

CONSTRUCTION AND USE OF INTEGRATED ACCOUNTING SYSTEMS
WITH ENTITY-RELATIONSHIP MODELING

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This paper reviews features of an entity-relationship (E-R) accounting model whose constructs differ fundamentally from those of traditional double-entry accounting. Aspects of the E-R accounting model examined include: (1) its historical background which contains the rationale for its introduction, (2) its declarative features which consist of sets representing economic events, resources, and agents plus relationships among those elements, (3) its procedural features which include context mechanisms (views) and triggered updates, and (4) its use during the process of database design which includes integration of accounting and non-accounting data.

1. INTRODUCTION

While the computer revolution of the past three decades has radically transformed many of the information processing and communication functions of business organizations, it has not yet affected, in a substantive manner, the fundamental methodology of financial reporting--double-entry accounting. Computers have clearly made the accounting recording and transmission process faster and better able to handle large volumes of data, but they have not yet altered the essence of the traditional system which mandates the following:

- (1) That the chart of accounts constitute the basic classification scheme for data concerning economic transactions and objects;
- (2) That these transactions and objects be measured primarily in monetary terms;
- (3) That equality of entry be maintained (debits=credits); and
- (4) That the characteristics of similar transactions and objects be aggregated across time and sections.

In the analysis and design of corporate-wide information systems, these tenets can be very restraining, and their continued use is not a state of affairs that pleases all accountants. Many theorists have called for a reevaluation of the accounting framework with a mind toward better integrating its operations with the capabilities of modern systems. Among these theorists are Wheeler [21] and Mathews [14] who have said:

There is no reason to believe that the methods appropriate to the quill pen in the fifteenth century will be equally applicable to the on-line computer systems of the last third of the twentieth century.

The principle reason for the lag in the application of computer technology to the accounting information system would seem to be incompatibility between the form of the double entry recording system, which it must be remembered has slowly evolved during the last five hundred years or more, and the data processing qualities of a computer.

In this paper, we will agree with Wheeler and Mathews and proceed one step further by demonstrating that the basis for the reevaluation they call for can be found in the entity-relationship (E-R) modeling techniques of Chen [6]. McCarthy [16] has shown that E-R modeling can be used in a database environment to produce "artifact free" accounting systems; that is, systems whose structures mirror closely the reality being modeled and exclude procedural elements of double-entry bookkeeping. We will review McCarthy's conventions here and illustrate how an E-R based accounting system can be used to integrate information that ranges across a number of the functional areas of a business. We will also illustrate some of the procedural aspects of data definition that facilitate the maintenance and use of accounting information over time.

In the next section, we will review briefly the fundamental nature of an accounting information system with the purpose of identifying features to be restructured with E-R modeling. This section will also contain a brief review of other database work in accounting, especially work relating to the concept of "events" accounting [20].

2. ACCOUNTING INFORMATION SYSTEMS

2.1 Conventional Model

The rules, conventions, and procedures of accounting have been conceptualized as an information system by Buckley and Lightner [4]. Their view of accounting is illustrated in Figure 1, and each of the system elements they identify is explained below.

- INPUT. Economic events are recognized in the environment of the company and then admitted to the system based on their compliance with the accounting rules shown.
- TRANSFORM-1. Each admitted event is analyzed in terms of its effect on the known elements of the accounting system (the accounts) and then assigned to two offsetting accounts using the debit-credit convention.
- TRANSFORM-2. All of the entries made to each account are gathered together and aggregated to give a balance for each classification element.
- OUTPUT. The information contained in the ledger accounts is processed in accordance with the accounting conventions shown and the generated output is made available to users.

As mentioned previously, many accountants have not been happy with the traditional methods shown in Figure 1. The large number and wide variety of their suggested improvements preclude specific discussion. However, for our purposes in this paper, we can identify and explain four major defects in the conventional framework [1,2].

