A SURVEY AND ANALYSIS OF INTEGRATED PROJECT DATABASES

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ABSTRACT

This paper is concerned with the development of an integrated project database for the construction industry. It briefly reviews the background to the growing interest in an integrated project database (IPDB) for construction projects, and examines the fundamental concept of an integrated project database by discussing the various definitions that have evolved, as well as the various approaches to its development. A detailed survey and analysis of recent UK projects that have sought to develop integrated project databases is also presented. The analysis is based on several criteria such as the application area, development environment, modelling approaches used, reusability, hardware and software requirements, and the use of standards. The paper concludes with an identification of gaps in current research and strategic advice on the future development of integrated project databases.

Keywords – integrated project database, survey, analysis, concurrent engineering

1. INTRODUCTION

The construction industry has largely depended on collaborative working between a number of professional teams brought together, often in an *ad hoc* manner, for the translation of its clients' requirements into physical constructed facilities. Whilst this has entrenched the practice of collaborative working, it has also reinforced traditional disciplines to the extent that, on many projects, an adversarial environment prevails and the fundamental ethos of collaboration is not fully evident. This has resulted in numerous problems for the construction industry with the result that the industry is highly inefficient compared to other sectors (Anumba et al 1995). Competitive pressures from within the industry as well as external political, economic and other considerations are now forcing the industry to re-examine and improve its *modus operandi*. One key philosophy which has taken root in the manufacturing sector and which holds much promise for improving integration in construction is Concurrent Engineering (CE). CE seeks to optimise the design of a facility and its construction process to achieve reduced lead times, and improved quality and cost by the integration of design, fabrication, construction and erection activities and by maximising concurrency and collaboration in working practices (Evbuomwan & Anumba 1995; Evbuomwan & Anumba 1996).

A vital aspect of the adoption of CE principles in construction is the need for an effective communications infrastructure that facilitates seamless inter-working between the disparate professionals involved in construction projects. Such an infrastructure needs to be based on

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the latest information and communications technologies and should facilitate information interchange between members of the project team and across stages in the project lifecycle. It has been suggested that the central kernel of this communications infrastructure should be inhabited by a shared construction project model (Anumba et al 1997). This paper is concerned with the concept of such an integrated project database, its requirements and potential, the approaches proposed for its realisation (including a detailed survey and analysis of current integrated project databases), and strategies for future developments.

2. THE INTEGRATED PROJECT DATABASE CONCEPT

2.1 Definitions

There are several views within the construction industry and the research community on what constitutes an integrated project database (which is also sometimes referred to as the shared construction project model). Some see it simply as an amorphous collection of all the information relating to a project, irrespective of the medium of storage (people's heads, paper drawings and specifications, CAD files, etc.) or the method of dissemination of the project information. Others see it in terms of a single database which holds all the information on a project and which is accessible to all members of the project team. Yet others view the integrated project database as an integration of product models (which hold information relating to the building product) and process models (which hold information regarding the construction and business processes required to translate the product information into a physical product - the constructed facility). These different perspectives are reflected in some of the following definitions:

Gann et al (1996): 'a single project database is an electronic data model to which all participants refer throughout the processes of design, construction, operation and maintenance'.

Bjork & Penttila (1989): 'project models are conceptual structures specifying what kind of information is used to describe buildings and how such information is structured'.

Fisher et al (1997): 'project modelling is object modelling applied to a project and including more information than just geometry'.

Although the concept of an integrated project database may be difficult to define precisely, the above definitions focus too much on the data representation aspects and thus, are neither wholly accurate nor comprehensive. Greater insight into what constitutes an integrated project database can be gleaned from its requirements and characteristics.

2.2 Attributes, Requirements and Characteristics

Several attributes, requirements and characteristics have been associated with the integrated project database. Many of these are reflective of the individual perspectives and biases of the authors whilst others are more robust and generic. There are also those that constitute no more than a wish list.

