An Integrated Information Model for Managing the Design and Construction of Building Construction Projects

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ABSTRACT

Information management in the Architectural, Engineering, and Construction (AEC) industries is changing toward the integration of information in all stages of building design and construction processes from planning to operation. This paper explains the development of a conceptual data model for managing this information. The model will represent the owners' point of view for generating, processing, storing, and retrieving data throughout the life cycle of the building, and it will focus on the stage of completion of planning and transferring information for design and construction. Existing design and construction industry standards, principal theories, and recommended practices in design, construction, and database management have been incorporated into the model. The model takes into consideration international standards for data exchange, product data modeling concepts, and construction industry data management classifications and practice.
Key Words
information technology; integration; data modeling; IDEF1x; construction

INTRODUCTION

Managing a construction project without access to timely and accurate information is often undertaken at great risk and will, at best, result in monetary losses due to lower productivity and reworking. The means of providing information to concerned parties in a construction project today has not changed significantly over time. Although many aspects of the process such as cost record-keeping have been computerized, industry does not yet have a working model of an integrated information system.

In every construction project a vast number of data will be generated and distributed to all parties involved but three most important attributes of data - quality, integrity and its timeliness - are not always considered in the process. Currently, no proper standards, guidelines, or models for generation, collection, storage and feedback of these data exist. The main reason for the lack of standards and guidelines is the nature of the industry, which is fragmented and project-based. And each project operates under different conditions, participants and disciplines. The format and the nature of required information in each project and flow of this information to team members are based on either delegating responsibilities as defined in the contracts of project team members, or by following laws and regulations, neither of which serve as a good model for flow and quality of required information in an efficient and effective operation.

General Background of Integration Research

"Integration" defined as the sharing of knowledge and data across the traditional phases of a project, is emerging as a necessary response to forces for change in the design and construction processes and as a major new challenge for management. Increasing the use of Computer Aided Design (CAD) and the availability of powerful Database Management Systems (Bjork & Penttila, 1989 & 1991) has prompted research aimed at identifying the opportunities for utilizing these data for construction and integrating the design and construction database. During the last decade, computer application during the various phases of a project has been a major area of research. Integration of design information has been advanced through CAD systems, and as a result of the development of intelligent CAD and the improvement in hardware efficiency and image processing technology, this field is rapidly growing. Two major areas in computer-aided design, solid modeling technology and virtual reality, have proven useful in the integration of design and construction information. Geometric models can potentially support analysis of designs and reasoning about them at several different levels of sophistication (Mitchell, 1991), and in the '90's, we should see more emphasis on integrating the higher level reasoning capabilities of these systems. Geometric models can be integrated with construction technology without traditional construction drawings as the medium for transfer of information, *eg*, computer-controlled laser cutters. Integrated databases using three-dimensional models to review constructability and improve productivity in projects have been applied in major construction projects and proven to be useful (Reinschmidt, et al 1991).

Research in integrating the various aspects of construction processes includes knowledge processing for construction database management, automated scheduling, integration of cost and time, use of artificial intelligence techniques for time and cost control, use of the Bar Code in construction, structural analysis, and work breakdown of project to objects for use in object oriented database. The need to integrate the data within the design and construction processes has been addressed and the modeling of these processes (Sanvido, 1991) has provided a framework for information modeling. Turner (Turner, 1990) has developed a Building Project Model as part of the International Standard Organization (ISO) work for the development of STEP (STandard for Exchange of Product data).

THE INFORMATION SYSTEM

The first task involved in designing an information system is to define data, information, and knowledge, and then list its required characteristics. Aktas (Aktas, 1987) has classified and defined these related terms as follows:

DATA are groups of characters recognized as having the lowest level meaning. They are raw facts and opinions.
INFORMATION has more meaning than data in that it is useful in a present decision situation.
KNOWLEDGE has the highest level of meaning because it represents information that can be potentially useful in future decision situations.
MESSAGE is a group of characters that is stored, processed, and transmitted in the information system of an organization.

Information systems have been defined as such aspects as a control tools for planning, strategic importance, corporate resources, and operational necessity, with its objectives and specifications in detail. However, each information system must have the following minimum requirements of design specification for the data and the system:

1. It must provide information at different levels of operation when and where it's needed. This relates to the TIMELINESS of data in the system and the availability of the data for decision making.
2. It must provide correct and accurate data to decision makers at the proper level of detail. This is related to the QUALITY of the data in the system.
3. It must have a built-in mechanism for checking the INTEGRITY of data, *ie*, correctness, completeness, consistency, and non-redundancy.
4. It must be in a format which is understandable by those who receive it, which has a value that elicits a response or an action, and which provides an expected result or user satisfaction. This is called the VALUE of data.
5. It must be technologically efficient and effective as well as flexible in processing data. This is called the EFFECTIVENESS of the system.