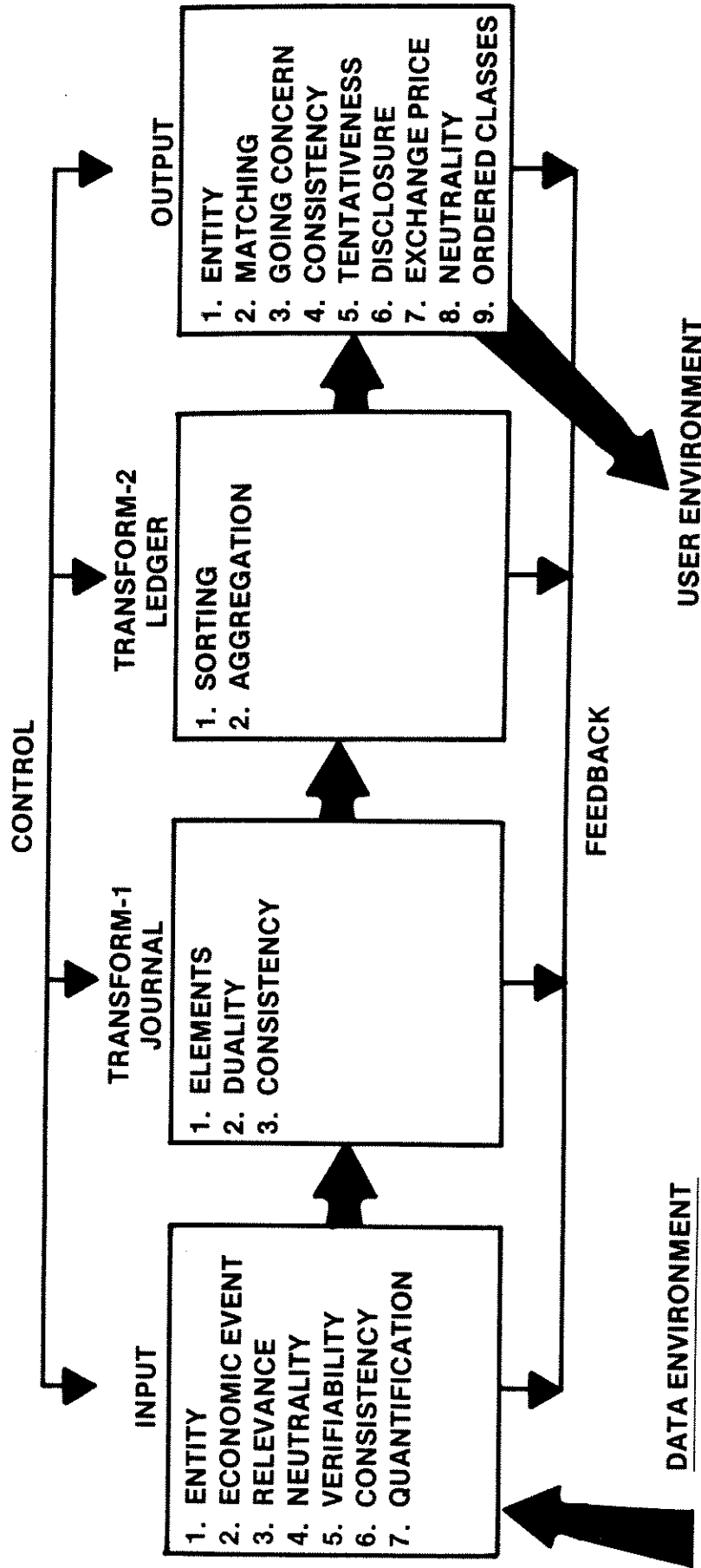


FIGURE 1
Conventional Accounting Model

- (1) Its dimensions are limited. Most accounting measurements are expressed in monetary terms: a practice that precludes maintenance and use of productivity, performance, reliability, and other multidimensional data.
- (2) Its classification schemes are not always appropriate. The chart of accounts for a particular enterprise represents all of the categories into which information concerning economic affairs may be placed. This will often lead to data being left out or classified in a manner that hides its nature from non-accountants.
- (3) Its aggregation level for stored information is too high. Accounting data is used by a wide variety of decision makers, each needing differing amounts of quantity, aggregation and focus depending upon their personalities, decision styles and conceptual structures. Therefore, information concerning economic events and objects should be kept in as elementary a form as possible to be aggregated by the eventual user.
- (4) Its degree of integration with the other functional areas of an enterprise is too restricted. Information concerning the same set of phenomena will often be maintained separately by accountants and non-accountants, thus leading to inconsistency and information gaps and overlaps.

