A Model-Driven Approach to Accessing Managerial Information: The Development of a Repository-Based Executive Information System

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ABSTRACT: Most executive information systems (EIS) are focusing on the delivery of information to executives on line. Clicking on icons or command buttons, executives can browse through a series of screens of tabular or graphical information organized in a hierarchical structure. There is, however, no underlying model to guide the navigation of the diverse data and applications used by executives. A repository-based and model-driven EIS that captures integrated organization and information system (IOIS) models of an enterprise is therefore needed. A prototype system, called Repository-based Executive Information System (R-EIS), designed to integrate instead of replacing various existing application systems to support managerial information delivery is presented in this paper. This integrated IOIS model can be used directly by executives to assist them in navigating a model from a business perspective in order to gain access to applications and information to support their decision making. The navigation paths become contexts for the information delivered. Executives who can use an explicit organization model in their navigation of large information bases may learn more about their businesses and therefore facilitate organizational learning.

KEY WORDS AND PHRASES: contextual information systems, data warehouse, executive

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tive information systems, information delivery, mental model, organization model, repository systems.

IN THE PAST DECADE, THE DEVELOPMENT OF EXECUTIVE INFORMATION SYSTEMS (EIS) has been inspired by Rockart [39] who defined EIS as a field of study, and by Mintzberg [34], who studied the nature of top executives' work. The availability of EIS software designed specifically for the building of EIS has emerged since the mid-1980s and has also made the development of EIS easier [51]. Several well-documented and publicized EIS success stories at corporations such as Lockheed [21], Quaker Oats Co., and Xerox make managers and IS professionals recognize EIS as a category of applications different from transaction processing systems or managerial reporting systems [50]. The focus of EIS technology is on access to managerial information on line. An EIS is designed to satisfy the unique information needs of executives by providing friendly user interfaces to access managerial information, including summarized business transaction data. In addition, an EIS also supports access to external news services, tools supporting decision analysis, and interpersonal communications software. One of the most important driving forces is that executives can use EIS to obtain relevant information on line to support their decision making in increasingly dynamic business environments.

A major limitation of current EIS is that they provide data in too much detail and summarize less than is necessary for painting a *big picture* of the business for an executive [4]. A constraint of current EIS is that they represent only implicitly a static and narrowly focused manager's mental model that is defined explicitly. Executives have to fit the information they receive from EIS with their own mental models of the business. Semantic guidance in using EIS to improve understanding of the information received by executives has been lacking. The prototype Repository-based Executive Information System (R-EIS) presented in this paper uses an integrated organization and information systems (IOIS) model to represent managers' dynamic and shared mental models that comprise their views of the enterprise and the underlying information systems. The IOIS model is defined in the R-EIS repository and is used to drive graph-based user interfaces to guide executives as they access large managerial information bases and launch applications. R-EIS provides new ways of accessing information in an EIS. Its architectural design and scenarios that illustrate navigating a sample IOIS model to access managerial information bases from various perspectives are presented in this paper.

Currently, EIS are most often implemented as stand-alone systems. However, there is an increasing need to integrate an EIS as part of the enterprise-wide information system architecture. Figure 1 depicts a generic information system architecture to illustrate the relationships between an EIS and other types of information systems as well as the target end users of these systems. Because users at different levels and functional areas in an organization have different requirements [18], various types of applications have been developed to serve their needs [53]. Transaction Processing

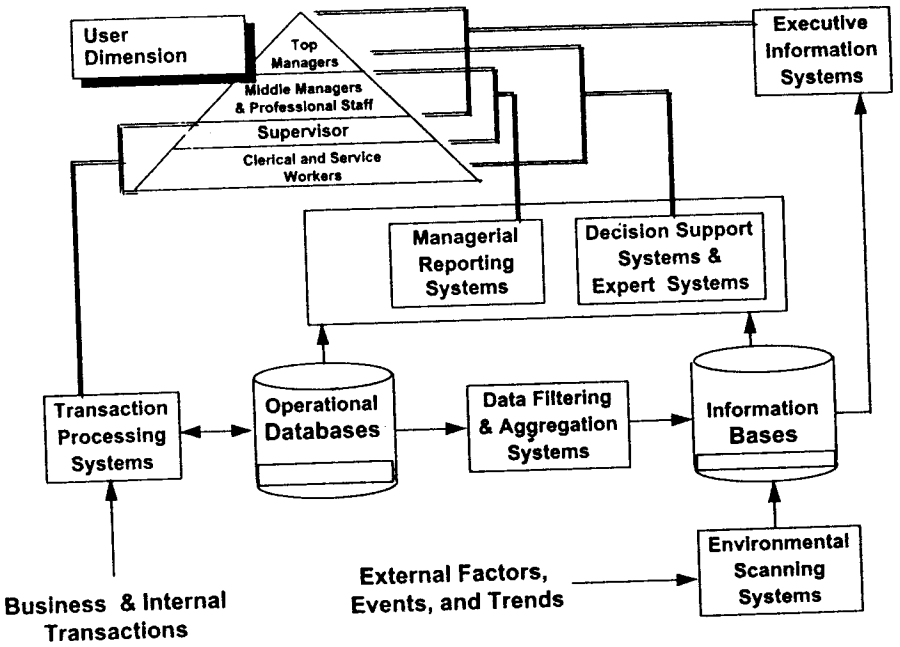


Figure 1. A Generic Architecture of Information Systems in Organizations

Systems (TPS) may be used by clerical and service workers and supervisors. When data-capturing technology or electronic data interchange (EDI) are used, TPS can be fully automated straight through—without human intervention. Managerial Reporting Systems (MRS) are used mainly by middle managers, professional staff, and supervisors. Decision Support Systems (DSS) and Expert Systems (ES) are used at almost all levels of an organization. Top executives, middle managers, and professional staff are typical users of an EIS.

Many EIS applications use data extracted from *operational databases* (also called production or transaction databases). The data in the operational databases are maintained by the TPS. Goodhue, Quillard, and Rockart [17, p. 378] define an information base as "a subject area database intended for use by staff analysts and line managers." They found that 35 percent of the companies they studied used the information bases to support their data resource management function. Data extracted and summarized from the operational databases by *the data filtering and aggregation systems* are stored in *information bases* that can be used by MRS, DSS, and ES. An information base is also called a decision support database. It is sometimes implemented as a multidimensional database to store the results of complex joins to increase the query performance and to support multidimensional analysis used in EIS [27]. Dimensions for a sale information base may include product, promotion, marketing channel, region, customer type, and time. Data warehousing tools can support the extraction of data from various operational data sources and the creation of information bases [23]. Companies such as Miles Inc. that deploy data warehousing concepts are using repository

systems to drive the development of operational systems and DSS/EIS [14]. However, the data models in data warehouse do not capture the organization model of an enterprise but only try to model the structure of consolidated data, which are still oriented toward business transactions.

Some EIS have direct access to operational databases, but most use information bases as their primary sources of information. Direct access to operational databases by EIS has some serious disadvantages: (1) the raw data in the operational databases are often fully normalized and are not organized for the most efficient retrieval [1]; (2) the complexity of EIS query processing may decrease the performance of TPS; and (3) data integrity is difficult to ensure if direct access to operational data is allowed. The recently emerged data warehousing or information warehousing concept focuses on the development of back-end information bases to support the development of enterprise-wide decision support systems and executive information systems [14, 23, 27]. Meanwhile, our research is focusing on a front-end mechanism for delivering managerial information and extending the repository contents to organization models, complementing industry efforts.

Executive Information Systems: An Overview

EIS ARE "COMPUTER-BASED INFORMATION DELIVERY AND COMMUNICATION SYSTEMS for senior managers" [36, p. 2]. The emergence of EIS signals a shift of emphasis from *development* of information systems to the *delivery* of information produced by information systems. Rockart and De Long [40] identify four basic functions of EIS:

1. *Communication tools* support executives' interactions with people using phone, voice mail, electronic mail, and fax. Groupware products, such as Lotus Notes, a multimedia computer conferencing tool, will be an essential component of communication support for executives.
2. *Organizing tools*, which include to-do lists, electronic calendars, group scheduling software, and project management tools, can be used to assist executives in organizing their tasks and managing their schedules.
3. *Data and status access tools* allow executives to have access to external information via electronic news services and external data banks. Executives can monitor critical performance measures of business operations stored in the information bases.
4. *Decision analysis tools* include spreadsheets, statistic and business graph packages, and data-driven and drill-down data analysis tools. These are important in providing insights regarding the information delivered to executives. Because group decision support systems such as GroupSystems [31] will enable executives to tap into human expertise in organizations, they will facilitate consensus-based decision making and will become an important addition to future EIS.

PC-based EIS software products such as LightShip are becoming much cheaper than mainframe-based EIS software products. The declining cost of EIS products and

executives' increasing needs to access critical business planning and control information have contributed to the widespread use of EIS applications throughout organizations. Since executives rely heavily on both external information and the analysis of information by professional staff, it is important that staff members be included in the loop to provide *soft data* to the information bases [20]. EIS are becoming a mechanism for enterprise-wide information delivery to all levels of organizations. Therefore, the EIS industry is changing the meaning of the EIS acronym from Executive Information Systems to Everybody's Information Systems or Enterprise Information Systems [16, 37].

