Executive Information System for Construction Contract Bidding Decisions

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ABSTRACT

This paper describes the development of an integrated Executive Information System (EIS) for supporting construction executives and senior managers strategic information requirements. The system focuses on the provision of organisational and external market information for contract bidding decisions. The system uses a proprietary microcomputer based EIS development environment to access 'synthetic' data structures representing the LAN architecture of a typical construction firm. This paper explains the theory and technologies related to the development of such systems. This is followed by a general discussion of the analysis techniques adopted for development and definition of the system. The bulk of the paper relates to a description of the proposed prototype system and its application. The system itself serves as a nucleus for access to a variety of data providing strategic information for contract bidding decisions. The development methodologies and the resulting prototype serve as a template for development of similar EIS and Visual Information Access (VIA) systems in a wider executive and senior manager information support role.

Key Words

contract bidding; tender adjudication; strategic information; executive support system; information scanning

INTRODUCTION

The day-to-day running and strategic planning of any organisation relies upon effective and efficient decision making by the organisation's executives and senior management. Information forms the basis for such strategic decision making, in support of this much empirical evidence suggests that, in dynamic environments a large portion of senior managers' time is spent scanning for information (Mintzberg, 1973; Feldman and March, 1981; March

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and Sevon, 1983). Studies by Munday (1979a,b) suggest that in the construction organisation executives and senior managers spend as much as half of their time collecting and analyzing data.

One of the contracting firms' recurring strategic dilemmas relates to contract bidding decisions. Hillebrandt (1977) suggests that the bidding decisions on any one project will have a significant effect on the short term profit or loss of the firm and therefore repercussions on the firm's long term strategic performance. Contract bidding decisions therefore, form an integral part of the construction organisations' strategy planning. Without such strategic planning the organisation '...is like a ship without a rudder, carried on a current of circumstances from crisis to crisis until it encounters a crisis that is too big to handle or that lasts just too long.' (Fellows *et al*, 1983).

Traditional support for contract bidding decisions however, has been based on the seminal works of Friedman (1956) and Gates (1967) and was based around maximising the bidder's monetary value (non-price factors are implicitly assumed not to affect the decision function). Such models generally focus on the single aspect of 'profit maximisation' in Contract bidding strategy. Wong (1978), Stark (1976), Lansley (1983) and Green (1989) are in agreement that such models based on the assumption of rationality are, in general, not favoured by contractors. Toffler (1971) and later Ahmad and Minkarah (1988), Eastham (1986) and Green (1989) suggest that many other factors and objectives, other than pure economic, are considered in contract bidding decisions.

Thus, despite the significance of such decisions, contractors are forced to resort to the use of heuristic decision making based on experience, judgement and perception. Gut feelings are relied upon to make decisions in the face of the risk, uncertainty, irrationality and imperfect knowledge endemic to the contract bidding scenario. Algorithmic or statistical models are unlikely to wholly replace such judgements in contract bidding decisions.

Cusack (1981) and Pin (1990) both suggest however, that although most contractors possess, or have access to, extensive information in one form or another, most of them fail to make full use of this information to support or improve their decision making processes.

Against this background a three year research programme has been undertaken with the aim of developing a computer based information system to facilitate direct access to the available information, both internal and external to the firm, relating to contract bidding decisions. This system will provide the decision maker(s), responsible for contract bidding strategy decisions, with access to the information and tools to support and enhance, rather than replace, the decision makers' own judgements and perceptions.

Relating Information to Contract Bidding Decisions

The decision making process itself is defined as three distinct stages, intelligence, design and choice (Simon, 1960), however, these stages are generally integrated by the decision maker into a single process. Figure 1 illustrates the relationship of these three principal stages.