These aspects of the conventional accounting process are by no means mutually exclusive. As a matter of fact, solutions to all of the problems mentioned above can be subsumed in a database approach to the development of information systems. Such an approach assumes that corporate data is to be shared among a number of users with highly diverse needs; it also implies that any one functional area should not have a disproportionate influence on the information structure of the enterprise. For accountants, adoption of a database philosophy means rethinking some existing practices with a mind toward facilitating use of accounting data by non-accountants.

2.2 Events-Accounting Systems

Most of the work aimed at integrating database ideas with accounting theories has been based on the events accounting concept first advanced by Sorter [20]. What Sorter proposed with his events theory was: (1) that all of the relevant variables surrounding an economic event be measured and recorded by accountants and (2) that this information be left in a company's records in atomic (disaggregated) form to be classified and aggregated by the eventual users. Sorter likened the reporting process that would follow to that of a television weatherman giving his viewers the various instrument readings and regional weather data and then letting them decide for themselves the accuracy of forecasted weather patterns. In contrast, his conception of a traditional accountant who simply reports net income and summarized financial statements would be similar to the idea of a weatherman who gives a single forecast without any of the supporting data.

A group of researchers at Purdue were the first to integrate events accounting with database systems. In [8], a method was devised for describing and coding economic events that facilitated their use and retrieval in a tree-theoretic structure. These concepts were extended in [10,12] where various features of hierarchical databases were developed using LISP data structures.

In [9], Everest and Weber, citing the hierarchical model's lack of data independence, developed a relational approach to events accounting. Using Codd's decomposition process [7], they constructed a set of 3NF relations for both financial and managerial accounting models. However, Everest and Weber were not en-

tirely satisfied with their results because they found that certain aspects of traditional accounting did not fit relational representations well. In closing their work, they called for further research to investigate the applicability of accounting models to this type of database system.

The two types of accounting systems mentioned above, plus others not built following "events" principles [11,18], approached the problem of integrating accounting with database management in the same manner. They all took the data elements and organization methods being used in manual or non-database environments and then converted them to the constructs of a first generation data model (hierarchical, network or relational). This development method leads to schemata that have procedural aspects of conventional accounting embedded in them and that also lack the semantic expressiveness of second generation conceptual frameworks [13]. The first accounting system that discarded this predisposition toward current practice was McCarthy's entity-relationship model [15,16]. Use of that model in the construction of integrated information systems will be discussed in detail in the next section.

3. THE ENTITY-RELATIONSHIP ACCOUNTING MODEL

3.1 Introduction

The entity-relationship accounting model developed by McCarthy differs from the conventional accounting framework shown in Figure 1 in two major respects:

- (1) It does not adhere to a strict interpretation of the given input rules in deciding the economic events (and the characteristics of those events) to be admitted from the environment. For example, admitted elements could include non-accounting events (such as customer sale orders), non-monetary characteristics (such as size and weight of inventory) and "soft" characteristics (such as opportunity costs).
- (2) It does not use classification and aggregation methods based on journals and ledgers. Instead, it models the data environment in terms of entity-relationship sets and uses an appropriate set-oriented language for processing.

The declarative and procedural aspects of the E-R accounting system are explained below.