This research addresses several issues concerning existing EIS design and implementation:

1. *Managers are overloaded with information.* A typical EIS accessed by an executive has 50 to 100 screens, and the number of screens is growing rapidly. It may take one to two hours for executives to browse through all these screens. However, because the screens have been organized hierarchically, the browsing time for a particular use of EIS could be a lot less. A study conducted by Houdeshel and Watson [21] found that the total number of screens for an EIS was 710, but the average number of screens viewed per executive per day was only 5.5.
2. *There is no mechanism to support organization learning.* Current EIS do not support a manager taking a new position in learning about applications and data that are developed and delivered to support his or her job functions. Information systems (IS) professionals have always assumed that managers should understand the meaning of the information delivered to them and know where to get the information, because they have defined the system's requirements in the first place. Future EIS should support the modeling of businesses and deliver a realistic on-line organization model to help managers learn more about their organization and supporting information systems. This individual learning enables managers to develop the organization model collaboratively and continuously, and therefore contributes to organization learning.
3. *There is no explicit model or structure to organize managerial information.* Most EIS are organized as hierarchical structures according to business functional areas (e.g., accounting, human resources, and marketing) or managerial activities (e.g., communications, controls, and organizing) [51]. This approach ignores the multidimensionality of information (i.e., information delivered as reports and screens can have multiple uses and interpretations across business functional areas). Current EIS do not give executives access to the underlying organization and information models. They only deliver information produced by target information systems.
4. *The inconsistency and unavailability of information in EIS often result from inadequate business systems design.* For example, in a case study that we conducted involving organizational use of EIS, the CEO requested a head count of administrative jobs. He wanted to use the ratio of administrative jobs to

research jobs to measure personnel overhead in support of the institute's research and development function. However, such information was not available because the personnel department did not classify jobs as being administration or research and would have to redesign its job classification system to obtain the desired information. These shortcomings are caused by the lack of enterprise-wide information architectures or data models. In many cases, implementation of EIS has meant that business systems have to be redesigned so meaningful data can be gathered to support managerial decision making.

5. *There is no mechanism to ensure integration of an enterprise-wide EIS implementation.* Although EIS are originally targeted for top managers, many organizations, including the one in the case study, have started to equip their professional staff and middle managers with EIS [36, 40]. Middle managers are demanding to be users of EIS because they are afraid that they may be asked by executives to explain EIS-delivered information of which they were unaware. Integration of EIS applications across various organization levels is critical to enterprise-wide EIS implementation. A repository-based approach can support such integration.

Technical components of existing EIS include: relational databases, graphical user interfaces, personal productivity tools, direct data import/export facilities, decision support tools, text and image management systems, and communication tools. Each of these addresses only part of the above-mentioned issues from a specific technical viewpoint, so they need to be integrated into EIS development environments. EIS software offers specialized tools for IS development. Although you can quickly develop typical EIS functionalities using this type of tool, current EIS software products do not have strong programmability and extendibility. There is no direct support for the modeling of organizational models, an important feature that we believe should be incorporated into future EIS. Hypertext/hypermedia systems enable the capturing of unstructured nonlinear multimedia information and provide better user navigation [11]; however, they rarely have direct support of data analysis and drill-down functions that are often found in EIS [3, 33].

None of the tools mentioned earlier supports the visualization of complex structured relationships within an organization. There is no intuitive way to build a high-level user interface to integrate the diversified sources of applications and information required in EIS. Current EIS do not provide contexts for information delivered to executives. The purpose of repository-based EIS is to provide semantic support in guiding managers in using their information resources and to offer contextual information.

R-EIS: A Repository-based Executive Information System

A REPOSITORY-BASED EIS (R-EIS) HAS BEEN DESIGNED to incorporate model-driven interfaces to represent complex relationships stored in an enterprise-wide repository. Executives are given direct access to the organization and information systems models

stored in the repository. By navigating through the models, they can launch applications and retrieve information directly. The navigation path recorded will be used as a context within which executives can better understand the information they receive. This paper describes the architectural design of a repository-based EIS (R-EIS) that uses an integrated organization and information systems model to support the delivery of managerial information. The structures of the repository and user interface of R-EIS are discussed. The foundation for the development of organization models is based on theories concerning mental models and studies of managerial thought processes. The use of R-EIS to assist the delivery of managerial information is illustrated in several scenarios for navigating a sample IOIS model.

The Architecture of the R-EIS

The R-EIS architecture is an extension of an integrated CASE environment [7] that has several unique features compared with existing EIS and CASE architectures. First, organization models of the business are integrated with IS models. Executives are allowed direct access to the *integrated models* to assist them in understanding the organization's structure and goals, as well as interactions between organizations and IS. Second, the repository is used to integrate not only CASE tools, but also other types of *development tools* for different target systems. Third, the R-EIS supports both the *development* of the target IS and the *delivery* of information to executives.

The R-EIS architecture is depicted in figure 2. The kernel of the R-EIS is a Repository System that is used to store and manage an IOIS model. The model is created and used by the systems development tools (e.g., DSS generators, CASE, and EIS tools) to build target applications systems (e.g., TPS, MRS, DSS, EIS, and ES). The R-EIS interface allows users to examine the underlying IOIS model from various aspects. Users can easily and directly invoke a target system via the interface. Physical access methods to target systems are hidden from users. There are four subsystems of the R-EIS architecture:

1. *Target information systems* include TPS, MRS, DSS, traditional EIS, and ES. Users seldom care what types of target systems they are using, as long as the business problems at hand are solved. The type of target systems and the mechanisms employed to invoke it should be as transparent to the users as possible.
2. *A set of development tools* consists of CASE tools, DSS generators, EIS tools, and ES shells. These tools share design data/models via a repository to achieve data integration. Target systems are developed using appropriate development tools.
3. *A repository system* stores an IOIS model used by development tools to build a target IS. A repository system is a specialized database and knowledge base system that is used for integrating systems development tools in information systems environments.
4. *A model-driven user interface* is a set of *information delivery tools* driven by

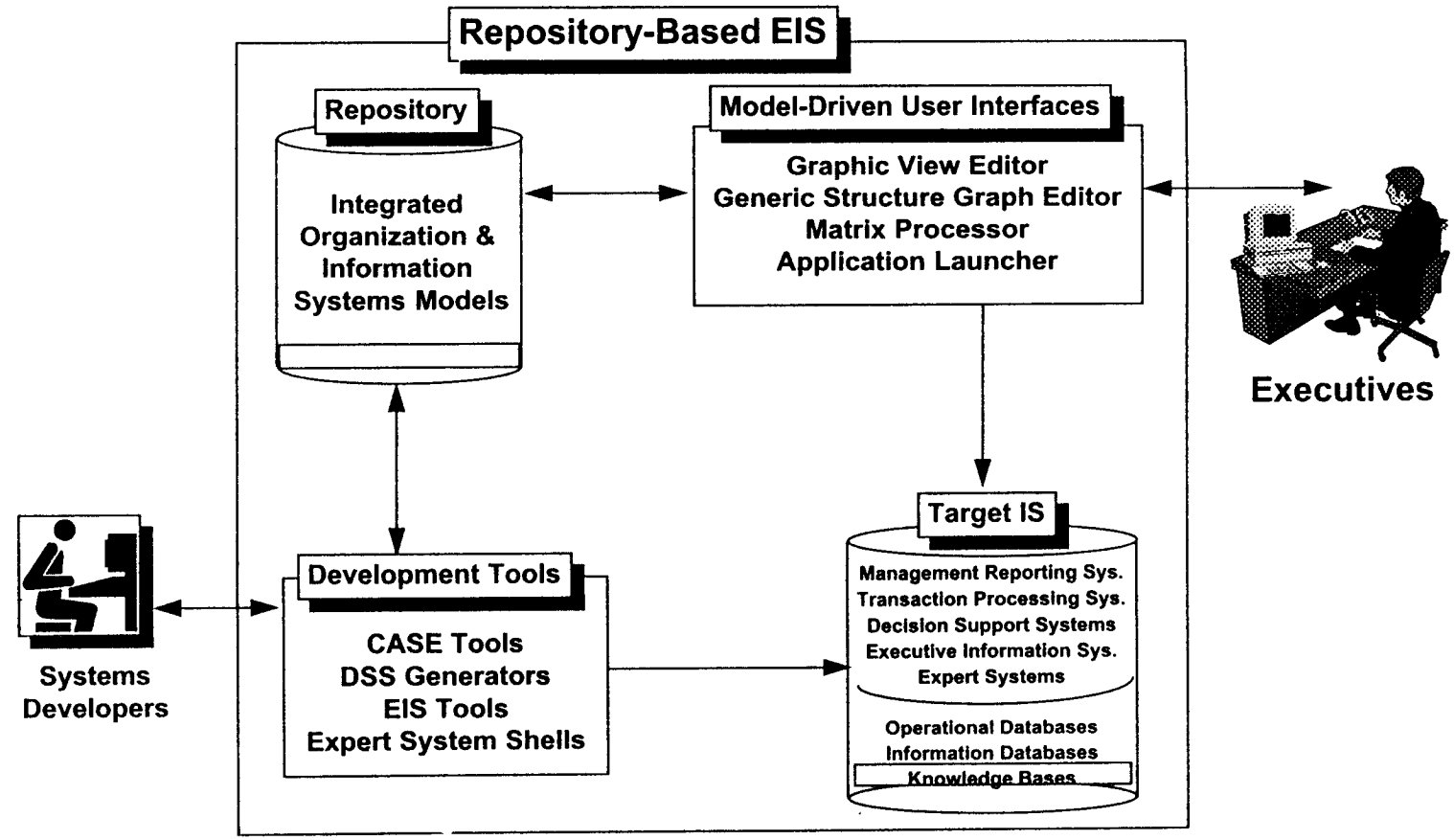


Figure 2. The Architecture of a Repository-Based EIS

the IOIS models stored in the repository to guide the users in accessing information or the target IS. A *graphic view editor* and a *generic structure graph editor* can be used to display the IOIS model from multiple perspectives. Executives can navigate through the integrated model from a business aspect (e.g., the business process aspect) and invoke a target system or retrieve information using a generic *application launcher. A matrix processor* can be used by executives to examine or enter relationships of two entity types. The user interface tools will be discussed in a later section.

