Knowledge-Based Technology in Executive Information Systems

Liu Shuhua
Institute of Systems Engineering
Tianjin University
Tianjin 300072
THE PEOPLE'S REPUBLIC OF CHINA

Vesa Savolainen
Department of Computer Science
and Information Systems
University of Jyväskylä
SF-40351 Jyväskylä
FINLAND

Abstract: As the rapidly growing frontier of computer-based information systems (CBISs) for managerial use, Executive Information Systems (EISs) have proved to be able to satisfy the information needs of executives better than earlier attempts. However, some problems still exist. While most of the conventional EISs are good at providing executives with easy access to business performance data, they are not so competent at supporting the executive's decision analysis process. To solve the problem, we propose the integration into EIS of decision support capability, together with ES (Expert System) and KBS (Knowledge-Based System) technology. Based on a review and comparative analysis of different kinds of CBIS, the concept of an Intelligent Executive Support System (IESS) is defined and discussed from multiple points of view. A conceptual framework for an IESS is presented and an IESS architecture is constructed.
Keywords: Executive Information Systems (EIS), Management, Decision Support, Expert System (ES), Knowledge-Based System (KBS), Intelligent Executive Support Systems (IESS)

Liu Shuhua was born in Shanxi, P.R. China in 1964. She graduated at the Northern Polytechnic University in Industrial Automation in 1984. She received her Master Degree in System Engineering from Tianjin University in 1990. She worked at the Institute of Systems' Engineering at Tianjin University from 1990 to 1993 as an assistant and a lecturer. From May 1993 until now she has worked at the University of Jyväskylä, Finland, as a researcher on the Executive Information Systems Project supported by the Finnish Ministry of Education. Her fields of interest include decision support systems, executive information systems, knowledge based systems,and management decision analysis.

1. Introduction

Executive Information Systems (EISs) and Executive Support Systems (ESSs) are the latest steps in the development of Computer-Based Information Systems (CBISs) to satisfy the information needs of executives in organizations. An EIS provides executives with easy access to internal and external information that is relevant to their critical success factors [44]. It gives executives an "information window" through which they can closely monitor their corporation's operations, performance, and business environment in a more timely and detailed manner, so that they can get a better understanding of their business and make better strategic decisions [43, 45].

The earliest CBISs for executives appeared in the late 1970's [16, 17, 30]. With the development of modern information technology, the properties of EISs have improved continually. They have been developed in a rapidly growing number of organizations, especially in recent years, with the availability of a wide variety of EIS vendor's software. Moreover, empirical studies reveal that EISs are spreading from top management to middle management, and even to the whole organization [14, 26, 27]. Green commented that "The E in EIS does not just have to mean Executive. Once targeted at the top brass, Executive Information Systems are now marketed to and used at other levels of the organization. EIS can mean Everybody's Information System to some and even Enterprise Intelligent System or Enterprise Information System to others". All these indicate that the concept of an EIS is evolving and extending beyond its original scope [7].

While most of the traditional EISs are good at providing executives with easy access to the current status and projected trends of the business, they are not so competent at offering support for decision analysis activities [24, 25, 41]. However, in practice many information requirements of senior managers cross the boundaries between traditional EISs and DSSs. The concept of an EIS has recently been related to DSSs [14, 20, 29, 41], and the term ESS (Executive Support System) is put forward to represent a CBIS for executives, but with a broader set of capabilities than an EIS. An ESS is viewed as an integration of EIS and DSS functions [40, 41]. It can provide its users not only with powerful data access and communication capabilities, but also with decision support capabilities.

An ESS can thus extend an EIS capability with decision support tools, especially decision analysis models. However, some other problems still exist. First, as most of the quantitative decision analysis models are usually elaborated as mathematical models, their use requires a considerable amount of specialist knowledge. This makes it difficult for the users, especially top-level managers to make effective use of the tools. Second, many important decision problems (ill-structured problems which are typical to executives) have important qualitative components that do not lend themselves easily to the calculus of real numbers. Many of the decision making tasks involve complexity beyond the reach of optimizing technologies, requiring not only algorithmic but also heuristic approaches. In these cases, we must seek help from other kinds of tools. In our study we try to introduce ES (Expert System) and KBS (Knowledge-Based System) technology into an ESS as a remedy.

Since the mid-eighties, it has become apparent that an ES/KBS can be used as an integrated part of a larger computer based information system. Currently, an ES/KBS is integrated into a wide range of other CBISs [41, 42]. With ES/KBS technology, expertise on model construction, model use, and result interpretation can be introduced into the system to assist users in using the decision tools more effectively. In addition, in solving those problems where quantitative computational algorithms alone are insufficient, inappropriate, inapplicable, or even impossible, the ES/KBS technology would be very helpful by making use of management experts' domain knowledge on decision makings.

The integration of an ES/KBS into an ESS results in the concept of an integrated ES-EIS-DSS or Intelligent ESS [41]. IESSs are still a new topic. There are a few discussions on IESSs in the literature [21, 31], drawing attention to this new field. Together with researches on ES applications in DSSs, they provided the foundations for further studies.

In this paper, we concentrate mainly on analysing how to integrate the ES/KBS technology with EISs and DSSs. First, in Section 2, the concept of an ESS is described based on a review of the concept of DSSs and EISs. Then in Section 3 a comparative analysis of ESs, IDSSs, and IESSs is made to reveal the characteristics of IESSs. A conceptual framework for IESS is presented. In Section 4, the whole IESS architecture is constructed and the subsystems inside IESSs and their relations are studied. Section 5 includes brief conclusions.

2. DSS, EIS, and ESS

2.1. Decision Support Systems (DSSs)

A Decision Support System (DSS) takes the responsibility of aiding managers in their decision making activities. In his famous decision-making model, Simon divided the human decision making process into three major phases: Intelligence, Design and Choice [34].

The primary task for the Intelligence phase is to find problems and opportunities, to identify the need for a decision-making activity, i.e. to scan and search the environment for conditions calling for decisions. Then, alternative courses of action in response to the problem diagnosed in the intelligence phase will be developed and analysed in the Design phase (i.e. to generate solutions and to test the feasibility of those solutions). In the Choice phase, the decision will be reached by choosing a specific course of action from the available alternatives. The choice is then made and implemented.

The concept of a DSS was first introduced in 1971 by Gorry and Scott Morton who defined it as a "supporting information system" for semistructured and unstructured decisions or human decision-making processes. It was distinguished from the concept of a Management Information System (MIS) which supports structured decisions and was sometimes also named a "Structured Decision System (SDS)" [9].

In practice, a DSS symbolizes the application of interactive technology to management decision making in organizations [1, 19, 36, 38]. It aims at providing a decision analysis environment that helps the managers to identify the problem, to define the decision objectives, to construct and modify the decision models, to construct alternatives, evaluate them and choose among them. All the analysis, comparison and judgment can be based on the repeated man-machine dialogue (i.e. the interaction process). In this way, a DSS aids decision makers according to their intentions. It organically combines the powerful data processing ability of computers with the creative thinking of decision makers. Thus it helps greatly in enhancing the decision making capability and level of managers.