3.2 Declarative Aspects

Chen's E-R methodology [6] begins with identification of entities that exist in the reality being modeled and proceeds with designation of relationships that connect those entities. If we discard "artifacts" and concentrate on the real phenomena being accounted for, we find that accounting object systems are composed of three generalized groups of entities: (1) economic events such as sales and cash receipts, (2) economic resources such as inventory and cash, and (3) economic agents such as customers and vendors. An E-R diagram showing some accounting entity sets and the relationships among them is illustrated at the top of Figure 2.

The semantic nature of identified relationships in the model can be ascertained by analyzing both operating policy and practice. For example, the relationship between "cash" and "cash disbursement" is shown as 1-to-n indicating that all payments are made from a single account at a time. Alternatively, the m-to-n relationship between "cash disbursement" and "general and administrative service" could mean that the company's policy necessitates the most general case in order to facilitate prudent cash management.

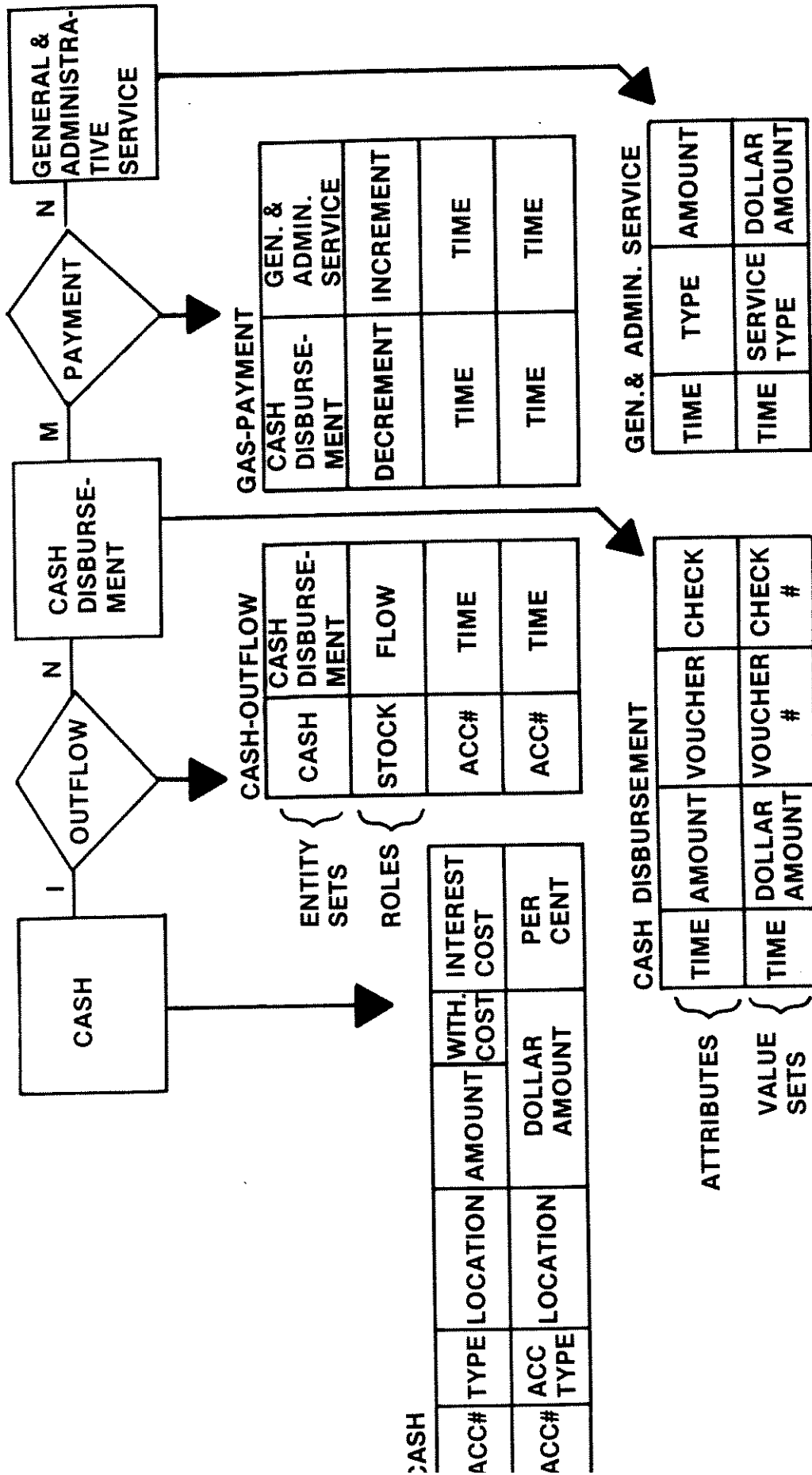


FIGURE 2
Accounting Entities and Relationships

Once an E-R diagram has been constructed, Chen's modeling procedure moves to the more detailed level of design illustrated by the tables at the bottom of Figure 2. These tables indicate the characteristics of each entity/relationship set that are of interest to potential system users. They also illustrate which entity sets will play the roles required by each relationship.

The accounting theories underlying the set declarations shown in Figure 2 are analyzed in [17]. It is important to note at this point that the declarative aspects of the E-R model form the base from which all accounting information is eventually derived. We will refer to these aspects as the base objects of the model and presume that they consist of sets representing economic events, resources, and agents plus relationships between those elements.