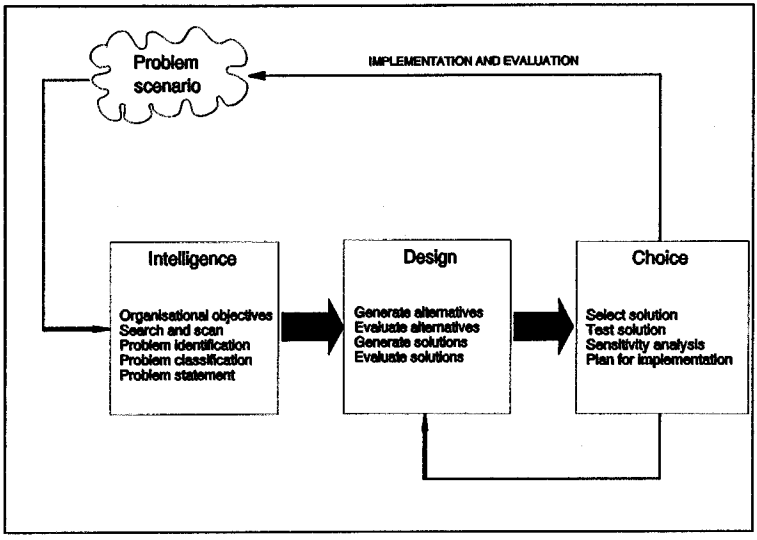


Figure 1. Stages in the Decision Making Process

The Intelligence phase involves the study of an environment for conditions requiring decisions. Data are collected from a wide variety of sources and subsequently processed to provide the decision maker(s) with information from which they may find ways of approaching decision problems.

Information is the basic input to contract bidding decision making. A direct relationship between the quality of information used by decision makers and the quality of their decision making performances has been well established (Halpin *et al*, 1971; Mintzberg, 1973; Manis *et al*, 1978; and March, *et al*, 1982). Information sources are discussed under two general classifications:

(a) **Location of the information source** - This refers to whether the information source is located inside or outside the organisation. Both Aguilar (1967) and Keegan (1974) use this external/internal dichotomy.

(b) **Medium of information transmission** - Mintzberg (1973) classifies access to information sources according to five basic media: mail, telephone, unscheduled meeting, scheduled meeting and tours. A more simple dichotomy would be verbal versus written media.

In the Design stage, the objective is to generate alternatives and invent, develop and analyze possible courses of action. This involves the development of models to carry out such explorations. Mintzberg (1973) suggests the information collected by executives and senior managers is used in four ways: (1) to disseminate it to others; (2) to develop value positions for the firm; (3) to identify business problems and opportunities; and (4) to develop mental images - 'models' of how the organisation and its environment function. Mintzberg contends that mental models help the executive deal with the complexity inherent in his job. He suggests, "In effect, the manager absorbs information that continually bombards him and forms it into a series of mental models of the internal workings of his organization, the behaviour of subordinates, the trends in the organization's environment, the habits of associates and so on". With respect to contract bidding decisions Ahmad (1988), and later De Neufville and King (1991), identify two principal areas of cognitive modelling relating to: (1) uncertainty and probability; and (2) preference and utility. Risk and uncertainty are generally assessed in terms of probability of outcome, whilst preference and utility are assessed against personal constructs ie., using the decision makers own personal judgements.

The contract bidding decision is highly influenced by factors relating to the assessment of uncertainties and risk. Generally it is the decision maker(s)' judgement in assessing the probability of these, largely project related factors (eg, degree of difficulty, degree of hazard, uncertainty in estimate, competition, etc), that dictates the final outcome environment, ie., loss, break even, or profit. Preference is evaluated in terms of subjective value, or utility, and the causal effect any one project has on the preference related attributes (eg, need for work, type of job, current workload, profitability, economic conditions etc).

The Choice phase involves the selection of the best and most effective course of action from those investigated. Depending on the influence of uncertainties arising from: the competitive situation; estimate accuracy; and contingency expenditures and in addition the ability to evaluate risks, the outcome may fall within any of three ranges. These ranges occur between the points of: (1) loss; (2) breakeven ie., meet overhead requirements; and (3) profit. The outcome on each bid may have a different perceived value to different bidders depending on their subjective attitude and perception of their own environmental situation.

Figure 2 provides a framework relating information and decision aspects of contract bidding decisions with Simon's basic decision model.

