The Organization and Management of Construction

SHAPING THEORY AND PRACTICE

VOLUME THREE

Managing Construction Information

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International Symposium for

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SHAPING THEORY AND PRACTICE

VOLUME THREE

Managing Construction Information

Edited by

D.A. Langford and A. Retik

Construct I.T.

Centre of Excellence

The National Network for the UK

IN ASSOCIATION WITH THE NATIONAL CENTRE
FOR EXCELLENCE FOR INFORMATION TECHNOLOGY

UNIVERSITY OF STRATHCLYDE
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CONTENTS

Preface ix
Introduction to Volume Three xv

PART I INFORMATION SYSTEMS AND METHODS 1

1 **The Internet and construction** 3

What constructors and construction managers need to know about the information superhighway
D. Corbett 4

Managing construction information effectively using integrated databases
G. Aouad 14

The construction alliance and electronic information exchange: a symbiotic relationship
A.N. Baldwin, A. Thorpe and *C. Carter* 23

Collaborative student design projects using the internet as a medium for the exchange and management of architectural design information
A.P.H. Dobson, W. Dokonal and *I. Kosco* 33

Development of environmental management systems
A. Griffith 43

2 **Knowledge engineering and construction** 55

The development of a knowledge based expert system for construction claims analysis
Myron W. Chin and *Anthony Lee Young* 56

Self-paced learning using graphics software
D.H.T. Walker and *B.M. Lloyd-Walker* 65

Integration in the construction process: the way of starting in developing countries?
Wilco Tijhuis and *Ger Maas* 78

Is briefing innovation?
P.S. Barrett, J. Hudson and *C. Stanley* 87

A knowledge-based environment for the management of housing development in China
Qiping Shen 96

Managing buildings for the next generation: asset management using spatial information systems
J. Roorda 106

PART II IT AND THE CONSTRUCTION PROCESS 123

1 **Design construction and IT** 125

Tendering documents for the design-and-construct competition
P. Pernu 126

Methodology of specialist contractors' involvement in design development for construction
Tomonari Yashiro 135

The use of VR in support of construction tasks
I. Faraj 142

Performance standards derived by the management of information and artificial intelligence
T. Kashiwagi 150

An object-oriented model based approach for evolving information representation
Y. Rezgui, A. Brown and *G. Cooper* 160

Computer-aided generation system of quality specifications for construction projects
Sou-Sen Leu and *Ho-Chien Liu* 170

2 Project control and IT 179

Optimization of linear construction projects using optimal control
P.W.M. Tam and *V.K. Handa* 180

Intelligent risk management for construction project control
E.N. Wirba, J.H.M. Tah and *R. Howes* 189

Automated real-time manpower productivity control
Eitan Goldscmidt and *Ronie Navon* 199

Computer aided conflict resolutions in construction planning and management
H.M. Al-Tabtabai 206

How can IT affect the construction process?
Jan Söderberg 217

An information systems model for concurrent construction project partnership environments
N.N. Mitev, F.A. Wilson and *A.T. Wood-Harper* 226

3 The construction firm and IT 237

Feedback from facilities management to design and construction – systems issues
J. Bröchner 238

Construction firm organizational effectiveness: a neural network-based prediction methodology
R. McKim, A. Adas and *V.K. Handa* 247

IT as a function of managerial strategy
B. Mraović 257

Technology management in construction: a management, teaching and research framework
Keith D. Hampson 267

Using action-research to compare the theory and practice of managing housing information
S. Allen and *A.J. Hinks* 276

Contemporary construction management graduate education: an industry-developed masters program
K.K. Bentil 287

PART III EDUCATION, INFORMATION AND IT 297

Some experiences in education for construction management and economics
Z. Prascevic and *S. Petrovic Lazarevic* 299

Capability learning and the construction professions
A. Ashworth and *A.J. Bridge* 307

The organisation of construction research in successful university departments
P.R. Lansley 317

Towards construction project management foundation classes and software components
J.H.M. Tah, V. Carr, L.G. Wang and *R. Howes* 325

The use of computer-assisted learning in the education and training of construction professionals
B. Sloan 334

Introducing information technology in construction: pains and gains
S.N. Tucker and *S. Mohamed* 348

Index 357

PREFACE

1. Introduction

This volume of the proceedings contains a selection of papers concerned with the management of information. Developments in information technology (IT) have increasingly seen economic activity become focused around information. Its effective management and application have become dominant issues in many sectors.

This is now applying to such an extent in construction that the study of information management, and its associated technologies, has become recognized as a subject in its own right. It has its own journals and conference series. It is also a subject that is of major importance to governments and companies looking to improve the operations of the industry and its competitive future. This volume is therefore timely in collecting together a picture of the current state of thinking in academic groups from throughout the world.

Innovation within a sector occurs through advancement in the leading edge of current practice. Such advancements are supported by the underlying state of thinking, knowledge and technological development in the scientific fields that support that sector. Research and scholarly endeavour in the wider field of construction management is to a varying extent converging on a pattern. This pattern can be defined by the subject, style, source of data, nature of contribution and sources of inspiration adopted by the researchers. This move towards cohesion within an academic field is seen as a sign of maturity. Maturity may be triggered by: collaboration between members of that field, the unifying influences of communications technology, the demands made by industry as the customer of that research, or the influences of research funders. Often such cohesion may arise naturally through traditions and communication that build up within organs of an academic discipline such as its leading journals or series of conferences such as these. The cohesion can be influenced by specific and deliberate activities.

Cohesion within a field is not necessarily a good thing in itself. Much of the richness of a field of endeavour can come from different groups taking different approaches towards those problems that each perceives as being most relevant at a point in time. However, with increasing international competition to research and innovation, a scarcity of global research funding and an acute current industrial need for progress, there is a strong current climate, certainly within the UK, for coordination of ongoing research and innovation activity. This is particularly the case with a field concerned with IT where the issues and benefits of integration are especially pronounced.

2. The Construct IT Centre of Excellence

The Construct IT Centre of Excellence in the UK is a concerted attempt to encourage cohesion within the field of Construction IT research. The Centre is a multi-University, industry-sponsored, government-endorsed network of organizations concerned with Construction IT research who seek to increase the effectiveness and coherence of their respective research efforts by aiming at synergy between them. Some of the specific research initiatives being undertaken by members of the Centre and others are documented or referred to elsewhere in this volume.