For design of an effective information system, some form of top down modeling, which can represent a high level view of the system and have capability of decomposition to lower levels is required. IDEF1x modeling technique is a proper tool for this type of modeling.

IDEF1x Basics

IDEF1x is a conceptual data modeling technique developed for the Integrated Computer-Aided Manufacturing project for United States Air Force. IDEF1x uses an entity-relationship approach to semantic data modeling (IISS, 1985). The basic constructs of the IDEF1x model are:

1. Things about which data is kept, *eg*, people, places, ideas, events, *etc*, represented by a box;
2. Relationship between those things, represented by lines connecting the boxes;
3. Characteristics of those things, represented by attribute names within the box.

The basic constructs are shown in Figure 1. The components of an IDEF1x model are

1. Entities
   - Identifier-Independent Entities
   - Identifier-Dependent Entities

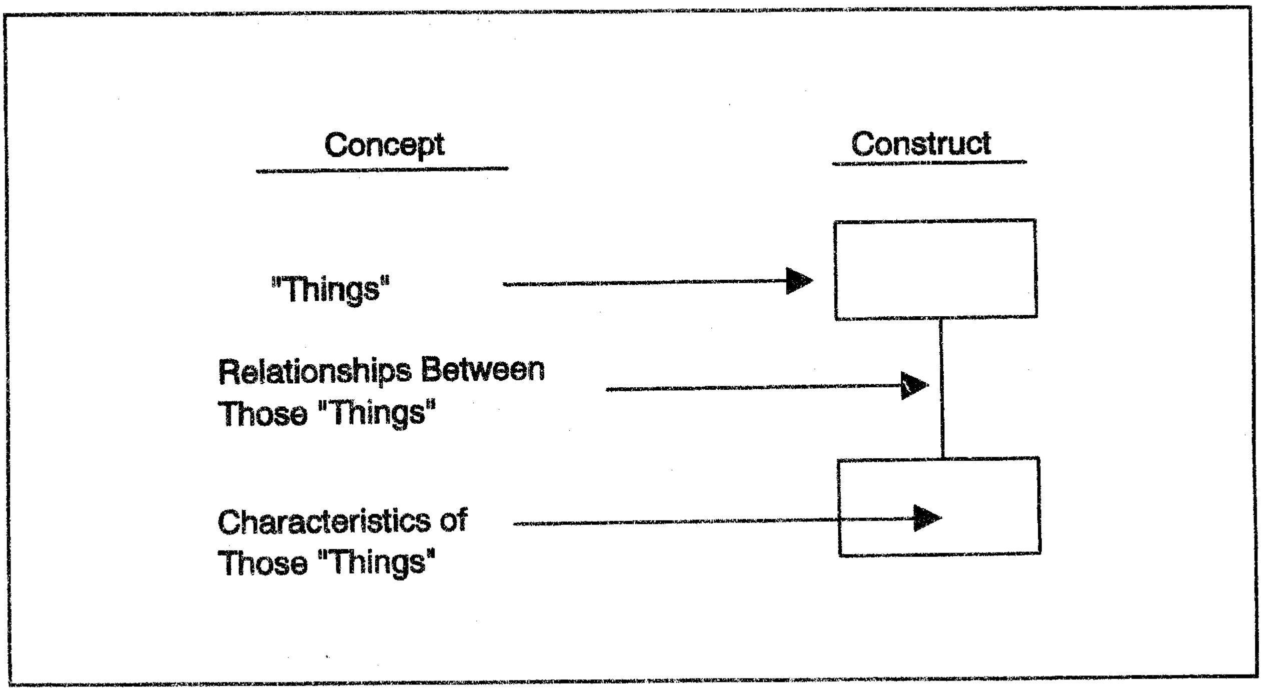

Figure 1 Basic Modeling Concepts

2. Relationships
   - Identifying Connection Relationships
   - Non-Identifying Connection Relationships
   - Categorization Relationships
   - Non-Specific Relationships

3. Attributes/Keys
   - Attributes
   - Primary Keys
   - Alternate Keys
   - Foreign Keys

AN INTEGRATED INFORMATION MODEL

The strategy used to develop this model (based on IDEF guideline) was based on the following primary assertions: (1) that the focus of information model should be on information directly used by the construction project participants in all stages of the process; and (2) that the ability to develop an information model that reflects real world characteristics depends on a clear understanding of each participant's role and responsibilities. Based on this strategy, an issue-based model for information system must be developed first, and then this model must be mapped into the organization structure to achieve a primary task model specific to the organization. The following illustrates a general conceptual data model that represents data flow and relationships within the building construction industry. The IDEF1x modeling technique has been used to represent the model.