Anumba et al (1997) see the shared construction project model or integrated project database as central to concurrent engineering in construction and vital for facilitating effective communications between project team members and between stages in the project lifecycle. They suggest that, as a minimum, it should support the following:

- individual discipline interactions with the central model;
- heterogeneous intra-discipline tools;
- configuration management;
- perpetuation of design intent and rationale across stages in the project lifecycle;
- emerging standards for information representation, interchange and interoperability;
- integration with a robust and multi-faceted project communications infrastructure;
- enhanced visualisation of design and construction processes based on multimedia, virtual and mixed reality, simulations, video, etc.
- an open architecture to facilitate extensions and customisation to suit individual project and team requirements.

Similar views on attributes, requirements, and characteristics are promoted by Construct IT (1996), Fischer and Froese (1992), Froese et al (1996), Arnold and Teicholz (1996), Law and Krishnamurthy (1996), and Gadient et al (1996).

These attributes, requirements and characteristics of a shared construction project model or integrated project database extend the definitions provided earlier well beyond the scope of just data modelling. They are reflective of the huge potential that many in the construction industry (researchers and practitioners alike) think is embodied within the concept of the integrated project database. Some of the general approaches being employed in the development of the integrated project database are summarised below.

2.3 Approaches to Development

Although there is a consensus that an integrated construction project database is highly desirable for computer-integrated construction, there is far less agreement on what form it should take. This was alluded to in the discussion of definitions of the term, 'project model' or 'integrated project database'. It is also reflected in the approaches that have been proposed or adopted so far in the development of the model. Some of these approaches are briefly summarised here with references, where appropriate, to research prototypes.

1. **Project Model as Reference Model** - This is the approach that many practitioners seem to favour. This is based on having a 3D CAD or Virtual Reality (VR) model, which simply acts as a common reference model for the project team. In this case, the model does not necessarily hold all project information but acts as a gateway to them.

2. **Centralised Project Database** - This approach involves the use of a single centralised database to which all members of the project team have controlled access (Figure 1). The main difficulty with this approach is that the database could become very large and unwieldy with consequent maintenance and information retrieval difficulties, particularly in a multi-user environment. This approach includes current systems that contain only project documents (Document Management System).

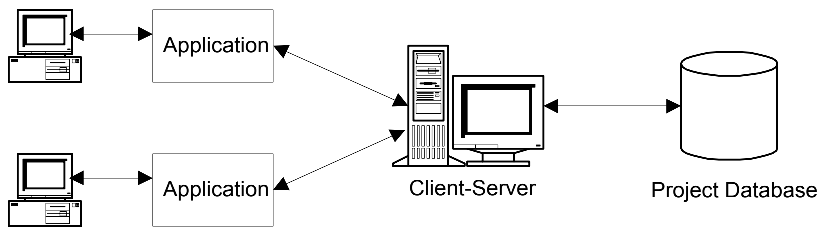

Figure 1: Centralised Project Database

3. **Distributed Project Database** - In this approach, there is no single repository. Rather, aspects of the project database (such as those produced by each discipline) are held at various locations and accessed via a common, standard interface (such as CORBA or DCOM). This approach requires that the different applications support the standard interface but is potentially very effective (Figure 2).

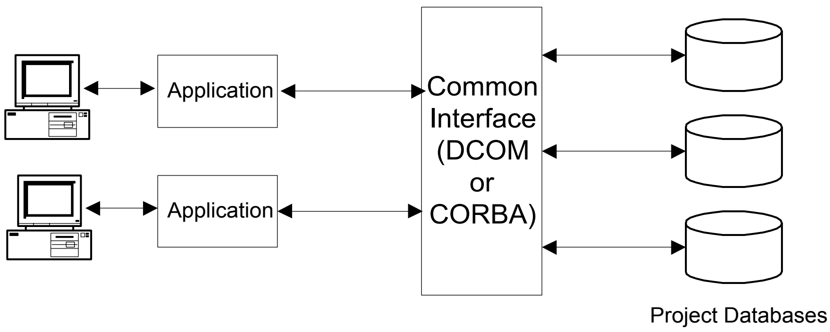

Figure 2: Distributed Project Database

4. **Neutral Format Project Database** - A neutral format database is the core of this approach which requires that individual applications transfer information to a central project database in a neutral (STEP[3]-based) format which can be read by other applications. This has potential for facilitating multi-lateral information interchange but requires that all applications have pre- and post- processors for effecting the bi-directional transfer of information. There is also potential for the loss of data integrity and semantics in this approach. Currently, the neutral standards required for this approach are not developed to an extent that makes this approach commercially feasible (Eastman & Augenbroe 1998).

