# Strategic information requirements in contract bidding: Framework for development of a decision support system

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# A DECISION SUPPORT SYSTEM FOR CONSTRUCTION CONTRACT BIDDING ADJUDICATION

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**Summary**

The results of a case study involving two major construction contracting companies are presented indicating the informational and other needs and considerations of construction contract bidding adjudication decision makers. A strategic information model is described and the development of prototype decision support system based on Executive Information System technology.

*Keywords*: Contract bidding, adjudication, decision support systems, executive information systems.

## 1. INTRODUCTION

Most construction work is awarded by competitive bidding. Under this system, the owner of a project invites a few prospective contractors to compete for a project by tendering bids or proposed bid prices. The award is made based on the proposed bid prices, the project generally being awarded to the lowest responsible bidder.

Any one particular project contributes a relatively significant part of a construction firm's turnover. Bidding decisions made on any one project have a significant effect on the short term profits of the firm with consequent repercussions on the firm's

long term strategy and performance (Hillebrandt, 1977). In addition, bidding decisions are not cheap. The cost of bidding is estimated to be an average of 1.2 per cent of total turnover for UK contracting firms (Cook, 1990).

There are many texts on cost estimating and bidding strategy, but these are predominantly **prescriptive** and based either on unsupported theories or plain old commonsense. What is lacking in the field, however, is some **descriptive** treatment of 'real world' contract bidding practices. The research described in this paper was concerned with providing such a description of contract bidding with a view to systemising 'real world' contract bidding decisions, focusing on decisions relating to final adjustment of cost estimates and formalisation of a suitable bid price. An empirical study is described where the bidding practices of two major construction are examined. A conceptual model is developed and the development of a type of Executive Information System (EIS) is proposed.

## 2. THE CONTRACT BIDDING PROCESS

The process of competitive bidding is loosely described by McCaffer and Baldwin (1986) as comprising two unique but interrelated stages, namely "cost estimating" and "tendering". Cost estimating commences upon receipt of the bid documents from the owner or owner's representative and is described as "...

calculating the probable cost to the contractor of efficiently carrying out the construction work if awarded the contract to construct the project." Tendering, on the other hand, is described as "... establishing the final price and terms for the contract that will be submitted [tendered] to the promoter or his representative. This involves an assessment of the likely margin of error in the cost estimate together with the risk and possible financial effects of undertaking the project." The term "bidding" however, is used to describe the generic bidding process, the term "bid adjudication" is preferred and is used here to describe this second stage. It is this stage of the bidding process that is principally the concern of this paper. Bid adjudication decisions form one of the two principal strategic decisions affecting contracting firms' work procurement and subsequent long term performance, the other being the earlier bid/no bid decision. Together these two decisions considerably influence the nature of projects undertaken by contracting organisations and consequently affect the strength of the firms in the industry.

The prescribed practice is that bid adjudication decisions are made at formal meeting that take place a few days before the final bid tender dates to allow sufficient time for finalisation of the bid documents prior to tender. Summary reports should be prepared, based on the cost estimating process, and presented at the bid adjudication meeting. The adjudicators, normally senior managers or directors reflecting the significance of such

decisions, are then to review the cost estimate and associated information and finalise the contract price (making any necessary amendments or additions for risks, uncertainties overheads and profit) as a *commercial* decision (CIOB, 1983).

Major decisions of these kind are expected to be aligned in some way with bidding firms' expressed or implied general objectives and goals to obtain. Decision makers are therefore urged to know what these objectives and goals are, how they are related to each other, what their relative importance is and how a particular decision on any one project is going to affect these objectives and goals. This implies the existence of supporting information concerning these aspects of the decision, structured in an appropriate form.

The literature on information structures for bidding decision support is limited to the OR models of Friedman (1956) and Gates (1967), focusing on an 'optimal' strategy from the bidders' perspective. By their formulation, adjudication is taken to be a matter of finding an optimal bid mark-up which maximises expected profit. This, like many other early OR approaches to real-world problem solving, suffers from a plethora of simplifying assumptions regarding the context of the problem. Although there is some scepticism concerning their general validity, surprisingly few of these assumptions have been tested in construction contract bidding situations.

The assumption of the profit maximisation objective, for example, has been most heavily criticised. Wong (1978), Stark (1976), Lansley (1983) and Green (1989) all indicate that such an assumption of rationality is, in general, not favoured by construction contractors. The work of Toffler (1971) and later Ahmad and Minkarah (1988), Eastham (1986) and Green (1989) indicates that other factors and objectives, many of a non-economic nature, are likely to be considered in bid adjudication. A further consideration is that endemic commercial pressures and time constraints may mitigate against 'rational' decisions being made even if they are desired. Thus, despite the importance of adjudication decisions, there are indications that contractors make largely heuristic decisions based on experience, judgement and perception in the face of the uncertainties surrounding the contract bidding task.

Empirical studies by Cusack (1981) and Pin (1990) however indicate that many contractors possess, or at least have access to, extensive and relevant information in one form or another but is not fully utilised to support or improve their decision-making processes. The potential of this information for use in supporting bid adjudication decisions is clearly an important issue.

What seems to be needed is fast access to relevant data concerning adjudication decisions. That many contractors may already have such data in their organisations is very

encouraging and suggests that, when suitably structured, relevant data could be made available in digestible form for decision makers. The next section describes some empirical studies carried out by the authors to the extent to which this might be the case.

## 3. EMPIRICAL STUDY AND EVALUATION

### Methodology

The empirical study was undertaken in two principal stages: the first stage was conducted in the form of semi-structured interviews; and the second stage involved a more detailed study, through passive observation, of the adjudication meetings on two live contracts within each of two collaborating major construction contracting firms.

A period of two weeks was spent by one of the authors working permanently in the cost estimating departments of each of the two firms. The objective of this period was to examine the general context of the adjudication scenario ie., the contract bidding process, and subsequently the general nature of the bid adjudication process. The initial objective was to identify the principal participants of the contract bidding strategic decision process and their general responsibilities. This information, in both instances, was obtained in the initial

induction meeting held with the estimating director (Firm A) and estimating manager (Firm B).

Semi-structured interviews were conducted with each of those individuals (or groups of individuals) principally involved in the contract bidding decision process. In addition, interviews were conducted with the information systems managers of each of the two firms. The objective here was to get some background on the current state and proposed direction of the two firms' existing information systems.

