

# USE OF AN ACCOUNTING OBJECT INFRASTRUCTURE FOR KNOWLEDGE-BASED ENTERPRISE MODELS

**Guido L. Geerts and William E. McCarthy**

Department of Accounting, N270 North Business Complex  
Michigan State University  
East Lansing, MI 48824, USA

E-mail: Geerts "23358MGR@msu.edu" -- McCarthy "21277WEM@msu.edu"  
Telephone: 517-355-7486 Fax: 517-432-1101

## **Abstract**

This paper reviews the basic tenets and structure of the REA (Resource-Event-Agent) accounting model, and it discusses how that model has been used in a wide variety of knowledge-intensive environments to facilitate automated reasoning concerning economic phenomena in business enterprises. The model's basic concepts and structures are reviewed at both higher (enterprise value chain) and lower (business process tasks) levels of abstraction. The use of REA in some prototype AI systems and its use in empirical assessments is also discussed.

## **Introduction**

Most corporate enterprise information is concerned with the acquisition, transfer, conversion, and sale of economic resources like cash, inventory, and supplies of labor and services. By definition, such data traditionally has been tracked primarily by **accounting** systems with individual computerized modules like payroll, accounts payable and receivable, job costing, order entry, and general ledger. In both small and large companies, the accounting system designers usually have a preemptive call on the basic schemes used to type economic data either because of statutory reporting requirements (to agencies like the IRS or the SEC) or because of private reporting requirements to creditors and shareholders. If accountants use these preemptive privileges to force traditional account coding onto the organization database as its fundamental classification architecture (in other words, if they require early journalizing of transaction data), then many dysfunctional effects arise. McCarthy (1982) first noted these, and his list was reiterated and expanded by Andros, Cherrington, and Denna (1992) in conjunction with work

that involved restructuring and consolidation of all of IBM's worldwide accounting systems. Prominent among these dysfunctional features of traditional accounting enterprise architectures were three that we intend to focus upon in this paper: (1) their inability to integrate well with knowledge-based decision tools, (2) their inability to accommodate process-oriented models of the enterprise, and (3) their inability to be used inter-organizationally. As a remedy for these deficiencies, we propose the application of the REA accounting model in the analysis, operation, and use of an enterprise information system. REA specifically incorporates the semantics of economic objects into the information architecture of a firm. Such embedding facilitates coupling with knowledge-based decision support systems. Additionally, recent advances in REA theory have incorporated its explicit top-down use as a process model of enterprise economic activities along a value-added chain. This allows the process semantics of a firm's constellation of economic objects to be viewed at multiple levels of abstraction and to be used in understanding and using the corporate database (Geerts and McCarthy, 1997).

The rest of this paper is organized as follows. We first give an overview of the REA accounting model, especially as it can be viewed as a top-down portrayal of the basic economic rationale for organizing and structuring a company. Somewhat informally, we refer to this rationale as the "business entrepreneur script." This script is simply a process model of the enterprise at different levels of abstraction. The term REA (which stands for resource-event-agent) refers to the prototypical economic object constellation associated with each process in this top-down script. Following illustration of the entrepreneur script, we move to an exposition of an architecture for the accounting object infrastructure, and we speculate on this architecture's use in the day-to-day operation of a business. Once done

with the architecture, we move to a comparison of systems built on REA principles with those built on conventional precepts. Our comparisons here will focus on the possibilities for automated reasoning and for coupling these systems with knowledge-based decision tools. We finish with an enumeration for both the near and distant future of the possible uses for our REA enterprise architecture. Our listing will emphasize immediate practical use of these ideas, and our explanations will include quick descriptions of three AI systems built with these ideas.

## REA Accounting as a Business Entrepreneur Script

In simple terms, all businesses enterprises operate in the same manner. Somebody has an idea about how to provide a new/improved service or product (e.g., a better mousetrap, a new way to cure some malady, a better/faster way to improve something, etc.). This entrepreneur then acquires some initial financing in the form of debt or equity for the enterprise. The entrepreneur then engages in a chain of purposeful economic exchanges with other parties (like vendors and employees), each time **giving up** some economic resource (like money) in return for **taking back** another resource of greater value where value is defined in terms of a deliverable portfolio of attributes attractive to the firm's ultimate customers. Hopefully, most entrepreneurs find that when they have consummated their final exchanges with their customers and paid off their creditors, they enjoy a justifiable profit from these activities (i.e., in the long term, they take in more cash than they give out). A successful entrepreneur cycles through such a chain of value-added activities on a continual basis. A corporation does the same, except in more bureaucratic fashion.