5. **Proprietary Approaches** - In addition to the above generic approaches, there have been a number of proprietary approaches which embody some features of the above approaches. A couple of these will be given a brief mention. Fischer and Froese (1992) propose an object-oriented system called OPIS that provides for integration of a product model, a process model, a resource model and an organisation model. It also allows for objects to be classified as either project-specific or project-independent. Tah et al (1997) describe a concurrent engineering environment for integrated design and construction (CEE-IDAC) which links CAD and project management applications using a central object-oriented database management system (OODBMS) and Microsoft's OLE/COM distributed computing standards. Knowledge-based system (KBS) techniques are also used to generate construction project programmes.

Irrespective of the approach adopted, the integrated project database offers numerous benefits to construction project team members. In the next section, a survey and analysis of current integrated project databases is presented.

3. SURVEY AND ANALYSIS OF INTEGRATED PROJECT DATABASES

3.1 General Overview of Systems

This survey and analysis covers the main UK projects that have addressed the development of an integrated project database for construction. The projects reviewed include COMBINE, ICON, OSCON, SPACE, COMMIT, ToCEE and WISPER.

3.1.1 COMBINE

The COMBINE (Computer Models for the Building Industry in Europe) project was a major European Union (EU) research project led by Delft University, The Netherlands. Its main objective was the development of intelligent integrated building design systems within which the energy, services and other performance characteristics of a proposed building could be analysed. The focus of the work was building services – energy and HVAC – and involved the development of data structures and tools for managing the information flows between members of a building design team (Augenbroe 1994).

3.1.2 ICON

ICON (Information Integration for Construction) was based on a research project at Salford University (Aouad et al 1994), which involved both academic researchers and industry practitioners. The project focused on assessing the feasibility of establishing integrated databases for the construction industry. The scope of the project was limited to design, procurement and construction.

3.1.3 OSCON

The OSCON (Open Systems for Construction) model was developed by researchers at Salford University and builds on the ICON model described above. Its primary objective was the use of case studies from real life construction projects to demonstrate the usefulness of integrating project information in a central project database. Stages of the construction process covered by the model include feasibility, early design, detailed design, procurement and construction (Aouad et al 1997).

3.1.4 SPACE

The SPACE (Simultaneous Prototyping for an Integrated Construction Environment) project at Salford University led to the development of the prototype Integrated Construction Environment (ICE). The ICE model facilitates the automatic generation of virtual reality (VR) models, specifications, construction plans, cost estimates, and site layout plans directly from CAD drawings. It transfers project information dynamically and at run time to and from individual construction application packages. Its application focuses on the detailed design and construction stages of the construction process (Alshawi 1996).

3.1.5 COMMIT

The COMMIT (Construction Modelling and Methodologies for Intelligent Information Integration) project at Salford University also builds on the ICON project. However, its focus is on achieving integration through information management. A COMMIT Information Management Model (CIMM) has been developed to support collaborative working with facilities for versioning, notification, object rights and ownership. The model also facilitates the recording of the intent behind construction project decisions, thereby providing a complete project history (Brown et al 1996).

3.1.6 ToCEE
The goal of ToCEE (Towards a Concurrent Engineering Environment in the Building and Engineering Structures Industry) is the development of systems for information exchange in support of a concurrent engineering environment. The key issues addressed in ToCEE include: distributed product and document modelling including intra- and inter-model operability, conflict management, information logistics, version management, legal issues related to electronic documentation, monitoring and forecasting, and cost control. The application fields are design process, construction process and facility management (Turk et al 1997).

3.1.7 WISPER
WISPER (Web-based IFC Shared Project Environment) is a Web and IFC-based distributed computer-integrated environment with a three-tier architecture where user interfaces, business logic and database are kept separate. The environment supports design, visualisation, estimating, planning, specifications and supplier information. WISPER enables project information to be exchanged through STEP Part 21 file and shared through the IFC database. Applications are distributed and can be accessed and interacted with remotely through a set of Web pages. WISPER is applicable to detailed design and construction (Faraj et al 1998).

