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An 'events' model for information aggregation

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Abstract

Aggregation is one of the key characteristics of information delivered by "information systems." It is important because the ability to design effective support systems depends to a great extent upon the degree of flexibility with regards to information aggregation that can be incorporated in the system. This paper sets forth a conceptual model of information aggregation based on the events theory of accounting. The model suggests that aggregation should be considered as a two-dimensional concept, comprising a temporal and sectional dimension. The two axes are further delineated in the form of "levels of summation" based on specified "events" of aggregation. These levels of summation representing various degrees of data aggregation could influence the value of the information delivered to a decision maker for a given "decision trait," namely, the "decision level" and/or "problem structure." This "events" model of information aggregation has important implications for the design of systems and future research.

Key words and phrases: Aggregation, Information, Data, Events theory of accounting, Problem structure, Decision level, Information Systems Design.

ACM Categories: H.0, J.0, J.1, H.m

I. Introduction

Information has been characterized by many different attributes. One of these attributes is "aggregation." Information can be presented in two basic ways: in summary or aggregate form and in detail or raw form. The notion of summation or aggregation is very important for information systems design. It is not only important because aggregated information may reduce uncertainty in decision making, but also because of its critical relationship with the effective design of presentation modes, report layouts, and flexible user-interfaces. The level of detailed data that is useful to decision makers depends to a large extent on the type of problem and/or the level of decision under consideration [Anthony, 1965]. Having the appropriate level of aggregation is important for all types of decisions, and is especially critical in the designing of accounting and financial systems. The objective of such systems is not only to provide the facility of storing detailed data, but to allow decision makers to summarize or aggregate data depending on their decision requirements and models. This implies that there needs to be some means of determining the appropriate nature and degree of aggregation that decision makers might use for different problems by maximizing the inherent value of the information.

This paper presents such a conceptual model for studying information aggregation based on the concepts of the events theory of accounting [Sorter, 1969; Johnson, 1970]. It lends support to the idea that, information systems, developed using the events approach could be more valuable to an organization. The proposed model describes a theoretical measure of information aggregation or summation. Various degrees of aggregations or "levels of summation" are suggested with regard to the gain or loss in value (if any) of information stemming from using predefined, theoretical summations as suggested by the value approach to accounting. The levels of summation described in this model assist in achieving some understanding of the desired degree of aggregation needed for different types of problems--on the structured/unstructured continuum [Simon, 1960]--and/or for the different levels of management--on the strategic/operational continuum [Anthony, 1965]. Therefore, the objectives of this paper are threefold:

1.To develop a conceptual model for studying information aggregation;

2.To develop logical propositions about summation levels and their relationships with decision levels and problem "structuredness" based on the conceptual model; and

3.To discuss the implications for systems design and further areas of research based on the conceptual model.

In accordance with the above objectives, the rest of the paper proceeds as follows. The next section (II) provides the motivation for this research by a review of the past literature on the notion of aggregation and the ideas behind the events theory of accounting. Section III develops the model for information aggregation, and section IV discusses the implications of the model. Finally, the last section (V) provides some concluding remarks.

II. Background and Relevant Research

Accountants, in the past and to a large extent in the present, have prepared reports and statements using predefined summations and definitions based on the assumption that "... users' needs are known and sufficiently well specified so that accounting theory can deductively arrive at and produce optimal input values for used and useful decision models" [Sorter, 1969]. This philosophy has been termed the value approach to accounting. The required input values and decision models are determined by accounting theory, and information systems are designed and built to gather and manipulate data according to these decision models to generate solutions.

There are several criticisms of this approach [Sorter, 1969]. One of the most important is related to the potential loss of information due to the design of information systems that provide the reports and statements based on the predefined models, but are unable to support other types of decision models. By designing these systems to support the theoretical decision models that have been developed, designers focus on collecting and processing the data necessary for these models only. They do not design the information system to gather, store, and maintain other types of data that may be useful in alternate decision models (or in models that are determined later). Nor do they design the system to allow the user to manipulate the data that is available.