In process terms, this entrepreneur script is illustrated at the top of Figure 1 at different levels of abstraction. The top-level process "I engage in value-added exchanges" is exploded to the three process bubbles just below it where each second-level process has identified economic resources as both input and output (R.M. = raw materials; F.G. = finished goods). Accountants would refer to the three second-level processes shown from left to right in Figure 1 as the acquisition cycle, the conversion cycle, and the revenue cycle. An REA process model of the firm can consider such a process hierarchy at great depths, although we have shown just two levels here. A typical enterprise model would have a much deeper and wider process hierarchy that would approximate a Porter-type (1985) value chain. The microeconomic rationale for these entire enterprise models is explained by Geerts and McCarthy (1994b).

Surrounded by a dotted line at the bottom of Figure 1, we have shown the REA object constellation (in entity-relationship form) of each exchange process. In general, each process explodes to eight entities, although there almost always is some overlap. Each exchange has an increment event (or possibly a set of events) linked with a decrement event (or set of events). The increment and decrement events have entity constellations that are actually mirror images of each other. Exact definitions for the economic resources, the economic events, and the economic agents follow from those given by McCarthy in 1982 as do the definitions for the different types of relationships involved in the prototypical object template.

To make matters a little more concrete, we note that the revenue cycle of Figure 1 (i.e., the bubble labeled "I sell finished goods") might have the following set of REA entities:

**decrement:** a *sale* event occurs which involves giving the resource *finished goods* by an internal agent *salesperson* to an external agent *customer*

**increment:** a *cash receipt* event occurs which involves taking the resource *cash* by an internal agent *cashier* from an external agent *customer*.