Application of Executive Information System (EIS) Technology

Recently, Executive Information Systems (EISs) have been introduced within a small number of major construction organisations. Such systems

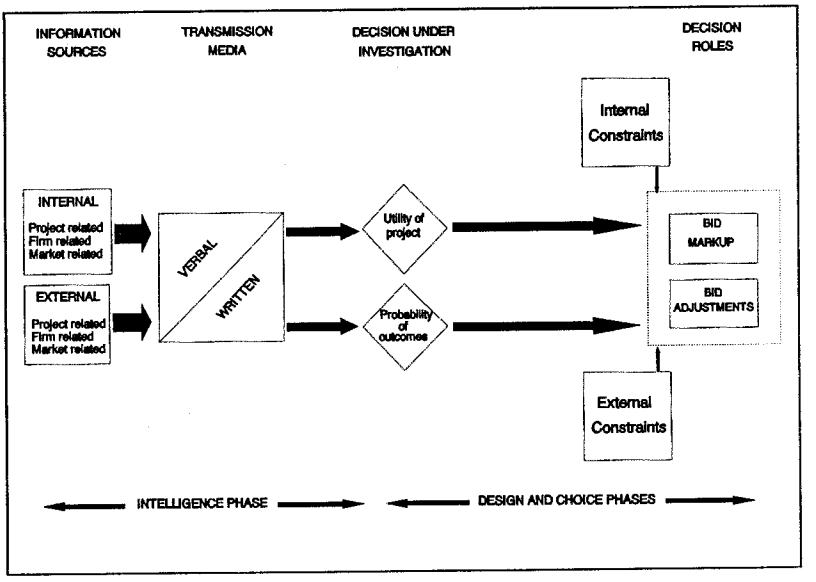


Figure 2. Contract Bidding Information Flow and Decision Criteria

serve as a point of access for senior managers and executives to vital information about their businesses, from both internal and external sources. An EIS is a hands-on tool that focuses, filters and organises executives' information so they can make more use of it using electronic information delivery. An EIS enhances the ease and effectiveness with which an executive can perform information-intensive activities that are inherently part the organisation's strategic planning and control processes.

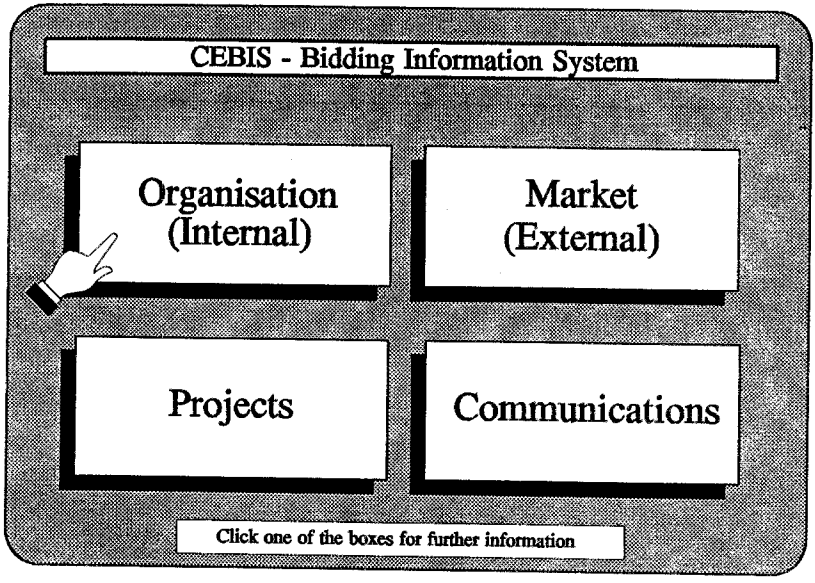
Unlike the currently 'in-vogue' knowledge based systems (KBS) an EIS does not attempt to represent or replace the cognitive heuristic abilities of the decision maker. An EIS focuses on providing access to data and information to support the executives own heuristic abilities.

Figure 3a and 3b show typical examples of EIS screens.