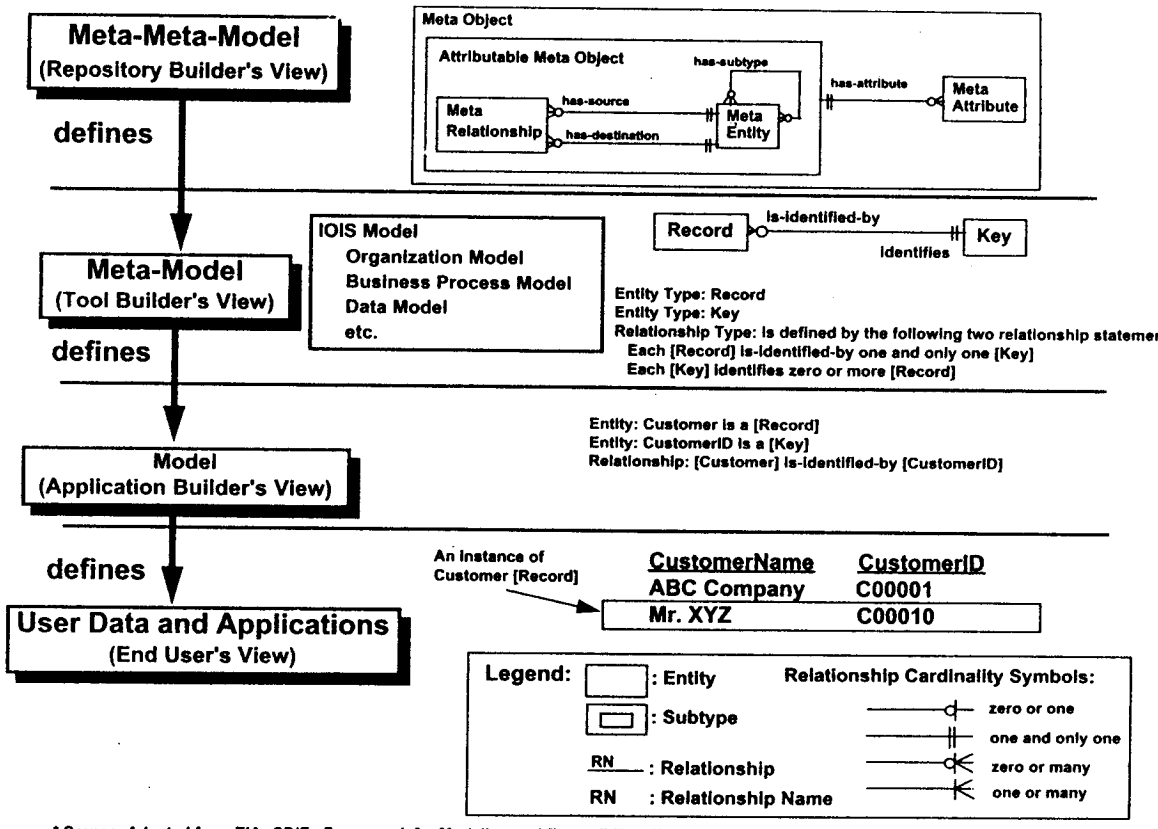
Structures and Functionalities of the R-EIS Repository

A repository is a specialized database and knowledge base management system for a system development environment. The contents of a repository are called model or meta-data, while the structure of the repository is called a meta-model. A meta-model describes the structure and meaning of data stored in the repository and therefore provides a basis for data sharing and integration among development tools.

The author has adapted a four-layer architecture as depicted in figure 3 to describe the structure of the repository. This approach has been used by the CDIF Technical Committee [13] and Information Resources Dictionary Systems (IRDS) [28]. IRDS is a proposed ANSI standard (under ANSI X3H4) and a U.S. Federal Information Processing Standard (FIPS 156). We are using the standard terminology defined in CDIF (CASE Data Interchange Format) to describe this architecture.

The first layer, our highest level of abstraction, is the *meta-meta-model.* It defines a set of primitives for describing structures of the *meta-model*, the second layer, of the repository and it represents the repository builder's view of the repository [46]. Several meta-meta-models such as Objects, Entity-Relationship-Attributes (ERA), Object-Property-Role-Relationship (OPRR), and Window-Object-Property-Role-Relationship (WOPRR) can be used as primitives to define the structures of the repository [52]. An extended ERA approach that allows the use of *n*-ary relationships with attributes is adopted to define the R-EIS repository's *meta-meta*-model. The ERA model, originally developed for conceptual database design [10, 47], has been used as primitives at the meta-meta-model level in repository standards such as IRDS, CDIF, and PCTE [45].

This first layer has four subtypes, including a Meta-Object and three of its subtypes: Meta-Entity, Meta-Relationship, and Meta-Attribute. In R-EIS, Meta-Objects are defined as a class. The three subtypes are implemented as its subclasses. Constraints can be defined as cardinality of relationships. For instance, we can define that "each Organization Unit is responsible for many Business Processes," and "each Business Process always has one and only one Organization Unit responsible for it." Consistency or completeness checking rules can be added to the meta-meta-model to enforce integrity of the repository [8]. For example, a completeness checking is shown in figure 4. Like any other repository system, the R-EIS meta-meta-model is determined by the repository system developers; it therefore cannot be changed by the tool builders, IS developers, or end users.



* Source: Adapted from EIA, *CDIF - Framework for Modeling and Extensibility*. EIA/IS-81, July 1991.