There were differences between the two firms but these were considered to be principally the result of their different organisational structures. Firm B had a much flatter organisational structure than Firm A, having not yet devolved to regional management. Hence the managing director of Firm B tended to have a much more 'hands-on' approach to management than the managing director of Firm A.

Besides collecting this basic information, an attempt was also made in the interviews to develop a picture of the general objectives and goals of the organisation and its adjudicators.
The second stage of this study involved the observation of two live adjudication meetings within each of the collaborating firms. The objective here was to gain a detailed understanding of the processes and information used by decision makers in an adjudication meeting.

## Results

*Overview of Bidding Decision Processes*. The scope of bidding activities is normally taken to cover the range of tasks that are carried out between the receipt of the bid documents, the decision of whether to tender a bid, and the point at which the bid is tendered to the client's representative (cf., Fellows and Langford, 1980; McCaffer and Baldwin, 1986; Betts, 1990). This definition of scope, although suitable for analysis of the functional aspects of bid preparation, was found in this research to be rather restrictive in examining the strategic decisions involved in bidding. Here the evidence supports the view that there are two distinct strategic decision stages in the bidding process, (1) the decision to bid for a specific project and (2) bid adjudication, where the level of mark-up is decided (see also Ahmad and Minkarah, 1988). It was also found that the decision to bid, or project selection decision, is often made long before receipt of the actual bid documents, and these two decisions, particularly the project selection decision, are made progressively, evolving iteratively over a period. This is very much in line with the findings of Harris and McCaffer (1983). They suggest that the decision to bid is made at three distinct points in time, during pre selection, upon receipt of the bid documents and after preparation of the cost estimate.

Fig 1 shows the scope of definition for bidding decisions found to be suitable for this study. The figure also illustrates the progressive and iterative nature of bidding strategy decisions (*cf.*, Hogarth, 1981).

*Strategic Planning and Bidding Policy*. The contractors operated a two tiered approach to corporate planning, as suggested by Skitmore (1989). Both contractors operated under a medium term strategy plan, based on a five year period, and a short term, 2 year policy plan. The medium term business plan is used to establish the general objectives of the managing directors and senior management for the strategic development of the firm, in consideration of the long term objectives. These general objectives are filtered down into the 2 year plans that set out, amongst other things, the firms' general bidding policies aimed at satisfying the objectives established in the medium term plan.

The firms' bidding policies are formulated from monetary, market related and other objectives. These objectives are analysed within the context of internal and external factors affecting the firm's environment (*cf*., Bahrami, 1981; Ansoff, 1984), in conjunction with information fed back in summary reports, outlining the general statistics of bid results and performance.

The general guidelines set down in the bidding policy determine targets for the amount and mix of future contract business, an acceptable level for the proportion of contracts won, and the average profit margin to be achieved on contracts (see also Ward and Chapman, 1988).

These policy rules and criteria are interpreted and regulated by the decision makers involved in project selection and bid adjudication decisions in consideration of the individual merits and outcomes of specific project opportunities.

*The Project Selection Process - Bid/No bid Scenario*. Of the two strategic decision stages identified, the project selection decision process proved the most difficult to delineate as a result of its complex and progressive nature. The procedure and process of project selection decisions within both the contracting firms was ill-defined and discursive. Often the decision to bid is made prior to receipt of the bid documents, largely as a result of marketing activity. The scope of marketing activity and its influence on project selection was observed to be far more significant than suggested in earlier works (eg., Lansley *et al*., 1979; Sidwell, 1984), a view supported by Fisher (1989).

The marketing departments within the contracting firms were well established and consisted of both business development (sales) and research activities. The source of project selection

decisions stems from a pool of project opportunities existing in what we term the project generating environment. Knowledge relating to the possibilities and characteristics of such project opportunities is sustained through active marketing relationships with existing clients, personal contacts and other historical information, and through a variety of external stimuli. These external stimuli take the form of a variety of published information (eg., trade papers and journals, records of planning applications, NEDO forecasts), externally compiled market research (eg., *ABI* and *Glennigan*), personal contact with the leading property, insurance and investment companies and also regular contact with design team consultancies (*cf*., Jepson and Nicholson, 1972:51; Rajab, 1981; Harris and McCaffer, 1983:182-8).

From this stream of project opportunities a pool of projects is selected that best fit the hierarchal existence, relatedness and growth needs of the firm (cf., Alderfer, 1972), and the objectives of the corporate strategy plan and bidding policy. Project selection at this stage was observed to be extremely subjective and lacking in any structured approach. However, several factors were identified that were considered to affect the outcome of such project selection decisions, in conjunction with the corporate bidding policy. These factors are grouped under the three distinct but inter-related headings:

- **Job or project related factors**

- **Firm related factors**
- **Market related factors**

Coincidentally, these sets of factors are identical to the factors considered at the bid adjudication stage. However, the level of detail is far coarser and the tradeoffs and emphasis of the factors are different. Following this decision stage the selected projects are tracked and efforts are made by business development teams whose primary task is to secure a place on the prequalification/tendering list.

At this stage certain projects emerge as having a greater potential utility to the firm than others or there may be a particular corporate interest in a specific project. Consequently at this stage the potential utility, together with the anticipated tender dates and workload, is discussed in regular meetings between the marketing, cost estimating, planning and buying departments of the company[1]. Such meetings are generally production oriented. Within both firms, however, the access and utilisation of the necessary information was poor, although the information needed was generally available. The result of these meetings is a report scheduling the likely tender dates of selected projects and, in the case of one of our collaborating firms, an alphabetical priority ranking of each

[1]In general, 75% of the project opportunities involve the contractors in some formal prequalification procedure prior to their being invited to tender a bid. In this case, information relating to (1) the project, client and clients representative and (2) the available and suitable personnel is necessary to put together a suitable prequalification team, is needed.

project. These priorities and anticipated tender dates are constantly reviewed as new project opportunities enter the system.

Formal invitations to tender bids then may be received as expected (eg as a result of successful prequalification) or just 'out of the blue', ie., without any prior knowledge or marketing activity. One firm suggested that up to 35% of invitations are a result of such *ad hoc* requests. Upon receipt of the bid documents, a formal bid decision is made based on the more detailed information contained in the bid documents. Corporate policy and the four groups of factors are considered at this stage in finer detail - the detail of the evaluation generally being proportional to the value of that particular project. Both firms then complete a formal record of the bid decision.