The following figures show series of conceptual data models in different levels of abstraction for building construction projects. Figure 2 is the highest level of abstraction, and it identifies the parties involved and their relationship to the project. This model is shown at the attribute level and some attributes of each entity are shown as an example. (FK) denotes Foreign Key and has been migrated to the entity through an identifying connection relationship.

Figure 3 is the General Model, which represents relationship among participants and processes. This model is shown at the entity level; in order to implement the model all attributes of entities must be identified and defined. However a working model needs to be defined in a lower level of resolution but this level is useful in the process of information system design to assure all entities and their relationships are considered.

Figure 4 is the lower level of the general model, which includes the Definition Model (DM) for programming, the site, and building and construction planning. Definition Models are data models based on the concept of the Product Data Unit (PDU), proposed by Gielingh (Gielingh, 1989) for construction. The product data model has been used in integrated systems in manufacturing (Hale, 1992) and it has resulted in improved production and operation.

Above assertions and IDEF1x guidelines for building information models will be reflected in the accomplishment of the following tasks, in sequence:

1. Data collection
2. Entity definition
3. Relationship definition
4. Primary Key definition
5. Attribute population
6. Model validation

In conclusion it must be noted, for development of the model, source data are collected from various sources, each of which represents a particular view, of the information. And each project participant has its own distinct view of that information and evaluate it differently. Therefore, the information required to develop and implement the model, and the underlying meanings and structure of information, should be analyzed, by comparing and evaluating each of these perspectives and view points. This will enable the modeler to develop an image of underlying reality. After model is developed, it must be validated by verifying relationships and attributes of each entity. Then it must be accepted and agreed upon by experts and informed laymen before it can be implemented.