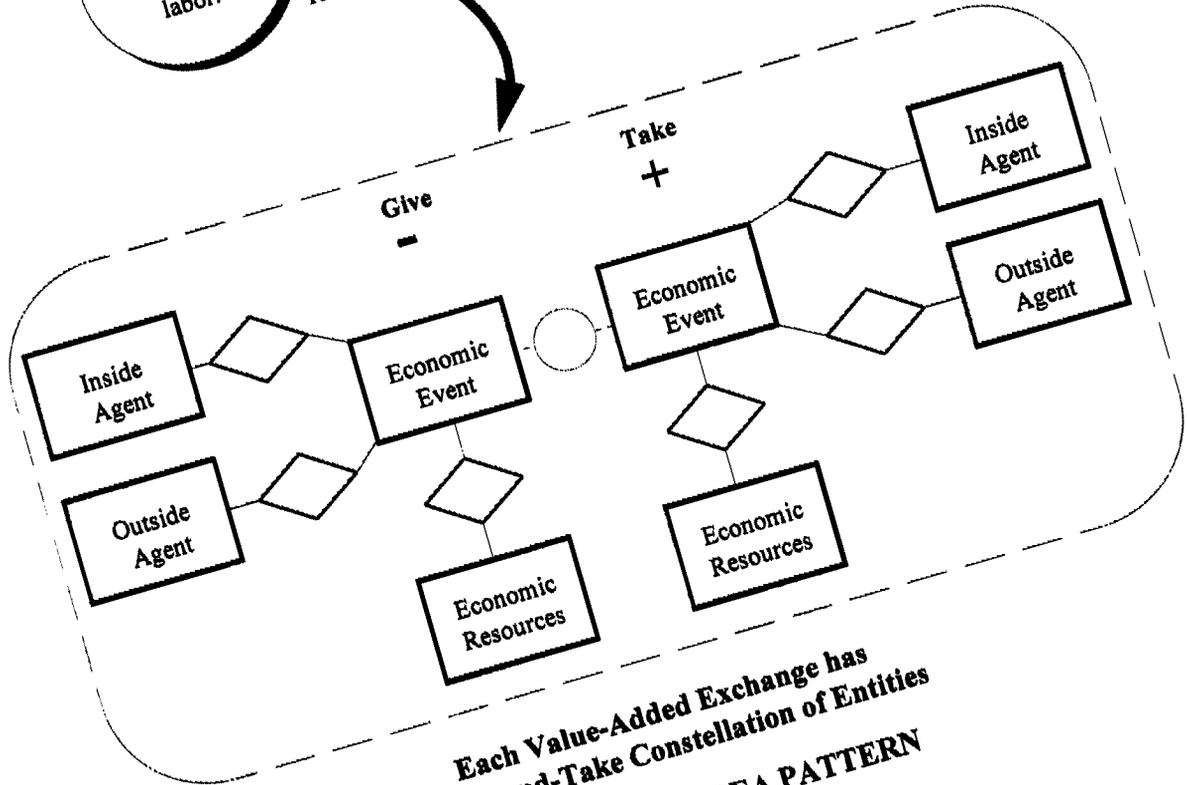
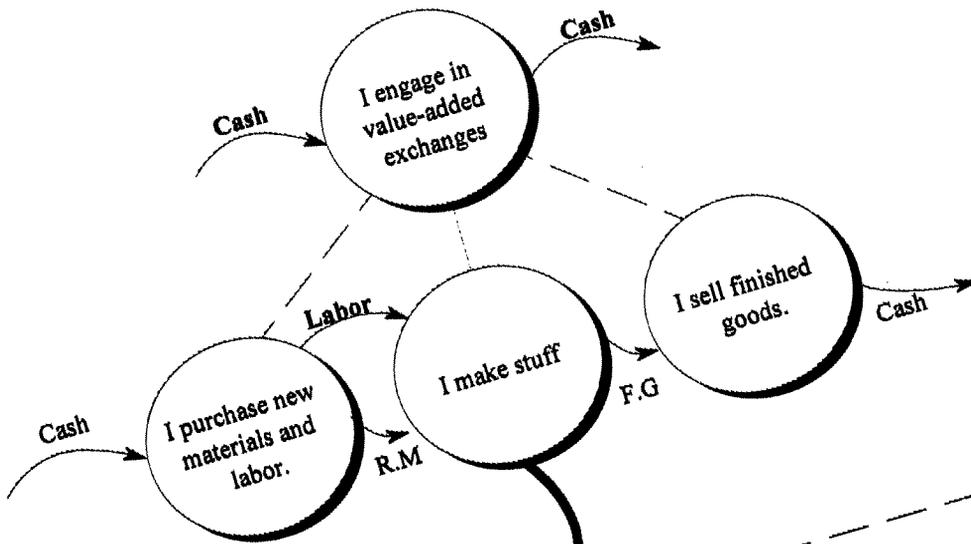
Readers interested in how such entity constellations can be implemented with database technology may consult Gal and McCarthy (1986).

## The REA Accounting Object Infrastructure

When the entrepreneur script is fully specified top down and when each leaf node in the process hierarchy is exploded to give its full complement of REA entities and relationships, a candidate enterprise schema for a company results. In almost all corporate cases, this schema will be augmented with many objects that do not relate directly to the acquisition, conversion, and sale of economic resources.

However, the REA components will undoubtedly form an accountability infrastructure for the corporate information architecture. The use and maintenance of this enterprise object model is portrayed in Figure 2.

We have attempted in the middle of this figure to show simultaneously both the process and economic object flavor of an REA infrastructure. The five processes each have their appropriate economic events portrayed, although space constraints preclude delineation of the economic resources and agents. Readers interested in seeing a full



**Each Value-Added Exchange has a Give-and-Take Constellation of Entities**  
**FIGURE 1 - REA PATTERN**

entity-relationship model for a similar manufacturing firm may consult David and McCarthy (1995). Additionally, each of the events illustrated may be further divided into a set of tasks needed to accomplish them (Geerts and McCarthy forthcoming).

On the top left of Figure 2, we have illustrated the inputs which might be associated with day-to-day use of a knowledge-intensive enterprise information system based on our explanations thus far. We note that most of the population of the concepts in the object structure of the firm would come from its transaction level input. However, other sources could be used systematically in an integrated fashion. These might include both managerial information and estimates from inside the firm (such as budget information or engineering specifications for a bill of materials) and publicly available data from outside sources (such as commodity prices or information on product substitutes/complements from competitors). The important point to remember for enterprise operation here is that REA specification of economic phenomena allows semantic integration of data from disparate sources. Thus a piece of inventory could be given an integrated description of its cost and availability (from transaction data), its physical specifications (from engineering estimates), and its competitiveness (from outside data sources). Such integrated semantics are impossible in traditional business information systems which rely on bookkeeping artifacts for classification purposes.

