USE OF INFORMATION FOR PROBLEM RESOLUTION ON CONSTRUCTION PROJECTS

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF APPLIED SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

Department of Civil Engineering

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

April, 1996

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Date APRIL 12, 1996

ABSTRACT

If construction managers are to carry out their responsibilities in the areas of construction and its support services, they need ready access to the right information [Lock 92]. Timely access to the right data, properly processed for decision making, can provide a competitive edge. And keeping track of information flow on a construction job site is a vital task that has a direct bearing on the timely and successful completion of a construction project [Rasdorf & Herbert 88]. Traditionally, in the construction industry data is collected at the departmental level, but there is very little exchange of information between the departments. Much less between companies. As a result, there is a great deal of duplication of effort and inconsistencies occur in data from different sources. The goal of this thesis is to analyze the information needs of project personnel and to develop a computer-based Project-Management Information Control System (PMICS) to enhance the problem-solving and information management abilities of construction-site management personnel. The use of the latest development in computer technology will be emphasized to manage all the information in such a way as to allow quick access to the right information at the right time and shared by various disciplines or parties. The PMICS builds upon the understanding of the functions and information needs of various personnel at construction projects, and the different documents used by them. The thesis consists of five steps: (1) an analysis of related literature and the current state-of-practice relating to project information; (2) the establishment of a matrix of document types and project

personnel; (3) the definition of personnel roles and information needs; (4) the establishment of the purpose, contents, and personnel involved in the preparation of different documents; and, (5) the development of a means for tracking project information. The system is developed for the PC platform and runs under Microsoft Windows™ operating environment using Microsoft Access and Excel software. The system developed in this thesis will help manage the production of information, will improve and expedite information, and will relieve technical personnel of administrative and clerical duties.

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Acknowledgments

I would like to thank my supervisor, Dr. Thomas M. Froese, for his guidance and encouragement throughout the preparation of this thesis. His dedication and patience are much appreciated.

I would also like to thank Dr. Alan D. Russell for sharing his knowledge and literature on the topic of contract control software. I wish to extend my appreciation and thanks to Dr. Thomas M. Froese, Dr. Alan D. Russell and Dr. William F. Caselton for reviewing this thesis and for their constructive comments.

Finally, warm and sincere thanks go to my wife Farhana for her financial supports and allowing me to concentrate on this work — And my daughter Kainat for her patience.

Dedication

This thesis is joyfully dedicated to my

— mother Saleha,

—wife Farhana, and

—daughter Kainat.

Chapter 1

INTRODUCTION

1.1 Introduction

This chapter introduces the basic problem of information management in the construction industry and gives an overview of the information control problem. The goals and focus of this thesis are explained, as is the research methodology. Finally, an overview of the thesis is given.

1.2 Goals

Accurate information is an absolute necessity for sound decisions. In the absence of timely decisions and actions, a construction project may face a number of problems. The problems may include excess cost and time, claims, safety concerns, etc. Contractors have become increasingly concerned with claims, their associated costs, the poor cost recovery prospects, and the time taken up by the process. Therefore, it is in the interest of every contractor and owner to avoid and resolve the problems at an early stage.

As technology progresses, construction projects are becoming increasingly complex. Construction engineers and managers are being bombarded by information at the site from

all directions. Unfortunately, the job-site office environment often does not lend itself to proper handling of all the day-to-day paperwork generated on most construction jobs. Proper maintenance of daily project information is crucial to successful project management. The more complete and informative the records, the more effective they will be in resolving any problems that may arise. To ensure safe and efficient operations at the project site, it will be necessary to develop and adopt a project-management information control system.

[Tidwell 92] states that there are three main areas of any project execution: Coordination, Communications, and Control. *Coordination* is the act of carefully planning what needs to be done to complete a project. *Communications* is keeping in touch with all the project participants or constituents. The third area is Control. *Control* is making sure that all our well-made plans are carried out. This thesis treats Control as one of the important areas of construction project execution.

