction managers and specialist/trade contractors, where HTML software is applied. The IT tool has five kinds of function to notice 'changes' to all related parties in construction team through the networks. These functions are; the change of scheduling, the change of activities, the rearrangement of specialist and correlated parties, the change of content of shop drawings and the changes of other items. All the information is displayed to all related parties through the network. Though the prototype need improvement in data security function, the prototype proves the potential of communication networks among construction team members. This is another example of down sized IT

support tools for construction management.

6. Concluding comments

The practices introduced in this paper suggest the potential of project-base development of IT tools for construction. The practices by Tokyu gave impacts on the other large contractors. One of the largest contractors in Japan is now implementing experiments to use project base developed tools in the big project in Tokyo, though they have more sophisticated and powerful system developed in R&D department in headquarters. The fact indicates the effectiveness and comprehensiveness of project base development of IT tools.

Once the tools are developed in one specific project, it is probable that these IT tools are used in other project through customization. This is not the top-down dissemination. This is horizontal dissemination. During the process of horizontal dissemination, tools are used in more smaller and 'ordinary' project. In this process, the tools are down-sized.

The facts introduced in this paper confirm that construction is a 'project-based (or at least project-led) economic activity (Groak, 1994)'. Practices in Japan provide the lessons that appropriate sized IT tools should be applied depending on the specific need in the project.

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