On the top right of Figure 2, we show the outputs associated with daily operation of the REA object enterprise model. Reports to managers might not differ much from traditional architectures, but coupling with decision support systems -- especially if those systems contain semantically specified components -- might change dramatically. An REA enterprise information architecture maintains its object-level and process-level semantics within itself. In a way, its meaning is conveyed with its data, and this makes any connection to another automated system less problematic because it leaves less room for misinterpretation. This "conveyed meaning" also makes automated use of components of the enterprise model easier for users outside the firm. Such use would facilitate the development for instance of "conceptual EDI."

At the bottom of the REA object enterprise model shown in the middle of Figure 2, we have portrayed a component of these systems which perhaps differentiates them the most from traditional accounting information architectures -- the specification of additional concept declarations. The use of such declarations in a knowledge intensive environment is

explained in detail by Geerts and McCarthy (1994a). What it entails however can be summarized quickly. The repeated use of a standard object template in the construction of an REA enterprise model allows automated reasoning (involving specific pattern matches on all appropriate object constellations) to occur at as high a level of concept definition as possible. Thus, instead of having to write multiple procedures to define various types of economic claims (which in REA terms are imbalances between sets of increments and decrements), we find that it is possible instead to define such a concept once and let a reasoner find its instantiations. Such use makes the semantics of such definitions much clearer by removing them from procedures and making them declarative.

### **How REA Object Enterprise Models Can Work with Knowledge-Based Tools**

At present, there have been only a handful of directed REA implementations in actual companies, although firms like Price-Waterhouse and IBM have adopted certain of its principles as guiding architectural features for accounting system design (Cherrington et al. 1993). None of these implementations have been full-REA models in the sense of the object enterprise model shown in Figure 2 where all processes and objects are specified and implemented without cost-benefit compromise. Empirical assessment of the possibilities for the accounting software marketplace to be able to move toward full-REA implementations is something we plan to do in the future. For the present section, however, we assume that the technology constraints of processing time and storage capacities could be overcome, and we speculate in Figure 3 how such full process models might be linked with certain types of knowledge-based systems. Such an assumption and its accompanying discussion is actually quite realistic in a methodological environment where the full possibilities for an architecture are considered thoroughly in an early assessment phase unfettered by cost and technology constraints.

Figure 3 illustrates how information about the real world (in the shape at the middle left) might be filtered through to financial decision makers (in the circle at the middle right) through two different types of accounting system. Both old (bookkeeping-based) and new (REA-based) accounting show proposed use of knowledge-based technology with lines emanating from the decision makers; however, the difference is in the nature of their linkages to the computerized information system of an enterprise. Both are described below.