Construction is going through a change in the routine approach to the execution of work. Managing a highly variable process such as construction involves the rapid processing of huge volumes of information in order to properly monitor and control project progress. The need has long existed for a resource to streamline the job of the construction professional. With advances in computer technology, computers have become a central component of information systems. A number of studies have demonstrated the potential benefits of computer-based information systems for construction projects ([Barnes 93],

[Chamberlain 91], [Krone 93], [Paulson Jr. 95], [Russell 93], [Tidwell & Leckington 94], [Tokar 90], [Wager 87]). Benefits claimed includes the following: rapid data processing, accuracy, quick retrieval of important data, maximizing project management efficiency, decision-making support, document reduction, responsibility tracking, historical documentation, etc.

[Walker & Hughes 87] suggest that a changing project environment requires project organization structures to be responsive and dynamic. They used linear responsibility analysis technique to develop case studies of project organization structures of private industrial projects, and they looked at organizational systems rather than data systems. They looked at people, the key players making strategic decisions, and at patterns of roles, responsibilities and relationships, that combine to form an organizational structure for a project. In his papers, ([Tenah 81], [Tenah 83], and [Tenah 86]), Tenah has also addressed the issue of management information organization and routing, and construction personnel role and information needs. These issues are also treated in this thesis.

A review of literature revealed several studies on project information system, but much of the literature deals with sophisticated and expensive systems. Small and medium-sized construction companies may not afford such systems. [Lock 92] states that in spite of all the great advances in computer and telecommunication technology, information processing and retrieval systems are associated with significant cost, depending on the accuracy, timeliness, and sophistication of the data systems requirements. He further

suggests that it is not surprising that with its potential for great cost saving and increased business effectiveness on one side, and substantial capital investment and operating cost on the other side, systematic information management has become an increasingly important part of overall organizational control.

With these things in mind, the primary goal of this thesis is to develop a project-management information control system suitable for small and medium-sized construction companies, and capable of tracking down problems. Specifically, the use of personal computer based software has been used. The secondary aim is to introduce a set of matrices for organizational structures and documents for a construction site including key decision makers; their roles, responsibilities and relationships; and their information needs. This thesis will also outline a number of information tracking logs typical for a construction project.

1.3 Objectives

The objectives of this thesis are following:

- The first objective is to collect and review literature to determine how different documents are used by construction-site management personnel for solving problems, pursuing claims, providing instruction to site personnel, etc.

- The second objective is to develop a computer-based project-management information control system to enhance the problem solving and information management abilities of site management personnel. The use of the latest development in the computer technology will be emphasized to manage all the information in such a way to allow quick access to the right information at the right time, and to allow it to be shared by various disciplines and parties involved in the project.

1.4 Research Methodology

For this thesis, the following research methodology has been adopted:

1.4.1 Literature Review

The first stage of research involved a thorough literature search of several fields of study, such as: documentation, organization, personnel roles, claims, risk, multimedia, integrated information management, economics and construction management, and civil engineering computing. This literature search has aided in the understanding of documents and their purpose, construction personnel role and responsibilities, the latest advances in integrated information technology, etc. The search has also aided in the development of the ideas and focus of this research, e.g. the analysis of results of literature review leads to the production of a framework for construction documentation, particularly a breakdown of

documents, a breakdown of participants, a document/participant matrix, and common data items across documents, etc.

1.4.2 System Development

The next step in the research involved the development of an information system based on the literature search and findings. It was found that much of the literature to date on project control dealt with sophisticated methods for information management which, in my opinion, will be expensive for a small contractor. Because of the diversity of the system options, cost can only be discussed in generalities. So, from a small contractor's perspective, a PC based software solution to manage project information is considered to be appropriate.

1.5 Overview of Information Control Problems

This section introduces and examines a number of the issues central to information control problems and puts forward some key concepts essential to the assurance of quality and value in the development of information systems.

1.5.1 Information Management and Construction Projects

Several papers have pointed out the shortcomings of traditional tools to provide information for construction project control ([Sanvido & Paulson 92], [Tokar 90], [Liu et al 94b]). These tools have been cost and progress reports comparing expended cost to the budget, and actual progress against scheduled activities, which evolved from accounting practices and project planning techniques. These reports focus only on one aspect of the process, namely the end product—they rarely identify the causes of problem when a problem occurs. Further, present day projects are complex in nature due to the involvement of a large number of individuals, firms, and organizations, and above all, more complex building systems. Hence, information required from management systems has increased.