*Preparation of the Bid Documents*. Preparation of the bid documents commences following a positive decision to tender a bid for a project. Although the preparation of bids is a complex process, as shown by Betts (1990), very little corporate strategic input occurs at this stage, other than purely profit or cash flow related considerations. There were some differences however between the two collaborating firms concerning the role of the estimator in making strategic financial decisions during the cost estimating process. For one firm, emphasis was placed on standardisation and continuity in preparation of the cost estimates and project schedules. Any possible bid unbalancing or other such profit related decisions were presented and discussed at the bid adjudication stage. For the other firm however, the estimators identified and implemented profit and cash flow related unbalancing policies, which were later in the adjudication meeting. The utility of each project and its anticipated bid schedule was continually reviewed throughout the bid preparation stage as new opportunities occurred.

*The Bid Adjudication Process*. The completed cost estimate breakdown, schedule and other various reports relating to the bid to be tendered were presented to senior management for adjudication in a bid adjudication meeting. The cost estimate was evaluated in consideration of the four groups of factors (ie., project related, resource related, market related and firm related) in conjunction with corporate bidding policies.

Adjustments for overheads, risk and profit were then made to the bid based on these considerations. Any late quotes or increased costs were also dealt with at this stage along with any necessary revenue recovery analysis.

This adjusted bid was then tendered to the client's representative who, for the successful bidder, issued an invitation to contract. Even at this last minute, the contractor may still decline the invitation. In practice however such an event is extremely unlikely.

*Decision Environment*. Bid adjudication decisions, although more readily defined than project selection decisions, are still the result of a complex decision-making process. These complexities are inherent in the nature of the problem and decision environment, ie., competitive situation, uncertainty in the estimated cost, elements of production risk and uncertainty, accelerated bidding periods and insufficiency and poor quality of information. These complexities are amplified by the dynamic nature of the construction market and by apparently irrational bidding policies in the face of reducing project opportunities, eg., 'buying in' work.

*Factors Considered*. Bid adjudication decisions, as expected, were observed to be largely subjective and intuitive - based on the decision makers experiences, judgements and perceptions - an observation supported in a questionnaire survey of bidding in

construction by Ahmad and Minkarah (1988). Because of the time constraints involved in the bidding process, it is not possible for decision makers to identify and analyse all the related factors that might form the basis of such decisions. The lack of any observed structured approach to bid adjudication decisions, however, results in only a small and inconsistent subset of the many possible factors that might be considered for each project. As previously discussed, the factors relating to decisions in bid adjudication may be grouped under three inter-related headings. *Job related factors* are those factors specific to each individual project, or type of project. Most factors are considered during bid preparation and the analysis presented in the bid adjudication meeting. *Market related factors* cover the external environment of decision makers who are aware of their influence even if they did not always consider them specifically. *Firm related factors* are closely associated with the corporate bidding policy and business plan of the company. In bid adjudication, the aim was to assess the outcome effect of the project on the objectives outlined in the general corporate plan. Again, these decision makers were aware of their influence even though they did not always consider them specifically.

In the companies studied, bid adjudication decisions involved analysis, evaluation and preference tradeoffs of a largely indeterminate and inconsistent combination of these factors. Most evaluations made were performed subjectively. Cash flow

modelling, risk estimation and other forecasting techniques were generally applied to only the largest projects, where the outcome effect was considered more carefully and results aggregated into corporate cash-flow requirements.

*Bias and Inconsistency of Decision Makers*. Bid adjudication was observed to be a quasi group decision-making process, although the final adjustment decisions were ultimately made by a single decision maker of corporate status. The decision was highly dependent on the advice and recommendations of those present in the adjudication meeting who had been involved in preparation of the bid documents. In general, the bid adjudication decision maker had little or no involvement in the production of the bid documents up to this stage. The project estimators had the most significant influence on the final bid decision by outlining the perceived principal characteristics, risks and potential profit areas of the project. Other parties with a lesser but still significant contribution were the planners, buyers and commercial/contract managers.

Besides the personal biases of adjudicators, an element of inconsistency existed due to the estimator, planner etc,. being different for each bid. The adjudicator is therefore also influenced by the biases and inconsistencies of a variety of human judgements, as suggested in many studies by Tversky and Kahneman.

The results of such biases and inconsistencies are that attention is focused on certain aspects a project more as a result of the personal biases of both decision maker and advisors than valid recognition of their intrinsic importance.

*Information Sources and Utilisation*. Information is a fundamental resource in decision-making. It has been said that bidding is largely a problem of managing and co-ordinating information (Betts, 1990). The information used by the decision maker in bid adjudication takes many forms, eg., reports and analyses formulated as part of the bid preparation process, subjective evaluation of project estimators, informal conversations with subcontractors and suppliers and miscellaneous information relating to the many internal and external factors stimulating the adjudication decision environment.

Very little value was placed by our collaborating companies on the analysis of historical information to support their adjudication decisions. For example, although information on the historical performance of competing contracting firms was available, suggesting that in some cases a particular competitor was 'buying work' for instance, the information was rarely used as there was no guarantee that competitors would continue to behave in the same way in the future as in the past. Despite this however, it was thought that it may be useful for decision makers to have access to information relating to the historical

performance of the company's own bids for differing types of projects in different geographical locations.

Information relating to the keenness of competition is normally obtained through subcontractors, suppliers and other personal contacts, rather than through any form of analysis or statistical extrapolation. Thus, feedback of information relating to the performance of bids is always incomplete - detailed information concerning the likely competition may be available for one auction, but not another.

The inconsistency and inaccuracy of information, particularly relating to competition has been the principal frustrations of the many probabilistic approaches to bidding models. Such models are based on a series of interrelated assumptions that suggest that firstly there is an adequate supply of information concerning competitors bids, secondly, that competitors will continue to bid as in the past and finally that there is no significant difference between the competitors' cost estimates (cf., King and Mercer, 1988).

## 4. STRATEGIC INFORMATION MODELLING

Concurrent with the interviews and observational studies with the two collaborating contractors, a conceptual model was developed of the information processing involved in adjudication

decision making. Martin's (1986) 'information strategy planning' (ISP) was adopted for analysis and a series of models were produced representing the processes and information used. ISP is part of a wider philosophy of 'information engineering' that follows a top-down approach to analysis. ISP forms the top layer of the information engineering strategy. Fig 2 shows the principal stages of the ISP methodology and sequence of analysis involved. This identifies the key areas of the business and information entities and attributes used within each area. The process allows the development of 'strategic information models' without the rigours of more structured approaches such as SSADM.