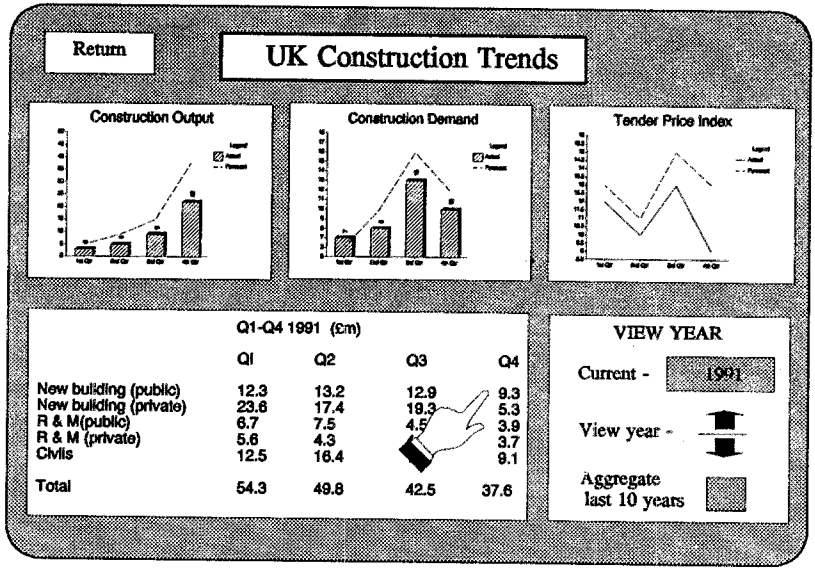
EIS Characteristics

Watson *et al* (1991) have collated from previous research the following principal characteristics of EIS:

- tailored to individual executive users;
- extract, filter, compress, and track critical data;
- provide on-line status access, trend analysis, exception reporting, and "drill-down" information navigation (drill-down allows the user to access supporting detail or data that underlie summarized data);
- access and integrate a broad range of internal and external data;



(a)



(b)

Figure 3. Typical EIS Style Data Screens

- are user-friendly utilising graphical interfaces, touch screen and mouse driven technology;
- present graphical, tabular, and/or textual information; and
- are used directly by executives without intermediaries.

The term "executive support system" (ESS) refers to a system with a broader set of capabilities than the basic EIS (Rockart and DeLong, 1988). The ESS may be seen as an integration of EIS, other support capabilities (E-mail, decision support systems, computer conferencing etc). The ESS technology may be conceptualised as the addition of the following capabilities to EISs:

- data analysis and modelling;
- ad-hoc access to data and data querying; and
- flexible use of analytic tools.

Once associated only with top executives, such systems are now able to run in PC LAN environments broadening EIS/ESS use to middle-level managers, fostering the philosophy that the more a piece of information is shared among different users, the more utility it has.

CEBIS - Construction Executives Bidding Information System

Objective of the Present System

The objective of this program of research is the development of a prototype executive information system for construction firms. The prototype focuses on the support of the strategic information requirements of one particular aspect of the construction organisations strategic decision functions, ie., contract bidding. The CEBIS prototype also serves however, as a template for similar development on a wider scale, rather than focusing on the single aspect of contract bidding strategy decisions.

Defining the EIS

The definition of the strategic information requirements is based around a detailed analysis of the contract bidding environment and specific adjudication decisions of two major UK contracting firms. The methodology adopted for defining the prototype system may be generally summarised into seven key steps, as shown in Table 1.

The methodology and techniques used in stages 1 and 2 have been adapted from the 'critical success factor' systems approach developed by Rockart (1979) and subsequent refinements, as made by Martin (1987). In this methodology, generically referred to as Information Strategy Planning (ISP), 'objectives' are defined as general statements about the direction of the firm, 'goals' are specific targets to be reached at a given point in time and 'critical success factors (CSFs)' as the limited number of areas in which

satisfactory results will ensure competitive performance and attainment of specific goals.