This preface aims to give an overview of the relationship between some of the individual pieces of work reported. It does so by attempting to draw a map of the ground upon which cohesion is being sought in the field of Construction IT research. In doing so it adopts some of the mechanisms and work of the Centre.

3. The technology-push and market-pull models of technological innovation

Contrasting approaches to innovation can be defined in terms of the technology-push and market-pull paradigms. The former assumes that pure technological experimentation in emerging technologies will enable applications to be identified and arise as innovations. The latter assumes a business need is perceived for which innovative solutions are sought. Solutions may take a number of forms of which one may be technology. Armstrong has rather eloquently illustrated the dangers of adopting an entirely technology-push approach to research and innovation by his analogy of rain dancers. The stages in considering the extent to which a rain dancer presents a solution to a perceived problem are as follows:

Stage One: *There's a drought – appoint a rain dancer.*
Stage Two: *The dancer is dancing but its still not raining.*
Stage Three: *'I know it didn't rain but didn't you like the dance?'*
Stage Four: *'Who cares why it rains? – I'm a dancer.'*

In attempting to build an overall model of innovation in Construction IT, a combination of the technology-push and market-pull perspectives is appropriate. Both are parameters within the map of Construction IT research being used for coordination within the Construct IT Centre of Excellence.

3.1 Emerging generic technologies

Developments in generic technologies most often come from outside of our field. Within it, we are in a position to look to apply those that offer innovative potential to our sector. This is a key focus of much of our research in Construction IT and many of the papers that follow in this volume are attempts at innovative applications of emerging generic technologies. Dominant generic technologies of importance to Construction IT research at present include:

- visualization – including virtual reality;
- communication – including video-conferencing and EDI;
- intelligence – including knowledge-based systems, case-based reasoning and neural technology;
- integration – including document management, object technology and applications in concurrent engineering; and
- automation technologies – including optical recognition and bar codes.

3.2 Levels of market-pull

There are clearly a whole variety of business drivers affecting construction worldwide. Dominant amongst these are issues of globalization, the environment, customer orientation, and concerns with productivity and quality. It is possible to classify a series of levels at which some of these apply:

- national;
- professional/institutional;
- construction enterprise;
- project/product;
- people.

Papers in this volume show examples of applications of generic technologies at each of these five levels. Each level represents a part of the ground over which we seek overall coordination of research in our field.

4. Managing information in the project process

Within the picture of a number of market-pull levels presented above, a dominant perspective is that of the basic operating level of the industry, its projects. 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

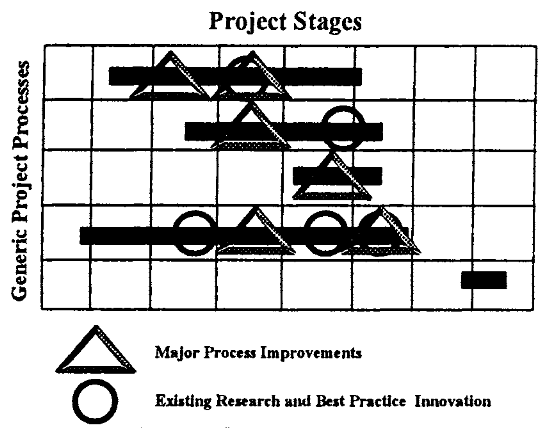

Figure 1 The process road map.

complete an extensive training programme. BAA are also using their project process as a basis for exploring the innovative potential of IT.

BAA are major players within the Construct IT Centre of Excellence. Their project process has been adopted by the members of the Centre as a basis for part of its work in attempting to identify and encourage cohesion in Construction IT research. Figure 1 illustrates this in principle by showing a process road map upon which current and future research may be navigated.

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 prioritized on the basis of the extent of process improvement that are possible.

5. Conclusions

Within a major conference, and in an associated publication such as this volume, an opportunity exists to take stock of where a discipline has developed to and where its future paths of evolution might lie. The mission of the Construct IT Centre of Excellence is to do this on an ongoing basis by both observing and influencing current patterns in Construction IT research. In order to do this, a picture of the field of Construction IT research is required. Such a picture can be viewed from many different perspectives. The use of generic technologies, levels of market-pull and parts of the project process are three interlinked perspectives being used within the Centre. They may be useful to consider the links between other papers within this volume.

6. Acknowledgements

The work of the Construct IT Centre of Excellence is directed by a Management Board led by Geoff Topping of Taylor Woodrow. Martin Jarrett, Graham Mathews and Matthew Bacon from the Board have been particularly influential in steering the research coordination work of the Centre. I am also grateful to my colleagues Andy Clark and Peter Brandon for their contribution to the thinking behind the work.

Martin Betts

Salford
April 1996

INTRODUCTION TO VOLUME THREE

Managing Construction Information is produced in conjunction with Construction IT Centre of Excellence – The National Network for the UK. The volume is broken down into three sub-themes and six sets of papers. These are:

Sub-themes	*Sets*
• Information systems and methods	The Internet and construction Knowledge engineering and construction
• IT and the construction process	Design, construction and IT Project control and IT The construction firm and IT
• Education, information and IT	[Construction education and research]

The first sub-theme looks at how the medium of the Internet can improve communications in our industry and then explores how information may be structured to enhance communications. This is amplified in the second sub-theme – IT and the construction process – where mechanisms for integrating design and construction are reported. The third sub-theme draws in the growing body of knowledge concerning how information is best transferred from researcher to industry and from teacher to student.

The structure of the volumes

To organize the range of topics covered by the W65 Commission the papers have been structured into three volumes. Each volume focuses upon a particular theme. These themes are:

- Managing the Construction Enterprise
- Managing the Project
- Managing Information

Within each theme there are sub-themes which collect together papers around a specialist area of interest and then within each sub-theme there is a further selection to collect together papers on similar topics.

This approach is intended to assist the reader in identifying and consolidating areas of special interest and to link together subjects appearing in each volume.