**Goals and objectives**

Senior managers from each of the two collaborating firms were interviewed, starting from the lower level managers and working up to the most senior managers involved in adjudication decisions, ie., the adjudication decision makers. At this stage informal semi-structured interviews were the main method employed to gain an initial overview of adjudication decisions, the internal organisation of the company and general management goals and requirements. From these initial interviews a provisional model of adjudication decisions and processes was developed, within the context of the total bidding process. The 'metastructure' for bid adjudication goals, processes and critical success factors are illustrated in Fig 3.

These interviews also identified the following principal aims (general statements about direction without stating specific targets to be reached at a particular point in time) and objectives (specific targets intended to be reached at a given point in time) associated with the firms bid adjudication strategy:

•Reduce overheads associated with bidding
•Increase profit margins on jobs
•Increase bid success ratio
•Meet corporate turnover requirements
•Satisfy clients
•Meet corporate overhead requirements
•Reduce the number of claims (from clients and agents)
•Increase throughput of bids

The next stage involved a detailed analysis of the adjudication decision process on the two 'live' bids preparations within each of the participating firms. All four of the projects analyzed were based on traditional lump sum contract apart from one design and build contract.

From this more detailed overview study, a series of data flow diagrams (DFDs) were prepared based on the notation used in the Gane and Sarson (1980) methodology. The DFDs represented three levels of detail:

- Level 0 - Bidding procedure (Summary Level)
- Level 1 - Bid adjudication (13.00)
- Level 2 - Expansion of adjudication processes (13.01 - 13.07)

The data flow diagrams, not reproduced here[2], model the processes associated with the bid adjudication. The identified principal processes and decisions were then used as the basis for mapping the strategic information requirements of the adjudicator.

**Critical success factors**

From our observations, the decision makers, to ensure competitive performance and achieve the bidding aims and objectives identified in the overview study, aimed to achieve satisfactory results in certain key areas. These specific areas, in which satisfactory results are paramount, are referred to here as the bid adjudication Critical Success Factors (CSFs).

The principal CSFs in bid adjudication were found to be:

- Profitability of job
- Optimisation of bids (Profitability vs competitiveness)
- Risk assessment of bids

[2] Full details of these can be found in Skitmore *et al* (1993).

- Optimisation of mark-up (overheads and profit vs competitiveness)
- Accuracy of cost estimate
- Meet or exceed specification requirements
- Meet or improve on schedule requirements
- Competitiveness of final bid value
- Maximise potential resource discounts
- Soundness of construction methods

**Critical decision/information set**

Associated with the achievement of these critical success factors are the critical decision/information sets. The critical decisions, or processes relating to the bid adjudication are represented in the Level 1 and Level 2 DFDs. These critical decisions are made based on data from the 'critical information set'. Together the critical decision and critical information sets formed the basis for the development of the strategic data model that is represented by a matrix of decisions against information.

## 5. SYSTEM DEVELOPMENT

**Overview**

The model illustrated in Fig 4 represents a general conceptualisation of the decision process and information flow relating to bidding adjudication decisions arising from the study.

Here we identify some fundamental requirements for the development of an effective adjudication decision system. Primarily that is for a system that deals with the wider internal and external environments, both on a qualitative and quantitative basis. Such a system subtends the philosophies of an array of goals other than just pure economic (Toffler, 1971; Johnson and Scholes, 1984; Skitmore, 1989).

The failure of mathematical optimisation models to replace managerial judgement suggests the need for a system that can inform the decision maker of the likely effects of decisions formulated by his own judgements and perceptions, a view supported by Wagner (1971). Similarly Cusack (1981) suggests that there is no shortage of available data, what is lacking is a quick and accurate method of analysis enabling evaluation of the alternative solutions.

Levinson (1953), and later Skitmore (1989), suggests the use of a combination of formal and informal methods. The more structured aspects of the decision problem are dealt with by quantitative formulation. These sub-optimised solutions can then be considered by the decision maker together with the more

unstructured aspects of the problem. The decision is therefore based partly on basic analytical techniques, on other information produced by the system but also on the judgement and intuition of decision makers.

Following this analysis it was clear to us that the principal requirements of the system should be as follows:

- evaluation should not be restricted to just pure economic factors
- information from both internal and external sources should be incorporated
- both quantitative and qualitative information should be supported
- provide analytical support for the more structured aspects of the decision problem
- provide suitable information to support judgement and intuition for the more unstructured aspects
- the system should facilitate 'what if?' analyses of alternative solutions

**EIS or DSS?**

The semantics and taxonomies of Executive Support Systems (ESS) and related Executive Information Systems (EIS) and Decision Support Systems (DSS) technologies are not of direct interest to

this paper. However, given the relative obscurity of these technologies in construction information management a brief outline is given below.

Fig 5 contrasts the principal characteristics and relationship of DSS and EIS technologies - the cornerstones of the ESS technology.

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

The term "executive support system", however, usually 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, DSS and other support capabilities (E-mail, computer conferencing etc.). For our scenario the ESS technology may be conceptualised as the addition of the following capabilities to EISs:

- data analysis and modelling
- ad-hoc access to data
- 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.

Such a hybrid 'executive support system' (ESS) supports many of the requirements identified for an adjudication decision system.

**Conceptual model: the 'multiple systems' approach**

In contrast to the current trend towards the development of 'monolithic' integrated databases the more traditional 'multiple systems' approach of MIS (*cf.* Crow, 1990) seems appropriate.

This approach recognises that the ideal 'integrated' system cannot be designed (Senn, 1990). The MIS multiple systems

approach integrates information from identified **functional area information systems** (eg., planning, cost estimating, marketing, accounts) to provide an encyclopedia of details and information.

The multiple systems approach, as illustrated in Fig 6, may be parallelled with the "schematic diagram" of our own brain and nervous system (*cf.*, Wooldridge, 1963). Ergo, it is a metasystem of related but independent information systems 'building blocks' that interface with each other, yet operate separately. These independent systems are often, however, organised into databases that are controlled to best meet all user requirements. This provides a core of data that can be used by each of the functional area systems within the metasystem.