For a contractor, the management of project information begins the day the decision is made to bid on a contract and continues well after the close-out phase [Kangari 95]. The construction industry is information intensive. It needs accurate, reliable, and timely information regarding legal requirements, building codes and standards, manufacturer's specification, site-specific data, and past projects, etc.

1.5.2 Data Sources

In a construction industry, data comes from numerous sources, including contract documents and agreements, project manuals, the master schedule, building codes, test data, survey reports, bid tabulation forms, estimates, cost records, quantity take-offs, value engineering studies, requests for proposal, requests for information, change orders, field reports, meeting minutes, RFI (requests for information) logs, shop-drawing submittal logs, and so forth.

[Tokar 90] defines the following two types of input data (with different input requirements): *objective* data is information that can be directly taken from the document, such as author, recipient and date; *subjective* data requires decision making and some level of expertise regarding the ultimate requirements of the system.

1.5.3 Information Reference Sources

[Leslie & McKay 93] states that a project decision will come from three major sources (Figure 1.1). They are: the personal knowledge and experience of the decision-maker or peer, reference sources (research, trade literature), and the current project description (an amalgamation of earlier project decisions).

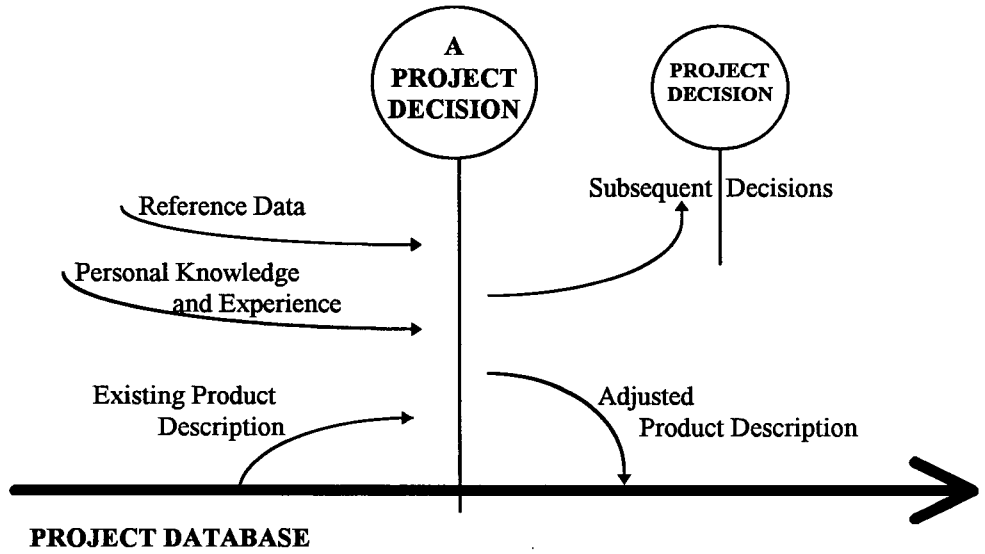


Figure 1.1 Information Transaction in a Project Decision
(Source: [Leslie & McKay 93], p 102)

[Couzen et al 93] have discussed information sources under the following two general classifications:

- **Location of the information source:** This refers to whether the information source is located inside or outside the organization.

- **Medium of information transmission:** This refers to five basic media: mail, telephone, unscheduled meeting, scheduled meeting and tours.

1.5.4 Information Users and Routing of Information

The term "information users" refers to who needs the information, or who information is sent to. In this category the users are: individual managers, departments within the organization, other project participants, etc. Control information spans across functional disciplines; for example, materials will be dealt with by estimators, buyers, planners, site managers, and surveyors. A matrix showing personnel and their information needs is one way to examine the users of the information systems.

[Peters 84] suggests routing of information to the right people by assigning tasks and responsibilities through a project responsibility matrix. In a project responsibility matrix, all functional specialists who have a role to play occupy a position in the matrix where their responsibilities are well defined. He writes that such matrix will also be a framework of an information system in which appropriate information is channeled to the right people in the project.

[Mintzberg 73] suggests the information collected by executives and senior managers is used in the following four ways: (1) to disseminate it to others; (2) to develop value positions for the firm; (3) to identify business problems and opportunities; and (4) to develop mental images—models of how the organization and its environment function.