Within the last couple of decades, DSSs have made great strides forward. Generally, a DSS has the following basic characteristics:

(a) It addresses nonstructured (mostly semistructured) rather than structured decisions.
(b) It supports managers' decision making processes rather than automates decision-making. Decision makers cannot be replaced by a DSS. Rather, their subjective judgment is integrated into decision-making processes via man-machine interaction.
(c) It aims at improving the effectiveness of management activities rather than the efficiency.
(d) It is oriented toward present and future behaviour of organizations rather than toward the past.
(e) It is typically used by middle managers and staff specialists rather than executives, although DSS users can be found at every level of management.
(f) It utilizes both data and models. Data access properties of the database technology and modelling, simulation and optimization techniques are united in a DSS.
(g) It is model and algorithm-based rather than data-based.

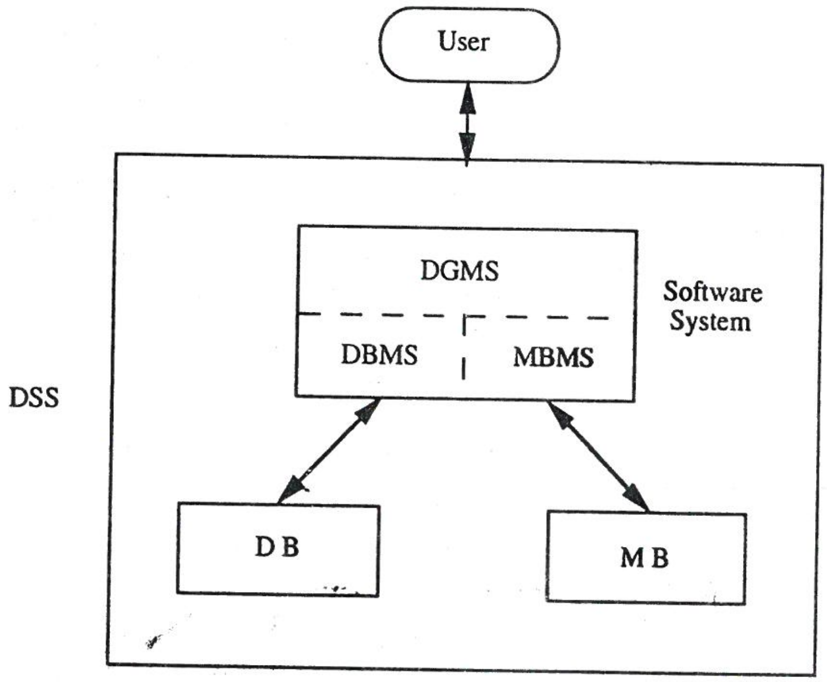

Figure 1. DSS Structure (Borrowed from [35])

(h) It focuses more on a specific decision problem or collection of decision problems than on ad-hoc problems.
(i) Its weakest point is the lack of user-friendliness in its interface.

A typical DSS architecture is shown in Figure 1. As it indicates, the basic components of a DSS include: a database (DB), a model base (MB), and a comprehensive software system (DBMS, MBMS and DGMS) that connects the user to every part inside the system [35].

The combination of DB and DBMS forms the database subsystem, which stores a large amount of data relevant to the decision problems. Data are collected and updated frequently and in a timely manner. They are independent of models so that they can be shared by all the models and decision processes. Data retrieval is done by means of the DBMS (Data Base Management System).

The combination of MB and MBMS constitutes the kernel of the DSS, which stores a large variety of models relevant to decision makings. By means of the MBMS (Model Base Management System), users can select and combine some models in the MB to construct the "decision support model" for solving a specific decision problem.

The DGMS (Dialogue Generation and Management System) ensures the realization of the man-machine interaction. It presents the outputs of the system to users and collects the inputs of the users to the system. All the capabilities and properties of the system are reflected through the DGMS.

2.2. Executive Information Systems (EISs)

The EIS first appeared as a concept in the late 1970's and early 1980's. The MIDS (Management Information and Decision Support) system at Lockheed-Georgia is one of the earliest examples of an EIS, beginning operation in 1978 [16, 17]. However, the term EIS was not used until Rockart and Treacy introduced it in 1982 to symbolize a top manager's use of computers - an executive information support system, which aims at meeting more effectively the information needs of top management in organizations [30, 40].

According to Watson, Kelly Rainer and Koh [44], an EIS is a computerized system that can provide top managers with easy access to internal and external information that is relevant to their organization's critical success factors. To reach this objective, the EIS utilizes the most modern methods of communication, graphics, data storage and data access. It offers a user-friendly interface - the most modern feature of an EIS [26, 27]. EISs provide executives with immediate access to relevant, concise and accurate information that is presented in convenient formats. It forms the information basis for executives to facilitate their reaction to the volatile, rapidly changing and challenging business environment more quickly and effectively so as to secure their organization's competitive positioning and strategic advantage.

EISs possess such characteristics as:

(a) Support of unstructured management activities rather than specific recurrent decision problems.

(b) Support of executives in Intelligence phase of decision-making process, with simple data analysis techniques.

(c) A user-friendly interface for the interaction between executives and the system. It is easy and intuitive in use. By means of the EIS, executives become hands-on users of computers.

(d) Help for executives in improving both the effectiveness and efficiency of their management activity.

(e) An orientation toward the present and future, rather than the past behaviour of the organization.

(f) They are typically used by top managers, although middle managers are also becoming more interested in it.

(g) They mainly utilize data, not models. They are user-driven. Advanced computer hardware and software technology, communication technology, and office automation technology are employed to provide executives with immediate and timely access to business information that is presented in convenient, customized formats.
(h) They support less structured, ad hoc and wider-ranging decision activities. They require a broader database - internal and external, hard and soft, numerical and symbolic data on a variety of important business variables (e.g. major general ledger accounting variables and non-financial substantial variables) through time and different business units and from multiple sources (competitors, customers, industry, market, government, international, etc.) - than a typical DSS.
(i) Their typical uses include: tracking critical success factors, exception reporting, drill-down or drill-across investigation, and preliminary trend analysis.
(j) They can be tailored to different individual executive decision-making styles.
(k) While a DSS focuses on problem-solving, an EIS concentrates on problem identification.

To get a better understanding of EISs, the internal structure of a commercial EIS vendor software (Command Center of Pilot Executive Software) is shown in Figure 2. The system is built around a central database (EIS database) on a mainframe. It distributes the system functions between a mainframe and any number of PCs. On the mainframe, DataBridge brings data from widely varying systems into the EIS DataBase. It integrates commercial databases and on-line public databases, as well as in-house systems. The EIS database is a retrieval oriented database that handles both numbers and text. The Menu System gives mouse or touch-screen driven operation controlled from the host [40].

On PCs, the Graphics module creates bar, line, scatter, and cross-sectional charts, and also mixed text and graphics, based on the data and commands sent from the mainframe. The Menu System here uses a local menu storage: menu screens can be stored on the PCs so that they do not have to be retransmitted from the host. The user interface makes the system accessible with non-keyboard pointing devices such as a mouse or touch-screen (keyboard access is an option). Smart communication exists between the mainframe and PCs for error-correction or data transfer.

Such a system structure gives users the benefits of both the PCs (superior displays, quick response, and highly interactive capabilities) and the mainframe (database power and systems logic controller capabilities).

2.3. Executive Support Systems

In the literature, the terms EIS and ESS both appear to represent the information systems that serve top managers. In most cases, they are not clearly distinguished from each other. In our opinion, ESSs and EISs are closely related but different concepts.