The adoption of this approach facilitates the use of information stored in existing systems and the flexibility to accommodate changes. In addition the continual flow of information between departments and units makes it possible to coordinate and control the activities that occur in each one.

The conceptual structure of the proposed system, as represented in Fig 7 is based on such a multiple systems philosophy.

**Development environment**

LIGHTSHIP 3.0 (Pilot Executive Software) was selected as the controlling development environment, running under WINDOWS 3.0 for IBM DOS on a PC 386 platform with additional XGA graphic capabilities.

This shell is only one of the development packages designed to build and run EIS/ESS applications specifically for PCs and Local Area Network (LAN) based architectures. LIGHTSHIP is a relatively inexpensive tool for building such applications, normally associated with elaborate and expensive host based systems. Running under WINDOWS 3.0, it provides an 'object oriented' development approach utilising the WINDOWS Dynamic Data Exchange (DDE) protocol, multitasking capabilities and other WINDOWS features to draw data from workstations and servers on a LAN, as well as external on-line data. Such features also allow LIGHTSHIP to interface to other software applications. These features are employed to develop the system structure, described in Fig 7. For development of the prototype system, however, the connectivity problems of the LAN architecture are removed by the encapsulation of the whole LAN environment on a single PC. This is achieved by a series of 'dummy' databases representing the various distributed functional area systems.

**ESS core**

LIGHTSHIP, operating as the ESS core, assumes the role of the central processor, or brain, of the metasystem. This core, utilising the techniques discussed above, 'sucks in' the relevant data, using either the WINDOWS DDE function or through an SQL request (flat files may also be used). The data may then be viewed from a variety of perspectives, defined by the decision maker, using the 'drill-down', 'slice and dice' and 'multidimensional', characteristics of ESSs. In addition the information can be analyzed using the core's integral analysis tool set or by paging out to subroutines for more sophisticated modelling functions.

Information is presented in pre-defined 'data-driven' screens, incorporating the use of icons and 'hot-spot' keys, with mouse driven selection, for user requests. Although the flexibility of information retrieval and analysis is bounded, a tradeoff has been made in favour of icon driven use and instant graphical display of the information.

**Databases**

For the prototype study, as previously suggested, it was necessary to represent the LAN, or other, distributed environment by developing a series of 'dummy' databases

representing the functional area information systems. SUPERBASE 4 (SPC Software Publishing) was selected to develop these databases, being one of the best-selling WINDOWS compatible relational databases. For the operational system data may be drawn, where possible, from existing information systems.

Databases are required to be constructed for each of the functional area information systems:

- cost estimating
- planning
- corporate (accounts etc.)
- personnel
- contracts
- marketing
- external sources

## 6. SUMMARY AND CONCLUSIONS

Contract bidding in general, and bid adjudication decisions in particular, necessarily have a significant correspondence with the strategy and performance of the contracting firm. Such decisions are highly context dependant relying on a multiplicity of objectives, goals, individual factors and subject to high uncertainty and severe time constraints. It is therefore not surprising that decision makers have found little use for formal

techniques such as OR, relying instead largely on experience and intuition.

The research described in this paper clearly identified the complex nature of strategic bidding decisions. Such decisions are related to two principal strategic functions, the decision to bid and adjudication/mark-up decisions. Despite (or perhaps because of) the complexity and many factors involved in such decisions, in practice they are still made largely based on intuitive heuristic techniques. Contractors rely on 'gut-feeling' and value judgements to make decisions that significantly affect the short and long term performance of the organisation. The need for a more structured approaches to making both types of strategic bidding decision was identified.

An ISP form of structure analysis, based on information strategy principles, was applied to the data collected in interviews and observational studies and found to be more suitable than other, more inflexible, systems of structured analysis. This analysis resulted in the production of a series of models describing the strategic information requirements of the adjudication decision maker. From these basic models of the adjudication process and the information attributes used in support of adjudication decisions, a model of the required system was developed. An ESS approach has been used to integrate and centralise the information and tools required for a prototype system. The

information is presented graphically via icon driven screens utilising user driven 'hot-spot' keys.

Future work on the system will involve the further development of the prototype system. Once at a suitable stage this system, together with its artificial microsystem representing the contracting firms' distributed information metasystem, will be introduced to the participating firms for iterative development.

The research described in this paper has focused on one aspect of one specific problem area, namely contract bidding. It is clear however that the principles of information engineering, particularly in the early stage of information strategy planning, could be applied to the generic scenario of the construction firm. The techniques described here could be used to develop a strategic model of the aims, objectives, functional areas, critical success factors, critical decisions and critical information relating to strategic management of the whole construction organisation. In short a structured analysis of what makes the firm 'tick', in terms of information feedback. Such models could be used to examine the nature of strategic information use by management with a view to creating a more generic executive information system. Such a system could provide strategic decision makers with until now lacking information critical to the strength of the firm.