Table 1 Principal steps in defining the prototype

Step number	Description
1	Identify the firms business strategy and objectives
2	Identify the strategic information requirements of contract bidding decision makers
3	Identify and separate internal and external information requirements
4	Become familiar with sources of information relevant to decision maker(s) needs
5	Identify and separate the needs that can be met in the initial prototype implementation from those that must be satisfied later
6	Determine the best ways to summarise, structure, and display the information
7	Evaluate hardware, software and communications environment

Figure 4 illustrates the principal activities involved in developing the 'strategic information models' representing the strategic information requirements associated with contract bidding decisions.

The initial stage involved a series of semi-structured interviews with senior managers and staff, of the two organisations, involved in the contract bidding process. A period of two weeks was spent working within each of the two firms. Interviews were conducted starting from the lower level staff and managers working up to the most senior manager(s) involved.

An initial overview model was developed based on the lower level interviews. Following development and ratification of the overview model an analysis was made of the objectives, goals and critical success factors (CSFs) of the more senior managers, ie, the decision makers, associated with contract bidding and adjudication decisions. These attributes are described in Tables 2 and 3.

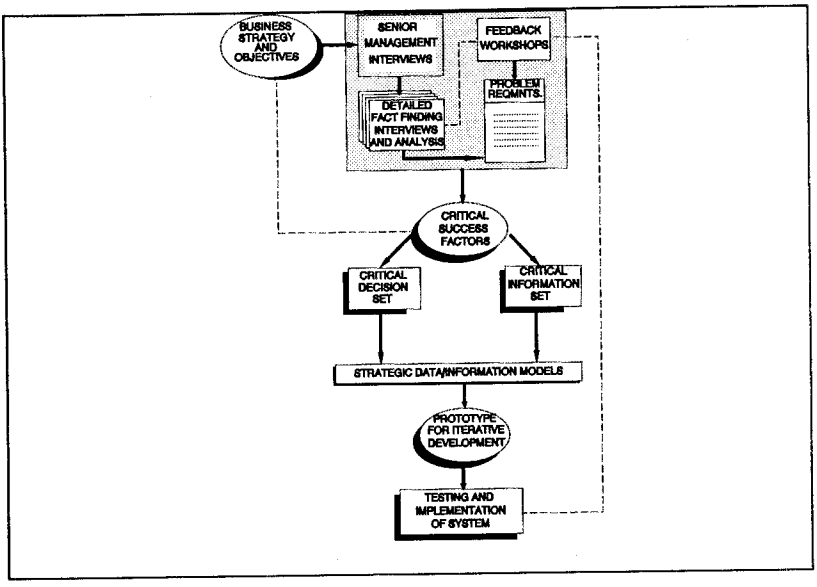


Figure 4. ISP Development Methodology

Table 2 Objectives and goals associated with contract bidding decisions

Objectives and Goals
Reduce overheads associated with contract bidding
Increase profit margins on jobs
Meet corporate turnover requirements
Client satisfaction
Meet corporate overhead requirements
Reduce the number of claims (from clients and agents)
Increase throughput of suitable contracts for bidding

The second stage of the analysis involved a more detailed study through observation of two live contract bidding adjudication meetings within each of the two participating firms. From this study a more detailed model of the tender adjudication process was developed.

Table 3 CSFs associated with contract bidding decisions

Critical Success Factors (CSFs)
Profitability of job
Optimisation of direct cost and prelims. estimates (profitability vs. competitiveness)
Risk assessment of bids
Optimisation of markup (overhead and profit requirements vs. competitiveness)
Meet or exceed specification requirements
Meet or improve on schedule requirements
Competitiveness of final bid sum
Maximise potential resource discounts
Soundness of construction methods

Following development of this more detailed model the next stage of the analysis involved the identification of the 'critical decision' and 'critical information' sets associated with the previously identified adjudication objectives, goals and CSFs. The critical decisions, identified in the adjudication model, were mapped against information attributes in a series of decision/information attribute matrices for each of the process/decision stages identified.

The internal/external information attributes are discussed in terms of the three principal groups identified by Skitmore (1989):

(a) project related;
(b) organisation related (internal); and
(c) market related (external).

The above components of the overall analysis model, ie.,: (1) objective and goals; (2) critical success factors; (3) critical decision set; and (4) critical information set, collectively represent an assertion of the principle motivations and strategic information requirements of the contract bidding decision makers within the two participating firms.