Maintaining standards

In line with the growing confidence and maturity of the discipline, the papers contained within the volumes have been subjected to exacting standards of refereeing. Of the 241 abstracts received, 183 were selected for development into full papers. All of the full papers received were then refereed and authors invited to incorporate the referees' comments into their papers. At the time of sending the material to the publishers 161 papers had been accepted. The standards achieved ensure that the papers presented in the volumes are of a standard expected in refereed journal articles.

Acknowledgments

We would like to record our special thanks to members of the organizing committee, the scientific committee and the conference organizers, Meeting Makers, especially Susan Miller and Elaine Bone. Particular thanks are due to Edith Henry of E & FN Spon for the painstaking attention to the detail associated with presenting the papers for the 8th International Symposium of the W65 Commission on Organization and Management of Construction.

Dave Langford
Arkady Retik
Glasgow, June 1996

Part I
Information systems and methods

1 The Internet and construction

WHAT CONSTRUCTORS AND CONSTRUCTION MANAGERS NEED TO KNOW ABOUT THE INFORMATION SUPERHIGHWAY

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Abstract

*'Telephony' - a science once reserved for those on the inside track of the communications industry responsible for design, layout and implementation of the **'telephone network'** as we know it: a process that just under one-hundred years ago may have involved a horse-drawn wagon, driven by the installation technician bearing fabric-entwined, copper cable to establish the voice transport medium commonly referred to as "dial tone".*

*Gone are the limitations imposed by physical barriers to 'hard-wired' systems and enter the **"Information Age"**. Today's intricate, **international telecommunications scheme**, a trillion dollar industry, involves the transfer of voice and data via digital circuitry using 'hi -tech' equipment.*

*This paper explores a number of the issues related to the future of the 'Information Superhighway' -- identifying some of the skills and experience-base required to **lead the construction industry into the 21st century**. It also highlights some of the technological issues created by the breadth and depth of these services as well as construction industry concerns regarding the access, availability and distribution of these services by firms in the future.*
Keywords: information super highway, telecommunications, digital technology, broadband network, regional holding companies.

Sommaire:

La Téléphonie, une science autrefois reservée pour ceux qui sont sur la voie intérieure de l'industrie des communications, responsables du dessin, de l'arrangement et de l'implementation du «réseau téléphonique» comme nous le connaissons - un processus qui le siècle dernier aurait peut être nécessité d'un chariot, conduit par l'instalateur qui aurait porté de câble en cuivre, entrelacé avec tissu, pour établir ce qu'on appelle aujourd'hui communement «la tonalité».

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Une industrie des milliers de dollars qu'inclut le transfert des images et des idées sur les ondes hertziennes avec l'utilisation d'équipment de pointe et des circuits digitals. Les limitations imposées par les barrières physiques sont disparues, «l'Époque de l'Information» est née.

Cet essai explore le chemin sur «l'Autoroute de l'Information» et identifie les habilités et la base d'expérience nécessaire pour guider l'industrie de la construction dans le 21^{e} siècle. Il decrit aussi quelques questions crées par l'ampleur et la profondeur de les services offre par les compagnies de télécommunications en plus de les inquiétudes de l'industrie de la construction sur l'accès, la disponibilité et la distribution de ces services.

1. Introduction

In little over a decade, the telecommunications industry has been transformed from a protected monopoly into a plethora of opportunity made accessible to competent competitors. Although the industry remains in many respects a regulated utility, many of the products, by-products, and services, resulting from the 1984 divestiture created by Judge Greene's historic decision, created a tremendous opportunity for expansion or the development into alternative markets for noteworthy contractors and related support personnel (i.e. - material/equipment suppliers, designers and planners).

2. Historical perspective

When Judge Harold Greene issued the *Modified Final Judgment*[1], effective January 1, 1984 resulting in the deregulation of the telephone industry. This **"divestiture"**, opened the gates of competition allowing any and all *qualified* constructors the ability to provide systems and services linking individual consumers to international telecommunications networks. Primary restrictions of the MFJ ruling prohibit regional Bell Operating Companies (RBOCs) from providing interLATA[2] (long distance) service and manufacturing customer premise (CPE) equipment. The break-up of **AT&T** caused a schism that sent tremors throughout the US communications industry leaving AT&T, the long distance company; Western Electric, major manufacturer of switches and equipment; the regional holding companies (RHCs) nostalgically nicknamed the "Baby Bells", Bell Laboratories and Bellcore, the centralized research arm of AT&T and the RHCs respectively; to navigate their way through the resultant turmoil of divestiture by forging a path of reliable voice and data transmission into the 21st century.

As a result, previous restrictions limiting the installation and maintenance of telecom facilities and equipment were no longer in effect. Local providers of telecommunications goods and services are insured "equal access" by the provisions set forth in the MFJ ruling. This provided equipment manufacturers, contractors, technicians and marketing personnel with their first opportunity in the history of telecommunications to capitalize on the provision of telecommunications services provided to <u>millions</u> of American homes and businesses.

---

[1] to the 1982 Consent Degree, AT&T antitrust suit

[2] local access transport area

3. Transformation of management philosophy

Increased competition in the respective markets has forced management to evaluate century-old practices and procedures, causing many entities to shed the *cloak* of monopolistic protection along with the *'Telephone Company'* image and enter the *'Age of Information'*.

Corporate *downsizing* and *quality improvement (TQM)*[3] *processes*, necessary to maintain favorable profit margins, have left telecom upper and middle management, supervisors, staff and field employees reeling in the wake of the industry break-up. The needs of consumers calls for effective management procedures and customer service plans which necessitates a flexible workforce, and diversified installation and repair techniques and shortened response times.

In order to compete successfully, construction firms interested in "cashing in" on **system placement** and **maintenance** opportunities must develop procedures to successfully withstand government bureaucracy, certification standards, long-term payment schemes and financing requirements specific to the telecom industry.

Competitive bid strategies, a concept not alien to the construction industry, is quickly becoming the method of choice for the award of telecom contracts. This provides an opportunity for related construction firms to enter the race to capture market share through a familiar medium. In addition, the acquisition of long term maintenance contracts are a definite means of ensuring repeat business. With a restricted number of qualified competitors available, even the introduction of training classes requiring significant effort and the commitment of resources may prove to be worth the initial investment.