3.2 Analysis Criteria

The analysis of the various attempts at the development of an integrated project database for construction project teams is based on a set of criteria. The criteria were intended to provide a common platform for comparison and, while every effort has been made to obtain the relevant information for each of the projects, there are still gaps in the information available. The criteria used in the analysis include: aim, application areas/coverage, development environment, modelling/integration approach, availability and usability, and current status.

3.3 Findings

The findings of the analysis of the various projects that have addressed the development of integrated project databases is summarised in Table 1 and discussed below. It should be emphasised that this is largely based on the information provided by the researchers themselves, as it was impossible to undertake a 'hands on' evaluation of all the systems to establish the veracity of the claims made by the system developers. Furthermore, where systems claim to address several stages of the construction process, it should be borne in mind that in some cases, this is simply limited to the provision of information for that stage and does not necessarily imply full support.

3.3.1 Project Aim
All the surveyed projects had as their prime objective the development of some kind of integrated project database or environment. While integration was a common theme between the projects, a database was not the intended end product in all cases. For example, the COMMIT system focuses mainly on distributed information management between the different members of a project team.

3.3.2 Application Areas/Coverage

The application areas and coverage of the surveyed projects were variable. Apart from the COMBINE project, which had a clear focus on building services (energy and HVAC) design, all the other systems were more general in application. The SPACE project, however, had a bias towards architectural design. The stages of the project life cycle that were most commonly addressed by the projects were detailed design and construction, with some coverage of early design and maintenance (or facility management) by one or two systems. The COMMIT system claimed to be applicable to all stages of the projects life cycle - from feasibility through design and construction to demolition.

3.3.3 Development Environment

Information was not readily available on the development environment for all the projects. However, from Table 1, it is evident that the majority of systems are PC-based with the others running on UNIX workstations. In most of the systems, commercial software systems were used in conjunction with bespoke software developed by the researchers. It was unclear, however, to what extent the commercial software systems were integrated with the new data models.

3.3.4 Modelling/Integration Approach

Object-oriented modelling concepts were deployed in all the projects surveyed. This is not surprising given the increasing popularity of object technology for the representation of engineering project information. While the earlier projects (COMBINE, ICON, OSCON and SPACE) favoured the use of a centralised project database, the more recent projects (COMMIT, ToCEE and WISPER) all adopted a distributed approach, with the WISPER system being Web-based.

3.3.5 Use of Standards

It was interesting that only some of the projects were based on either established or emerging standards. Apart from OSCON, ToCEE and WISPER, which are based on IFC Version 1.5, the others utilise proprietary models. This relative lack of standardisation has implications for the reusability of the models. This is discussed further later in the paper.

3.3.6 Availability and Usability

In most of the cases, the models developed by the projects are available from the researchers. The COMBINE model is not available as whole but parts thereof are available from the various project partners. The ToCEE model is still under development and so is not yet available. All the models that are available from their developers are being used for teaching purposes. However, it is clear that they cannot be readily utilised by others as detailed knowledge of their internal architecture is required to make use of them and the time to deploy them or develop new models based on them could be up to 12 months.

3.3.7 Current Status

Apart from the COMBINE model, which has largely been abandoned, all the others are research prototypes that have not been developed commercially. Some of these models claim to have been 'looked at' either by potential end-users or by commercial software developers. In the case of COMBINE, individual project partners are actively pursuing extensions to some of its parts.