1.5.5 Information Generator

As mentioned earlier, a construction project involves a number of individuals, disciplines or departments within the organization, and other participants. Each one is a generator of information within the scope of his responsibilities. Again, the same matrix as discussed in section 1.5.4 will help identify these sources.

1.6 Overview of Databases and Database Management Systems

A database can be seen as an attempt to overcome some of the limitations imposed by conventional filing systems, such as uncontrolled redundancy, inconsistency, difficult data sharing, and modification inflexibility. It is a database management which allows users to create and maintain a database system. This section presents an overview of some of the concepts used in the database system design.

1.6.1 Database Concepts

[Burger & Halpin 77] states that the database concept provides a suitable environment for a sophisticated user-oriented project information system. Data used and generated at the project level is stored and maintained in a highly integrated structure instead of separate application files. The approach permits organization of data in hierarchical, network or relational system. [Tenah 83] states that the planning, designing, and controlling of

information and information systems rely on an extensive database of high quality to be a useful tool in solving the complex problems of today and of the future. [Bengtsson & Björnsson 87] advocates computerized data-base systems for timely and easy retrieval of data, as the traditional methods for data gathering, such as stop-watch studies and random observations, are time-consuming and often expensive. [Bowler 94] points out the importance of a relational database management program (RDBMS) in the engineering office. He discusses the use of database applications in the following areas: technical, project management, business development and administrative applications.

[Townsend 92] states that a database systematically stores information for retrieval or analysis, and describes two types of databases that dominate small computing, namely: flat-file and relational databases. In a flat-file all the data or information are entered in one large file, and accessed individually. This type of database works well for small amounts of data, and includes some duplicated data. Flat-file databases are typically easier to use and less expensive than relational databases. These systems are usually for single users. A relational database breaks its data into logically grouped parcels or files, stores information in tables or forms, and avoids duplication of data. The information in different tables can be related through links established by a column or field. A relational database management systems (RDBMS) can be utilized from simple to very complex database requirements.

A database can be seen as an attempt to overcome some of the limitations imposed by conventional filing systems [Bamford & Curran 91]. It is the database management which allows the user to create and maintain a database system. The database is a physical implementation of an information or data model. Entity relationship (ER) diagrams are one means of formally expressing a data model.

[Hamilton 91] states that by using a relational database, record management process can be made easier. For instance, tracking down information about progress and location of shop drawings within a firm; listing of present and past projects; correspondence, calculations, telephone memorandums, etc.

[Lock 93] states that the foundation of any MIS (Management Information System) is its data bank which contains the raw data that will be accessed by the MIS user, either directly or indirectly via analytical method or models. For this purpose a Database Management System (DBMS) is needed which permits simultaneous access to the many different data banks that exists throughout the company.

1.6.2 Top-Down Planning versus Bottom-Up Design

[McFadden & Hoffer 88, p67-68] state that both top-down planning and bottom-up designs are required for the development of corporate databases. As shown in Figure 1.2, the top-down planning starts with basic organizational goals and objectives, including

functions, processes, activities, entities, etc., and then develops an information model followed by databases. Whereas in bottom-up design, design begins with user views of data followed by normalization to develop detailed data model. In database design, the data models are checked against the information model to ensure that they are complete and accurate.

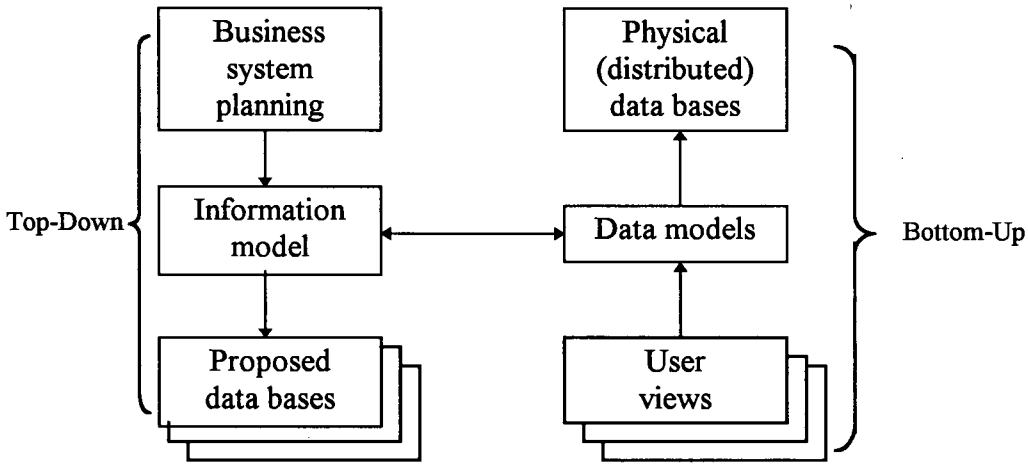


Figure 1.2 Top-Down Planning versus Bottom-Up Design
(source: [McFadden & Hoffer 88], p68)