3.3 Procedural Aspects

Accounting systems measure the effects of economic events over time; however, they are also required to produce information "snapshots" taken at periodic intervals. These are two decidedly different types of requirements, and it is imperative that both be accommodated by an accounting data model. The difficulties involved in maintaining a proper balance between time-limited and time-unlimited aspects in an information system are discussed in [3].

In the paragraphs below, we will illustrate two procedural methods for materializing conclusions, that is for producing snapshots from records of continuing events. The first of these methods involves accounting for the interplay of "stock" resources with "flow" events and illustrates procedures that actually change characteristics of base objects in the data model. The second method involves simple aggregation of information and illustrates procedures that do not affect base objects. The general nature of the techniques involved in conclusion materialization are described in [22]. For simplicity sake here however, we will use SEQUEL [5] implementations of those techniques.

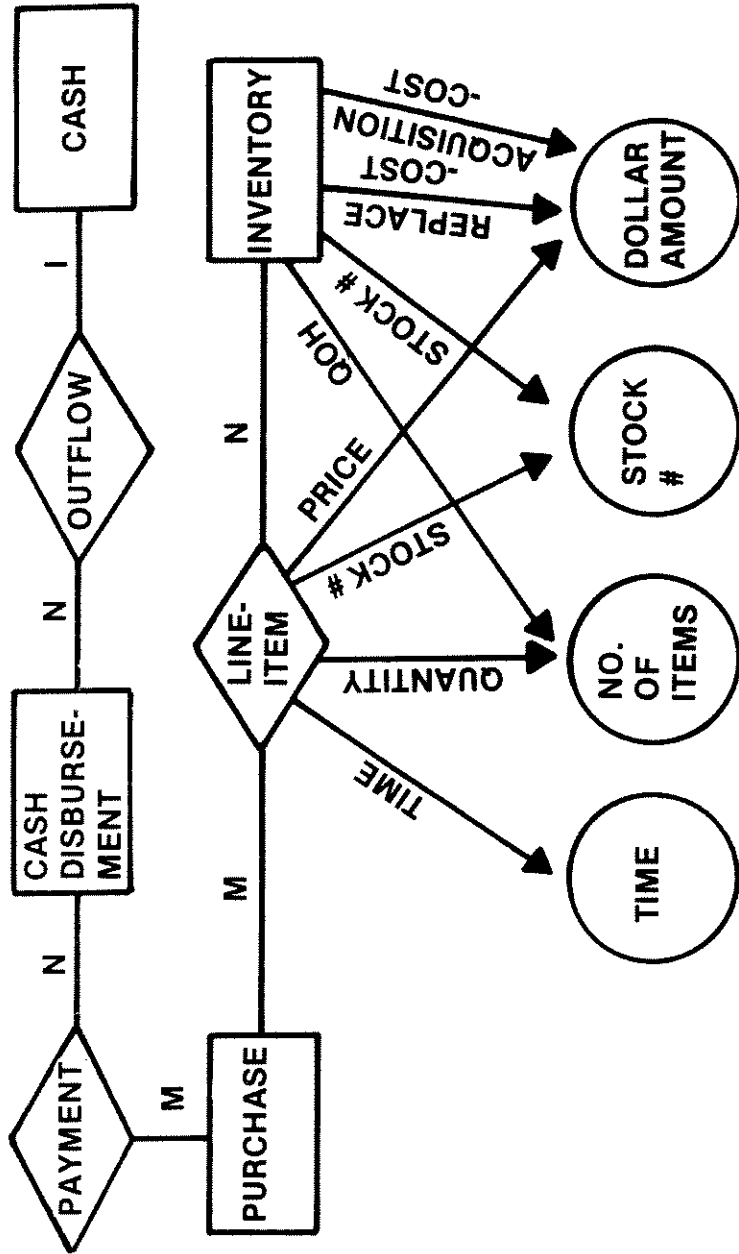
In traditional systems, stock-flow interplays are accounted for by double-entry convention. For example, purchase of inventory for cash would involve a credit to "cash" (indicating a cash payment) and a debit to "purchases" (a nominal account that would later be closed to "inventory"). In a data model however, the interaction must be effected by defining triggered updates to the stock resource that will be invoked upon the occurrence of the flow event. For the purchase transaction mentioned above, the SEQUEL form of the invoked procedure is shown in Figure 3. A similar declaration would have to be made for an update of "cash" upon the occurrence of "cash disbursement".