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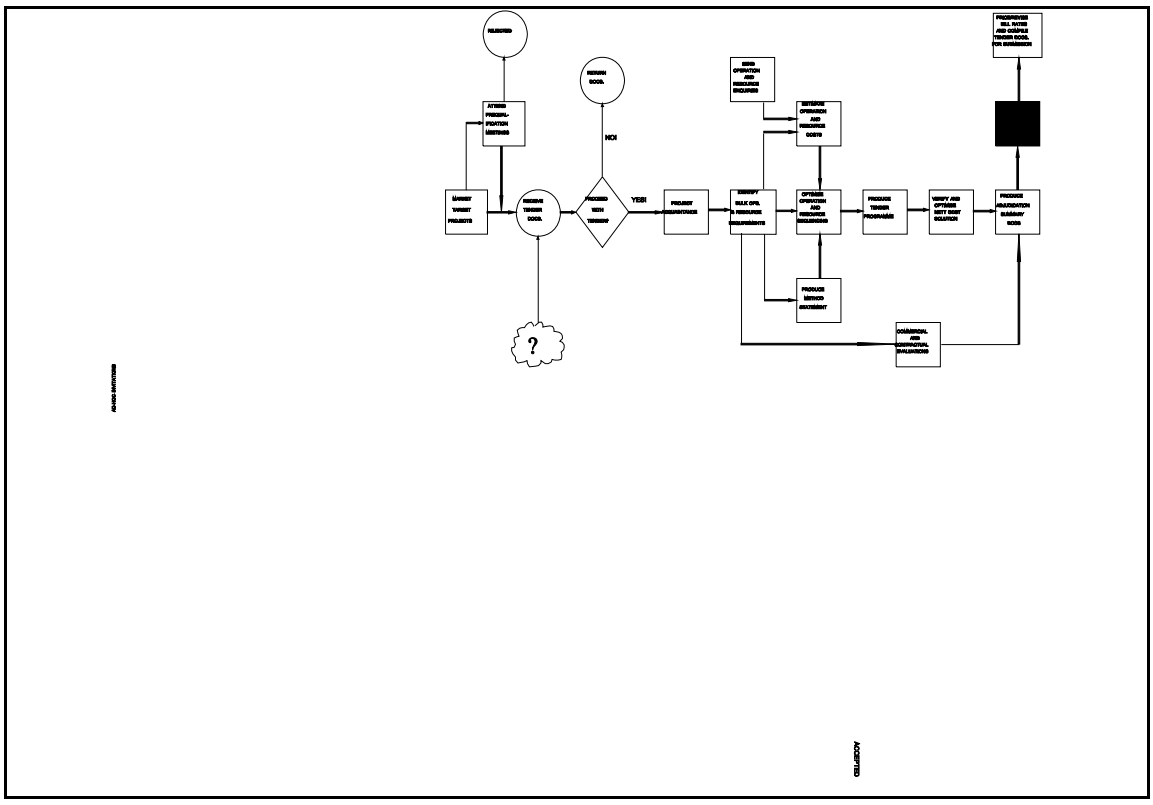