Figure 3. The Four Model Layers in the Repository with Examples

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IF
      object type of an object = Organization Unit AND
      the object is not involved in relationship(s):
      [Organization Unit] is involved in [Business Process]
THEN
      incompleteness type = "This Organization Unit is not involved in
      any Business Process"
```

Figure 4. An Example of a Completeness Checking Rule

The *meta-model layer* consists of a set of Entity Types (e.g., [Organization Unit] and [Business Process]), Relationship Types (e.g., [Business Process Responsibility]), and Attribute Types (e.g., Level of Involvement). It defines the *meta-model* of the repository. A Relationship Type consists of two or more than two sets of Entity Types (e.g., [Business Process Responsibility] relationship can be expressed in a structured statement as [Organization Unit] is responsible for [Business Process]). Attributes Types are attached to Entity Types and Relationship Types (e.g., [Report] has an attribute type: Reporting Period). The *meta-model layer* is used to describe and control the *model layer*, the third layer. A view (i.e., semantic model) which is a subset of the meta-model represents a specific aspect of the meta-model. For example, a set of semantic models (such as organization structure model, business process model, data flow model, and entity relationship model), can be defined as views of the IOIS model. Repository managers are allowed to customize the repository structure by defining the meta-model. Tool builders are the *users* of the meta-model layer.

The *model layer* consists of a set of Entities (e.g., [Order Fulfillment] is an instance of Business Process, [Sale Unit] is an instance of Organization Unit), Relationships (e.g., [Sale Unit] is responsible for [Order Fulfillment], and Attributes (e.g., "Reporting period of Customer complaints report by region is: monthly"), which are instances of meta-model constructs. The *model layer* contains the integrated model of the target IS developed by IS developers via the use of CASE or other development tools.

User data and applications are the fourth layer. Because procedures for accessing the IS applications and data can be stored in the *model layer*, the user can invoke the target IS to retrieve the information via navigating the meta-model and the model. The information and knowledge delivered by the target IS are maintained in operational databases, information bases, or knowledge bases. Target systems are developed by using respective applications development environments (e.g., database management systems, ES shells, and EIS tools).

The repository system of R-EIS contains a set of utilities to assist in the management and use of the repository by repository managers, tool builders, or IS developers. These utilities include [9]: (1) *import/export facility*, which will allow a repository manager to exchange repository models via a syntactically and semantically encoded flat-file; (2) *command language*, and *menu- and form-driven interfaces*, which allow users to

define structured statements that interact with a repository system to define the meta-model and model stored in the repository; the repository system is extensible, therefore its users can incorporate their own extended meta-models into the repository by adding new entity types, relationship types, and attribute types to an existing meta-model; (3) *Application Program Interface (API)*—a set of functions made available to development tool builders—is sometimes called a tool service that is intended to provide *tool wrappers*; development tools can be built with tighter integration with the repository; (4) *reports and query facilities*, which are provided by the repository system to assist repository managers in reviewing repository contents in various forms, such as tables, structured statements, or structure graphics.

A repository system is an essential component in integrated CASE tools such as IEF and ADW. Using data models and user views stored in the repository to drive the application development can be also found in client/server development tools such as PowerBuilder and Uniface [2]. David Friend [15], an EIS visionary and CEO of Pilot Executive Software, predicted that future EIS should incorporate CASE-like development tools. Microsoft and Texas Instruments have also teamed up to develop repository structures to support future desktop application development tools [48]. The intention is to allow developers to use a repository. We are going to see more repository-driven or model-driven applications development.

However, most repository systems are used to model information systems, although one may argue that IS models are a reflection of the business models. Applications developers often focus on the aspects of the business models that are directly related to the application development and therefore do not try to capture business or organization models from the perspectives of business users and managers. The access of the resulting IS models stored in the repository is limited to application developers. The models stored in the repository, having been elicited from users to reflect their views of businesses, may help users to understand their businesses and the managerial information delivered to them. R-EIS extends the use of repositories from applications development to information delivery. It integrates EIS and CASE through an IOIS model stored in the repository. By extending existing IS models to incorporate organization models, it becomes possible to integrate CASE and EIS so as to support both IS development and delivery. The theoretical foundation and rationales for building an IOIS model are discussed in the next section.

Integrated Organization and Information Systems Models and R-EIS User Interfaces

TRADITIONAL EIS HAVE BEEN DEVELOPED TO ADDRESS INDIVIDUAL information requirements, and the use of the critical success factors (CSF) method and prototyping have been popular approaches for defining EIS requirements [40]. Friend [16, p. 328] points out that "by addressing individual needs instead of those of the organization, the EIS does not become part of the corporate culture and remains tied to the continuing sponsorship of the executive." To make EIS enterprise-wide information delivery systems, Volonino and Watson [49] propose the Strategic Business Objective (SBO)

Method for EIS development. The SBO method starts with identifying strategic business objectives and business processes for achieving these objectives. Then priorities are assigned to the objectives and the critical business processes. Information necessary to support the business processes is specified to serve as a basis for EIS development. However, neither the CSF method nor the SBO method incorporates entity types and relationships of important organization concepts that have been identified during EIS development into the resulting EIS applications.

The IOIS model stored in the R-EIS plays an important role in supporting systems development and delivery. Research in mental models from cognitive sciences, studies of managerial thought processes, and findings from studying EIS usage are discussed to provide the rationale for modeling an organization explicitly. An example of an IOIS model is described below.

Mental Models

Kenneth Craik, who coined the term "mental model," suggested that "thinking is the manipulation of internal representations of the world" [25, p. x]. Many problems encountered in implementing new strategies and organizational structures lie with "failing to recognize the importance of prevailing mental models" [44, p. 353]. Senge et al. [43] define mental models as images of other people, institutions, and every aspect of the world. They believe that managers consciously create mental models to improve their understanding of how a business works within its environments. This inner model of reality is critical to managers' success and managers need to share some common view of their organizations. Pounds [38] studied fifty executives and found that a key aspect of their business problem identification process is captured by the mental models in which they represent differences between current status and the model. Isenberg [24, p. 90], in a second study that focused on how senior managers think, suggested that "managers should never deal with problems in isolation. They should always ask themselves what additional *related* issues they should be aware of while dealing with the problem at hand." Managers can facilitate the process of identifying a set of problems or issues and mapping relationships among them.

In their studies of EIS usage, Rockart and DeLong [40] came to believe that the most significant benefit of EIS may be its potential to enhance executives' mental models of their businesses. They also believe that an underlying conceptual mode is being used by executives when they look at data. Since current EIS do not represent mental models explicitly, the enhancement to mental models is an unintended purpose of EIS. Mintzberg [34] argued that the quality of managers' mental models may determine how effective managers are in using information to make decisions. Therefore, the IOIS model in R-EIS should represent shared mental models of managers explicitly in order to facilitate their access to large information bases.

Johnson-Laird [25] believed that it is appropriate to use a *relational model* to describe physical and abstract mental models. A relational model consists of a finite set of *entities*, a finite set of *relationships* between entities, and a finite set of *properties* (i.e., attributes) to describe entities and relationships [25]. R-EIS use Entity-Relation-

ship-Attribute as the primitive constructs for modeling the integrated IOIS model to represent the relational mental model. This is different from Carlson and Ram's [5] approach that uses frames to represent mental models. Using ERA to represent relationships *explicitly* allows us to have a better handle on complex relationships in organization models. ERA meta-model is supported by many commercial repository systems.

The complex environments in business are reflected implicitly in the data captured and delivered in business information systems. Many data delivered via EIS or other business applications are numerical data. Executives need to look at the trend of major business indicators to understand the changing environments and the dynamics of the organization. Qualitative information about the organization and its environments can be explicitly represented in the R-EIS repository as part of the organization model, to complement the numerical data delivered by current EIS.

Mental models may be created and they determine what we see: "Human beings cannot navigate through the complex environments of our world without cognitive 'mental maps' " [43, p. 235]. The externalized and shared cognitive mental map is called an organizational model. It can be integrated with existing information systems models to form the IOIS model in R-EIS and to guide users in accessing managerial information.

Organization Models

Executives should be able to act on and react to environmental changes by constantly reexamining and redefining its goals and strategies, redesigning the business processes of various organizational units, and reconfiguring the interrelationships among these units. Many organizations have repeatedly gone through dramatic organizational changes because of merging, reorganization, and consolidation due to increasing competition. However, top managers do not have tools to assist them in managing these organizational changes and people do not have a mechanism that helps them understand the up-to-the-minute status (e.g., current goals, strategies, and policies) of an organization. Developing an explicit *organization model* elicited from and deliberated upon by people in an organization may help managers to construct and use the shared visions to run the organization.

Developing organization models involves explicating and sharing managers' assumptions [44]. For example, an explicit organization model can help managers to visualize the business processes, track the performance and quality measures of the processes, and monitor the efficiency and the unit cost of primary outputs of the processes. They can relate organization goals, strategies, and critical success factors to their organizational units and the business processes for which they are responsible. The organization model can serve as a mechanism to assist managers in coping with the complexity and dynamics of an organization.

What should be the contents of an organization model? Let us use IBM's AD/Cycle Information Model as an example [22]. AD/Cycle's Enterprise Submodel consists of: a planning and organization model, an information model, a process model, and an

Table 1 A List of a Subset of Entity Types in IBM's AD/Cycle's Planning and Organization Model*

MISSION Component	PROBLEM Component
MISSION	PROBLEM
GOAL	**INFORMATION NEED**
PLANNING Component	REQUIREMENT
ASSUMPTION	RESOURCE Component
OBJECTIVE	RESOURCE
CRITICAL SUCCESS FACTOR	**APPLICATION**
STRATEGY	**DATABASE**
ACTION ITEM	**SYSTEM COMPONENT**
RECOMMENDATION	ORGANIZATION Component
OPPORTUNITY	POLICY
BUSINESS RULE Component	ORGANIZATION UNIT
PROCESS	PROJECT
EVENT	LOCATION
BUSINESS RULE	

* Entity types that are directly related to information system models are in bold.

information flow model. Table 1 lists the principal entity types of six component models in the planning and organization model. The table illustrates how complicated an organization model can be. The overlapping and linkages between an organization model and an information system model are obvious. We can define relationships between entity types in organization models and entity types in IS models to form an IOIS model.

Currently, most information systems are developed by first analyzing the objectives of the system, users' requirements, and the business processes to be supported by the system. An information system model is developed in order to build the target application system. Process models and data models, such as data flow diagrams and entity-relationship diagrams, are all part of an information system model. With the advent of planning toolsets in integrated CASE tools such as Texas Instruments' IEF and KnowledgeWord's ADW, many organizations are developing primitive enterprise models in the information strategy planning (ISP) phase. Many entity types and relationships captured in this phase describe the organization. However, the purpose of conducting ISP is to define an enterprise-wide information systems architecture consisting of data architecture, application architecture, and technology architecture. ISP was not specifically created to support organization modeling. Managers usually do not have direct access to ISP toolsets to explore these primitive organization models. We can enhance existing ISP models by incorporating additional entity types and relationships that are important to managers' understanding of the structures and

dynamics of their own enterprise.

The schema (i.e., the meta-model layer) of an organizational model can vary from organization to organization. For example, one company that we study used the concept named "issue" to describe what is important to the organization; other companies may prefer to use terms such as "problem" or "critical success factor" for the same concept. This is why *a meta-system approach* [6] is taken to allow the user of R-EIS system to define the meta-model layer so that an organization can customize an IOIS meta-model according to its concepts and business languages. Users' participation in the model-building process becomes critical in order to ensure that the *meta*-model and model of an IOIS represent managers' collective views of their organization and information systems. In the following subsection we present a sample IOIS model to illustrate how we can develop such a model to support the delivery of managerial information.

An Example of an IOIS Model

An example of a simplified sample *meta*-model of an IOIS model is depicted in figure 5, which employs entity-relationship diagramming notation used in [29]. We assume that an enterprise uses critical success factors to identify its executive information needs and that it is engaged in business process reengineering. The enterprise would like to define an IOIS model to support these organizational initiatives and integrate them with existing information model. The resulting integrated model would consist of several *views* (i.e., semantic models or perspectives) such as Critical Success Factors model, a Business Process model, and a Data Flow model. Each semantic model represents an external view that is a subset of the underlying meta-model.

Since the meta-model of the repository is extensible, an organization can customize the meta-model to define an IOIS model in its own terms. The Business Process model (i.e., a view) is a subset of the IOIS meta-model and is highlighted in figure 5. It represents order of precedence among Business Processes and the responsibility of Organization Units to Business Processes. An example of a Business Process model defined as structured text is presented in figures 6 and 7. We will use this sample IOIS model to illustrate how R-EIS can support managers' access to managerial information.

Model-Driven User Interfaces in an R-EIS

MOST CURRENT EIS FOCUS ON PACKAGING EXISTING INFORMATION so that it can be delivered to executives via some friendly user interfaces, such as large icons/command buttons, touch screens, graphical user interfaces, and remote control panels [51]. EIS can be viewed as a series of screens that contain information or applications required to support executives' information needs. These screens are categorized hierarchically by functional areas or by executive activities. Such a categorization does not capture the multidimensionality of the information required or the activities performed by executives; nor does it reflect the shared vision of executives about their organizations.

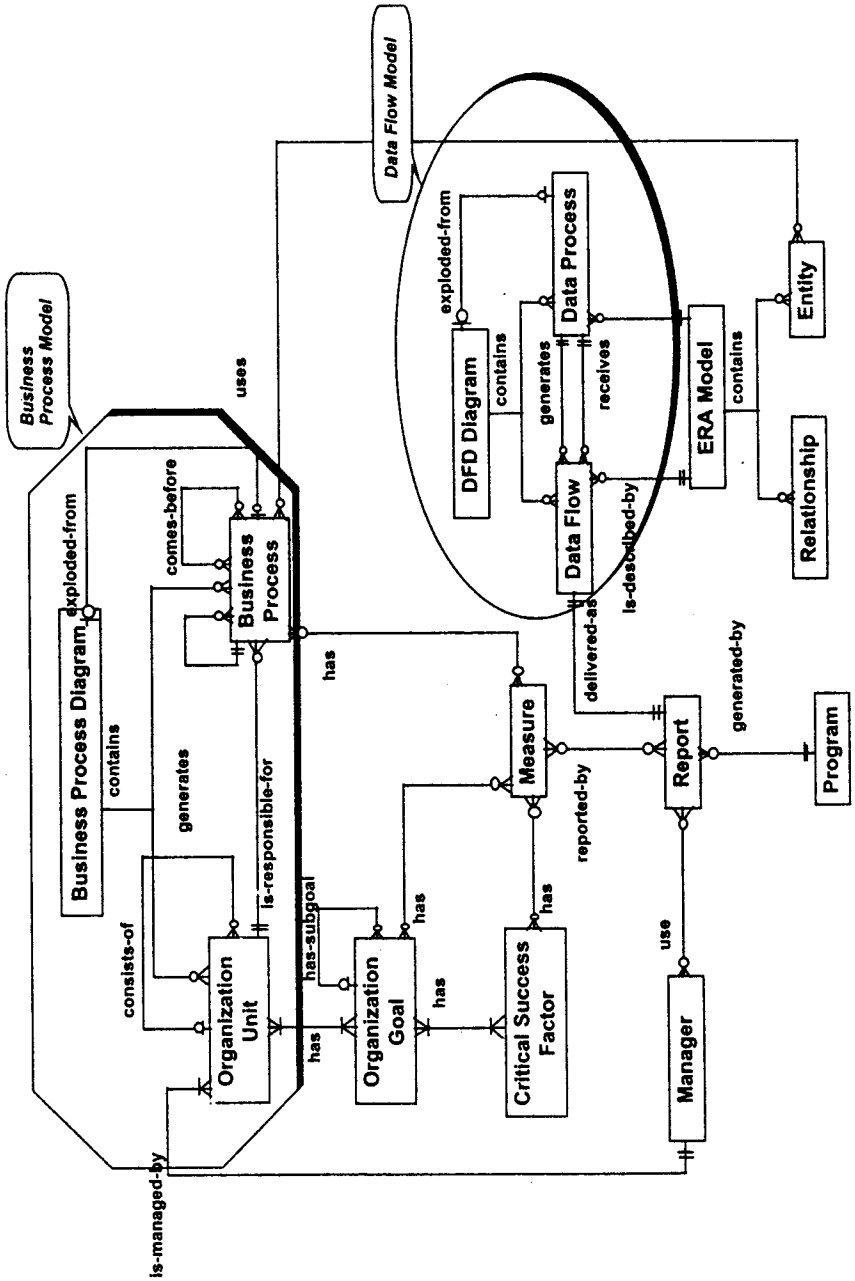

Figure 5. A Subset of a Sample Integrated Organization and Information Systems Model