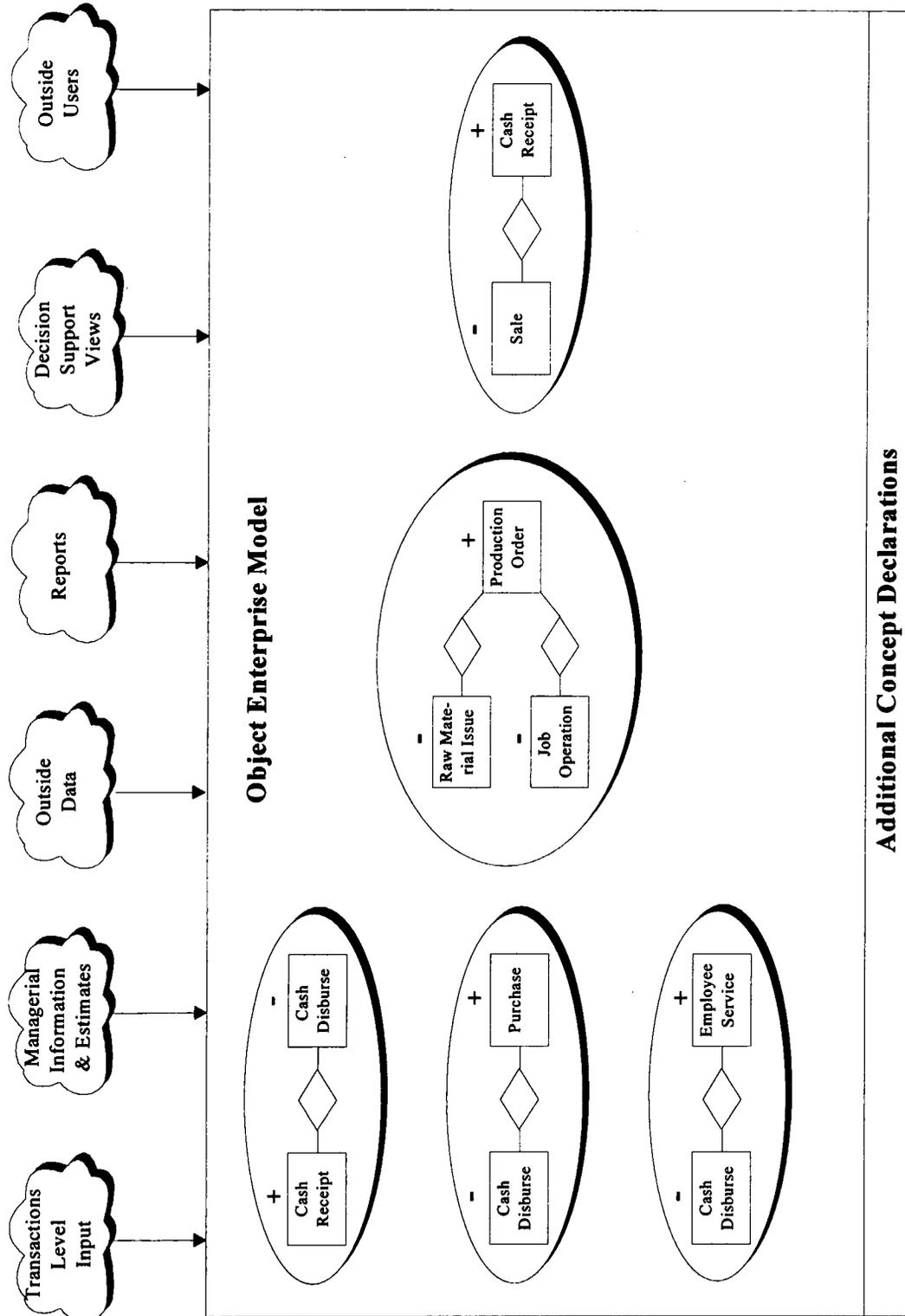
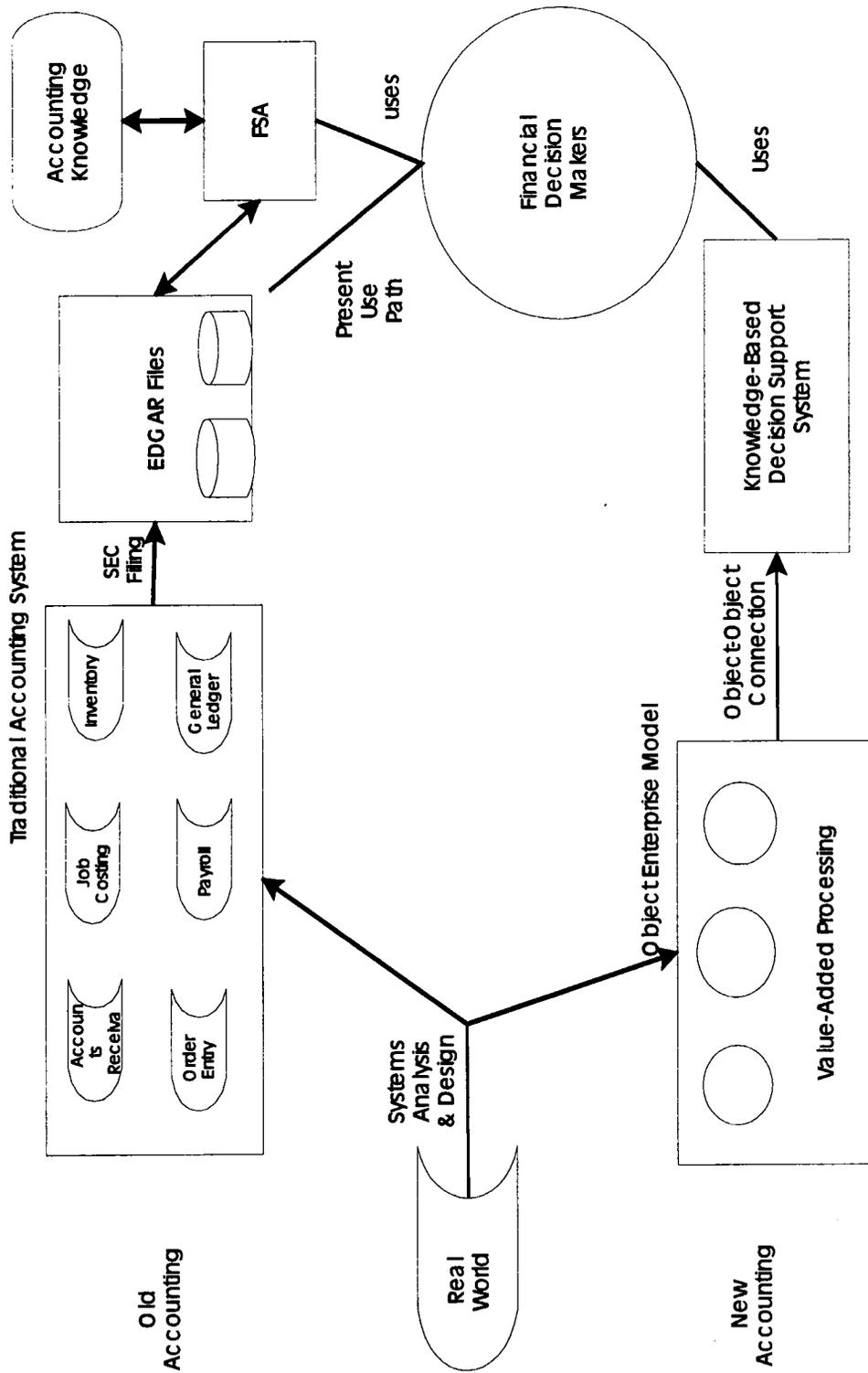