Table 1: Comparison of Integrated Project Database Projects

Projects / Criteria	COMBINE	ICON	OSCON	SPACE	COMMIT	ToCEE	WISPER
Aim	To develop an operational computer-based Integrated Building Design System (IBDS)	To assess the feasibility of establishing an integrated database for the construction industry	To demonstrate usefulness of integrating project information in a central project database	To develop a prototype integrated construction environment	To achieve integration through information management	To develop systems of information exchange to support a concurrent engineering environment	To develop a Web and IFC-based computer integrated environment
Application Areas/ Coverage	Building services (energy, HVAC); Early design and detailed design	General; Design, procurement, Construction management	General; Feasibility, Design, Procurement, Construction	Architectural; Detailed design, Construction	General; Information flow throughout project life cycle	General; Detailed design, Construction, Maintenance	General; Detailed design, Construction
Development Environment	Hardware - Unix Software - Micro-Station and Services design software, AutoCAD	Hardware - PC Software - AutoCAD, Superproject	Hardware - PC Software - CA - Superproject	Hardware - PC Software - AutoCAD, World Toolkit, KAPPA PC	Hardware - PC Software - None specified	Hardware - Unix (+ PCs) Software - None specified	Hardware – PC (NT) Software – AutoCAD Excel, MS Project, Netscape.
Modelling/ Integration Approach	Centralised project database. Object-oriented modelling	Centralised project database Object-oriented modelling	Centralised project database Object-oriented modelling	Centralised project database Object-oriented modelling	Distributed information modelling. Object-oriented modelling	Distributed product and document modelling. Object-oriented modelling	Distributed object-oriented modelling
Use of Standards	Bespoke product model	None specified	IFC Version 1.5	None specified	CORBA	IFC Version 1.5	IFC Version 1.5 STEP Part 21
Availability and Usability	Parts available; whole system not available	Available from Salford University	Available from Salford University; Used for teaching	Available from Salford University; Used for teaching	Available from Salford University; Used for teaching	Not available for use	Available from Salford University; Used for teaching
Current Status	Abandoned (but extensions being developed but some partners)	Research prototype	Research prototype	Research prototype, CD-ROM demo available	Research prototype	Research prototype	Research prototype

4. SUMMARY AND CONCLUSIONS

4.1 Key Findings

The key findings from the review of the seven major UK projects that have sought to develop integrated project databases/environments for construction can be summarised as follows:

- there is support for the detailed design and construction stages of the project life cycle, some support for the early design and facility management stages, and virtually no support for the briefing and decommissioning stages;
- the majority of prototype systems are PC-based with a few UNIX-based systems;
- all the projects adopt the object-oriented modelling paradigm, which has proved useful for engineering applications;
- only some of the models are based on the emerging IFC standard for interoperability in the construction industry;
- very few of the models are readily re-usable by other researchers and there is little evidence of building on existing systems;
- none of the systems has been taken up commercially; they remain research prototypes with limited use for teaching;
- many projects favour a central project database while others adopt a distributed approach.

4.2 Recommendations

The projects reviewed in this paper represent useful and, in many cases, pragmatic approaches towards the development of integrated project databases for construction project teams. From the review undertaken, it is clear that the ultimate goal of an integrated project model that is able seamlessly to communicate project information between all members of a construction project team and across all the stages in the life cycle of a project remains elusive. In this regard, several recommendations can be made:

- integrated models which cover the whole project life cycle from conception to demolition need to be developed. There is still much contention as to whether fully integrated models can be developed, currently small models seem most practical. Any support for model development needs to be in a more formal and quality ensured environment than currently supported (akin to software development);
- there is a gap in research into the development of appropriate models for the briefing, conceptual design and demolition stages of the project life cycle;
- there is a need to ensure the reusability of models to avoid duplication and waste of resources. In this regard, researchers should be required to make their models readily available on the Internet or from a central library;
- the use of established and emerging interoperability standards (such as STEP and IFCs) should be encouraged. This will have a positive impact on model re-usability, longevity, and interoperability with legacy IT systems in the construction industry;
- the use of a centralised project database has serious maintenance and other limitations that makes it of only marginal benefit to virtual construction project teams. More emphasis

needs to be given to approaches based on a distributed architecture that can support a variety of applications and non-collocated project team members;

- many enabling information and communications technologies (such as intelligent agents, telepresence, virtual and mixed reality, the Internet, intranets, information exchange standards, etc.) are now available; their applicability to the development and operation of integrated construction project databases/environments should be investigated;
- the involvement of software vendors in research projects will increase the commercial take up of research prototypes.

4.3 Conclusions

In conclusion, it must be stated that the concept of an integrated project database for construction projects is exciting, particularly given the huge potential that such an integrated model has for facilitating seamless integration between the disparate disciplines involved in construction projects. The UK projects reviewed here go some way towards achieving this goal but much more still needs to be done. With the availability of numerous information and communications technologies, and the high level of research activity in this field, it will not be too long before an appropriate model evolves.

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