4. Technological Outlook

In the past, access to technical training classes for contractors and design professionals were restricted to phone company employees and selected vendors and supply agents. Telecom forms have begun to establish training "Academies" which offer technical training necessary to design, install and maintain distribution networks. In selected cases, experienced retirees form alliances which allows them to act as 'in-house' trainers or consultants. With the creation of new opportunities for planning, installation and maintenance of these complex distribution networks, local municipalities will be required to establish procedures for access to facility records and network distribution systems.

Equipment, facility and network engineers of local utilities which may include electric, telephone, and more recently cable, jointly manage the distribution networks of necessary facilities in response to public need in a manner compliant with regulator requirements and industry standards. "POTS", or plain old telephone service lines, made of copper wire, are connected to analog and digital switches in central offices (COs), distributed via buried, aerial and underground (conduit). These cable pairs are terminated in strategically

[3] Total Quality Management

placed 'terminal' boxes throughout neighborhoods, business districts and industrial parks constituting the basis for voice and data transmission for most of the continental United States.

To address the concern for the maintenance and control of municipal underground facilities many states have instituted "One Call" programs whereby utility and private excavators are required to notify state authorities of the proposed excavation or demolition project prior to beginning construction. All facilities present at the proposed site must be clearly marked to provide a more reliable infrastructure for the maintenance of utility systems. Existing service providers, impending contractors and facility administrators are therefore challenged with establishing practices and procedures which provide 'controlled' management of facility networks as well unlimited access to responsible contractors and service providers.

In some cases the technical expertise required resembles other forms of construction practice (e.g. electrical). Other areas require advanced training. The use of lightwave transmission via fiber-optic cable with digital cross-connect switches and bandwidth management systems has upgraded the equipment installation worksite from manholes to controlled environmental vaults which once completed must be closely monitored for air quality and moisture content. Optic cable encases single-mode optical fiber placed almost exclusively for new, digital applications. These optical fibers, (only slightly thicker than human hair), although five times stronger in tension than conventional copper wire, are highly sensitive to abrasion and twisting and therefore require special handling and installation techniques. As a result of impending system upgrades, cable splicers and installation technicians of emerging network constructors require specialized training which includes the ability to maintain and restore systems 'cut-over' from '*in-situ*' copper cables and introduce *pressurized*[4], '*clean*-air' conditions in routine and emergency situations. Skilled personnel must not only attend regular training sessions, but must also become accustomed to performing under more restricted conditions in a more competitive, high-tech environment.

5. **Regulatory Reform**

In 1995, the U.S. Gross Domestic Product (GDP), used to gage domestic economic growth, cites a modest upward trend in this industry which employs nearly 80% of all employees in the broadband service-producing sector directly and indirectly in the production of value-added communication and information services. With the anticipated regulatory relief efforts, commandeered by telecom, cable and other interest groups, *toll service* growth predictions of 30 to 40% by the turn of the century may prove conservative.

The Federal Communications Commission (FCC), the agency charged with monitoring and maintaining national communications integrity, faces the challenge of telecom regulation without limiting the fantastic growth potential of this widening market. Approximately 25% of RBOC activity remains under FCC jurisdiction.

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[4] air pressurized and vacuum-treated to prevent moisture absorption

Regulatory reform has quickly become a key factor in the success of information and technology transfer between regulated competitors. Industry trends since divestiture, clearly indicate a major thrust toward an fully **integrated services network** which incorporates telephone, computer, television and cable services on one syncretized, information transport mechanism. Currently, there is no **one distribution network**, in position to distribute all these services to home or business locations without the resolution of a number of structural, regulatory and transmission issues due to the entanglement of the respective industries.

For example, current regulations limit *individual* ownership of television stations to fifteen. A telecommunications, television, cable or construction firm interested in establishing a single distribution channel for these integrated services would be required to pioneer legislation to remove the restrictions associated with a particular market The design, installation, testing and maintenance of the resulting network would require a unprecedented combination of resources, skills and management insight. This concept presents a major opportunity for growth in the telecom and construction industries.

6. **System requirements/network standards**

Entering the telecommunications market involves an increased understanding of the industry norms and developing standards and system requirements.

The ***Broadband Network*** refers to the range of frequency(ies) utilized for digital signaling by television and cable companies. Telecom (industry) transmission, regulated and limited to a comparatively *narrower* and more *restricted* airspace is currently engulfed in numerous legislative efforts to relieve restrictions thereby allowing telecom firms to enter the *'broader'* market available for the use of interactive goods and services. Although the television and cable companies have a distinct advantage regarding programming capabilities due to network access, they are constrained by technological limitations imposed by existing equipment and network capabilities.

As a result *network architecture*, the design and layout of planned distribution systems and *interactive programming* requires a customer-focused, innovative and effective management team to anticipate customer demand and to meet dynamic and fluctuating market objectives. This uncanny combination of innovation, opportunity and market demand has resulted in the creation of a *'whirlwind'* of corporate mergers, new product offerings and service expansion.

For the most part, previous television and telecom transmission standards were generated internally by the respective management entities; while plant and equipment placement, connection and distribution practices were governed by construction industry standards.

Even television, essentially unchanged prior to the 1984 divestiture, now provides, what is considered by many to be the single, most promising opportunity for expansion in the communications realm. Innovations such as cable and high definition television (HDTV), video-on-demand, and the inevitable convergence of computers, telephone and on-line services has redefined a market, now unbridled in possibilities.

Construction and maintenance engineers and technicians will be required to perform immediate recovery that may affect thousands of lines and service delivery concurrently. The selection of equipment is a critical aspect of the system planning process. Typical feasibility and cost analyses should anticipate 5 to 10 year preventative (equipment) maintenance plans. Proper training, equipping and simulations for emergency repairs represent a new challenge for technicians and maintenance personnel.

System field engineers are challenged with the task of assessing existing plant, recommending and implementing system upgrades to meet current market demand as well as anticipate future growth and expansion. Outside plant engineers are no longer afforded the luxury of instituting long-term construction and maintenance budget and planning techniques. Labor projections, capital budgets, equipment depreciation, system performance and testing methodologies must constantly be evaluated to insure compliance with regulatory requirements, industry standards, organizational and quality objectives.