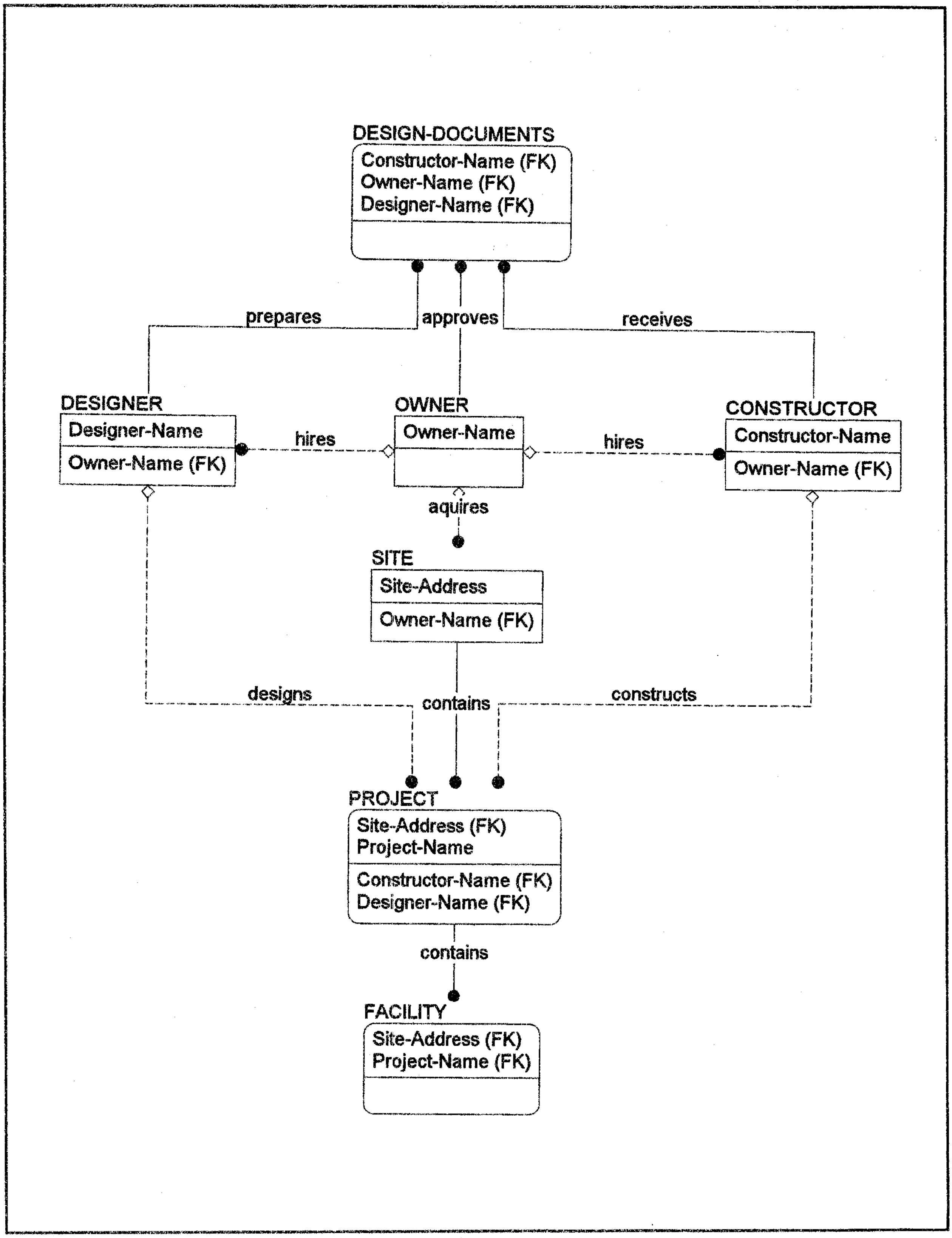

Figure 2 Project Participants and Relationships

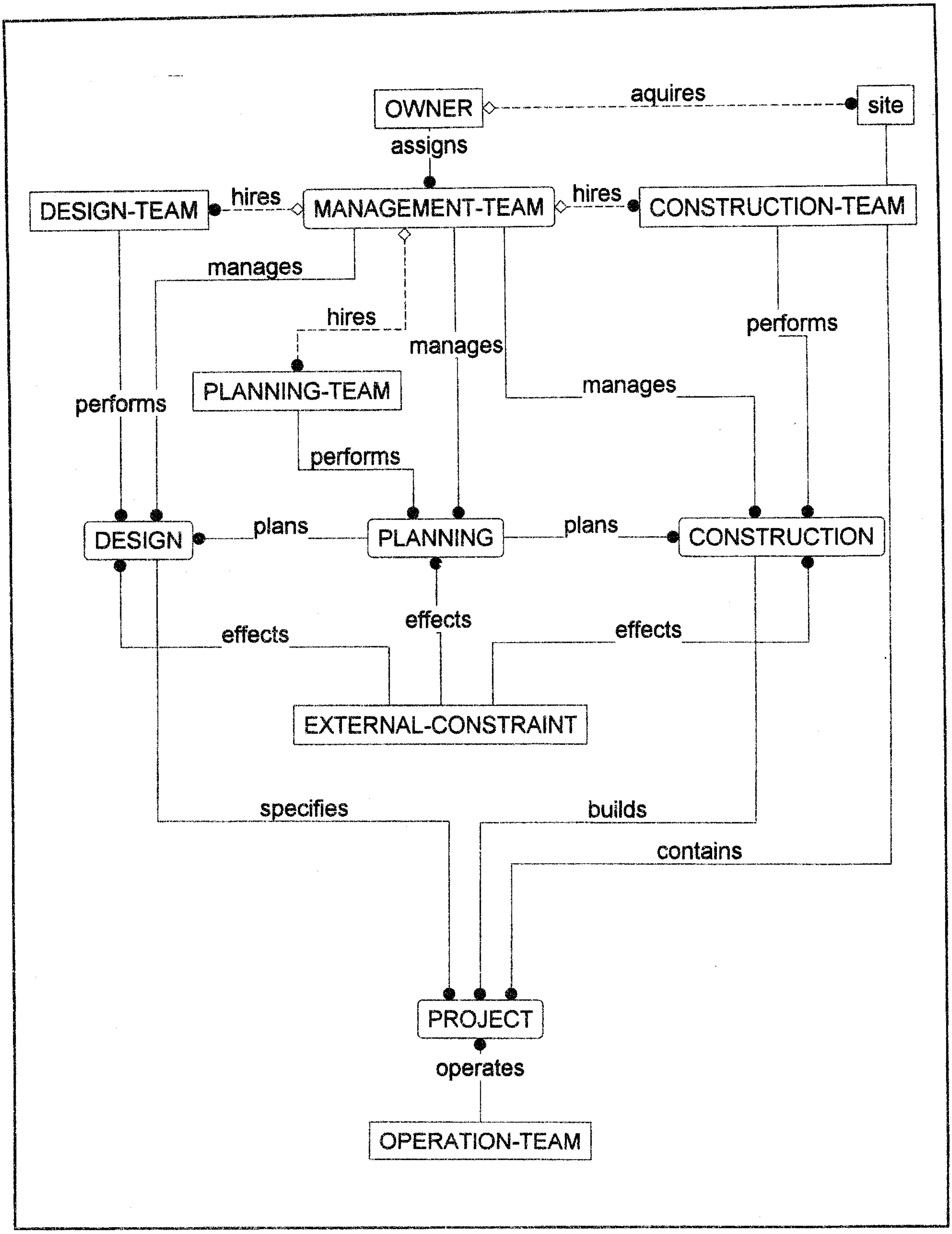

Figure 3 Proposed General Model