A potential solution to this problem is to base the design of information systems on the "events" theory of accounting. This approach was first proposed by Sorter [1969] and developed further by Johnson [1970]. The events theory suggests that "... the purpose of accounting is to provide information about relevant economic events that might be useful in a variety of possible decision models" [Sorter, 1969]. This approach to accounting seems to offer some advantages over the value approach. Specifically, the events approach allows decision-makers to describe, develop, and use whatever data, aggregations, and decision models they find relevant for particular problems. Another important feature of the events approach is the fact that the theoretical, predefined, and deductively-developed summations and decision models from the value approach can still be supported.

The use of the events approach to accounting has significant implications for the development of information systems [Lieberman and Whinston, 1975; Colantoni et al., 1971]. Sorter [1969] claims that the "real difference between the two schools lies in what degree of aggregation and valuation is appropriate ... and who is to be the aggregator and evaluator." He then advocates making less aggregated data available to the user.

While various authors may disagree about how the aggregations (or summations) relate to the two accounting theories, they do recognize the importance and affects of the "degree of aggregation/summation" incorporated in the information used by decision-makers. The importance of aggregation and the need for allowing decision makers to decide these degrees of summation of detailed data can be readily gauged from some of the extant research done in many diverse areas in the social sciences. For example, Kleijnen [1980] asserts that "... detailed data can always be transformed into summary data in order to answer unexpected needs for some aggregated information. However, aggregation of data means that the details are lost... Using aggregated data when detailed data are needed creates errors... The degree of aggregation might be quantified by the average number of elements falling into a class." Kleijnen [1980] also provides a synthesis of the theoretical and empirical research on aggregation/summation and the value of information, and other information attributes.

In a study of individual differences and decision making using experienced territory managers as subjects, Lederer and Smith [1988-89] investigated the level of aggregation or summation in management reports, and found evidence to indicate that decision makers almost always preferred detailed data--irrespective of whether the decision makers had analytic or heuristic cognitive styles. They used three predefined levels of aggregation in this study. A high aggregation report, medium aggregation report, and a low aggregation report. These aggregation levels were decided by former territory managers who had been promoted to VP of sales. They also referenced some of the important past research on the relationship between the cognitive styles of decision makers and the desired level of aggregation. For example, Benbasat and Taylor [1978] and Benbasat and Dexter [1979], have suggested that differences in cognitive styles--analytic versus heuristic, affected the level of information aggregation desired by decision makers. On the other hand, Tiessen [1976] and White [1981], found only limited evidence to associate cognitive styles with aggregation. There is obviously some inconsistency in the results regarding the association of cognitive styles and levels of information aggregation. Although, there is no difficulty in recognizing that the "psychological type" [Mason and Mitroff, 1973] of the decision maker may be important to the level of information aggregation requested, it is not the primary focus of this paper. In other words, whatever the cognitive styles of the decision maker, the issue of how much or how to aggregate is very critical to the design of effective support systems.

In a case study of the effects of the introduction of J.I.T. (Just-In-Time) manufacturing in the Hewlett-Packard Company on Cost Accounting and some other variables, Patell [1987] noted the importance of providing flexibility in information systems in terms of the levels of data aggregation available to managers. Patell emphasized the critical need for understanding the costs and benefits of the various levels of data aggregation through a continual evaluation process. Sol [1985] used simulation analysis of decision making in a hypothetical multi-divisional firm and found that global decision effectiveness would be damaged by the use of aggregated local decision data. He suggested the provision of simulation techniques in decision support systems in order to allow the ability of testing the effects of disaggregated data and their local impacts.

In discussing the changes affecting marketing research practices, one author argues that information gathering will move from data aggregation to disaggregation [Cushing and McGarvey, 1985], and that computer-based systems will need to allow the integration of detailed data on the basis of user-defined relationships [Webber, 1986]. In a similar vein, Armitage and Skelton [1987] used surveys and interviews of corporate executives to determine that requests for non-routine information where very poorly handled by traditional financial reporting systems. They reported that these systems were not "designed" to provide detailed data to executives. Executives felt that data stored in the system was already too highly aggregated. (This finding is consistent with research done on executive information systems). Consequently, this resulted in their requests for detailed data being very restricted. Along the same lines, in a paper discussing the design of database systems and management reports, Rapp and Poertner [1986] criticized the standard format of MIS reports. They argued that these reports included too much data, and advised the need for matching the level of aggregation to the level of the target audience. This aspect of aggregation is a key component of the model proposed in this paper.