```
Entity types: Organization Unit, Business Process;
      Relationship Types:
            Business Process Decomposition: (1:M)*
                  [Business Process] consists of [Business Process],
            Business Process Precedence: (M:N)
                  [Business Process] comes before
                  [Business Process],
            Business Process Responsibility: (1:M)
                  [Organization Unit] is responsible for
                  [Business Process];

* (1:M), (M:N), or (1:1) defined after a relationship name is the cardinal-
ity of the relationship.
```

Figure 6. The Constructs of a Business Process Model

```
Entity Type: Organization Unit
  Has Instances: Order Department, Warehouse Department,
  Accounting Department;
Entity Type: Business Process
  Has Instances: Take Order, Check Credit, Ship Product,
  Bill Customer;

Relationship Type: Organization Unit's Responsibility to Business Pro-
cess
  Has Instances:
      [Order Department] is responsible for [Take  Order],
      [Accounting Department] is responsible for [Bill Customer], [Check
        Credit],
      [Warehouse Department] is responsible for [Ship  Product];
Relationship Type: Business Process Precedence
  Has Instances:
      [Take Order] comes before [Ship Product], [Check  Credit],
      [Check Credit] comes before [Ship Product],
      [Ship Product] comes before [Bill Customer];
```

Figure 7. Instances of a Business Process Model

In R-EIS, an IOIS model is used to drive the EIS user interfaces. This approach can be used to complement the existing EIS interfaces. There are several R-EIS user interface tools that support the creation or browsing of an IOIS model in R-EIS. A *graphic view editor* is a diagrammatic representation of a view. An example of a graphic view editor for a business process model is shown in figure 8, in which an instance of an entity type is represented as a shape (e.g., a square represents an

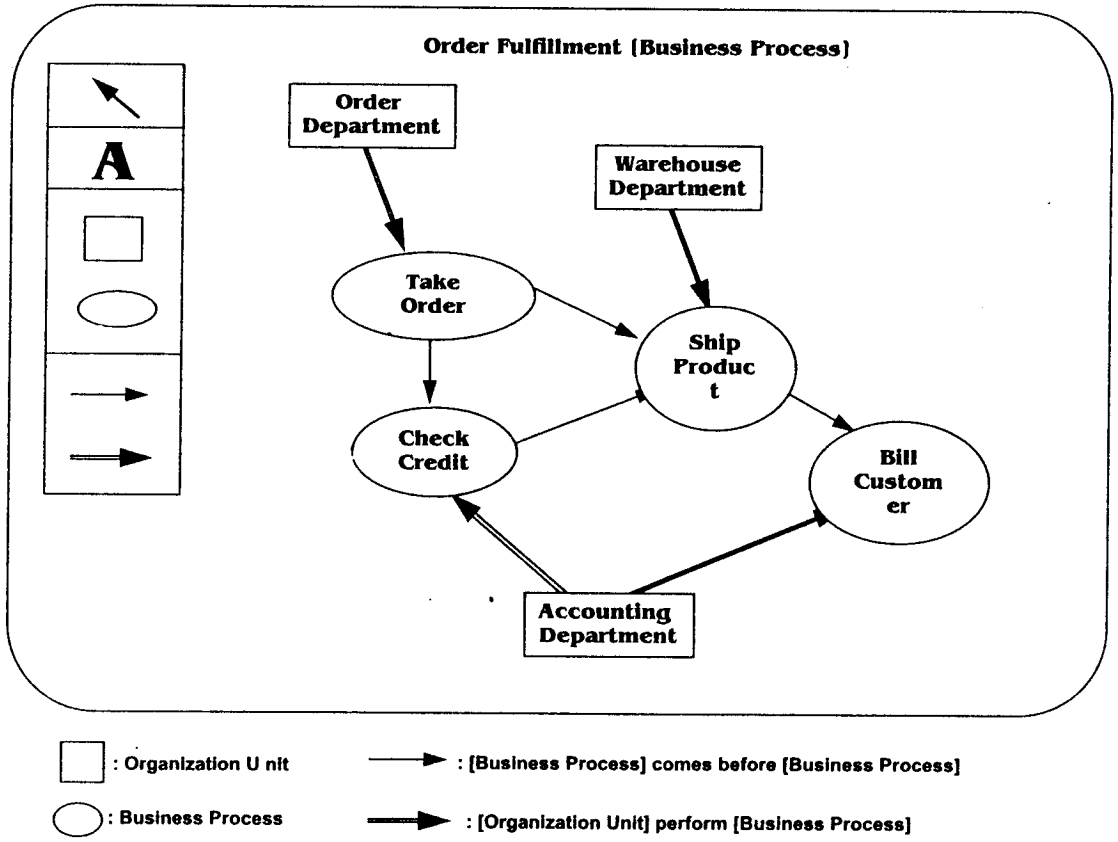

Figure 8. An Example of a Graphic View Editor that Uses the Business Process Model

Organization Unit, and an oval represents a Business Process), and an instance of a relationship type is represented as a line (e.g., an arrow-headed line represents the precedence of business processes, and an arrow-headed double-line indicates that an Organization Unit has responsibility over a Business Process).

A symbol such as an arrowhead can be attached to the end of a line to represent the cardinality or directionality of a relationship. Attributes of entities and relationships can be entered or displayed through an attribute editor. The graphic view editor maintains the connections of an entity when the user moves the entity to a new location. CASE shells such as VSF's Virtual Software Factory, CADWare's Foundry, and Intersolv's XL/Customizer, can be used to customize structure graph editors for each view [30].

A *generic structure graph browser*, as depicted in figure 9, can be used to assist users in navigating through the IOIS model using the meta-model. It can be used to display the hierarchical structure of a recursive relationship (e.g., [Business Process] consists of [Business Process]) or one relationship at a time among two entity types or to invoke the graphic view editor to retrieve a view of a highlighted entity.

A *matrix processor* such as the one in the IEF's Information Systems Planning Toolset is another tool that can be used to display the interactions of two entity types. As shown in figure 10, a matrix is used to display the involvement of an Organization Unit in a Business Process. Once the information has been entered, an executive can visually detect problems in the current system design. For example, Organization Units that are not involved in any Business Process may be candidates for elimination. A Business Process involving too many Organization Units may be a target for a business process reengineering project. Executives can utilize the clustering function in the matrix processor to group Organization Units and Business Processes that are closely related to each other into clusters during organization redesign. An executive can also highlight an instance of an Organization Unit and navigate to another viewing mechanism to see relationships between this organization unit and other entity types.

An object-oriented user interface can be used to guide the user in exploring the IOIS model by prompting the user with context-sensitive menus within the graphical view editor, generic structure graph browser, and matrix processor. For example, if the user selects Accounting Department from a list of Organization Unit instances, the system will pop up a menu like that shown in figure 11. If the user chooses "Show Structure Relationships," another menu will pop up, as depicted in figure 12. The system retrieves all the relationship types in which *Organization Unit* participates in the meta-model and displays them in the pop-up menu.

A Context-Based Approach to Information Systems Delivery

MOST EIS RESEARCH AND APPLICATIONS FOCUS on the representation formats of information residing in existing application systems. Rockart and De Long [40] believe that using EIS may enhance users' mental models of their own business processes. Such enhancement comes mainly from the users' exploration of data and decision models in EIA. There is no explicit representation of a user's mental model in current EIS. In R-EIS, the IOIS model is used as an explicit mental model to provide

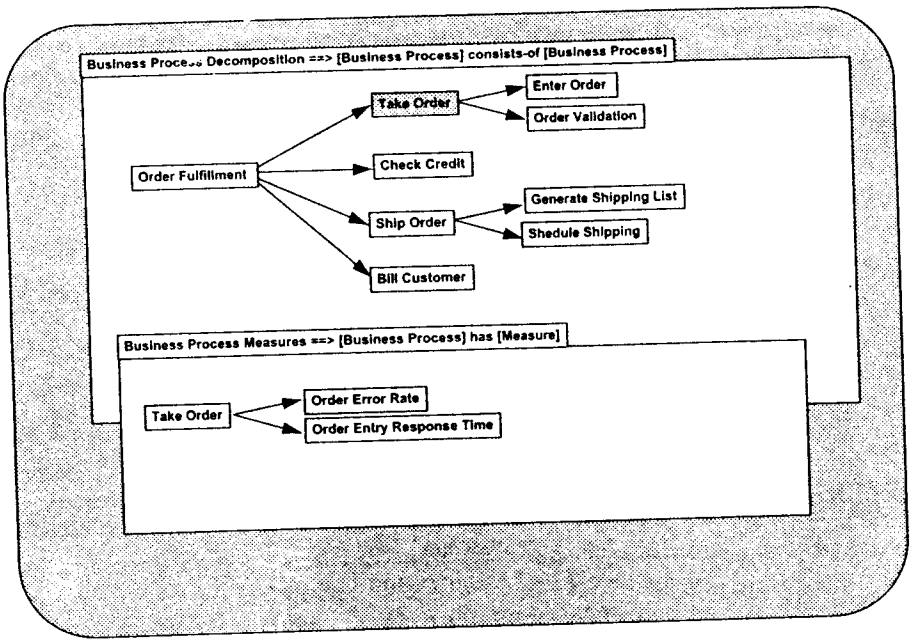

Figure 9. An Example of the Generic Structure Graph Editor

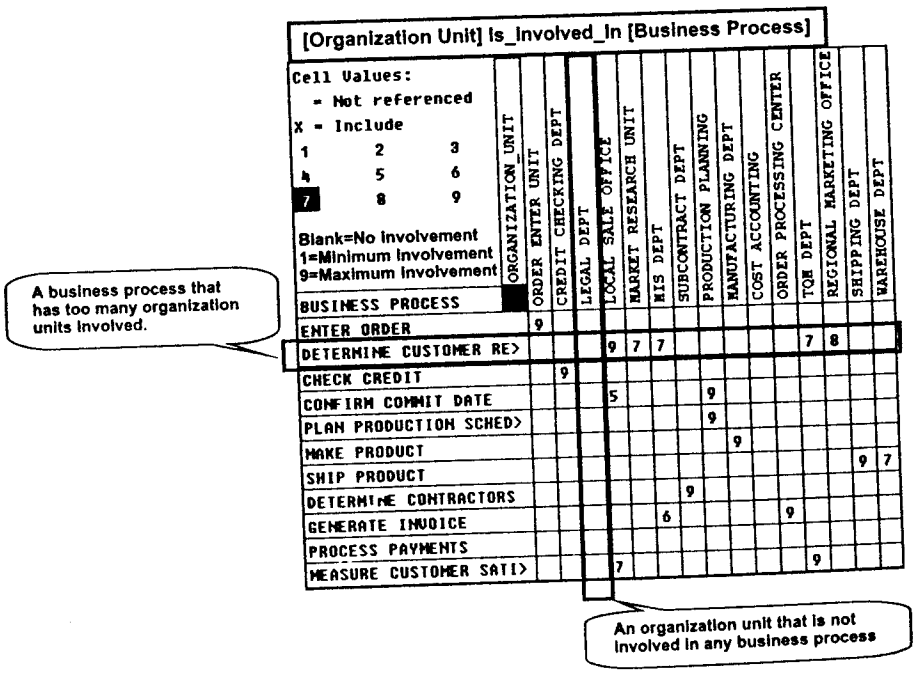

Figure 10. An Example of Using the Matrix Processor to Define and Analyze the Involvement of Organization Units in Business Processes

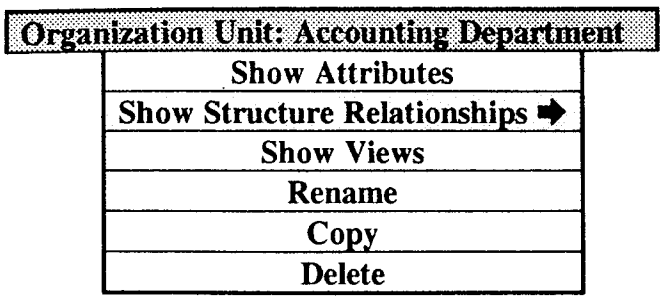

Figure 11. A Menu for Manipulating an Entity

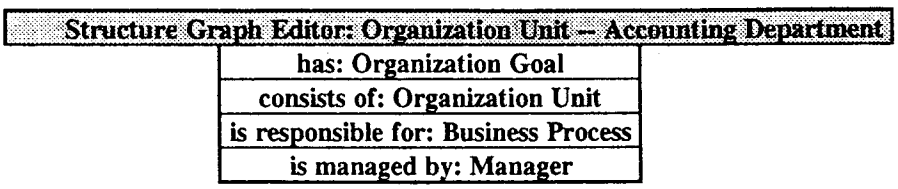

Figure 12. A Menu for Choosing a Relationship Type before Using the Generic Structure Graph Editor

a context in which executives can understand information delivered by an EIS.

The Key to the Understanding of Information Delivered: Context

In isolation, individual pieces of information mean nothing; they become useful only in a particular context. Context can help managers maintain their perspective. Providing a strategic context is a high-level objective. Mutual awareness of a context can unite people from various functional areas so that they can work together productively [19].

People in organizations use languages to communicate. Languages are learned and used within a context that provides background information to help people understand the problems or issues under discussion. Without a shared context, communication becomes difficult, if not impossible. A context serves as a basis for managers' understanding a situation that includes tasks they must perform, the roles they play, the relationships of a task to other tasks in the company, and high-level organizational goals and strategies.

Managers are increasingly involved in many cross-functional projects and often participate in multidisciplinary business teams. Because continuous interruptions occur in managerial work, they have to switch contexts when they are reengaging in a task. It is the context that tells people what has been or should be done, why it has to be done, and how to get it done [41]. Important contextual information associated

with a task is often lost in the context-switching process. In the absence of a proper environment to support this process, decisions made by managers may not align with overall organizational goals and strategies.

Contexts within an organization have seldom been formally captured and represented. The closest things to formal documents of organizational context are organizational charts and information systems models. The former represent only a simple reporting relationship among organizational units, while the latter are only used during information systems development processes. The IOIS model in the R-EIS can be used to facilitate the managers' context-switching processes, to integrate systems development and delivery, and to drive a high-level user interface with information systems, and eventually to support human and organizational learning [42].