1.6.3 Database Terminology

Some of the terms used to describe data and its presentation, as defined by [Atre 80] and [Bull 90], are as follows:

An *enterprise* is any kind of organization. For example, a bank, a university, a company, or a hospital. A single object is called an *entity* about which information is recorded. For example, person, place, thing, event, or concept. Each individual entity must be unique so that it is distinguished from others. Properties of objects included in data entities are called *attributes*. For example, a house can be described by its size, color, age, and surroundings. A *data value* is the actual data or information contained in each attribute. The values taken by the attributes can be quantitative, qualitative, or descriptive, depending on how the attributes describe an entity. For example, account type (checking), account number (1234567), and account balance (20.53).

A *key attribute* of an entity has the property that identifies the data values of other attributes of the same entity. Key attributes can also be called *entity identifier.* A *data record* is a collection of values taken by related attributes. The data records are stored on some medium. For example, a piece of paper, a human brain, a memory of a computer, or a computer disk. A *data file* is a collection of data records. For example, a manager's report.

A *relationship* is the association of an entity with other entities. A relationship exists between two entities if they share one or more common attributes. An entity does not exist in isolation, but is associated with other entities by means of a relationship. If relationships are considered logically, there will be, at the most, five possible types of relationship. They are as follows: one-to-one, one-to-many, many-to-one, many-to-many and none-to-none.

In a one-to-many relationship, the entity at the one end is called the *master entity* and that at the many end is called the *child* or *detail entity*.

The view of data of an individual user is called *user's view.* Each user's view will be just a small subset of the entire data within the database. The actual data which falls within each user's view at any particular moment is known as an *instance* of the view. Whenever a data value is changed, added to a new record or deleted from an old record, the user's view stays the same but the instance changes.

A *sub-schema* or *external schema* is the description of the data contents of each view. Each sub-schema will represent one *local data model.* During the requirements analysis, a number of documents, screen layouts and reports are obtained, produced and designed which form a part of the proposed computer system. There will be one sub-schema for each document, and it will contain all the data which is necessary to support the document. A *schema* or *global data model* is the description of the entire database.

1.6.4 Data Modeling

The first step in designing a database is to determine which objects to represent within the database and which of the objects' properties to include. This process is called data modeling. Several authors have explained the data modeling in details ([Atre 80], [Bamford & Curran 91], [Jennings & Person 93] and [McFadden & Hoffer 88]). The

process of generating a working database involves the creation of the following three separate models: the conceptual model, the logical model and the physical model.

The *conceptual model* is based on the perception of an organizational area or a problem which is being examined. The term can be applied to an informal model which can consist of reports in use, documentation produced by fact finding, and so on. The term can also be applied to a more formal model which shows entities and their relationships but is independent of any particular database management systems (DBMS). The conceptual model gives an overall view of the flow of the data in the organization.

The logical model is derived from the conceptual model and is a formal representation describing data items and their structural relationships. The conceptual model is translated into a data model compatible with the chosen DBMS. It is possible that the relationship between entities as reflected in the conceptual model are not implementable with the chosen DBMS. The various DBMSs impose a number of constraints and rules for implementation to the physical database. For example, some DBMS insists that only two relationships need be used on the data model: one-to-one and one-to-many. Many-to-many relationships must be resolved into two one-to-many relationships by the introduction of a third link entity. In such situations, a modification to the conceptual model is made to reflect these constraints. The version of the conceptual model that can be presented to the DBMS is called a *logical model*. The logical model is either a relational, a hierarchical, or a network data model.

The final stage of data modeling is to translate the logical schema into the physical database. The *physical model* is the actual implementation of the database consisting of the data tables or files with supporting software. The translation process of the logical schema to a physical model is performed by the DBMS software.