Following completion of the remaining stages 3 to 7, as described in Table 1, work commenced on the development of the prototype system.

System Outline

CEBIS is a PC based prototype executive information system for supporting contractor's strategic contract bidding decisions. The system filters data from various organisational and external databases to provide a nucleus of strategic information for supporting contract bidding decisions, or

indeed other similar strategic decisions within the construction organisation.

The general architecture of the prototype system is presented in Figure 5. CEBIS serves as a focus for information contained within various organisational and external databases. The core system contains a hierarchy of integrated graphical screen templates which are populated with data from the various sources when accessed by the user. For development of the prototype system the problems of communication with the various distributed data sources was removed by creating a series of representative data bases, within the PCs environment, representing the various organisational and external data structures.

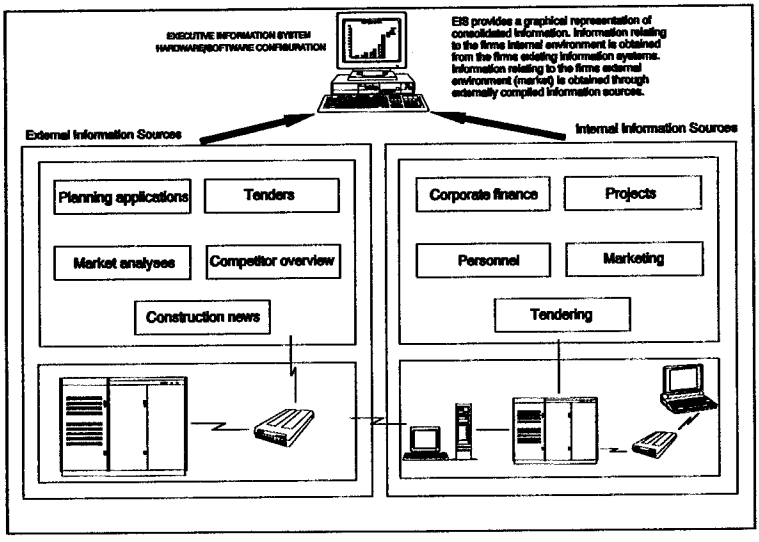


Figure 5. Conceptual System Architecture

A single screen template may be populated with data from a variety of text based, numerical, and graphical sources. In addition, interactive screen templates allow the user to issue complex data queries with only the use of screen icons, requiring no knowledge of SQL or similar query languages. Figure 6 illustrates the general structure of the menu templates, and the data screen templates for the market information module.

LIGHTSHIP - Executive Information System Building Tool

CEBIS was developed using LIGHTSHIP (version 3.0), an object-oriented graphical development package for creating Executive Information Systems, marketed by Pilot Executive Software. LIGHTSHIP is a PC based WINDOWS application developed primarily for use in a Local Area Network