The term ESS was first proposed and defined by Rockart and DeLong as "the routine use of a computer-based system, most often through direct access to a terminal or personal computer, for any business function. The users are either CEO or a member of the senior management team reporting directly to him or her. Executive Support System can be implemented at the corporate level or divisional level" [29].

In their work, Rockart and DeLong differentiate an ESS from an EIS by endowing it with office support (communication) capability as well as query and analysis capabilities. Similarly, Turban and Watson define an Executive Support System as "a computer-based application that supports the executives' planning, analysis and communication needs in addition to their information needs" [41]. With the development of EIS in practice, the concept of an EIS is extending beyond its original scope. Office support capability has become an implied function of an EIS. Thus here in our study, we regard an ESS as different from an EIS mainly in that it implies more abundant decision support capabilities than EIS. In practice, it means the combination or integration of EIS and DSS

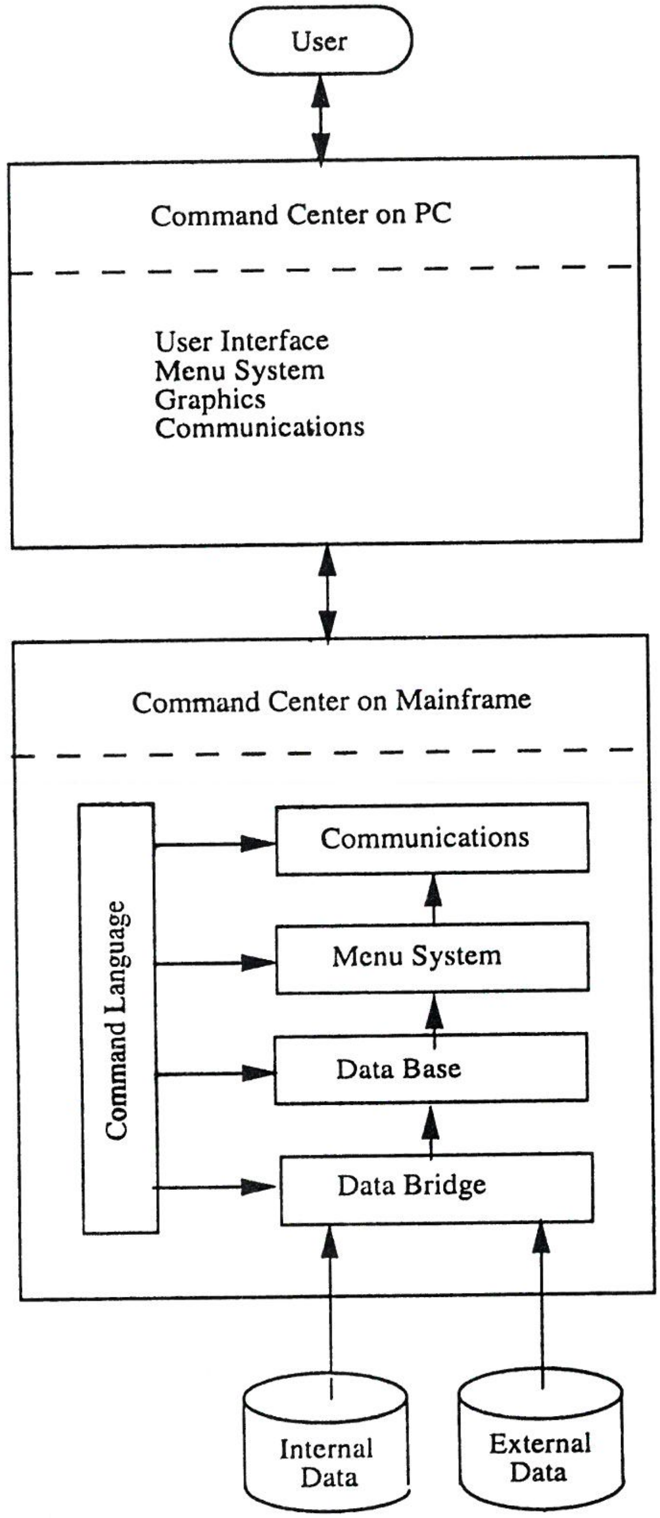

Figure 2. Structure of an EIS Product (Command Center)
(Courtesy: Pilot Executive Software)

capabilities into a unified system, as shown in Figure 3.

(e) It utilizes data (with a wider range than a DSS), communication tools, and models. It is both data-based and model-based. It can be both data access oriented and data analysis oriented.

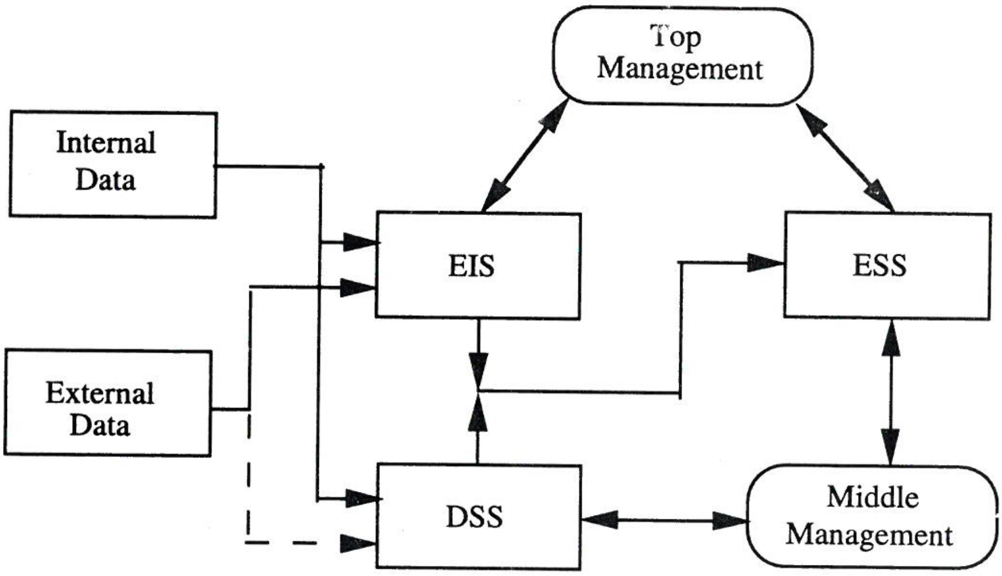

Figure 3. ESS Concept

The characteristics of an ESS can be described as follows:

(a) It offers help not only in the decision making processes, but also in managers' routine work.
(b) It focuses on management activities, both semistructured and unstructured, as well as on specific repetitive decision and ad hoc problems.
(c) It provides support for the decision-making process not only in the Intelligence phase, but also in the Design and Choice phases.
(d) It can serve two major groups of users: firstly top managers, and secondly middle managers and staff specialists. It can provide executives with a decision analysis facility as well as with a powerful data access ability. It can also provide middle managers and analysts with easy access to the same data sources as accessed by executives, together with the decision analysis tools they need.
(f) It provides a user-friendly interface and analytical capabilities. The concept of an ESS well supports the idea that DSSs and EISs are by no means mutually exclusive domains. They are different but complementary products. In the view of organizational management activities, many of their information requirements cross the boundaries between conventional EISs and DSSs.