*Fig 1: Overview of strategic decision process in tendering*

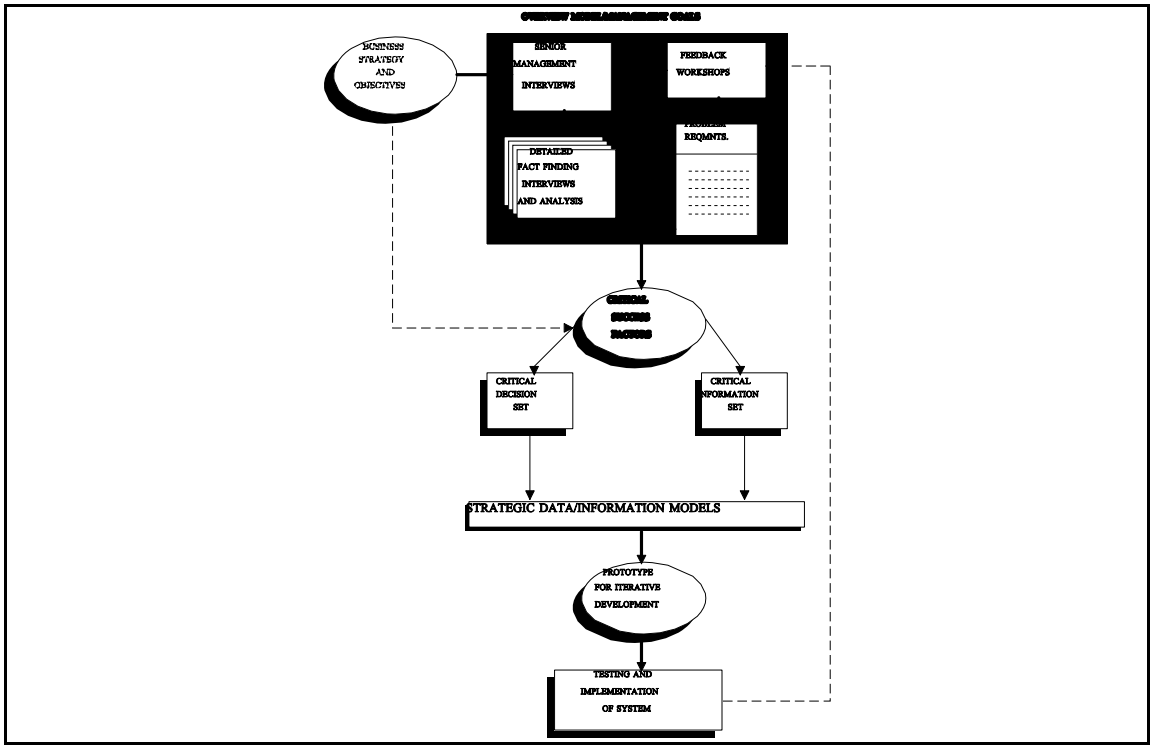


*Fig 2: ISP top-down analysis methodology*

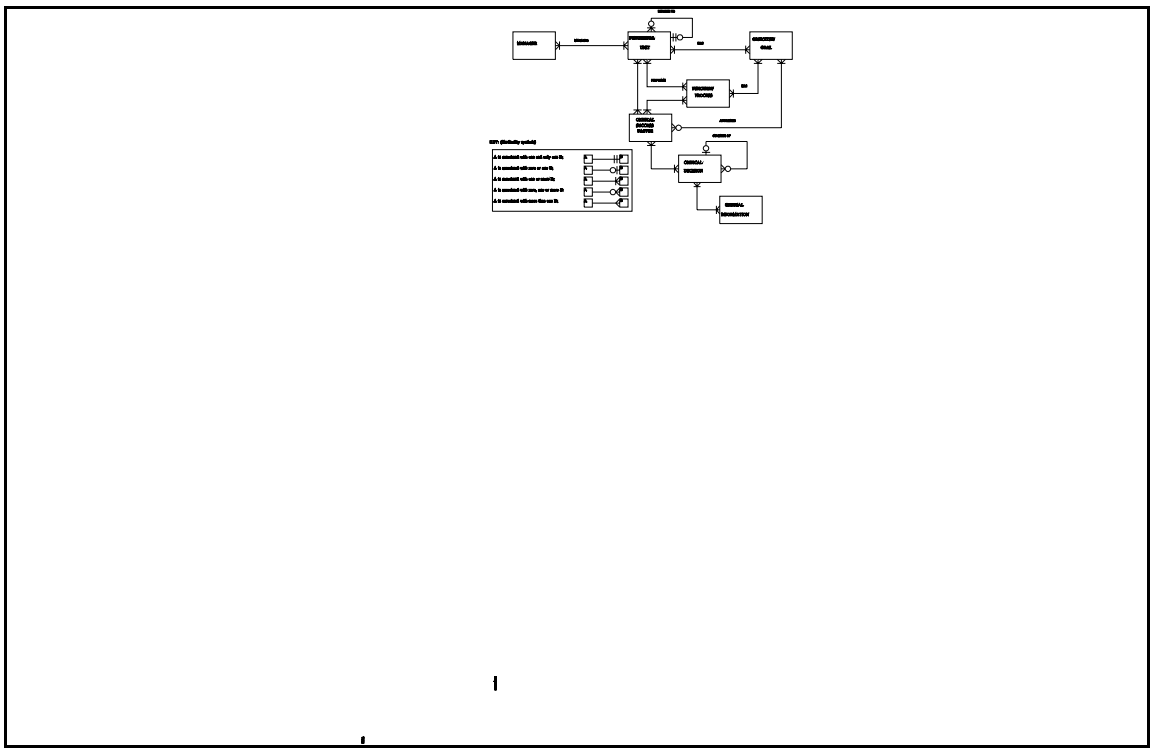

*Fig 3: Metastructure for tender adjudication goals and CSFs*

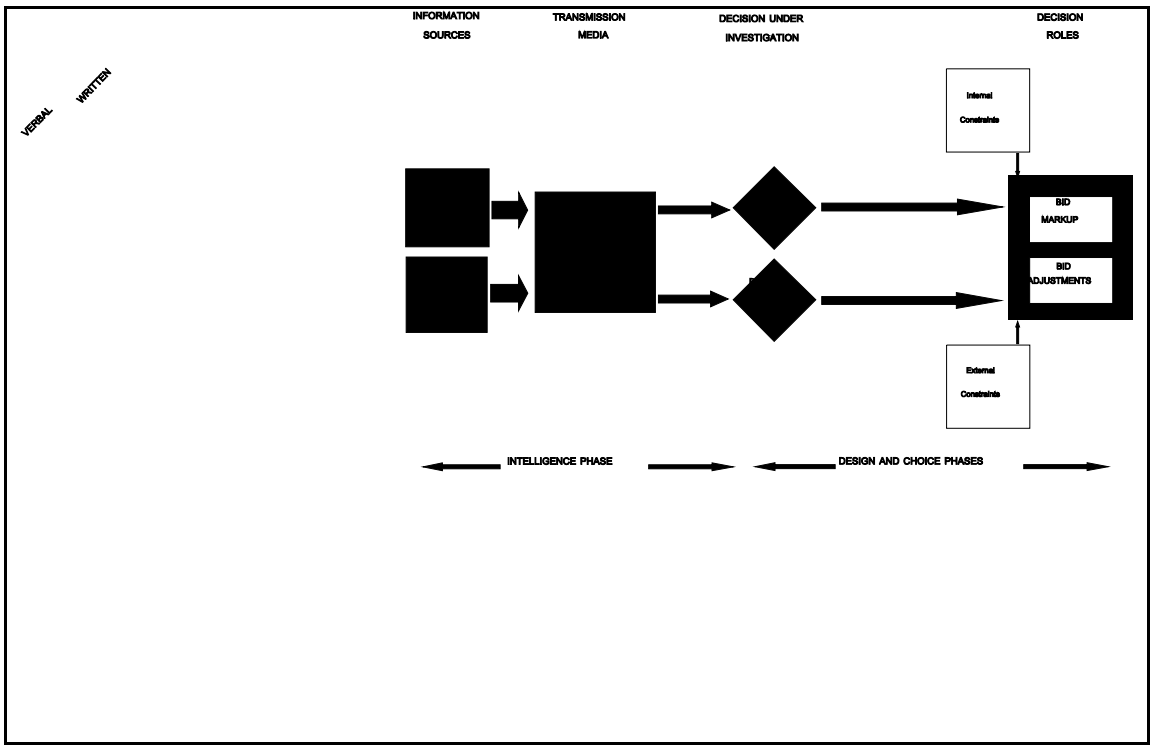


*Fig 4: Adjudication information flow and decision criteria*

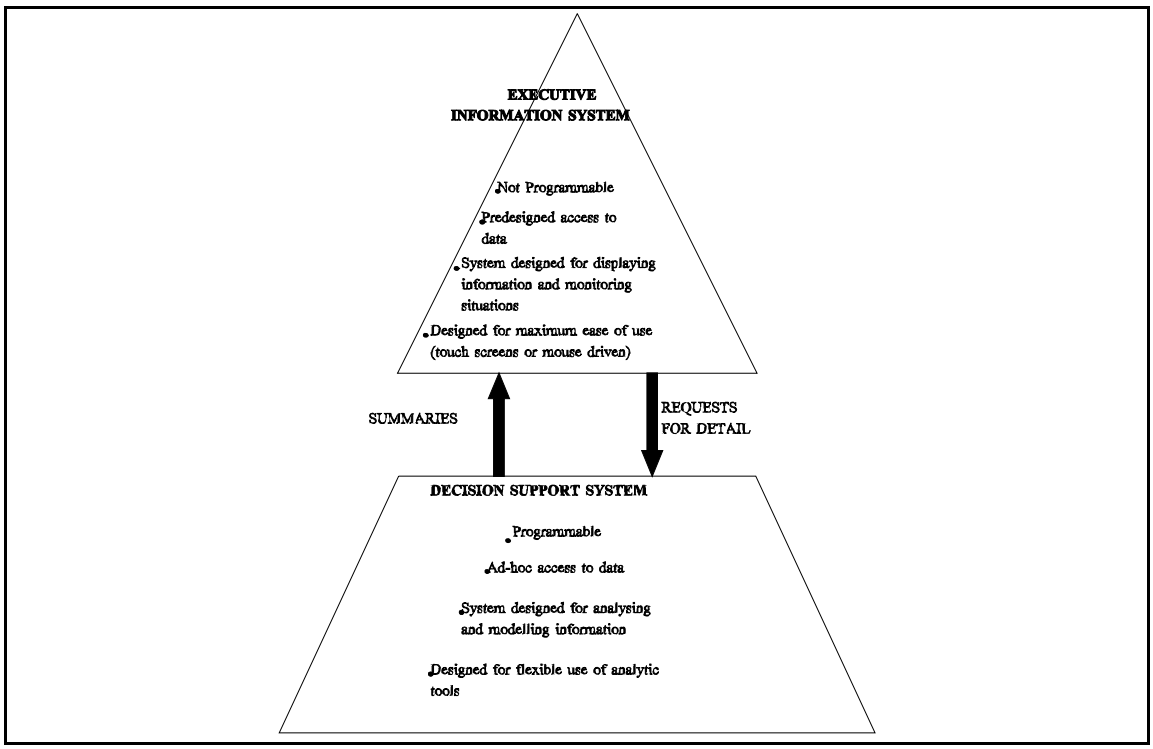


*Fig 5: Contrasts between Decision Support Systems and Executive Information Systems*