The impetus caused by the decreased regulation of the telecommunications industry and the concurrent expansion of satellite and video transmission services has forced the establishment of network standards to govern the format and processing of digital signaling. ANSI[5] has formed a committee comprised of numerous telecom vendors and service providers to facilitate design, placement, management and maintenance of emerging network architecture to be used in the voice and data transmission of telecom, audio- and visual signals.

In 1988 the ANSI SONET (synchronous optical network) T1X1 committee agreed upon *Phase 1* specifications governing optical parameters, signal format and processing requirements used by the telecommunications industry. Since that time the SONET standards process has diversified to address a variety of service applications, rapidly becoming the blueprint for circuit provisioning, allocation and interconnectivity between remote and centralized (network) office locations.

Opportunities in wired and wireless communications include the provision of information 'Real Time' services, video and entertainment technology. The efforts of Ted Turner, entrepreneur and emerging telecommunications mogul, have recently been rewarded with Time Warner's receipt of *Communication Technology's 1995 Service in Technology Award.* The Full Service Network (FSN) team has received international recognition for its ability to address consumer needs in the design of its network and creation of new services.

7. **Economic incentives/market-growth**

From 1982-1994 RHC cumulative total returns have increased to as much as 5 times the amount of twelve years ago, averaging double the rate of increase of the Standard & Poors' returns for the same period.

Many of the same indices monitored to chart traditional growth in construction and related industries also predict trends and demands of the next generation of telecom development. For example, United States demographics reveal that between 1984 and present, national population growth peaked at 10.4% during 1995 with the number of

[5] American National Standards Institute

households increasing by 17.1%. While median income per household averages $34,017, telephone penetration, the percent of eligible (POTS) telephone users, has risen to 94.9% -- fueled largely by the increase in technology and the drop in consumer costs for domestic equipment over the past few years.

In the mid-Atlantic region 1994 toll revenues represent $7.4 billion and $1.4 billion inter- and intraLATA markets respectively. Due to the large investment required to place and maintain plant and equipment, RHCs can capitalize on economies of scale resulting from minimal incremental costs in the maintenance of local distribution networks by establishing inter- and intraLATA[6] toll pricing schemes.

Network access, measured (and priced) in minutes of use (MOU), is a primary growth opportunity for revenue generated by sale to large businesses and interexchange carriers (IXCs). By controlling the 'plant in place' local utility companies and potentially, contractors and emerging constructors are able to secure a market share by controlling access to the information network(s) of limited geographical areas. The resolution of issues regarding access security to prevent the breach of programming integrity will undoubtedly contribute to access line charges depending upon if a *scrambling algorithm* accompanied by a "smart card" is merely installed or whether field surveillance is prescribed as the security method of choice.

Federal (government) system requirements, largely affected by communications and technological needs of the federal government has 'opened the flood gates' of competitive government contracting opportunities. Although contract awarding procedures are highly regulated, federal buying, accounting and payment procedures are well documented and closely monitored. Additionally, successful bidders stand a good chance of receiving extended contracts and repeat business. In 1994, Federal System contracts - made up of 200 military and civilian agencies - exceeded $300 million with a projected increase in contract value of 10% in 1995. The (US) *President's National Performance Review* proposes the use of efficient and cost-effective transmission networks to improve government performance and reduce costs. Current ongoing U.S. government projects include:

- General Services Administration (GSA), **7 year** project for 10,000 Digital Centrex lines **($18.7 million)**
- Washington Agency Telecommunications System (WITS) Project **10-year** project for 143,000 Centrex[7] and 10,000 ISDN[8] lines **($262 million**
- Telecommunications Modernization Project (TEMPO) - Department of Defense **10 year ISDN** contract **($600 million)**
- Public Health Service **10 year** contract servicing 41,000 voice and data lines **($120 million)**
- Department of Energy - Savannah River Project, Aiken, SC **10-year** cable infrastructure and voice/data contract for 300 square-mile campus **($83 million)**

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[6] Local Access Transport Area - 165 geographical (service) area created by divestiture, allocated among the resulting eight (8) RHCs

[7] internal telecom network linking multiple locations and providing signal transfer using 4-digit extensions (e.g.- x1234)

[8] Integrated Services Digital Network - allows transmission of voice and data

8. Quality assurance

Reliable testing methods, trouble-shooting techniques and recovery plans are critical to the maintenance of digital and *remaining* analog transmission systems. (The MAJORITY of telecom plant in place is copper - due to significant initial investment required and the regulation of pricing and depreciation scales used, system upgrades, cut-overs and replacements incorporated in (long term) capital budget plans or used in the recovery of extreme failure or deterioration of network distribution systems.) With the increased use of *emerging* and *hi-tech* solutions, network systems are subjected to 24-hour demand and deteriorate quickly from acceptable performance quality to *complete failure* once line integrity is compromised. Digital tests such as bit error rate (BER), modulation error ratio (MER) coupled with error correction coding, pre-equalization and signal recovery procedures require the precise coordination of field testing, installation and repair crews to ensure reliable service.

The operating environment has a great deal of influence on overall system performance. Heat sink fins and dissipaters are mounted on electronic equipment to regulate transfer heat to the surrounding area. Equipment subjected to any extreme ambient conditions or restrictions will most likely suffer severe loss in service life expectancy. The ability to establish and maintain *controlled* operating environments is critical to construction and installation firms' ability to remain competitive in today's market.

9. The competitive edge/ international opportunities

Currently RBOCs control the majority of the *plant* in place which allows telecom access to consumer homes in the form of (copper) wired pairs. Consequently, with the onslaught of satellite and video-technology, local television and developing cable networks are in the prime position to take advantage of the unprecedented market expansion realized with the offering of interactive, new home entertainment services.

Maintaining a competitive, high-growth, high-margin, national and global business strategy requires that construction firms become highly specialized. For example, Bell Atlantic - the mid-Atlantic RHC that serves as a gateway for 11 million household and 1.2 million small-business customers, experienced nearly a 20% turn-over in its marketing personnel during its transformation from the *Ol Telephone Company'* the primary provider of telephone service -- to the tenacious, ten-year old provider of interactive "POTS" and wireless communications services ever-present in malls and other highly visible distribution points throughout the world.