The focus of an EIS is on aiding a decision maker in assimilating information quickly and in identifying problems and opportunities quickly and accurately, while the focus of a DSS is on helping the decision maker in problem analysis and solving. The combination of an EIS with an DSS conforms well with the needs of management decision-making in organizations. A simplified structure of an ESS is shown in Figure 4 (Adapted from [41]).

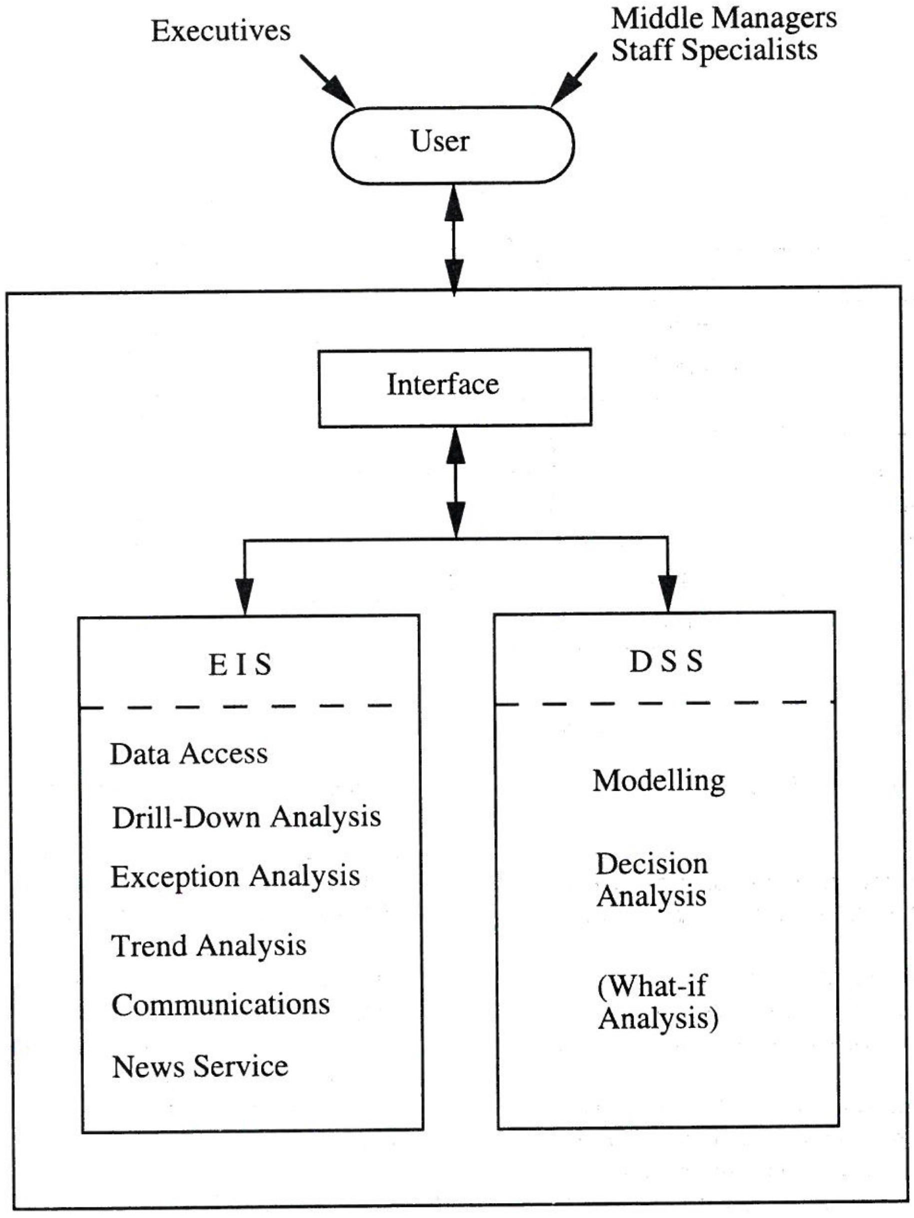

Figure 4. ESS Structure

3. IESSs as an Integration of ES/KBS Technology into EISs and DSSs

3.1. Expert Systems and Knowledge-Based Systems

Expert Systems (ESs) came into being in 1965 with the success of the DENDRAL system [2]. Since then, it has found various kinds of applications (such as diagnosis, interpreting, designing, planning, controlling, etc.) in many fields, including medicine, chemistry, geology, manufacturing, education, economics and management.

An ES is designed to mimic human experts. It is in essence one kind of information system in which specific domain knowledge, especially heuristic expertise from domain experts, is stored and can be utilized in the way human experts use it to solve complex problems in a narrow problem area. Its performance will attain expert level or an even higher level.

ESs are Knowledge-Based Systems (KBSs). All KBSs differ from conventional information systems in that they perform symbolic reasoning rather than numeric calculations when carrying out the tasks. More important, they can handle unstructured and uncertainty situations where a strictly numeric solution would be difficult or even impossible to reach [28]. Knowledge based systems are characterized by the following:

(a) They are hopefully as good as humans in some restricted area, but they cannot replace a human.
(b) They perform more qualitative reasoning, whereas traditional systems perform more information processing.
(c) They can perform when strict algorithmic solutions are not feasible.
(d) They are based on a model of human experts.
(e) They utilize data and knowledge.
(f) They acquire improvement and enhancement of their performance through being used.
(g) They exhibit awareness and a sense of the system itself.
(h) They assist in absorbing facts, insights, and the whole decision-making process. The usefulness of a KBS depends heavily on its knowledge base.

To give an essential image of a KBS, the basic structure of an ES is illustrated in Figure 5 (Adapted from [28]).

The *Inference Engine* is in fact a kind of general problem-solving knowledge. It is the mechanism designed to employ domain knowledge. It controls the process of invoking and selecting the specific pieces of knowledge (e.g. rules) that are related to a specific problem-solving process.

The *Explanation Generator* gives a description and interpretation about the system's operation and the system itself.

The *Knowledge Base* is a collection of domain knowledge which may include heuristics, common sense knowledge and principal knowledge. Heuristics should be the largest portion. Although the heuristics may have no strict theoretical evidence, they are usually more effective for solving practical problems.

The *Knowledge Acquisition Tools* are techniques used to extract knowledge from domain experts and represent it in the system.

Relevant data, facts and also the transient status of problem-solving (e.g. current reasoning paths employed by the system in solving a specific problem) are stored in the *Data Base.*

3.2. Intelligent Decision Support Systems (IDSSs)

The different types of information systems such as MISs, DSSs, and ESs were originally designed and implemented as stand-alone systems. As ES/KBS became commonplace in business organizations, it turned evident that they could be used as an integral part of a conventional CBIS.