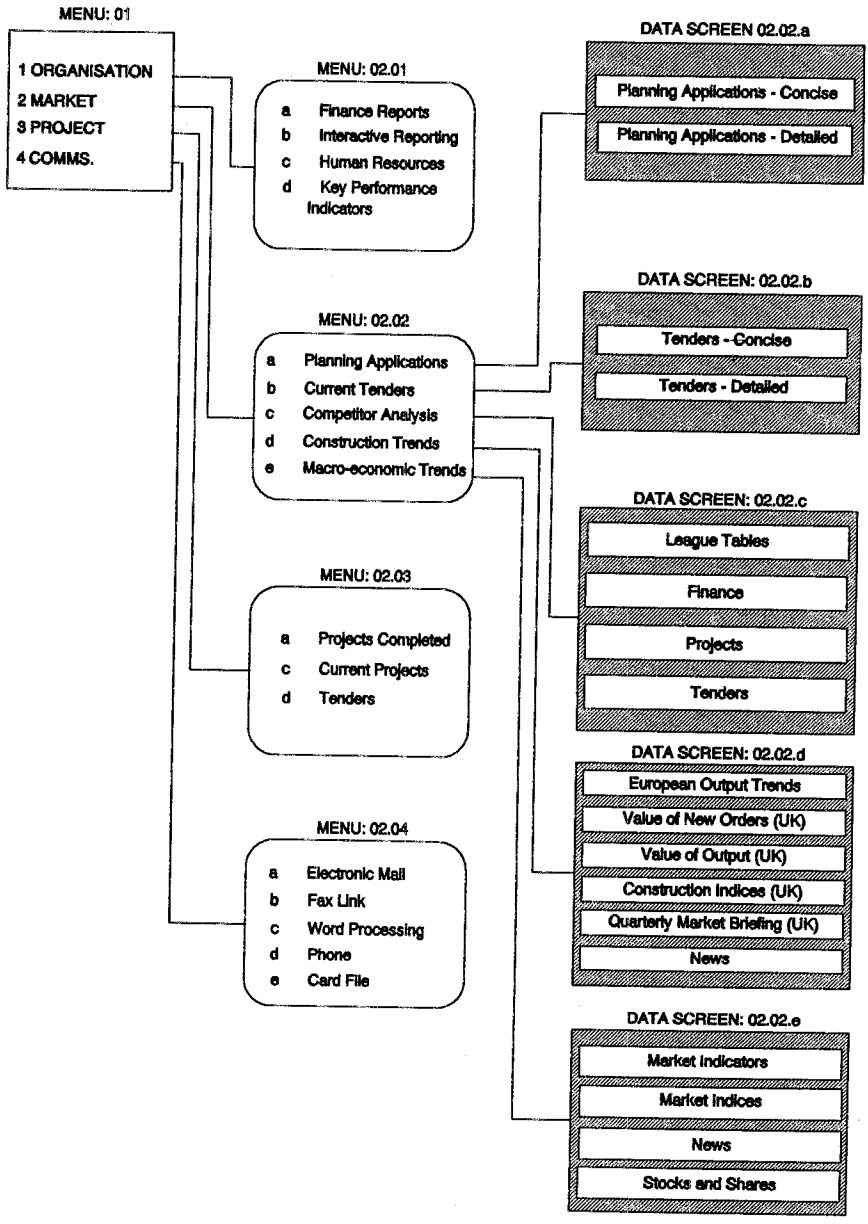


Figure 6. CBEIS Data Query Paths

(LAN) environment. This shell was, at the time of selection, one of the only development packages designed to build and run EIS applications specifically for PCs and Local Area Network (LAN) based architectures. LIGHTSHIP is a relatively simple and inexpensive tool integrating an array of computing methods to develop EIS applications providing:

- data display (including spreadsheet data, charts, text, and graphics);
- open data access with active software links;
- drill down information navigation;
- variance reporting; and
- trend analysis.

LIGHTSHIP only facilitates direct access to data from ASCII text files and other MICROSOFT WINDOWS compatible applications using WINDOWS Dynamic Data Exchange (DDE). However, with the addition of LIGHTSHIP LENS, a Dynamic Link Library/Cacheing utility add-on to LIGHTSHIP, applications can access, with a 'live' connection, data from a wide variety of corporate and external information systems. Figure 7 illustrates the elements required for access to a variety of data sources using LIGHTSHIP.