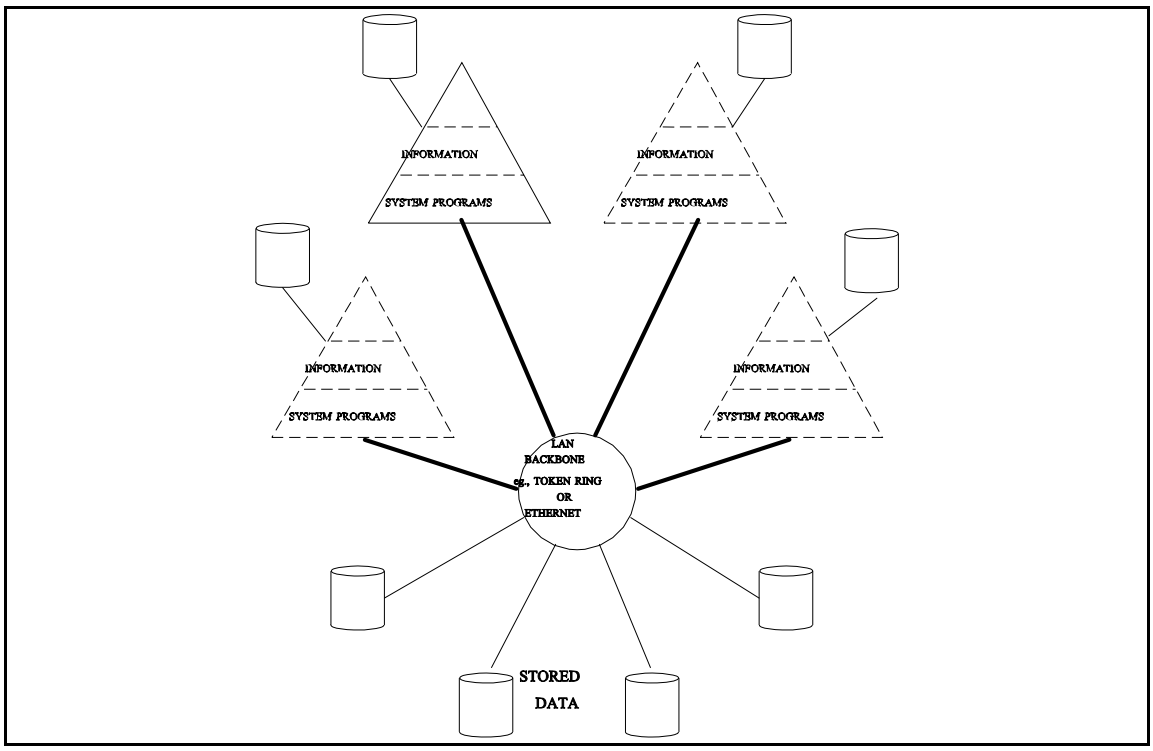


*Fig 6: Metasystem of functional area information systems*

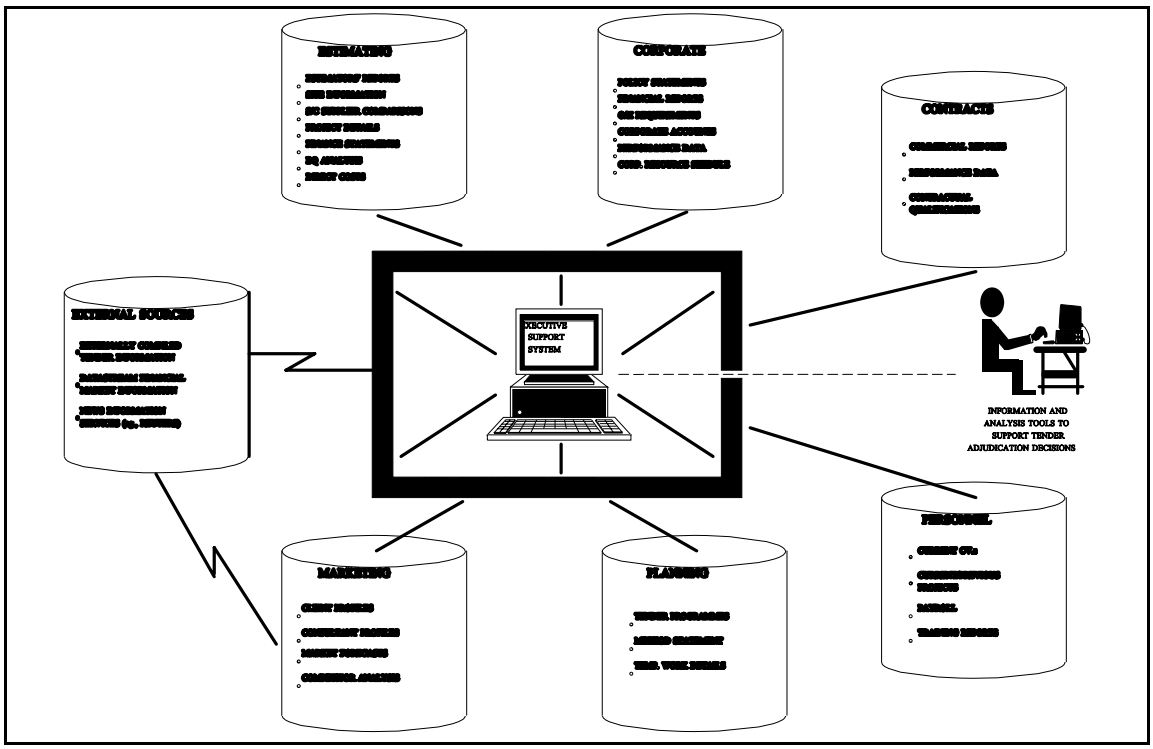


*Fig 7: ESSTA - Conceptual system structure*