The introduction of ES/KBS technology into conventional CBISs began early 1980's, and much attention was paid to their integration with DSSs [3, 4, 5, 6, 10, 11, 12, 13, 15, 18, 22, 32, 33, 37, 39]. The integration of ES/KBSs to DSSs brings forth what we call Intelligent

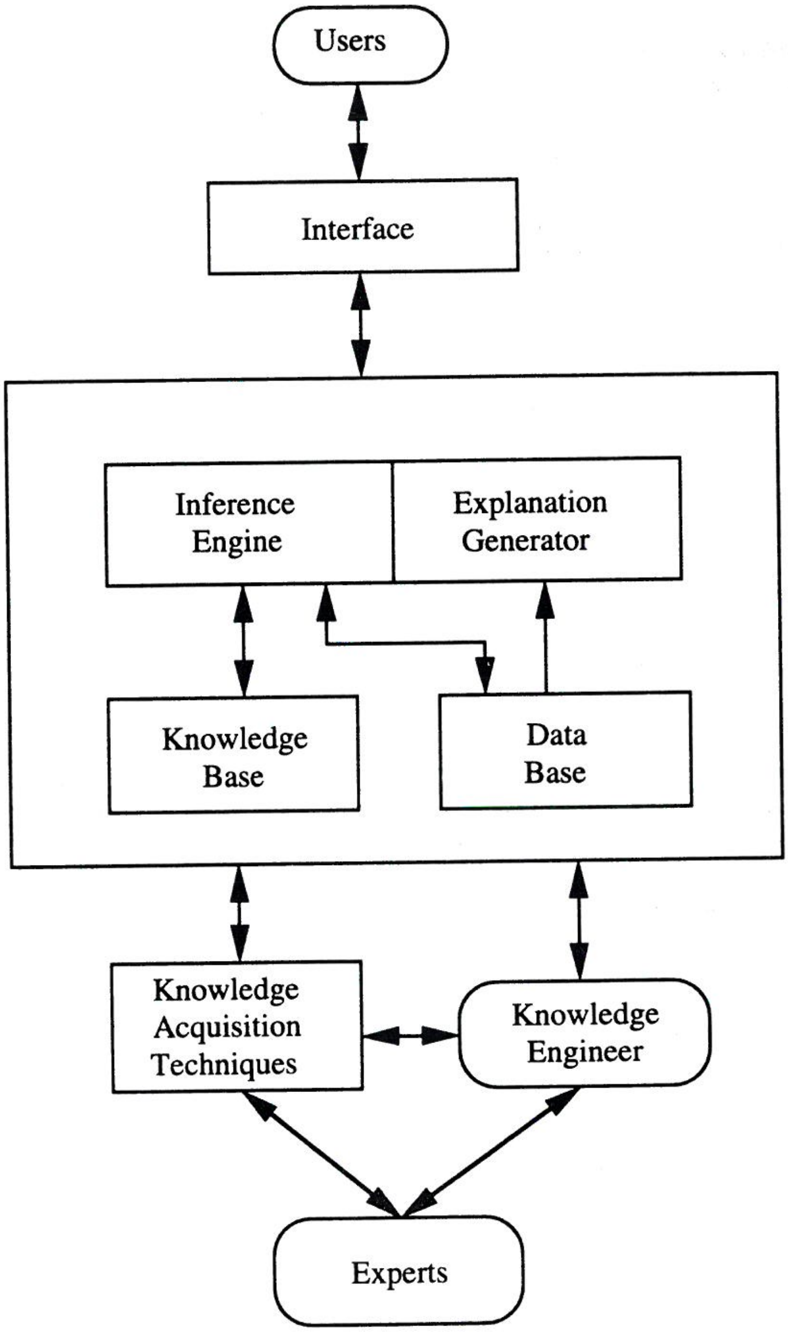

Figure 5. Expert System Structure

Decision Support Systems (IDSSs). Such an integration can increase the effectiveness of a DSS as well as enable the use of a DSS to solve rather complex problems.

To date, many attempts have been made to integrate ES/KBS technology with databases, model management and the dialogue system (i.e. every component of a DSS). The enhanced capabilities and characteristics of an DSS are reflected in the following aspects:

(a) It is endowed with inference capability in data processing and problem-solving.
(b) It enables tackling of unstructured decisions.
(c) It can support an expanded query process.
(d) It provides help in problem identification, model construction, and model using.
(e) It provides interpretation of the output.
(f) It offers improved man-machine interface.
(g) It uses data, knowledge, and quantitative models.
(h) Compared with ESs, an IDSS can handle more extensive and more complex problem. While the knowledge in an ES is "deep and narrow", in an IDSS it is "rich and wide".
(i) In an IDSS quantitative calculation is combined with qualitative reasoning.

The structure of an IDSS is shown in Figure 6 (Adapted from [5]). Generally, it consists of three major parts: a Language System (LS), a Problem Processing System (PPS), and a Knowledge System (KS).

The Language System contains all the communication facilities which are made available to users by the system. It provides a language for stating the problem. The Knowledge System is a generalized conception. It refers to the system's body of knowledge about the problem domain. It includes large volumes of facts (in data form), models, and expertise. The Problem Processing System acts as an interface mechanism between expressions of knowledge in the KS and expressions of problems in the LS. It contains a DBMS, and MBMS, as well as an Inference Engine for reasoning.

3.3. Intelligent Executive Support Systems (IESSs)

In recent years, several experiences have indicated that ES/KBS technologies are being integrated into a wide range of other CBISs, resulting in substantial benefits [23, 42]. On the one hand, this integration is made for the refinement and higher usefulness of conventional CBISs. On the other hand, many ESs often need to formulate and execute conventional CBIS applications (e.g. database and information retrieval systems). The availability of modern technologies that have developed fast over the past years, makes the integration technically feasible. Now the integration of different information systems has become an important trend. An IESS is just a product from the integration of ES/KBS technology with an EIS and a DSS (see also [41]). Such an integration may take multiple forms:

(a) (ES/KBS + EIS) + (ES/KBS + DSS)
(b) (ES/KBS + EIS) + DSS
(c) EIS + (ES/KBS + DSS, i.e. IDSS)
(d) ES/KBS + (EIS + DSS, i.e. ESS)

No matter in what form it is, the integration of an ES/KBS, EIS and DSS makes sense only if the integration of an EIS and a DSS makes sense. So neither EIS nor DSS functions should be missing from the system.

In our work, the concept of an IESS is put forward as an improvement of an ESS. The ES/KBS technology can improve the system mainly in the following aspects:

(a) It can provide interpretation of the vast amount of information monitored by the system. It helps managers greatly in finding problems and opportunities.
(b) It provides explanations to questions that may be raised by users about the reasoning process or the conceptions of the system, making an on-line system transparent to the user.
(c) A knowledge base that contains knowledge about search strategy helps the users access relevant data in databases, especially commercial databases.