1.6.5 DBMS versus Data Models

[Atre 90], [Date 90] and [McFadden & Hoffer 88] describe the different data models and their related database management systems software. This section is limited to the description of the different data models.

The data models in use as the underlying structures for database management systems are the following: relational, hierarchical and network. The main difference between the three data models is the way they represent the relationships of entities. All the three approaches have been as the basis for commercial-scale data base management systems.

In a relational model, the entities and their relationships are presented with two-dimensional tables. The relationships are also called entities. Every table represents an entity and is made up of rows and columns. The relationships between the entities are of the one-to-one and the one-to-many type. C.J. Date, one of the earliest contributors to relational-database theory, defines a relational database as "a database that is perceived by

its users as a collection of tables (and nothing but tables)" (1990, 112). This concept is fundamental to a relational database because it allows for data independence, the isolation of data from the mechanism the DBMS uses to access that data.

A hierarchical data model is made up of a hierarchy of entity types, and is presented as a set of tree structures. The chief elements are segment and the parent-child relationships. A segment is equivalent to the node of a tree structure. Segments are grouped into segment types, and each segment type has a name. A parent-child relationship is a one-to-many relationship between two segment types. The parent type is at the one end and the child type is at the many end.

A network model presents its data as a series of records linked one to another within their relationships. The word set is used to denote relationship between entities. The relationships are of many-to-many and one-to-many type. The relationships between record types in any one area are described by set types. The owner record type is at one end of the relationship and the member record type as at the many end.

1.6.6 Relational Databases Terminology

Some of the common terms of the relational databases, as explained in [Bull 90] and [MS Access 92], are presented in the following paragraphs. The example is based on the table shown in Figure 1.3.

A relational database is organized as a set of tables of data called relations (tables or files). Each table has a name and comprises a number of tuples (rows or records) and attributes (columns or fields). The domain of an attribute is the set of the possible values of an attribute for it. For example, the domain for the attribute Employee Number in Employee relation is all integers of 4 digits. The identifying attributes of an entity are called the primary keys. For the relation the primary key is Employee Number.

A table has the following properties: each relation has a name; no two tuples can be the same; the order of tuples is not important; each attribute must have a unique name; the order of attribute is significant; at the intersection of any attribute and tuple there is a single data value; the values in any one column are from the same domain; each tuple is uniquely identified by its primary key made up of one or more attributes; the primary key must not be null.

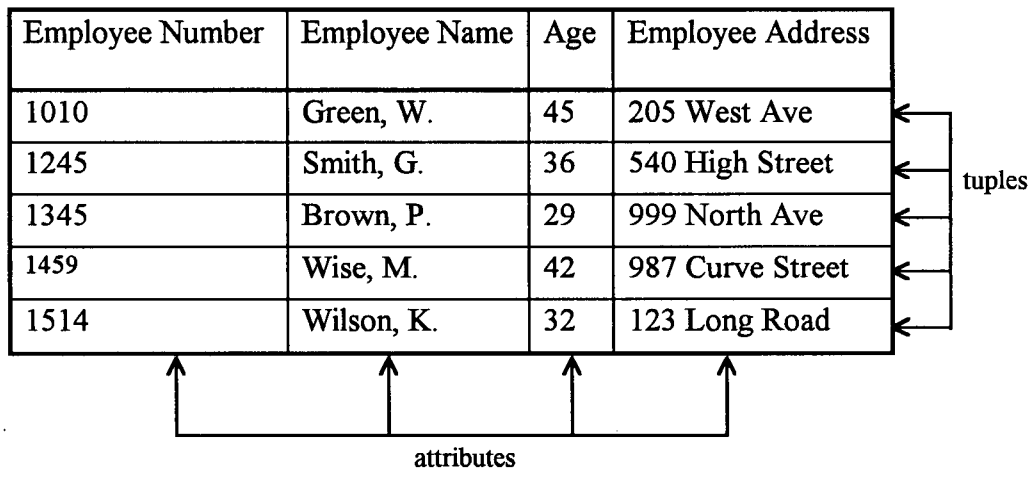


Figure 1.3 Relational Database Example

The number of columns in a table is a measure of the *degree* of relation. A relation of degree 2 is called a pair. A relation of degree n is called an n-tuple. The above relation is of degree 4 that is, a 4-tuple. The number of tuples in a table is a measure of the *cardinality* of the relation. The Employee relation shown above has a cardinality of 5. A relation can be described by a schema consisting of the name of the relation, the attributes enclosed in brackets, and the primary key underlined. For example:

Employee (Employee Number, Employee Name, Age, Employee Address)

If each tuple is identified by a composite key made up of more than one attribute, then all the identifying attributes will be underlined. A relation which has no repeating groups, as discussed in section 1.6.8, is known as a *flat file*. A relational database can be implemented fairly easily by means of a flat file.