It is a rare occasion where three or more *'qualified'* bidders are relegated to attending a pre-bid meeting and extensive prequalification program; given 30-60 days to prepare a bid submission; and await with anticipation, for an equivalent period for the lowest, responsible bidder to be awarded the bid. Quite the contrary -- oftentimes the installer of high-tech, digital, transmission equipment and facilities is sought after by the owner or entity responsible for providing the resulting service(s)

In May 1995, Bell Atlantic (BA), one of industry's foremost leaders in communication's services announced its plan to construct a ***full-service network*** to service six major markets in the midAtlantic region and surrounding area(s) which includes a state-of-the-art Digital Production Center and a merger of domestic cellular capabilities with Nynex (New York Network Exchange, north Atlantic RHC) as well as joint-venture partnerships with Nynex, U S West (midwestern RHC) and Pacific Telesis (west coast (US) RHC) respectively for the formation of a wireless, service and nationally branded home entertainment alliances.

International pursuits include the deployment of *Stargazer*, an Italian Video Services and Telecom effort using ADSL technology. International agreements, such as those recently executed by Telecom New Zealand (TCNZ) and Grupo lascell (Italy) for (broadband) network and infrastructure modernization respectively, require that the implementation of the construction phase(s) differs notably from traditional agreements which typically governing construction projects.

10. Conclusion

A **"synergism"** is required which allows the owner, design professional, manufacturer and installer to work in concert with one another from the conceptual and planning stage of the proposed telecommunications construction project to insure that the customer receives a timely and cost-effective solution. Positive project results frequently generates repeated and long-term business relationships. This *modified* design-build delivery process does not necessarily eliminate or minimize the role of the design professional. In fact, with increased levels of management responsibility, interactive design solutions, multi-level partnership agreements dynamic programming requirements, fluctuating regulatory environments and constantly upgraded equipment -- it may prove impossible to typify the delivery system most effective in addressing the needs of today's telecommunications consumer.

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[9] National Society of Black Engineers

MANAGING CONSTRUCTION INFORMATION EFFECTIVELY USING INTEGRATED DATABASES

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ABSTRACT
An integrated project database can be looked at as a central repository system used for the storage of data and processes required by the various disciplines working during the lifecycle of a project . Ideally, every piece of information whether it is a fact, a figure, etc should be stored only once in the database and the client, designers, suppliers, contractors and external bodies should have access to the same database. This ensures that information in the database is consistent as all disciplines have access to common data.

This paper addresses the issue of developing a framework for an integrated database which can facilitate the design and construction processes of a project . Such databases can be used by both building and civil engineering projects. It is envisaged that integrated databases will allow the construction industry to better structure its information, thus benefits in terms of improved efficiency, better management and enhanced performance can be realised.

A historical background of integrated databases is included in this paper. The benefits such databases can offer to the construction industry are highlighted. Also, the problems facing the development of such databases are discussed. In addition, a strategy for the development of these databases is specified. Finally, a reference to the ICON integrated database project being developed at Salford University in the UK is made. The experiences learnt so far from this project are discussed. State of the art information modelling techniques used by ICON in order to develop a framework for an integrated database, namely Information Engineering, Object oriented analysis and design and CASE (Computer Aided Systems Engineering) tools are detailed and discussed. The various contextual (Strategic) and conceptual (object, process and activity) modelling techniques employed by ICON are also addressed and described.

SOMMAIRE
Une base de données projet peut être considérée comme un systèm central fédérateur, au sein duquel sont stockées l'ensemble de données ainsi que des procesus nécessaires aux différents acteurs concourants à la production d'un projet de construction au travers de

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son cycle de vie. Dans un tel context, it est evidemment souhaitable d'éviter toute redondance des données, de façon à assurer l'intégrité et la cohérence de l'information produite et manipulée par l'ensemble des acteurs du projet.

La présente publication décrit le cadre conceptuel relatif au développement d'une base de données intégrée visant l'amélioration de processus de conception et de realization d'une opération de construction. Une telle base de données, destinée ou secteur du BTP (batiment et travaux publics), devrait permettre une meilleure structuration de l'information, contribuant ainsi à une amélioration substantielle de la gestion, de la qualité ainsi que des performances de l'objet bati.

Un historique décrivant l'état de l'art est présenté. L'accent est en particulier mis sur les enjeus sous-jascents pour la profession qu'offrent l'utilisation des bases de données. Il est de même fait référence aus problèmes potentiels inhérents à une telle enterprise. De plus, la stratégie ayant trait au développements des bases de données est spécifiée. Au final, it est fait référence au projet de base de données integré ICON développé à l'université de Salford en Angleterre. Les enseignements acquis par le dit projet sont présentés. La présente publication décrit également l'état de l'art relatif aux techniques de modélisation de l'information utilisées par tle projet ICON pou le développement d'un cadre de base de données intégré. Il est également proposé une présentation des techniques utilisant les outils supportant les méthodologies relatives à l'ingénierie de l'information, l'analyse et conception orientée objet ainsi que la technique CASE (Computer Aided Systems Engineering). Les différentes techniques de modélisation contextuelle (stratégique) et conceptuelle (objet, processus, activité) utilisées par le projet ICON sont également mises en avant et décrites.

1 Introduction

The requirement for integrating information and improving communications in the construction industry has been addressed by many researchers in the last few decades. However, fruitful results have failed to emerge. This may be partly attributed to the fact that research has been undertaken on ad-hoc basis resulting in stand alone integrated applications which are not contained within a structure or framework. In this paper, "Integration" is defined as the ability to share information or sub-set of information between different actors/disciplines using a common model developed within a sound and reliable framework. Such integration can occur at the international/ national/ industry/ enterprise or project level. It is envisaged that such integration can be realised using integrated databases coupled with communication means such as networks, satellites, and supported by data exchange standards such as electronic data interchange (EDI). The subject of this paper is integrated databases at the project level.