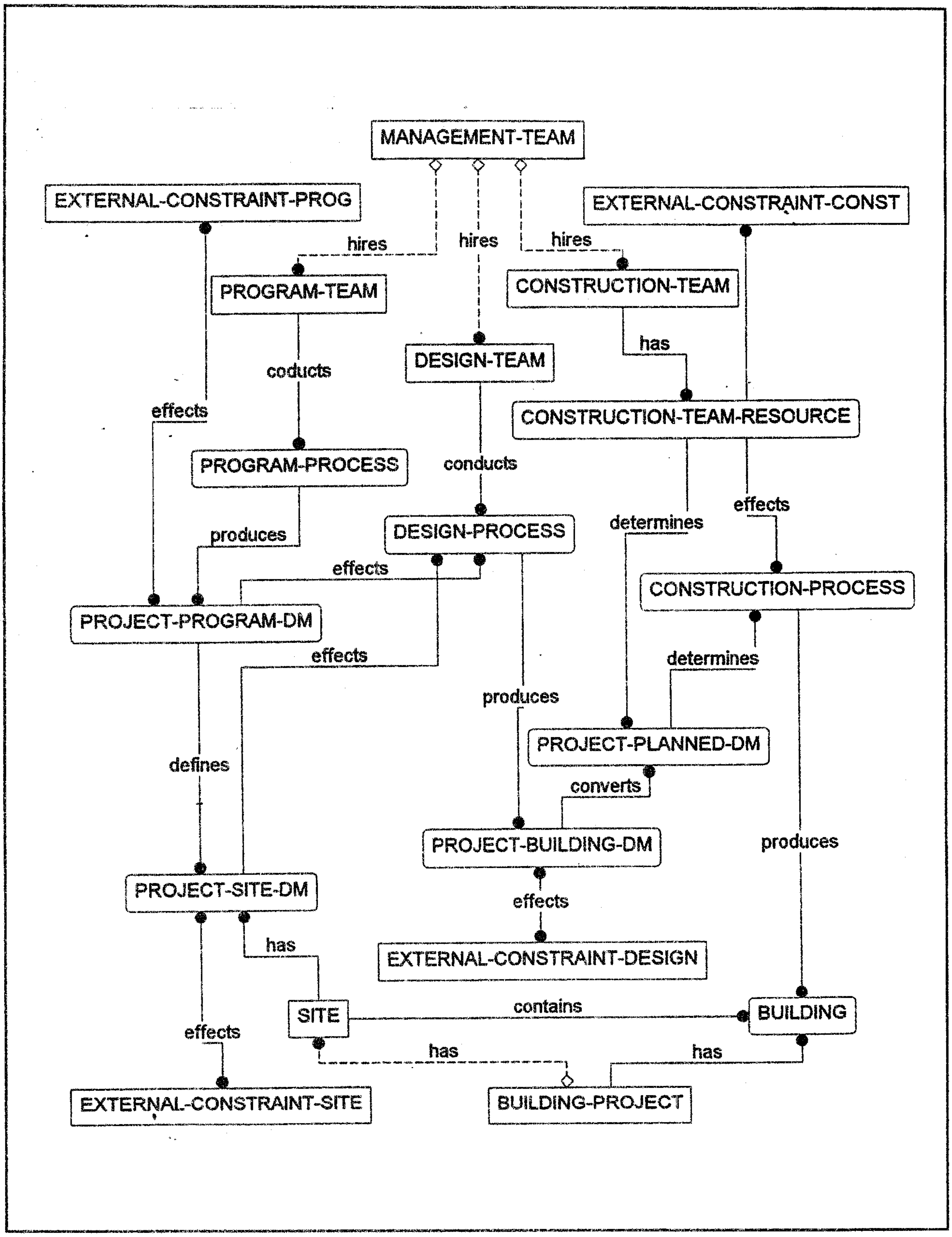

Figure 4 Proposed General Model with Definition Models

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