Quigley [1986] in discussing effective decision making and information systems design asserts that **information systems** have a "*... vital role to play in determining the level of aggregation ... delivered to decision makers*." While discussing the philosophical basis for combining forecasts, Winkler [1989] suggests that aggregation of data is important for achieving a reduction in uncertainty. With respect to aggregation over time horizons, Kleijnen [1980] asserts that such "temporal aggregation" is different from aggregation at specific instances in time ("sectional aggregation"). On a similar note, a study on the aggregation of temporal data in three major commodity markets in the agribusiness industry provided substantial evidence to indicate that the "level or degree of time aggregation" of market prices was very important to analysts [Blank, 1990]. This study confirmed the basic problem faced by analysts of the agribusiness industry: "*... the available data are aggregated to a degree that obscures the underlying decision process*."

In summary, a review of past research on information aggregation (or disaggregation) leads one to the following conclusions. That, 1) information aggregation is very important for effective decision making, especially for non-routine decisions/problems; 2) the degree of aggregating or summarizing detailed data probably depends more on the problem type or the decision level, rather than the cognitive style of the user; 3) information systems should store data in as much detail as economically possible; 4) models for aggregating data should be available to the user--especially in accounting and financial systems were a majority of the fundamental relationships between raw data are well-grounded in theory and practice; 5) on the other hand, systems should also provide sufficient flexibility to the user, so as to allow access to as much detail as the user needs from a specific aggregation--in other words the user should be able to disaggregate summarized information and look deeper into the pieces that make up the aggregate; and 6) the user should also have the flexibility to define their own relationships and establish a degree of aggregation that matches the needs for the problem under consideration.

Keeping the above analysis of the extant research on information aggregation/disaggregation in mind, the subsequent sections to provide further insight into the aggregation/disaggregation issue through the development of a conceptual model for information aggregation based on the events accounting theory.

III.Model Development

In order to provide a common basis for the subsequent discussions, some of the important concepts utilized in this paper are defined and explained in the following paragraphs.

Information

For the purposes of this paper information will be defined as "... data that has been processed into a form that is meaningful to the recipient and is of real or perceived value in current or prospective actions or decisions" [Davis and Olson, 1985]. In addition, information is also characterized as a "... tangible or intangible entity that serves to reduce uncertainty about some state or event" [Lucas, 1986].

Value of Information

It is clear from the above definition that information has value only as it affects decisions made by particular individuals. The value of an information system to the entire organization is then dependent upon the value provided to every individual user of the system, when facing some problem. Furthermore, the value of information provided by different data and decision models used with this data depends to a large extent on the individual--the point being that the value of information is based on user perceptions and the ability of the system to deliver the relevant information. Therefore, the phrase *value of information* for the purposes of this paper, can be defined as *the measure of perceived worth of the information delivered to the problem solver with regards to a specific problem.* From this, it also follows that the information systems that maximize the value of information provided to all the system users relative to the costs of providing this information would be the most "valuable" systems. Information is of value to a decision maker only to the extent that he/she learns from information--that is, the value of information increases as there is a positive change in the decision makers' performance over time [_e_ez-kecmanovi_, 1983].

Types of Summations of Data

Johnson [1970] described various ways of putting data together for accounting purposes. He referred to these as summations instead of aggregations because the various ways of putting the data together all involve the mathematical operation of addition at the lowest level. (It should be noted that the terms aggregation and summation are used equivalently throughout this paper). The following paragraphs define the different types of aggregation based on Johnson's ideas:

Aggregation: The simple addition of the same kind of measurement on numerous occasions of the same kind of happening (e.g. sales of a product are totalled for a month). Aggregations can be temporal or sectional.

Combinations: The addition of numerous measurements of the same characteristic of different kinds of happenings (e.g. sales receipts and disbursal for a cash flow figure). These can also be temporal and sectional.

Composition: The addition of numerous measurements of different characteristics of the same or different kinds of happenings (e.g. financial ratios or reports)

Temporal: The summation of measurements over some arbitrary time period. The temporal aspect necessarily involves "flow" quantities (e.g. sales for a year). But, the "stock" quantities may also have temporal aspects (e.g. the average accounts receivable for some period).