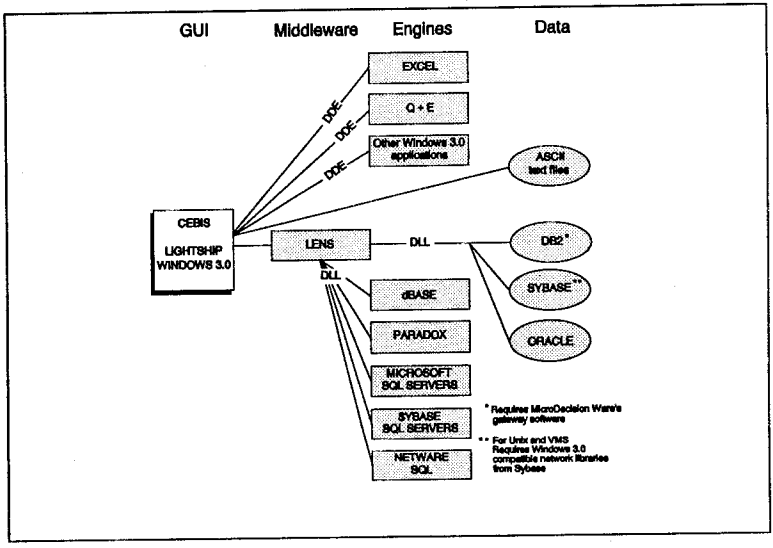


Figure 7. Data Links Available Through CEBIS

For the prototype system, in view of the characteristics and architecture of the proposed system, and the criteria established for selection, LIGHTSHIP was considered the most suitable tool for development. However, despite a wide range of functions, the development environment offered by

LIGHTSHIP is perhaps too inflexible and too basic for development of an operational system requiring cross-platform communications.

Sources of Data

For the present prototype study, as previously stated, it was necessary to artificially construct the LAN data environment by developing a series of representative databases representing organisational and external data systems.

The first stages in the development of the CEBIS prototype involved the development of a series of 'synthetic' data sources within the PC environment. These data structures were created using a combination of ASCII text files, dBASE IV, and EXCEL for WINDOWS. These tools were used to create data stores populated with sample data collected from the participating contracting organisations and a number of external data sources. The following organisational and external information data sources were recreated:

(a) Organisational Data (Internal):
- tendering (estimating, planning, buying);
- corporate (finance, accounts etc);
- personnel;
- projects; and
- marketing (performance indicators, competitive analyses etc)

(b) Market Data (External):
- planning applications;
- current tenders;
- market analysis (construction and macro-economic);
- competitor analyses; and
- news.

These databases collectively represent the data contained within a LAN environment with a suitable gateway to external sources of information.

Potential Uses and Future Development

The potential benefits outlined by this prototype system are substantial, offering seamless visual information access and analysis, not only for contract bidding but for a wide variety of other information dependent strategic decisions within construction organisations. CEBIS, and EIS systems in general, offers the following benefits to construction executives and senior managers:

- single point direct access to organisational and external environmental information tailored to the user's needs;
- the ability to scan a wider information environment more efficiently;
- 'Drill-Down' ie., the capability to start with aggregated summary data whilst allowing the review of more detailed information as time and necessity

dictate;

- the capability to combine text and graphics from various sources on the same screen; and
- a non-keyboard interface, mouse, touch screens, using pop-up and pull-down menus.

CEBIS however, can only serve as a template for development of similar EIS based systems within construction organisations. The computing environment and data sources of each organisation are largely unique, such a system would therefore have to consider the availability of data and the data communications environment for each bespoke development. Such problems do not arise however, for external data sources, BCIS, Glenigan, ABI, Datastream, Reuters etc, which are commercially available to all subscribing organisations.

The prototype system itself therefore, is of limited value outside of the organisations particular information and computing environment. However, the development methodologies for definition of the system, discussed in this paper, are applicable to the development of such a system within most organisations and therefore possibly of more interest than the end product itself.

In terms of future development and research work the next logical step would be to redefine and expand the existing prototype to serve as a template for a more general, corporate EIS system for construction organisations.

Once developed within a particular organisation, the modular architecture of such systems means they are easily expanded and maintained as the organisations information requirements and data structures evolve.

CONCLUSIONS

CEBIS is a prototype executive information system aimed at supporting the strategic organisational and external information requirements in contract bidding decisions, rather than attempting to replace the manager's own judgement and expertise. This prototype system is a pilot study for the development of an operational system within the computing and information environment of contracting organisations. The prototype is based on a study of contract bidding, and the strategic information requirements for such decisions, within two major UK construction firms.

In addition it is hoped that this pilot study will increase the awareness of the utility and technologies involved in the development of similar EISs and Visual Information Access (VIA) systems.

Such systems are the key in equipping executive non-computer users with the necessary tools for 'seamless' access (ie, direct dynamic access with automatic log-on requiring no knowledge of query languages) to historical organisational and external data and the means to aggregate it into useful

strategic information, via multimedia graphical user interfaces.

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