The importance of developing integrated applications has been highlighted by many researchers and professionals in the last few years. In fact, the notion of shared information has been around for approximately thirty years. However, it has to be said that fruitful results in the area of integrated applications and databases have failed to emerge largely because of the lack of a strategy or framework which is suitable for development. In addition, to a great extent, the construction industry is not aware of recent developments in the IT field, in areas such as information modelling and analysis. This paper puts forward the view that the adoption of a development strategy or a framework coupled with the powerful emerging IT technology, namely CASE (Computer Aided Software/Systems Engineering) tools, Information Engineering and Object Oriented Analysis Methods will facilitate and enhance the development of integrated databases resulting in improved efficiency, better management and enhanced performance.

2 History of integrated databases

General ideas regarding information sharing can be traced back to work on data coordination in the 1960's in the UK. However, the requirement for an integrated project database was first established in the early 1980's by the Advisory Board on the Built Environment of the National Academy of Science and Engineering in the USA [1]. At the same time, Stone and Webster in the USA [2] established a computer system for engineering design and construction incorporating many of the principles identified by the Advisory Board. Since then, the idea of integrated databases has started to gain more momentum and recognition [3]. Computer Integrated Manufacturing (CIM) was established first by the manufacturing industry to address the issue of fully integrated manufacturing environment [4]. More recently, Computer Integrated Construction (CIC) centres have started to appear in construction firms and universities to deal with the aspect of integration, including the integrated databases feature [5]. Active research in this area is being undertaken in many countries including Finland, France, Netherlands, and the USA . The ICON integrated database project being developed at Salford University is amongst the latest in this field.

3 Benefits of integrated databases and problems facing their development

The ideal integrated project database will contain all information about the project and its environment. Information such as the client's requirements, the designer's specifications and design representations, the estimator's cost estimates, the planner's time estimates, the external authorities's requirements and constraints should be stored in the database and retrieved by authorised users as required. It is the integrated database which should be used as source of information and common interface, not the drawings, for the activities required by the various disciplines. This implies significant changes to the way the construction industry operates as, traditionally, drawings are considered as the main sources of information for the planner, architect, civil engineer, contractor, etc. However, drawings are just a particular representation of information which could be expressed in a number of different ways. Drawings can also be subject to misinterpretation by the various disciplines and can date quickly becoming unreliable. They are often incomplete and not available when required.

The benefits that integrated databases can offer to the building and civil engineering professions are numerous. Most importantly, communications between the various parties involved in a construction project will be improved, thus better products can be produced at lower cost. In addition, such databases ensure that all parties have access to authorized common data. For instance, quantities such as areas, volumes, schedules, etc generated by one discipline can be stored in the database and used by another. This ensures that time savings can be realised resulting in increases in the profit margin.

The development of an integrated database is a cumbersome and complicated task. It is anticipated that problems will be encountered in achieving such a task. The problems facing those involved in the development of integrated databases can be classified under the headings of technical, organisational,and financial [6]. The technical problems include those related to the huge processing power required to retrieve information from a complex database, the limited ability of the disk operating system (PC based) in terms of multi-using and multi-tasking, the lack of standard data exchanges and data formats, and finally those problems associated with data management and control in an integrated environment. The organisational problems are those associated with the way the construction industry is structured which makes information flow inefficient. Finally, the financial problems are those related to the purchase of hardware and software, in addition to those costs associated with the training of personnel using the database, and finally the costs associated with the expensive task of running and maintaining the database.

4 A strategy for the development of an integrated database

The integration of construction information, particularly within an integrated database environment, has been tackled so far on ad-hoc basis. The importance of adopting a strategy or framework for development is not fully appreciated. It is suggested in this chapter that the successful development of an integrated database, due to its complexity, can only take place if a strategy is specified and followed. This allows the identification of the critical factors which should be considered in order to achieve the required results. These factors are detailed as follows:

1- Participation: in the past, academic research with regard to complex integrated databases has taken place without the involvement of industry, professional institutions, etc. It is our view that the parties involved in eventually using the databases should be at the centre of the database development. Examples of the parties who should be involved in such development include: industrial organisations, Professional Institutions, organisations dealing with standards, institutions/companies undertaking work of similar nature, researchers/professionals of IT and construction backgrounds, and governmental departments.

2- Development plan: A plan should include the requirements in terms of resources, time schedules, cost schedules related to a phased development. Project management techniques should be employed to meet such requirements.

3- Framework/context: A high level contextual model of the information and processes of the construction industry should be established as a framework for the structuring of an integrated database and its future development.

4- Methodologies: Sound and powerful IT methodologies should be adopted to handle the complexity of information modelling in the construction industry(eg, Information

Engineering, Object Oriented Analysis and Design, CASE tools).

5- Knowledge-based systems techniques: Advanced information/knowledge elicitation techniques should be employed in order to elicit the huge amount of information spread across the various disciplines involved in a construction project (eg, protocol analysis, etc).

5 ICON (Information/integration for construction)

ICON (Information/Integration for CONstruction) is a research project sponsored by the EPSRC (Engineering and Physical Sciences Research Council) and being undertaken at the University of Salford in the UK with its primary aim to assess the feasibility of establishing an integrated database for the construction industry. To achieve this task, ICON is using state of the art information modelling techniques namely Information Engineering, Object Oriented Analysis and Design and CASE (Computer Aided Systems Engineering) tools. The overall picture of the ICON project is shown in Figure 1.