An important property of the E-R accounting model is that the base objects, those sets and characteristics directly modeling the underlying reality, are maintained in as disaggregate a form as possible. This requirement necessitates procedural mechanisms for producing accounting information that allow various summations and aggregations yet do not alter base elements. Wong and Mylopoulos [22] call these devices "context mechanisms": procedures which allow different users to view data elements in different ways. The context mechanism in SEQUEL is a "view," and Figure 4 illustrates views derived for accounts-receivable and period expenses in the E-R model.

We have now completed our treatment of the declarative and procedural aspects of the E-R accounting model. In the next section, we will discuss its use in the development of integrated information systems.

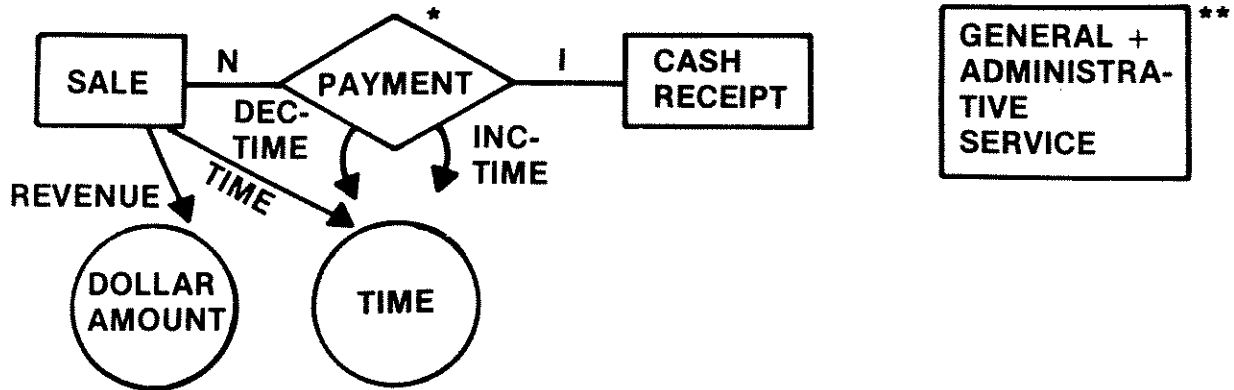
3.4 Integration with Other Functional Areas