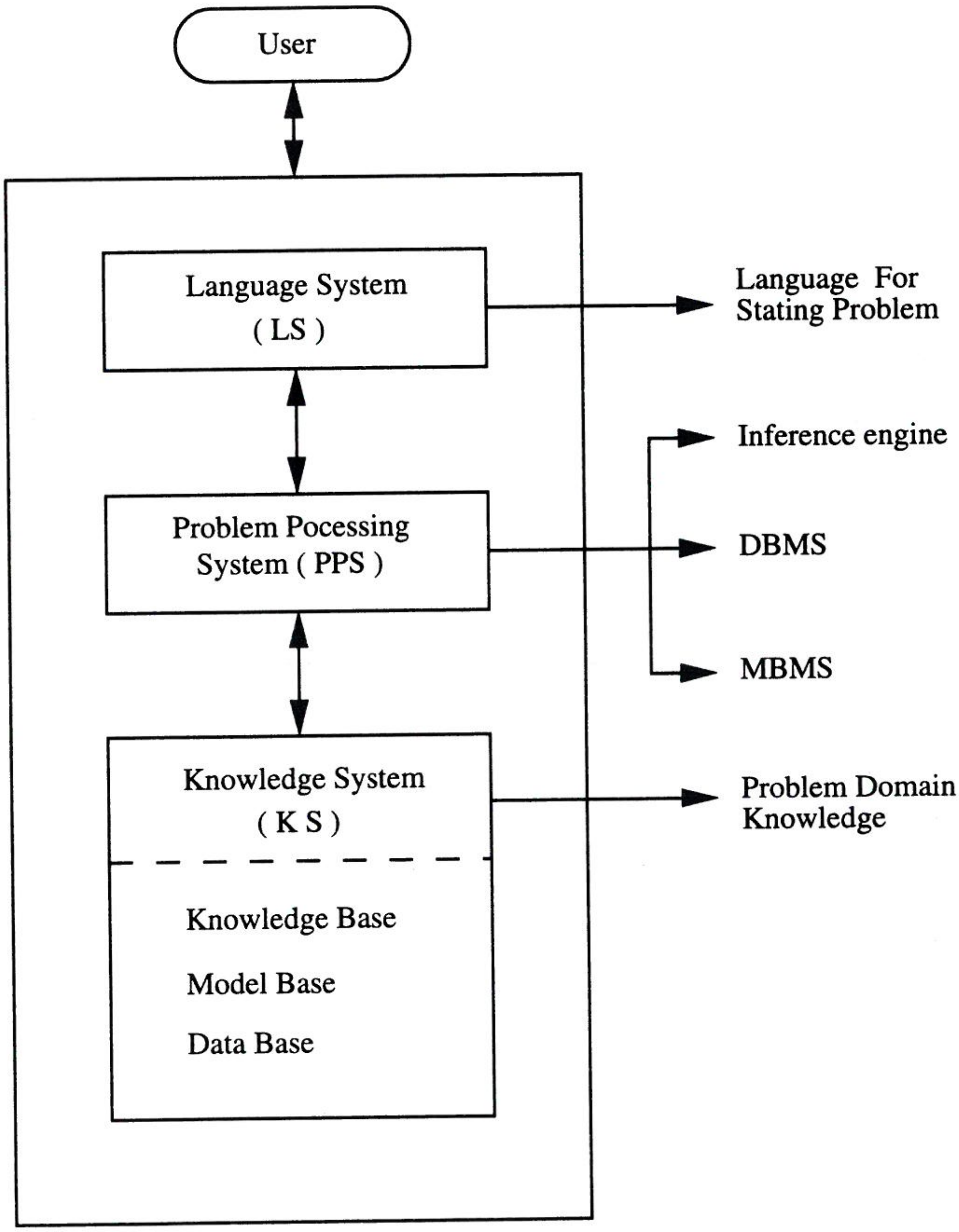

Figure 6. IDSS Structure

(d) The IESS provides users with advice and suggestions in using unfamiliar office support facilities.

(e) The IESS helps users in model formulation and algorithm operation as well as in the interpretation of results, thus making better use of analysis tools while performing the decision making activity.

(f) The IESS gives a solution to a problem through reasoning with domain knowledge when numerical, quantitative calculation is nonfeasible or insufficient.

Based on the above description, a conceptual framework of an IESS is given in the next paragraphs.

3.3.1. System Goal

An IESS aims at providing executives with not only easy access to internal and external information that is relevant to their critical success factors, but also easy access and effective use of analytical tools and capabilities.

3.3.2. Users

Executives (or their secretaries) and middle managers (or staff specialists) are the primary users of an IESS. An IESS is not only a development step of an EIS, but also an improvement of a DSS. In fact, it forms a common fundamental basis and tool for users at a wide range of levels within the organization. It can serve not only top management but also middle management activities.

3.3.3. System Functions

An IESS provides three groups of functions to users.

(a) Tracking the business performance and environment

The user-friendly interface and powerful data access capabilities to multiple data sources provide an easier and faster way for executives to monitor the organization's business performance and the environment, so as to find the problems and opportunities as they emerge.

(b) Decision Analysis and Problem Solving

Once a problem has been captured, related decision analysis is needed. An IESS offers not only models for quantitative analysis, but also knowledge processing abilities for qualitative reasoning. It aids users in using models to perform decision analysis and it ensures at least a tentative solution to the problem.

(c) Controlling

An IESS offers office support capabilities which make the routine office system much more effective. It helps executives to communicate more efficiently with more relevant people. It allows more spontaneous communication of ideas. It extends, to a certain degree, executives' control of the organization, so as to increase their visibility into the business. Moreover, this office support capability also provides a convenient channel for communication between middle management and top management.

3.3.4. Qualitative Capabilities of IESSs

Qualitative capabilities refer to the system's features to control the system, its user interface, and data presentation [27]. An IESS possesses customization attributes (customized production of task oriented reports, user oriented reports, user oriented graphics, menus, etc.), graphics attributes (graphical interface, graphics representation, graphical menus and coloured graphics) and easy control attributes. Besides, an IESS has an explanation capability inherited from ES/KBS. This contributes greatly to the transparency of the system and makes the system more easily understandable and the solutions more easily accepted by users.

So, there exist shared characteristics as well as distinctions between various kinds of information systems: DSS, EIS, ESS, ES, IDSS and IESS. These are summarized in Table 1.

Until now, we have been concerned with the implications of the concept of an IESS. In the following section, we shall come to the technical structure of an IESS to show how the integration of ES/KBS, EIS and DSS is made and how an IESS works.

4. Structure of Intelligent Executive Support Systems

The integration of computer-based information systems can take place at two different levels: the application system level and the development

Table 1. Comparison of Central Concepts in Managerial CBISs:

DSS, EIS, ESS, ES, IDSS, and IESS

	DSS	EIS	ESS	ES	IDSS	IESS
Decision Making Phases Served	Design and Choice	Intelligence	Intelligence, Design and Choice	Design and Choice	Design and Choice	Intelligence, Design and Choice
Typical Organizational Level Served	Middle, Few Top	Top, Some Middle	Top, Middle	All Level Management	Middle	Top, Middle
Primary Purpose	Support Semi-structured Decisions	Internal & External Information Monitoring	Performance Monitoring, Semi-structured Decisions	Unstructured Decisions	Support Semi/Unstructured Decisions	Performance Monitoring, Semi/Unstructured Decisions
Primary Outputs	Analytical Reports	Pre-defined or Customized Presentation	Pre-defined or Customized Presentation, Analytical Reports	Suggestions	Analytical Reports, Suggestions	Pre-defined or Customized Presentation, Analytical Reports, Suggestions
User-friendliness	No	Yes, very	Yes, very	Yes	Yes	Yes, very
Office Support	No	Yes	Yes	No	No	Yes
Data Base	Internal and External (if needed)	Internal and External, Multi Sources	Internal and External, Multi Sources	Internal and External (if needed)	Internal and External (if needed)	Internal and External, Multi Sources
Model Base	Yes	No	Yes	No	Yes	Yes
Expertise and Heuristics	No	No	No	Yes	Yes	Yes

tools level. This integration has two different types: functional integration and physical integration, and it employs different approaches, as shown in Figure 7.