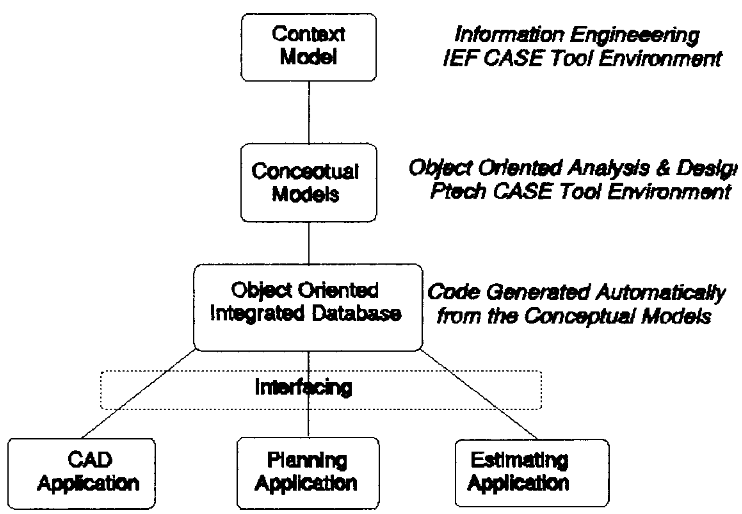

Figure 1 The overall picture of the ICON model

The project is being developed by a group of nine researchers of IT and construction background, assisted and guided by a steering group of ten members including industrialists and representatives of the major professional institutions in the UK (RIBA, RICS, CIOB) and representatives of building standards (NBS). The wide spectrum of expertise used on this project gives ICON strong credibility since it involves both academia and industry working together to establish an information framework. However the scope of this project is limited to those of design, procurement and management of construction. These areas fit properly within a context model defined by ICON which establishes the framework for an integrated database. The ICON project also considers issues such as knowledge elicitation, information modelling including contextual/strategic modelling and conceptual modelling as vital elements for the success of a project of such complexity.

5.1 Contextual/strategic modelling

The use of strategic/contextual modelling will allow the construction industry to improve the structure of its information. Contextual modelling assists in the definition of a top level view of the information architecture which can form the basis for a consistent information base which has capability for expansion. This top level model should take into account the strategic views of the business or industry, thus an alignment between the business requirements and the information architecture can be established at the strategic level.

The Information Strategy Planning (ISP) stage of the Information Engineering Method [7] is one technique which can be used to define such a top level model. It is critical to have the ability to identify areas suitable for integration and automation at the strategic level. These areas provide a top level model which keeps the construction project as a whole in perspective. Information Strategy Planning (ISP) can be used to define such a top level model. This model should contain logical areas or divisions within the construction industry rather than historical ones. These divisions should be based on information requirements rather than the roles performed by disciplines. The ultimate result is the definition of a top level model of areas or activities which can be performed independent of the nature of the discipline involved. The technique described in this paper is that of clustering matrices using the Information Engineering Facility (IEF) CASE tool which is based on the Information Engineering Method. 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 analyzed 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 prioritizing potential areas in terms of information requirements.

5.2 Conceptual modelling

Once a contextual model for the integrated database has been established, the next phase of modelling was mainly concerned with the conceptual modelling of the areas of design, procurement and management of construction using object oriented techniques. The object oriented paradigm supports the notions of encapsulation, abstraction, inheritance and polymorphism [8] which were considered as a must to handle the complex task of information modelling. Encapsulation permits objects to have properties (data) and actions (operation). 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 according to whether the beam is a "rectangular beam" or "T beam", etc.

The object oriented paradigm also supports the notion of "perspectives" which is central to the ICON project. This notion allows the construction professional to view the information from his own perspective. For instance, the architect is interested in features such as colour, aesthetics, texture, etc. whereas the construction planner is interested in features such as time, resource, etc. To illustrate this, we will take the concept of a wall which can be viewed from different perspectives. An architectural wall has attributes such as dimensions, colour, texture. A construction planning wall has attributes such as dimensions, time, etc. It is therefore logical to store common information in the supertype Wall which can be inherited by the architectural wall, etc. The notion of perspective will be addressed in a separate section.

Conceptual modelling is aimed at the identification of concepts/data, relationships between concepts, attributes, and operations which are to be supported by the database. This task should be done independently of any implementation platform. It is the translation of the conceptual models into tables, classes, etc which establish the structure for a physical integrated database. Such a database can be relational, object oriented, etc as desired. In the ICON project, conceptual models such as activity, object and process models have been produced using the Ptech OO CASE tool [9] which can generate code compatible with the Ontos OO database. These conceptual models are described in the coming sections.

5.3 Activity modelling

The ICON top level context model consists of a hierarchy of the main activities performed in building construction. This top level model is decomposed into further hierarchies through activity modelling. The activities of design, procurement and management of construction which are within the scope of the ICON project have been decomposed into further sub-activities. At each level, more detail is added until a stage where it becomes meaningful to describe an activity in terms of the information which can support such an activity. Such an approach gives the analyst more flexibility as more hierarchies can be added to the activity model if required. Each activity is represented by a perspective in the information model. Therefore, information describing a specific activity can be defined at any level. In the ICON project, the information describing an activity is in the form of object models which will be covered in the following section.

5.4 Object and process modelling

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.

An object model is very similar to an extended Entity Relationship Diagram (ERD), except that operations can be attached to the objects. Using object oriented methods, the analyst can examine one object at a time with its required data and operations, thus scoping can be achieved and complexity tackled. In process modelling, the analyst describes graphically the computer program required to implement the operation.

6 The notion of perspective

As mentioned earlier, the notion of perspective is at the heart of the ICON project [10]. Using such perspectives, information can be shared and integrated as required. In ICON, we managed to identify three types of perspectives: domain, integration, and application perspective [11]. A domain perspective describes the information required by a certain domain/activity/task. Examples of these domains are: construction planning, conceptual design, determine procurement systems. An integration perspective describes the information required to integrate more than one domain perspective. Finally, an application perspective describes the information required to map a domain perspective such as construction planning into a commercial planning application such as Artemis.

7 Conclusions

Integrated databases which can handle efficiently the aspect of information sharing between the various disciplines involved in a construction project have considerable attraction in the construction industry. These databases will eventually be used as common interfaces between the various disciplines instead of drawings as occurring in current practice. It is envisaged that these databases will offer many benefits in terms of improved efficiency, better management and enhanced performance to the construction industry as a whole. However, the development of such databases may encounter technical, organisational, and financial problems. It is therefore suggested that a solid and reliable strategy should be adopted for development. Critical success factors such as industry involvement, framework, project plan and advanced information modelling and knowledge elicitation techniques should be observed for the success of such a complicated task. ICON's integrated database being developed at the University of Salford is using such a strategy. It is finally anticipated that integrated databases will be in full use by the construction industry by the next decade provided that development is addressed within a contextual framework and not on ad-hoc basis.

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