The Use of an R-EIS

Most existing information systems do not provide users with contextual information or the underlying IS models related to the semantics of information delivered. In R-EIS, the IOIS models are explicitly represented to model business organizations and can be accessed by managers through appropriate interfaces. IOIS models are linked to an executable target IS that can be used to support managerial tasks. By accessing information systems from the IOIS model, managers are provided with proper contexts for information and knowledge delivered by these systems.

The IOIS model of an R-EIS can be viewed as an organization model that serves as an infrastructure to integrate information and expertise across the enterprise. The meta-model and the model can be used to assist managers in monitoring ever-changing business environments, strategies, and assumptions. Embedding the access methods of various target IS in the linkages between the model and the target IS enables the users to browse through the organization model from various business perspectives (e.g., business process perspective or data flow perspective) and invoke the underlying target IS. Navigating the organization model not only provides executives with model-driven interfaces that allow them to interact with systems, but also gives users enough background information (i.e., context) to understand the information and suggestions received. By sailing through the meta-model and the model, users will have a better understanding of the organization. Some potential interdepartmental conflicts may be resolved or avoided through the shared view of higher-level strategies and objectives.

We describe two scenarios using an R-EIS to demonstrate the technology's potential. Figure 13 shows the navigation history of the first scenario. A manager who is concerned with the organization goals for which she is responsible logs on to R-EIS. She first browses through a list of meta-model entity types such as Business Process and Organization Goal. She selects Organization Goal and R-EIS responds with a list of instances of Organization Goal. By highlighting an instance of Organization Goal (e.g., Increase profit), she chooses to examine the [Organization Goal] consists-of [Organization Goal] relationship. The system uses the generic structure graph browser to display the decomposition of Organization Goal instances. Clicking the right mouse

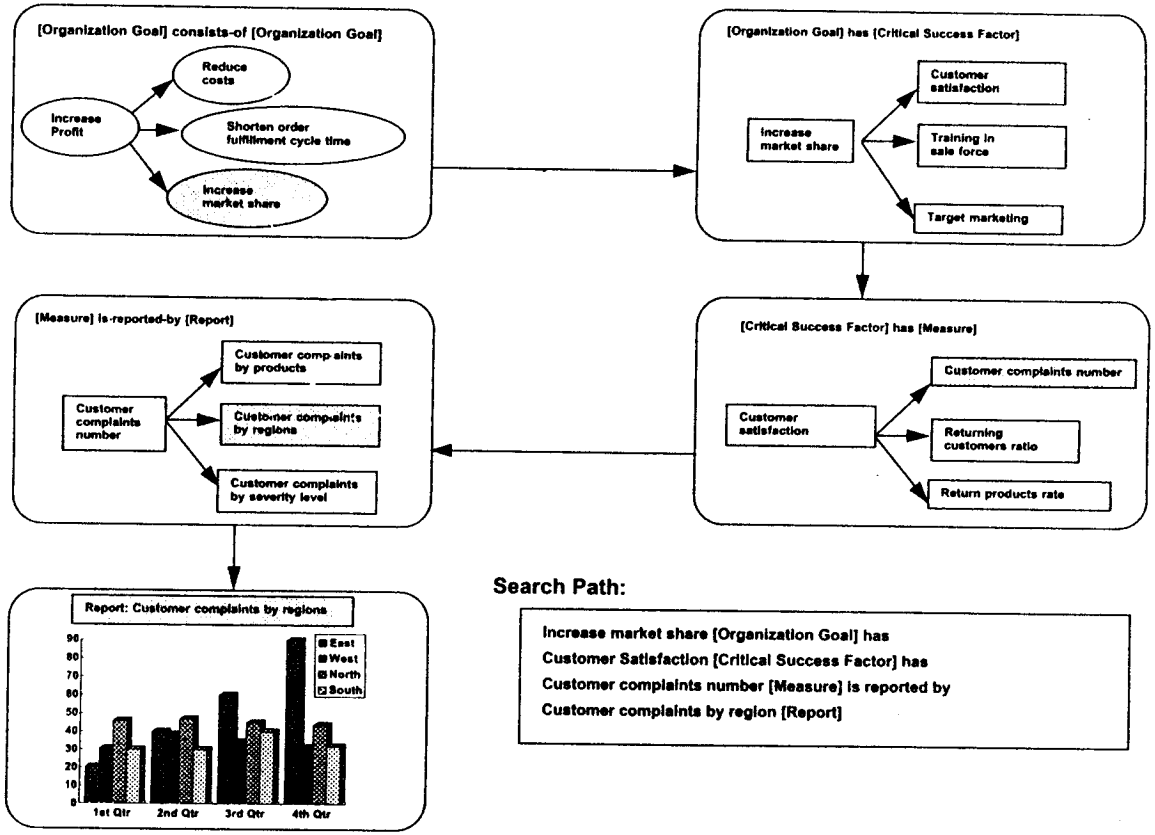

Figure 13. An Example of Navigating an IOIS Model to Access Managerial Information

button highlights the "increase market share" goal and a browsing menu showing all the possible relationships with Organization Goal is displayed. The manager decides to check out all the instances of Critical Success Factor associated with the selected goal. After choosing one of many Measures (e.g., customer complaint number) of a particular Critical Success Factor (e.g., customer satisfaction), the manager determines to review Reports (including off-line reports and on-line queries). By clicking on the icon of the Report for "customer complaints by regions," the system executes the reporting program that displays the report on the screen. She looks at the trend of customer complaints in the last four quarters and finds out there is a steady increase of customer complaints in the East region. She calls the Customer Service Manager of the East Region to discuss the problem.

Neilsen [35] suggested several mechanisms for *increasing the sense of context* while navigating in the hypertext space: overview diagrams, backtracking, and interaction history via timestamping and footprints. In R-EIS, the *search path*, as shown in figure 13, is recorded by the system and can be displayed and used by the manager as a context to assist her in understanding and interpreting information. The IOIS model can be used as a front end to guide the navigation of various managerial data and to provide an access mechanism to many *executable* business applications, such as MRS, ES, and DSS.

Managers often receive information but do not know how to interpret its meaning within the organizational context. Another way of using the R-EIS is to navigate the IOIS model from the information systems perspective in order to identify the organizational contexts of delivered reports. Several paths may link a report to organizational goals or measures for business processes. These links will help users to interpret a report from multiple perspectives.

The following scenario shows how a CEO of a manufacturing firm starts her navigation of R-EIS from the information delivered to her. She receives a Monthly Sale Analysis Report that can be analyzed and interpreted from different angles. She first logs on to R-EIS and finds all the instances of Measure that are related to the report. These measures include: actual as a percentage of meeting sale target, percentage increase in market share, and *percentage increase in international sale*. She looks at a report that has a number indicating a decrease in percentage of international sales in the last season. By navigating in R-EIS, she finds out that this measure is related to a Critical Success Factor named *expanding international market*. By looking at all the instances of Measure related to the expanding international market CSF, she starts to retrieve several reports that can be used to measure the success of international market expansion. One of these reports indicates that several countries have tightened up their import regulations in the company's major line of products. She decides to call a meeting to discuss this issue with the Vice President of International Sales. During her navigation, she also finds out that the expanding international market CSF is related to an organization goal stated as "increase profit" that has a subgoal called "shorten the cycle time of the order fulfillment process." "Shorten the cycle time of the order fulfillment process" is a new organization goal, recently added to the IOIS model because of a finding in an order fulfillment process reengineering project. She tries to retrieve information to measure the cycle time of order fulfillment process, but

discovers that there is no measure or report defined in the IOIS model. She contacts the MIS director immediately and requests that an application be developed to keep track of cycle times of the company's critical business processes.

The Benefits of R-EIS

The IOIS model is a shared view of the organization. R-EIS provides a collaborative environment to foster a team spirit among executives. Managers can easily communicate and coordinate, share ideas, and learn from each other because they have a common *big picture* of the organization. Working with the R-EIS is therefore learning. Contexts of information delivered include business strategies and policies, critical success factors and assumptions, as well as goals and objectives, all of which should be explicitly represented and made accessible to people. R-EIS allows people to challenge the status quo, to avoid tunnel vision, and to empower employees at all levels of an organization. By surfacing assumptions of strategic plans, better planning results can be generated [32]. By capturing design rationales (not just technical rationales, but business ones), better information systems can be designed [12].

Using R-EIS for organizational modeling and information delivery will support organizational learning. The model and meta-model of IOIS in R-EIS allow executives to learn not only what their organizations are, but also how they should view and describe their organizations. An IOIS model can be an important resource to new managers who need to understand the organization and learn to use information technologies to perform their jobs. Organization models will also serve as the context for interpreting information delivered and for guiding the exploration of information available to managers. The organization model itself will help managers to understand what the shared visions, goals, objectives, strategies, and business processes are, as well as how they relate to each other. Senge and Sterman [44] reported that the benefits of using dynamic simulation process models in management training included reducing the learning period for new managers, improving communication skills, and so on. The IOIS is a superset of the dynamic process models. It supports organization learning and relational thinking (thinking about complex relationships and concepts that executives have to manage).