One of the criticisms leveled at the conventional accounting process in an earlier



DEFINE TRIGGER TI
 ON INSERTION OF PURCHASE-LINE-ITEM
 (UPDATE INVENTORY
 SET ACQUISITION-COST = (QOH + ACQUISITION-COST +
 QUANTITY*PRICE)/
 (QOH + QUANTITY)
 SET REPLACE-COST = PRICE
 SET QOH = QOH + QUANTITY
 WHERE INVENTORY.STOCK# = PURCHASE-LINE-
 ITEM.STOCK #)

FIGURE 3
 Triggered Update of Resource Set



DEFINE VIEW AIR-CONTROL (DATE, AMOUNT) as
 SELECT MAX (TIME), SUM (REVENUE)
 FROM SALE
 WHERE TIME IS IN
 (SELECT TIME
 FROM SALE)
 MINUS
 (SELECT DEC-TIME
 FROM SALE-PAYMENT)



A/R-CONTROL	
DATE	AMOUNT
79-12-25	50,000

DEFINE VIEW PERIOD-EXPENSES (TYPE, AMOUNT) as
 SELECT TYPE, SUM (AMOUNT)
 FROM GENERAL + ADMIN. SERVICE
 GROUP BY TYPE



PERIOD-EXPENSES	
TYPE	AMOUNT
RENT	1600
ADVERTISE	1000
TRANSPORT	7000
CLEANING	650
DEPREC	145
SUPPLIES	70

*SALE-PAYMENT ATTRIBUTES HAVE
 BEEN QUALIFIED BY ROLE
 NAME (DECREMENT & INCREMENT)

**ATTRIBUTES FOR THIS SET WERE
 DISPLAYED IN FIGURE 2

FIGURE 4
Accounting Views

section was that its degree of integration with the other functional areas of an enterprise was too restricted. This situation occurs because the double-entry form of recording captures only selected characteristics of economic phenomena and then confounds the situation by aggregating those characteristics over time and sections. Non-accountants interested in the same phenomena are faced with the dilemma of taking the accounting data as given or developing separate information systems.

In the E-R accounting model, there is no reason for this non-integration to occur. The base objects of the system are intended only to model aspects of the real world and only non-loss aggregation is allowed. Once the accountants have decided the entities, relationships, and characteristics of interest for financial reporting purposes, other users may add on characteristics, connect other entity sets, or construct their own "views" of the data.

In Figure 5, integration of accounting and non-accounting elements of an information system is shown. The sets drawn with broken lines represent non-accounting phenomena which have been added to some base objects of the E-R accounting model. On top of this structure could be added additional user views such as "open orders" which would represent the aggregated imbalance between "sale order" and "sale."

4. CONCLUSION

Our presentation of the E-R accounting model is now complete. Its declarative and procedural aspects have been outlined, and its use in the integration of accounting requirements with the information needs of other functional areas has been explained. We will close by mentioning three aspects of the design methodology that have not been specifically considered here, but which are covered in related research [17].

First of all, in both this paper and in [16], the E-R approach was used to design a data model with full temporal generality, that is one where data concerning all events was maintained perpetually in disaggregate form. Quite obviously, storage considerations would preclude such a situation in an actual information system. The point to be remembered, however, is that in an E-R model compromises to the ideal are made knowingly, hopefully by the database designer and accountant together, and are not an intrinsic part of the accounting process. Some of the design tradeoffs involved in requirements analysis of accounting systems are described in [17].

Second, the model as presented here does not consider type/subtype classification or "ISA" hierarchies [22]. In [17], the generalization abstractions of Smith and Smith [19] are combined with E-R modeling in an analysis of accounting object systems.

Finally, this paper uses but does not outline specifically the basis in accounting theory for inclusion of individual entity and relationship sets in the data model. Again, these aspects of the E-R model are covered explicitly in [17].