Figure 2



**FIGURE 3 - Linkage of DSS Tools with Corporate Transaction Systems**

The top of Figure 3 illustrates the architecture needed for FSA, one of the early AI prototypes intended to be used with the EDGAR system. (Mui and McCarthy 1987). FSA (Financial Statement Analyzer) was able to take automated corporate filing data (from a 10-k report for example) and calculate any number of financial ratios commonly used by analysts in assessing the financial well-being of a corporation. This seems like a relatively straightforward task, and indeed, it is one that is often taught in undergraduate finance and accounting classes. Having a machine handle the task completely however caused the FSA designers from Arthur Andersen to confront the highly idiosyncratic nature of old accounting systems. First of all, an exhaustive chart-of-accounts knowledge structure had to be built into FSA because of the individualistic and synonymous naming conventions used by many companies to label various asset, liability, equity, income, and expense accounts. Second, because much of the actual account information is buried in textual footnotes, FSA also had to be equipped with NLP capabilities for certain limited cases such as the contra-accounts for depreciation (on inventory) and sub-leases (on rental expense). These are adjustments that expert human analysts find somewhat easy, but which cause significant interpretation problems for a fully automated system.

FSA worked well in its very limited domain, although it did require a high level of expertise with knowledge representation structures and tradeoffs, with knowledge acquisition problems, and with object-oriented programming techniques (in KEE) to make it operational. A companion AI system called ELOISE (used for natural language processing of other 10-k material) was also built for EDGAR by Arthur Andersen at approximately the same time. However, neither of these systems nor any similar AI efforts were part of the production versions of EDGAR that were implemented in the 1990s (Therefore the only actual use option for prospective users is the indicated direct link to the EDGAR files). The rationale for this exclusion was not made public, but a compelling case can be made for one reason why it was not attempted. All the semantics necessary for a system like FSA to function had to come from the AI tool itself because of the idiosyncratic and syntactic nature of the accounting reporting systems. A good example of such idiosyncrasies were the many conventions needed to cover receivables (These are explained in Figures 2 & 3 in Mui and McCarthy (1987)). As we mentioned in our last section, REA coverage of such claims is much more direct and declarative. If the accounting systems in question had more of a semantic base, building expert systems to work on (or with) them might not have been such a daunting hurdle. As EDGAR

exists in 1996, its disseminated output contains lots of data but very little assistance in determining the meaning of that data. Therefore it is no surprise that technologically sophisticated efforts are under way to "intelligently process" EDGAR output for users who find its present offerings less than usable.