IS professional and managers often complain that information systems planning (ISP) models are not kept up to date and that information systems architectures quickly become outdated. By looking into the situation, we discovered that the primitive organization models stored in the current I-CASE repository had been used only to derive the original ISP models. Once the ISP was done, these models were not maintained by the organization because they were used by neither managers nor IS professionals. If IOIS models are used to deliver information systems, managers will demand that the IOIS models be up to date. As illustrated in the second scenario, if any change in the organization model is made, R-EIS can ensure that the information systems will be changed accordingly to ensure the alignment of IS and business.

Conclusions: Limitations and Future Research

WE HAVE DESCRIBED A REPOSITORY-BASED EIS designed to facilitate access to repository information by managers, using a repository as a gateway to all managerial information. R-EIS approaches enable managerial information access in a manner that previously has been impossible. R-EIS allows managers to navigate back and forth between organization models and information models by means of structured graphic-based front-end user interfaces. R-EIS improves the traditional EIS approach to accessing managerial information. The benefits of using R-EIS include: (1) support for continuous business improvement based on the performance measures established in the model, (2) improvement to the business reengineering process by providing the ability to model and analyze the organization, (3) easy navigation and exploration of the IOIS model that helps executives understand the goals and objectives of the organization, (4) guidance for the development of IS models to ensure that they are aligned with the business objectives, (5) establishment of a common mental model of the business to support organizational learning, and (6) a basis for delivering information in the business context.

We are building a working R-EIS, based on experience gained through the development of the prototype system and integrating repository-based CASE tools and traditional EIS according to the architecture design described. We would like to move out of the prototyping stage because we believe all the supporting technologies are ready and organizations are recognizing information delivery as an important issue.

The approach taken in this research, however, is not without its limitations. First, managers are forced to *share* an enterprise-wide mental model (i.e., the IOIS model), so they must externalize their mental models and then try to consolidate these models into an enterprise-wide and consensus-based model. The building of an IOIS model will not be easy. It will be a major effort and resources have to be allocated to keep the IOIS model up to date. We suggest that companies interested in this approach "start small, but never forget the potential" [46, p. 429]. Tannenbaum argued that the ultimate use of a repository would be as the gateway to all corporate information. She believed you must introduce business perspectives into the contents of the repository and provide access to the repository.

Second, the interfaces to an R-EIS repository need to be opened up so that application development tools can be integrated into it. A reverse *organization* engineering tool for capturing existing organization models to reduce the workload of populating the IOIS model needs to be developed to ease the effort of implementing R-EIS. Currently, end users are not allowed to specify their own mental models using the underlying meta-language. The only customization is use of a subset of the complete meta-model to integrate their applications and information. We would like to implement an R-EIS repository in an existing commercial repository product. Currently, the R-EIS repository is implemented as persistent Smalltalk objects. IBM's difficulty in promoting its AD/Cycle repository and the recent joint effort between Microsoft and TI to develop a client/server-based repository are indications that an open repository system is important to application integration but can be very difficult to implement.

Third, we believe that R-EIS will also be an effective tool to support organizational learning and to increase managers' understanding of information that is delivered. We would like to set up R-EIS learning laboratories, such as the ones Senge and Sterman [44] have developed for their system dynamic modeling tools, to assist managers in learning more about their organizations. Case and field studies must be conducted to validate the efficacy of the contextual approach and its impacts on executives. The difficulty in these studies will be determining how to define and measure the effects of organizational learning.

Fourth, *information overloading* is still a problem that we need to deal with in R-EIS, because of the size and complexity of the IOIS model. We have designed and introduced a *software trigger* into R-EIS, giving it the ability to evaluate the information to be delivered and apply predefined checking rules to determine the urgency and importance of the screens/reports. We can extend the definition of *Measure* in the example IOIS model by allowing users to define a set of critical indicators such a the employee turnover rate, customer satisfaction rating, or progress of major projects. The upper bound and lower bound of these critical indicators can be defined. We are planning to use the trigger mechanism [26] in relational database management systems to invoke the checking rules when these critical indicators are updated and to check whether the values of these indicators are over the upper bound or below the lower bound. Electronic messages can be sent to executives to alert them about urgent situations when they arise or such situations can be added to a hot-event list. Executives should be advised to review this list first thing every morning. With this additional feature, R-EIS not only could deliver information to managers with contexts, but also could play a more active role in alerting managers about exceptional situations. The navigation mechanism is designed to let managers browse through various aspects of the organization's model and the data associated with the model to obtain a holistic view of the organization. The software trigger is designed to actively disseminate urgent information directly to managers.

Another disadvantage of R-EIS is the long navigation path managers have to traverse before they reach the relevant information. One possible solution is to add hypertext ability into R-EIS. Managers could attach unstructured links between instance of entity types. For instance, a manager could directly add a hypertext link between "reduce costs" Organization Goal and "activity-based costing analysis" Report. She then could bypass many intermediate relationships and directly retrieve the report. Using the hypertext feature in R-EIS, managers could add individual links on top of IOIS models to augment organizational contexts with individual ones.

In order to implement R-EIS successfully, companies first need to recognize the importance of information systems delivery and the usefulness of organization modeling. Building and maintaining the IOIS will be the most likely problem, but we believe, once the potential benefits of R-EIS are realized, organizations will commit enough resources to support the building of R-EIS. The potential first candidates for R-EIS implementation are companies that are using repository-