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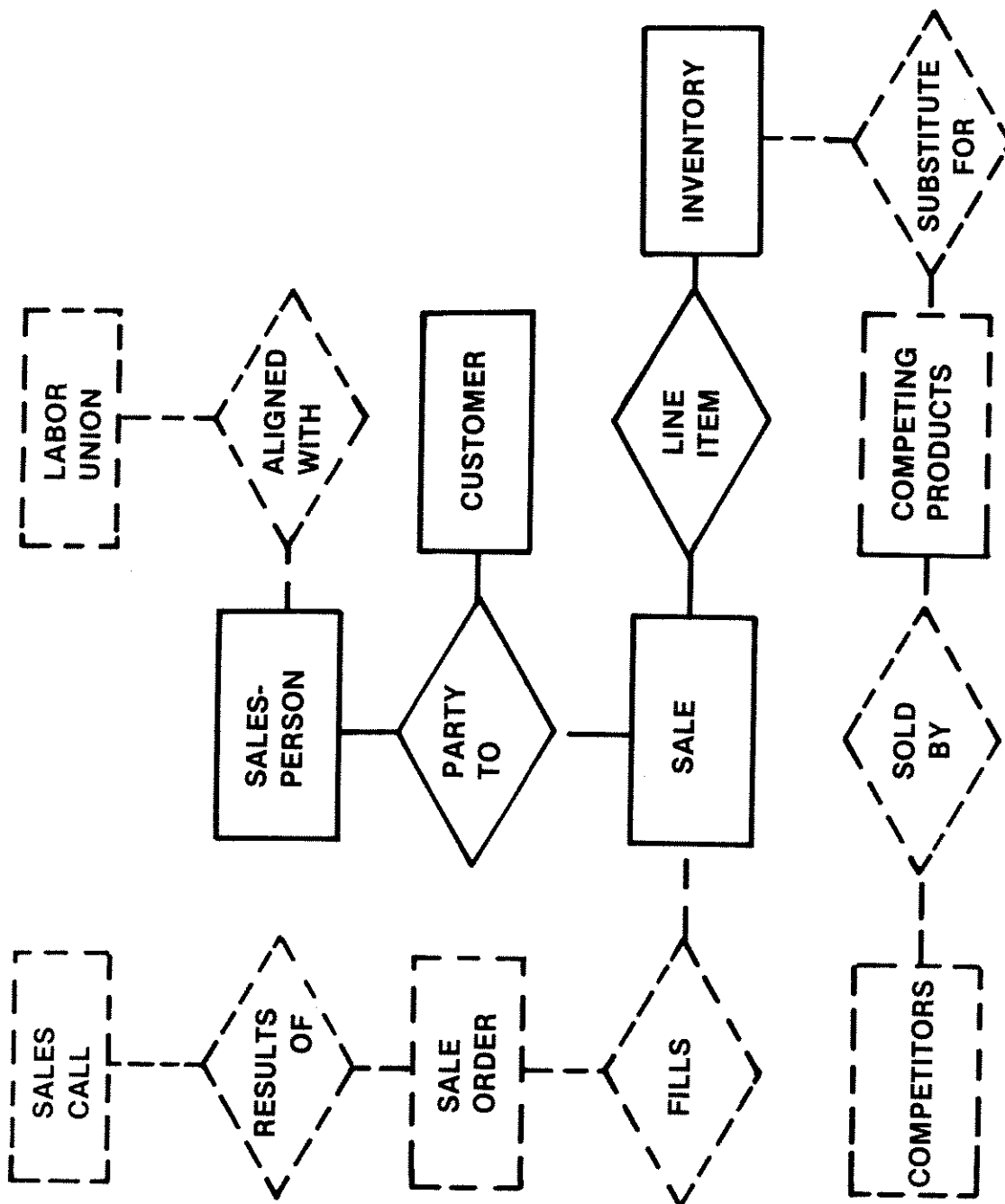


FIGURE 5
Integration of Accounting and Non-Accounting Elements

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