Sectional: The summation of measurements according to arbitrary entities. The customer sales for a branch, a region, a territory, the entire organization, or an industry are all examples of sectional aggregation.

Levels of Summation (Aggregation)

The level of summation at which the data is maintained in the information system for usage by the decision-maker is a constraint that restricts how the user can view the data. It must be underscored that the term "level" really refers to the notion of "degree"--that is, a level of summation is in its literal sense a question of degree.

The value approach to accounting assumes that certain standard summations can support all the decision-makers in an organization. This approach implies that the data that is identified as relevant by accounting theory is maintained at a high level of aggregation or summation and that the decision-maker does not need or want to see the data in its disaggregate form. The events approach to accounting proposes that by maintaining the data at lower levels of aggregation more value can be obtained at an organizational level because each decision-maker can define and use their own summations. One of the problems with the events approach is that it does not specify at what level the disaggregate data should be maintained. The implication for information systems developers is that the data should be maintained at the very lowest level possible. This way the decision-makers can determine for themselves how low, in terms of degree of aggregation, they want to go. The model proposed in this paper is a step towards understanding these "degrees of aggregations" and their theoretical relationship to the "degree of problem structuredness" and the decision level under consideration.

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*** Figure 1 goes about here ***
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A Conceptual Model For Information Aggregation

Using the kinds of summations proposed by Johnson [1970], the following model of the possible "degrees of information aggregation" attempts to integrate the information requirements for different decision levels [Anthony, 1965], the problem type--problem "structuredness" [Simon, 1960; Mintzberg et al., 1976] and the detail of data desired by decision-makers. Figure 1 illustrates this conceptual model. The model visually describes the discussions in the previous sections. It shows that *the value of information (and consequently, the value of the system) is enhanced when different levels of aggregations--based on events relating to the problem under consideration--are* ***matched*** *with the* ***decision-traits*** *as described by either the* ***decision level*** *or the* ***problem structure***. This notion of **fit between aggregation and decision traits** is the crux of the proposed model. Clearly, there should exist an **optimal** level of sectional and temporal information aggregation that is a match for the character of the decision or problem, in terms of its "value" to a decision maker, for a given decision level or problem structuredness.

It should be reiterated that problem structuredness and decision level are closely related in terms of the frameworks developed by Simon [1960], Anthony [1965] and Mintzberg et al. [1976].

Thus, the level of summation (or degree of aggregation) can vary in relation to either the decision level or the structure of the problem under consideration. In other words, problem structuredness as described by the unstructured-structured continuum and decision level as described by the strategic-operational continuum are mutually exclusive in the model proposed here. Since, the "decision traits," decision level and problem structure are well established in *a priori* research, the major emphasis in this paper is on establishing the concepts relating to "information aggregation."

The construct "degree of aggregation" or "level of summation" in the context of the proposed conceptual model is built around two dimensions, the **temporal** and **sectional** axis. These two axes are further delineated in the form of "levels of summation" based on specified "events" of aggregation. Each axis has thresholds for increasingly higher levels of summation. Each of the levels of temporal and sectional aggregations are further explained in the following paragraphs and in Tables 1 and 2. Specific examples illustrate the practicality of each summation level. A casual glance at these tables shows how quickly information can be lost due to summation.

The Temporal Axis

The temporal thresholds are based on logical time periods beginning with level 0 and ending with level 8. Level 0 indicates time periods of "seconds" while the latter refers to information aggregation for time periods exceeding ten years. These summations can involve aggregations, combinations, and compositions. The temporal axis is presented in Table 1.

The Sectional Axis

The sectional axis is developed directly from the kinds of summations possible at a given instance in time. The degree of summation begins at level 0 for the "raw" data elements and proceeds to a level of compositions involving complex aggregations and combinations. The Sectional Axis is presented in Table 2.