At the bottom of Figure 3, we have illustrated how a reconfigured decision support system like FSA might work for financial decision makers in an REA environment. The process and (more importantly in this case) the object semantics in an REA implementation remain intact and reside with the enterprise model. Unlike FSA which had to be augmented with account hierarchy and footnote schemata knowledge structures, our new knowledge-based system would need only the structures associated with the specific decision expertise (such as whether to invest in a certain type of stock). If this expertise were coded as a semantic network, the coupling between the two systems would be especially close. Essentially, the expert system would specify the concepts only at the type level with individual consultations being instantiated with direct object-object connections. The organizational and capital market ramifications of such direct corporate database to decision-maker links involve a set of issues described by a number of accounting theorists. These arguments were summarized and analyzed recently by Geerts and McCarthy (1995).

### **Possible Migrations toward REA Enterprise Models and Uses for Research Results**

In this paper, we have outlined the REA approach to building object infrastructures for enterprise process models. We would like to emphasize that, although it is certainly true that our models look quite different from traditional accounting architectures built upon bookkeeping ideas, it is also the case that there are enterprise software packages that afford hospitable implementation platforms for systems built upon REA principles (for examples, readers may consult McCarthy, David, and Sommer (1996). This is because many of the database tenets on which REA was originally based in 1982 -- such as an emphasis on strong semantics, an insistence on versatile use and delayed procedural aggregation of economic transaction data, and a strong orientation toward wider communities of users to include both accountants and non-accountants -- are features that make accounting software attractive in the 1990s. We believe that it is possible to take a strong directed REA approach to building enterprise models that can serve both as blueprints for strategic information architectures and as initial database schemas

that can be compromised by cost-benefit considerations in individual companies. In this sense, our REA frameworks are like the "prototypical models" for certain lines of businesses that some analysis methodologies advocate as starting points for information system design. With such possibilities in mind, we finish by mentioning how some of the REA research accomplished thus far can affect practical design of enterprise models that facilitate knowledge-based use.

Our research and practical implementation work with REA modeling of accounting phenomena has progressed on a number of software engineering and empirical validation fronts, summaries and assessments of which are listed in Dunn and McCarthy (forthcoming). For example, we have built the following knowledge-based systems with these principles.

- a. **REACH** -- This is a CASE tool for view modeling and view integration that integrates three different types of knowledge: (1) *first order principles* of the REA template, (2) *heuristic* guidance of implementation compromises based on object pattern matches, and (3) *reconstructive* ideas for prototypical models based upon library guides for the design of account-based bookkeeping systems (McCarthy and Rockwell 1989).
- b. **CREASY** -- This is also a CASE tool that supports conceptual and operational design of full-REA models. The CREASY environment embeds both methods knowledge (of semantic modeling structures and constraints) and domain-specific knowledge (of REA accounting) for automated use by novice modelers and users (Geerts and McCarthy 1992).
- c. **REAL** -- This is a knowledge-based decision support tool of the type identified in our discussion of Figure 3. REAL is an expert system for purchasing that embodies semantic network representations of certain logistical facts such as the location of transportation vehicles and the patterns of past deliveries of raw materials. These expert system intensional structures are linked to REA databases for actual operation wherein the object concepts are instantiated for a particular consultation (McCarthy and Rockwell 1991).

These and other knowledge-based REA tools are reviewed in an integrated methodological fashion by Geerts,

McCarthy, and Rockwell (1996) who suggest many other possible ways where the REA mindset can assist an enterprise modeler. Additionally, there has been some initial empirical assessments undertaken of (1) how REA principles fare in promoting better decision-making environments (by controlling complexity with object-level interfaces able to manipulate levels of semantic abstraction) for individuals (Dunn 1995). and (2) how REA adherence in actual accounting system operation can affect perceived levels of competitive advantage associated with an accounting system (David, 1995). Results of these empirical assessments have been tentative and mixed; we plan to continue a program of such assessments to pinpoint ways in which REA principles can be best used in actual operation.

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