The final goal in the construction of the IESS structure in our study is to verify the concept of an IESS that has been discussed above. In this paper, the integration will be made at the development tool level and the embedded

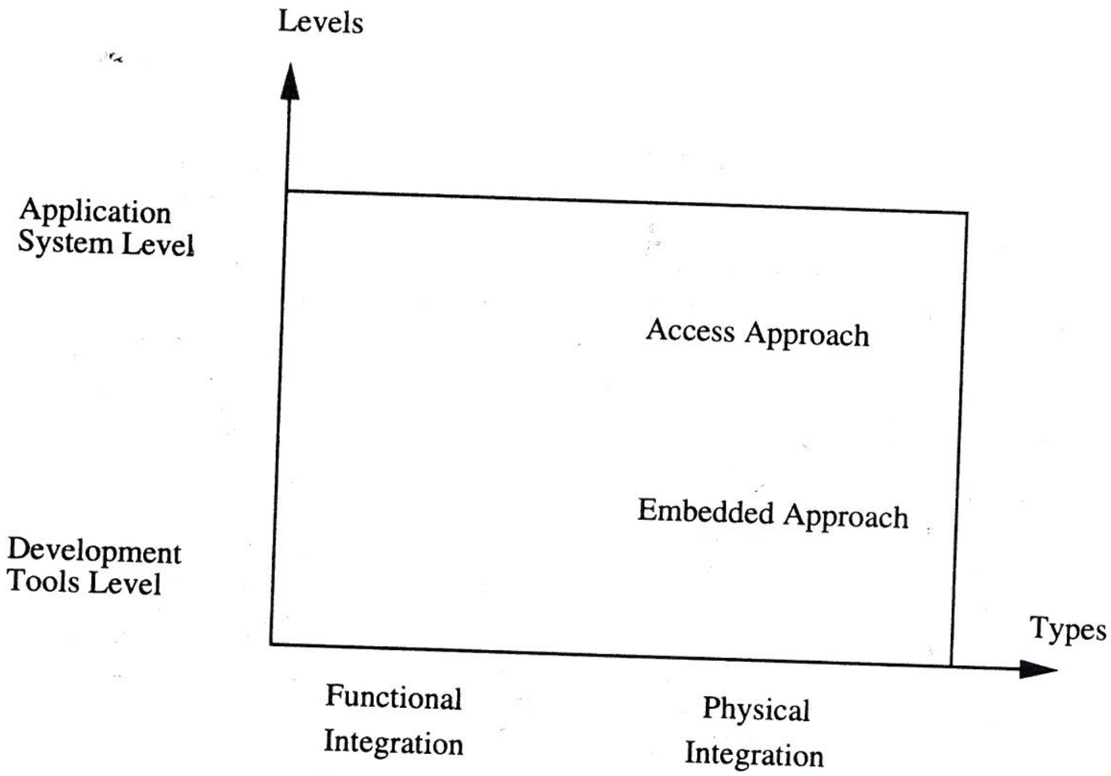

Figure 7. Integration: A Framework

Functional integration implies that different support functions are provided as a single system. The users can access the appropriate functions through a single, consistent interface, and can switch from one to another as necessary. Physical integration refers to the packaging of hardware, software, and communication features required to accomplish functional integration. Generally, physical integration can be done in two ways: the access approach or the embedded approach. The access approach means that ES/KBS development tools or application programs can access an EIS, a DSS or other programs. While in the embedded approach, ES/KBS software is embedded in an EIS, a DSS or other programs [41, 42].

approach is adopted. The IESS system structure is shown in Figure 8. It consists of six parts: the Interface, Office Support Subsystem (OSS), Data Base Subsystem (DBS), Model Base Subsystem (MBS), Knowledge Base Subsystem (KBS), and WorkSpace (WS). In the following paragraphs, each of them will be discussed in detail.

4.1. The Interface

The *Interface* is the connection between users and the system. On the one hand, it presents relevant information from the system to the users. On the other hand, it collects inputs and commands from users and then delivers them to the system. In an IESS, the interface connects directly with the OSS, DBS, MBS and KBS. It

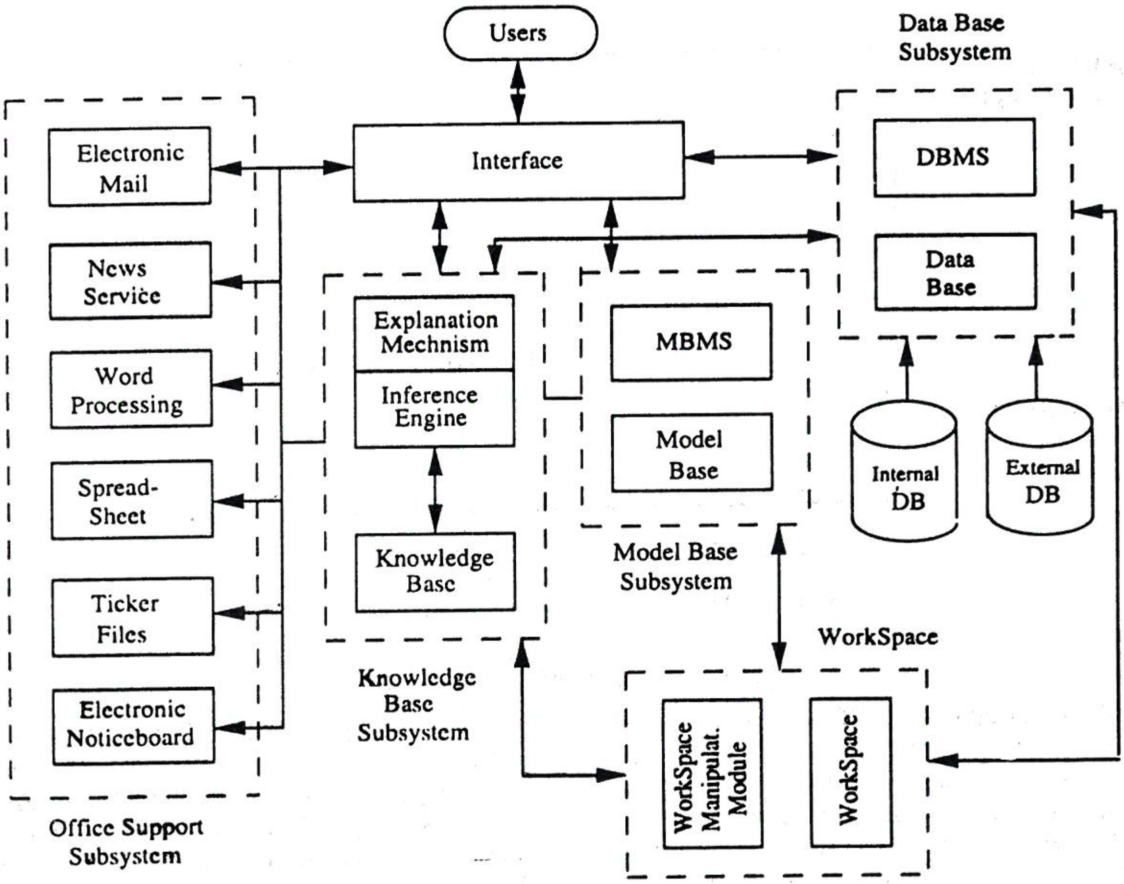

Figure 8. Sketch Map of IESS Architecture

allows users to access the database so as to track the business easily: it also allows users to access various office support facilities to carry out office work, to access the MBS and KBS, to perform decision analysis based on quantitative analytical models or by means of the qualitative reasoning ability of the KBS.