TABLE 1: THE TEMPORAL AXIS

LEVEL (DEGREE) OF AGGREGATION	TIME FRAME	EXAMPLE
Level 0	Seconds	Information concerning airline reservations must be updated and retrieved in "real time." This information is usually not summed temporally; it always reflects a point in time.
Level 1	Minutes	Information concerning raw material usage in a production situation may be summed at this level.
Level 2	Hours	Information gathered about sales from shifts of a 24-hour convenient store would be a summation at this level.
Level 3	Days	Daily sales, production, or expense reports are examples of level 3 summations.
Level 4	Weeks	Weekly or Biweekly reports on stock conditions for product management and promotions.
Level 5	Months	Monthly income statements.
Level 6	Quarters	The quarterly cash flow statements.
Level 7	Years	The annual financial statements; the national trade deficit; GNP; Short-term sales forecasts.
Level 8	> 5 Years	Information summed over more than 5 years has value in some circumstances. An excellent example of this is the accumulated national debt over the last five years. In general, the aggregates at this level include all "flow" items that span long time horizons e.g., historical sales.

TABLE 2: THE SECTIONAL AXIS

LEVEL (DEGREE) OF AGGREGATION	DESCRIPTION	ILLUSTRATION
Level 0	No summation. The data are presented as individual economic events.	The sale of some quantity of an item to a customer at a given price is a single event.
Level 1	Simple Aggregations. Aggregations involving only one entity. An entity being some logical unit from the real world.	The total amount of an item sold.
Level 2	Simple Combinations. These are combinations involving only simple aggregations or data elements.	The multiplication of the quantity of an item sold by the price to come up with the sales amount.
Level 3	Simple Compositions. These would be compositions using simple aggregations and/or simple combinations.	The sales amount less the cost of an item to obtain a gross profit amount for a single item.
Level 4	Complex Aggregations. A summation involving the addition of a measurement on more than one entity.	The total quantity of an item sold to all customers.
Level 5	Complex Combinations. Combinations using complex aggregations, simple combinations, and/or simple compositions.	The sales figure for a specific salesperson or branch.
Level 6	Complex Compositions. These would involve the complex aggregations and complex combinations.	An income statement for a sales branch.
Level 7	Aggregate Compositions. The addition of complex compositions that are identical in content for entities increasing in scope.	Combined financial statements for branches, departments, or divisions to produce the organization statements.

IV. Some Implications Of The Model

The model has numerous implications for the design of systems. It is clearly related to some of the variables of investigation currently used for researching management information systems. By using the proposed model to classify the type of information used for solving various categories of problems occurring at different levels of management, it may be possible to gain more knowledge about developing systems to support these functions.

In relating the conceptual model developed in this paper to the Mason and Mitroff [1973] program for research on management information systems, it can be asserted that the model is a description of one aspect of the presentation mode of the evidence generated to solve a problem. This presentation mode is directly related to the evidence generated. There have been some empirical studies that have investigated the relationship between the decision-makers psychological type to the preference of aggregated or disaggregated data presentation (Section II referenced a number of these studies). These studies could have benefitted from the use of the model of summation levels developed in this paper.

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*** Figure 2 goes about here ***

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*** Figure 3 goes about here ***

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Figure 2 and 3 summarize some of the important implications of the proposed model. These figures display the expected relationships between the levels of summation (degree of aggregation) and the organizational decision level, and between the levels of summation and the "structuredness" of a problem. In addition to reinforcing the discussions explicated in the earlier

paragraphs, Figure 2 and 3 also provide an insight into how this model could impact the value of information delivered to the decision maker. The key implication suggested by the conceptual model (Figure 1) and the graphs shown in Figure 2 and 3 is that, in general,
there are ***optimum*** *combinations of sectional and temporal levels of summation that are possible--in terms of its value to the decision maker--for a given decision trait i.e., problem structure and/or decision level*. The figures show the extremum for these combinations. Intermediate levels of sectional and temporal summation would be needed for information to be valuable to decision makers for semi-structured problems and/or tactical decisions. This notion of being able to develop such "optimum aggregations" is crucial to the design of new systems. It is important because the *value of a system impinges to a large extent on the value of the information delivered to the decision maker for a given problem*.

In addition to the above, based on an analysis of the model and past literature, it is possible to assert the following implications. This discussion also includes some arguments and reasoning behind each of the stated propositions.

1.1 In general, the value of information will increase for unstructured problems as the temporal and sectional levels of summation increase.

1.2 In general, the value of information will increase and then decrease for semi-structured problems as the temporal and sectional levels of summation increase.