based CASE tools (e.g., TI's IEF, which allows users to define meta-model-level entity types and relationships), have developed EIS applications, or are interested in a data-warehousing approach. Potentially, we can extend the repository to capture organization models and use the model-driven interface tools as described in R-EIS to add high-level interfaces to existing EIS and other business applications.

REFERENCES

1. Armstrong, D.A. How Rockwell launched its EIS. *Datamation* (March 1, 1990).
2. Baum, D. C/S apps without the heavy lifting. *Datamation* (February 1, 1994), 22–24.
3. Bieber, M., and Kimbrough, S.O. On generalizing the concept of hypertext. *MIS Quarterly, 16*, 1 (1992), 77–93.
4. Blanning, R.W., and King, D. *Human Organizations as Intelligent Systems*. Tutorial, 25th Annual Hawaii International Conference on System Sciences, January 1992.
5. Carlson, D.A., and Ram, S. HyperIntelligence: the next frontier. *Communications of the ACM 33*, 3 (March 1990), 311–321.
6. Chen, M. The integration of organization and information systems modeling: a metasystem approach to the generation of group decision support systems and computer-aided software engineering. Ph.D. dissertation, University of Arizona, 1988.
7. Chen, M., and Norman, J.R. A framework of integrated CASE. *IEEE Software, 9*, 2 (March 1992), 18–22.
8. Chen, M., and Nunamaker, J.F. Integration of organization and information systems modeling: an object-oriented approach. *Proceedings of the 22nd Annual Hawaii International Conference on System Sciences*. Los Alamitos, CA: IEEE Computer Society Press, January 1989, pp. 70–79.
9. Chen, M., and Sibley, E.H. Using a CASE based repository for systems integration. *Proceedings of the 24th Hawaii Annual International Conference on Systems Sciences*, vol. II. Los Alamitos, CA: IEEE Computer Society Press, 1991, pp. 578–587.
10. Chen, P.P. The entity-relationship model—toward a unified view of data. *ACM TODS, 1* (1976), 9–36.
11. Conklin, J. Hypertext—an introduction and survey. *IEEE Computer, 20*, 9 (1987), 17–41.
12. Conklin, J. Design rationale and maintainability. *Proceedings of the 22nd Annual Hawaii International Conference on Systems Sciences*, vol. II. Los Alamitos, CA: IEEE Computer Society Press, 1989, pp. 533–589.
13. Electronics Industries Association. *CDIF—Framework for Modeling and Extensibility*. EIA Interim Standard, EIA/IS–81, Electronics Industries Association, Washington, DC, July 1991.
14. Francett, B. Decisions, decisions: users take stock of data warehouse shelves. *Software Magazine* (August 1994), 63–70.
15. Friend, D. Open window for EIS. *CIO, 4*, 4 (January 1991).
16. Friend, D. EIS and the collapse of information pyramid. In H.J. Watson, R.K. Rainer, and G. Houdeshel (eds.), *Executive Information Systems*. New York: John Wiley, 1992, pp. 327–335.
17. Goodhue, D.L.; Quillard, J.A.; and Rockart, J.F. Managing the data resource: a contingency perspective. *MIS Quarterly, 12*, 2 (June 1988), 373–392.
18. Gorry, G.A., and Scott Morton, M.S. Framework for management information systems. *Sloan Management Review, 13*, 1 (Fall 1971), 59–70.
19. Heany, D.F. *Cut Throat Team Mates: Achieving Effective Teamwork among Professionals*. Homewood, IL: Dow Jones–Irwin, 1989.
20. Houdeshel, G. Selecting information for an EIS: experiences at Lockheed-Georgia. *Proceedings of the 24th Annual Hawaii International Conference on System Sciences*, vol. III. Los Alamitos, CA: IEEE Computer Society Press, 1991, pp. 178–185.
21. Houdeshel, G., and Watson, H.J. The management information and decision support (MIDS) system at Lockheed-Georgia. *MIS Quarterly, 11*, 1 (March 1987), 127–140.
22. IBM. *AD/Cycle Information Model-Reference Volume 1: Enterprise Submodel*. SC26–4842–02, 3d ed., March 1992.

23. Inmon, W.H. *Building the Data Warehouse*. Wellesley, MA: QED Information Sciences, 1992.

24. Isenberg, D.J. How senior managers think? *Harvard Business Review* (November–December 1984), 81–90.

25. Johnson-Laird, P.N. *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness*. Cambridge, MA: Harvard University Press, 1983.

26. Khoshafian, S.; Chan, A.; Wong, A.; and Wong, H.K.T. *A Guide to Developing Client/Server SQL Applications*. San Mateo, CA: Morgan Kaufmann, 1992.

27. Kimball, R., and Strehlo, K. Why decision support FAILS and how to FIX it. *Datamation* (June 1, 1994, 40–43.

28. Law, M.H. *Guide to Information Resource Dictionary System Applications: General Concepts and Strategic Systems Planning*. NBS Special Publication 500–152, 1988.

29. Martin, J. *Information Engineering, Book II: Planning and Analysis*. Englewood Cliffs, NJ: Prentice-Hall, 1990.

30. Marttiin, P.; Rossi, M.; Tahvanainen, V.-P; and Lyytinen, K. A comparative review of CASE shell—a preliminary framework and research outcomes. *Information and Management, 25* (1993), 11–31.

31. Martz, W.B. GroupSystems 4.0: an electronic meeting system. In *Proceedings of the 24th Annual Hawaii International Conference on System Sciences*, vol. III. Los Alamitos, CA: IEEE Computer Society Press, 1991, pp. 799–804.

32. Mason, R.O., and Mitroff, I.I. *Challenging Strategic Planning Assumptions: Theory, Cases, and Techniques*. New York: John Wiley, 1981.

33. Minch, R. Application and research areas for hypertext in decision support systems. *Journal of Management Information Systems, 6*, 3 (1990), 119–138.

34. Mintzberg, H. *The Nature of Managerial Work*. Englewood Cliffs, NJ: Prentice-Hall, 1980.

35. Nielsen, J. The art of navigating through hypertext. *Communications of the ACM, 33*, 3 (1990), 296–310.

36. Paller, A., and Laska, R. *The EIS Book: Information Systems for Top Managers*. Homewood, IL: Richard D. Irwin, 1990.

37. Pinella, P. An EIS for the desktop. *Datamation* (May 1, 1991).

38. Pounds, W.F. The process of problem finding. *Industrial Management Review, 11*, 1 (Fall 1969): 1–19.

39. Rockart, J.F. Chief executives define their own data needs. *Harvard Business Review* (March–April 1979), 81–93.

40. Rockart, J.F., and De Long, D.W. *Executive Support Systems: The Emergence of Top Management Computer Use*. Homewood, IL: Dow Jones–Irwin, 1988.

41. Schrage, M. *Shared Minds: The New Technologies of Collaboration*. New York: Random House, 1990.

42. Senge, P. M. *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York: Doubleday, 1990.

43. Senge, P. M.; Roberts, C.; Ross, R.B.; Smith, B.J.; and Kleiner, A. *The Fifth Discipline Fieldbook*. New York: Doubleday, 1994.

44. Senge, P. M., and Sterman, J.D. Systems thinking and organizational learning: acting locally and thinking globally in the organization of the future. In T.A. Kocha and M. Useem (eds.), *Transforming Organizations*. New York: Oxford University Press, 1992, pp. 353–370.

45. Sommer, R.; Chen, M.; and Sibley, E.H. CASE standards and integration. *Proceedings of the 25th Hawaii International Conference on System Sciences*, vol. III. Los Alamitos, CA: IEEE Computer Society Press, January 7–10, 1992, pp. 320–330.

46. Tannenbaum, A. *Implementing a Corporate Repository: The Models Meet Reality*. New York: John Wiley, 1994.

47. Teory, T.J.; Yang, D.; and Fry, J.P. A logical design methodology for relational database using the extended entity-relationship model. *ACM Computing Surveys, 18*, 2 (1986), 196–222.

48. Vaughan, J. IEF meets OLE. *Software Magazine* (August 1994), 33.

49. Volonino, L., and Watson, H.J. The strategic business objectives method for guiding executive information systems development. *Journal of Management Information Systems, 7*, 3 (1991).

50. Wallis, L. Power computing at the top. In H.J. Watson, R.K. Rainer, and G. Houdeshel

(eds.), *Executive Information System: Emergence Development Impact*. New York: John Wiley, 1992, pp. 301–314.

51. Watson, H.J., and Satzinger, J. Guidelines for designing EIS interfaces: meeting executives' information needs. *Information Systems Management* (Fall 1994), 46–52.

52. Welke, R.J. The CASE repository: more than another database application. In W.W. Cotterman and J.A. Senn (eds.), *Challenges and Strategies for Research in Systems Development*. New York: John Wiley, 1992, pp. 181–218.

53. Whitten, J.L.; Bentley, L.D.; and Barlow, V.M. *Systems Analysis and Design*, 3d ed. Burr Ridge, IL: Irwin, 1994.