4.2. Office Support Subsystem (OSS)

Office support capabilities have proved to be very useful in organizational management work, especially in increasing its efficiency. Here in the system, some of the modern OA (Office Automation) technologies (in standard packages) are listed. They can be made available to users via the interface.
The communication based applications, such as electronic mail, news service and word processing, extend an executive's communication capability. They provide a way for executives to obtain easy access to external information and "soft" textual information.

Data analysis based applications, such as a spreadsheet, are valuable for supporting versatile data analysis, as well as planning and control purposes.

Organizing tools such as ticker files enable the executives to pay due attention to details whenever necessary, and to follow up more effectively. An electronic calendar allows executives to manage their schedules (especially for meetings) on a terminal.

4.3. Data Base Subsystem (DBS)

The *Data Base Subsystem (DBS)* consists of a Data Base (DB) and its manager DBMS (Data Base Management System). The DB stores data on a variety of important business variables (both internal and external). The DBMS is responsible for data collection, data maintenance, data retrieval, data security, and interfacing with other parts of the system.

In an IESS, the DBS connects with the Interface to provide the basic data requested by the user. The users can get exception reports, perform drill-down investigation, and do some preliminary trend analysis based on this connection. Moreover, the DBS connects with the WorkSpace to send relevant data to it for supporting model calculation or knowledge reasoning.

4.4. Model Base Subsystem (MBS)

The *Model Base Subsystem (MBS)* provides tools for quantitative analysis. It consists of a Model Base (MB) and a Model Base Management System (MBMS). A variety of basic models (or unit models), e.g. financial analysis models, forecasting models, and optimization models are stored in the MB as primary elements for the users to construct decision support models for their specific decision problems. In this way, the IESS can support not only one specific decision problem, but a wide range of problems.

The MBMS and MB are inseparable. They provide management with the ability to create, update, store, recall, operate and control unit models, and construct and modify user decision models.

The MBS connects directly with the Interface to allow middle managers or staff specialists who are familiar with modelling analysis to use the tools directly. In addition, the MBS connects with the WorkSpace to get data input for the model calculation and to send back simulation output to it for subsequent use or storage in the DB. It also connects with the KBS to transmit results that need further interpretation there.

Models are, in essence, abstractions of the fundamental structure of a complex phenomenon and environment. While the users can employ the model simulation function to explore alternative scenarios on-line, to perform what-if analysis and ad-hoc analysis with the aid of models, they may improve their understanding of the business. So modelling and intuitive analysis ability act as complements to each other. If we say that the DBS and OSS mainly support the problem finding phase (i.e. the Intelligence Phase) of a decision making process, then we can say that the MBS, together with the KBS which will be discussed later, mainly helps in problem-solving and the final decision making phases (i.e. Design and Choice Phases).

4.5. Knowledge Base Subsystem (KBS)

The *Knowledge Base Subsystem (KBS)* can perform qualitative analysis based on domain expertise in its Knowledge Base (KB). It connects with the OSS to provide users with help in utilizing office support facilities. It also connects with the MBS to help users in using quantitative analytical tools and to integrate model analysis with knowledge reasoning. It connects with the DBS to make interpretations of data monitored by users, and with the WorkSpace to send problem solutions or transient solutions to the WorkSpace for other parts to use.

To realize these functions, the KBS comprises a KB, an Inference Engine, and an Explanation Mechanism.

4.5.1. Knowledge Base (KB)

The Knowledge Base (KB) stores various kinds of knowledge:

(a) knowledge on model construction and model utilization;
(b) knowledge on data (raw data, simulation results, solution) interpretation;
(c) knowledge on office support facilities;
(d) knowledge on system conceptions; and
(e) knowledge on problem-solving (domain expertise).

In a general sense, an analytical model also carries knowledge and it is usually computing procedures that reflect the basic principle and relationships of a field. For our purpose, we use the term knowledge to refer especially to heuristic and symbolic knowledge.

4.5.2. Inference Engine

To support the decision making process effectively, the system must be able to deal flexibly with varying situations. The capability of responding to varying situations depends on the ability to infer new information from existing facts and knowledge, i.e. the ability to reason. This reasoning capability is just on the responsibility of the Inference Engine.

The Inference Engine searches appropriate knowledge in the KB according to environmental conditions and then executes the corresponding operations defined by the selected knowledge. In this way, new information can be inferred and at the same time sent to the WorkSpace and the DB to cause the DB be updated.

4.5.3. Explanation Mechanism

The Explanation Mechanism is often one of the most important components of Knowledge Based Systems (KBSs). The presence of the explanation facility is another striking feature that distinguishes KBSs from traditional CBISs.

Although the explanation capability is less important for fully automatic operating systems, it is of great importance to systems that are used as advisers, consultants, or assistants, where users often interact with the system during its operation (like most CBISs for managerial use). A further reason that contributes to the importance of the explanation facility is the possibility for the system to produce incorrect results, which is a typical by-product of an incomplete knowledge base of any KBS [31].

With the explanation mechanism, the system can explain, to some extent, the reasoning process that leads to a conclusion, rather than simply reaching a conclusion. In addition, the explanation mechanism gives clarifications of terms and concepts used by the system. All these help the users to understand the system properly, increase their confidence in the system, and enhance their personal levels of expertise.

4.6. Work Space

The Work Space is an auxiliary component of the system. It acts as a dynamic interface for different IESS components and for sequential processing.

The Work Space is, in fact, a re-usable data area. It connects with the MBS to store the results of model units. Using the Work Space as an interface, data exchanges amongst model units are carried out and thus result in linking model units, and lead to the development of a decision support model. The Work Space also connects with the KBS to store the conclusions of the reasoning process and the data that invoked that reasoning. It connects with the DBS to accept data from the DB and to return data to the DB to cause relevant data items in the DB be updated.

The Work Space manipulation module controls the DBS, MBS and KBS to accept input data from and send output data to the Work Space.

5. Conclusions

In this paper, a new concept, Intelligent Executive Support Systems (IESSs), was described based on a critical review and comparison of different kinds of computer based information systems for managerial use. A conceptual framework of IESSs was presented and an IESS architecture was constructed.

The IESS was put forward as an improvement of ESSs. It is an integration of multiple technologies and applications: ES/KBSs, EISs and DSSs. It shares a quantitative modelling analysis capability with DSSs and IDSSs; it shares user-friendly interfaces and good system properties with EISs; and it shares qualitative reasoning ability and explanation ability with ES/KBSs. It integrates all these capabilities into one unit. Compared with DSSs, an IESS possesses a more user-friendly interface, more powerful data access ability and office support ability. Compared with EISs, it greatly enhances the decision support capability. Compared with ESs, it reaches far more extensive problem domains, and compared with ESSs, it offers more competent problem-solving capability and provides the users with great help in more effectively using the management support facilities.

With its abundant functions and capabilities, an IESS can better meet the information needs of both top and middle management activities. It can better support business performance monitoring, problem finding, problem analysis, problem-solving, and management control.

An IESS consists of six main parts: the Interface, Office Support Subsystem, Data Base Subsystem, Model Base Subsystem, Knowledge Base Subsystem, and Work Space.

In recent years, the EIS has been developed in a rapidly growing number of organizations. Currently, it is spreading from top management to middle management and even to the whole organization. Our study on IESSs attempts to enrich the original concept of an EIS and to make comprehensive use of modern methods and technologies to better meet the organizational needs. It seems that this will be an area of much significance in the future.

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