1.3 In general, the value of information provided to the decision-maker will increase for a structured problem as the temporal and sectional levels of summation decrease.

The above conclusions (illustrated in Figure 2) can be deduced by examining the definition of an "unstructured problem" in terms of information needs. Yadav and Chand [1989] proposed using the criteria of data, report form, and process to decide whether a problem is structured or unstructured. Thus, cases where all three of these entities are known is considered a structured problem, whereas if only one of the three is known then there is incomplete knowledge about how to solve the problem and it is considered unstructured. From this definition it is noticeable that part of the problem revolves around discovering relationships between data in order to identify relevant data and develop the models and processes to be used in solving the problem. To successfully establish these relationships the decision-maker may need to have data that is at a high level sectionally, and at a high level temporally, i.e. the data represents a wide span of time. The opposite is true for structured problems. Since a model and the process for solving the problem is known, the decision-maker would want the information presented using the model, i.e. the results of the model. Temporally, for structured problems the decision-maker is concerned with a particular time-frame set of identified data and would not be concerned with a wide time horizon.

The next set of implications are concerned with the organizational decision levels and the appropriate amount of summation needed for these decisions (see Figure 3). It is important at this point to state a caveat in the overall influences between the various constructs displayed in Figure 1. We are well aware of the fact that it is quiet possible that ill-structured problems are addressed at the operational level of decision making rather than only at the strategic level. Consequently, we do not make any assertions regarding the relationship between the decision level and problem structure; rather that both these constructs do require that their be a **fit** with the degree or level of summation of data made available.

2.1 The value of information will increase for strategic management decisions as the temporal and sectional levels of summation are increased (or as the ability of summation increases).

2.2 The value of information will increase and then decrease for management control decisions as the temporal and sectional levels of summation increase.

2.3The value of information will increase for operational decisions as the temporal and sectional levels of summation decrease.

The above assertions follow from the characteristics ascribed by Anthony [1965] and other researchers (e.g. Simon [1960]; Mintzberg et al. [1976]) to the types of decisions that decision makers make (Strategic-Operational continuum). Strategic decisions are characterized by a long-range planning horizon, overall organizational factors, and environmental situation. All of these characteristics indicate the need for information that is summarized to a high level. The management control decisions are concerned with meeting the objectives of the organization as laid out by the strategists. This requires information that ranges from daily summations to annual reports, and from managing sales branches to the entire distribution system of an organization. The levels of summation for these decisions will accordingly vary widely. The operational decisions are concerned with the day to day operations and therefore need information at a very low sectional level. The information for these decisions needs to be timely and detailed.

V. Concluding Remarks

This paper has developed a conceptual model for studying the levels of summarization of data for presentation to decision-makers. This model is based on two axes: the temporal, that describes aggregations over time, and the sectional, that describes the summations over logical units of interest at any given instant in time. The model is predicated on the fundamental notions regarding aggregation in the events theory of accounting. It suggests that, hypothetically, one could find data at a level of summation (or degree of aggregation) that exactly **fit**s a given decision trait--decision level or problem structuredness; thus delivering information that would be most valuable to the decision maker.

The model has many important uses and implications. It is useful for describing some of the relationships between the presentation mode, level of summation, and other variables of interest including the structure of problems, the level of organizational decisions and the psychological type of the decision-maker. The model also has some important implications for system designers and developers. It provides a basis for developing systems that at the minimum would allow for the degrees of summations proposed in this model. Finally, it also emphasizes the importance of aggregation in designing data-based systems and the relationship of the various levels of information aggregation with the decision level and the problem "structuredness." Finally, from a pragmatic standpoint, the model for information aggregation developed in this paper suggests that systems need to be designed so that they incorporate the capability and flexibility that allows decision makers to view they underlying detail regarding a piece of aggregated information, in terms of both the data elements of aggregation and the process or model used to aggregate the data -- with the caveat that this has to be achieved without sacrificing its economic viability.

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APPENDIX:
VALIDATING THE 'EVENTS' MODEL FOR INFORMATION AGGREGATION

1.The XYZ Company: Sales Support System

2.Area Scheduling System

3.Cognitive Lens Support Systems (CLSS)

4.Comprehensive Advisement Monitoring System