1.6.7 Normalization

[Bamford & Curran 91], [Date 90], [McFadden & Hoffer 88], and [Rasdorf & Herbert 88] have described the normalization process in a database design as follows:

The technique of normalization is used to transfer conceptual data model into a form acceptable to relational database. It is a method used by relational data model designers to

design a good data-base schema by creating data-base tables that eliminate redundancies in the stored data and protect the data-base from insertion and deletion anomalies (problems), thus preserving its correctness and its integrity. This way, when changes are made in a well-designed database, errors will not occur and meaning will not be lost. Thus normalization is the process of decomposing large tables into smaller ones that are free from anomalies. The general aim of normalization is to produce a set of entities which will support the users' needs and which will conform to the requirements of the database.

The standard steps of the normalization process are shown in Figure 1.4. The first step is to remove any repeating groups from the relation. When this step has been taken, the data is said to be in the first normal form (1NF). The second step is to ensure that, if the relation has a composite key then any data attribute in the relation should be functionally dependent upon the whole key and not just a part of the key. A data attribute which is functionally dependent upon just a part of a composite key is removed to form a new relation. When this step has been taken, the data is said to be in the second normal form (2NF). The third step is to remove any attributes which are functionally dependent upon other attributes, and to put these in a separate relation. When this step has been taken, the data is said to be in the third normal form (3NF).

It is claimed that relations in the third normal form are sufficient for most practical data base design problems. There is some academic discussion about Boyce/Codd normal form (BCNF), fourth normal form (4NF) and fifth normal form (5NF).

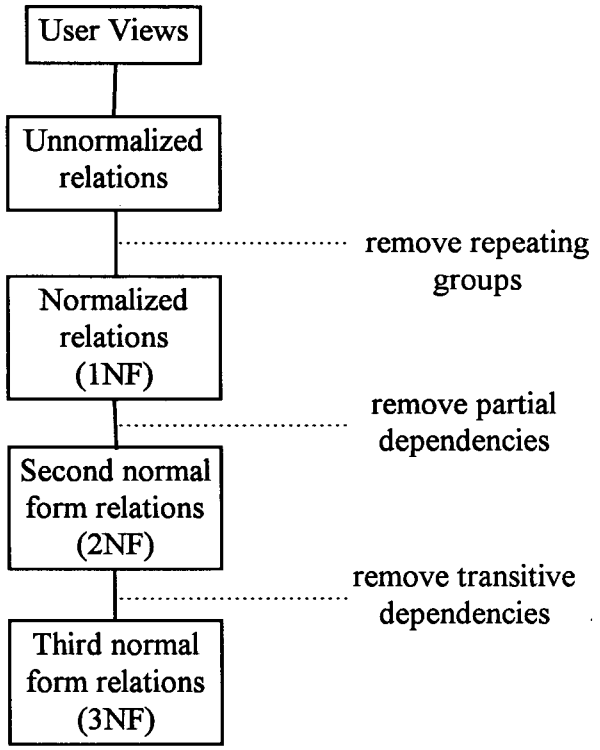


Figure 1.4 Steps in Normalization
(source: [McFadden & Hoffer 88], p249)

1.6.8 Repeating Groups

The concept of repeating groups is explained through the following examples. It is assumed that a construction organization has several projects, and each project has several trades. A relation for a project can be expressed by a schema in the following form:

Project (ProjectID, Project Name, Address)

The above expression shows the name of the relation and the attributes which it contains. The primary key which identifies the tuple is underlined and the attributes are enclosed in brackets. As discussed in the section 1.6.6 that at the intersection of any tuple and any attribute there is a single data value. However, when investigating the real world data, one may find that certain pieces of data are repeated. That is, within one entry of the table, a certain attribute may have multiple data values. For example, if it is decided to maintain details of budget of the trades. Then the relation Project can be written as:

Project (ProjectID, Project Name, Address, (TradeID, Trade Name, Budget))

The innermost bracket of 'TradeID, Trade Name, Budget' is known as a *repeating group*. In some cases repeating groups may be present within repeating groups. For example, a bidder may bid for several trades on a project. then the relation Project can be written as:

Project (ProjectID, Project Name, Address, (TradeID, Trade Name, Budget, (BidderID, Bidder Name, Bid Amount)))

The relation Project contains two sets of repeating attributes (attributes within inner brackets), where there will be several sets of (ProjectID, TradeID, BidderID, Bid Amount). For a given occurrence of ProjectID there will be many TradeID, and for a

given ProjectID and TradeID there will be many BidderID. If a relation contains a set of repeating attributes, the relation is said to be unnormalized.

1.6.9 Normalization Examples

The normalization process is explained through the following examples. The users' view or the sub-schema for the Bid Summary Sheet (BSS), as discussed in section 4.5.2, is expressed as follows:

> BSS (ProjectID, Project Name, (TradeID, Trade Name, Budget, StartDate, EndDate, Bid Due Date, Lowest Bid*, (BidderID, Bidder Name, Bidder Contact, Bidder Phone, Bid Pkg. Sent, Bid Received, Bid Amount, Difference*, File Ref. no.*)))

The entity BSS contains two sets of repeating attributes (attributes within inner brackets). For a given occurrence of ProjectID there will be many TradeID, and for a given ProjectID and TradeID there will be many BidderID. As discussed in section 1.6.8, if a relation contains a set of repeating attributes, the relation is said to be unnormalized. The remainder of the section deals with the ways in which repeating groups can be removed, and the normalization process. The entity BSS is normalized as follows:

- *First normal form (1NF):* To normalize the above relation to (1NF), the repeating groups are removed and the entity identifier of the original entity is made an attribute of the new entity, resulting in the following relations:

Project-1 (ProjectID, Project Name)

Trade (ProjectID, TradeID, Trade Name, Budget, StartDate, EndDate, Bid Due Date, (BidderID, Bidder Name, Bidder Contact, Bidder Phone, Bid Pkg. Sent, Bid Received, Bid Amount))

The entity Trade uses both TradeID and ProjectID to identify an occurrence of the entity, as it is assumed that each ProjectID is unique but the same trade may be present on several projects. To complete 1NF, the entity Trade is converted into 1NF by removing repeating groups as follows:

Trade-1 (ProjectID, TradeID, Trade Name, Budget, StartDate, EndDate, Bid Due Date)

Bids-1 (ProjectID, TradeID, BidderID, Bidder Name, Bidder Contact, Bidder Phone, Bid Pkg. Sent, Bid Received, Bid Amount)

Thus the original entity BSS has now been normalized into three new entities, Project-1, Trade-1, and Bids-1.

- *Second normal form (2NF):* Only entities which have more than one identifying attributes are involved in the transformation from first to second normal forms. As entity Project-1 has a single identifying attribute, its 2NF is same as 1NF. Trade-1 has two identifying attributes. Their relationships with other attributes is explained as follows:

Trade-1 (ProjectID, TradeID, Trade Name, Budget, StartDate, EndDate, Bid Due Date)

It is obvious that only 'Trade Name' depends on TradeID, where as the attributes Budget, StartDate, EndDate and Bid Due Date depend on both TradeID and ProjectID, as all these attributes vary for a trade from project to project. So, Trade-1 becomes as follows:

Trade-2 (TradeID, Trade Name)

TradeDetails-2 (ProjectID, TradeID, Budget, StartDate, EndDate, Bid Due Date)

Similarly, the functional dependencies of Bids-1 are explained as follows:

Bids-1 (ProjectID, TradeID, BidderID, Bidder Name, Bidder Contact, Bidder Phone, Bid Pkg. Sent, Bid Received, Bid Amount)

It is found that the attributes Bidder Name, Bidder Contact and Bidder Phone depend only on the identifying attribute BidderID, but the attributes Bid Pkg. Sent, Bid Received, and Bid Amount depend on all the three identifying attributes (BidderID, TradeID, ProjectID)

because, as it is assumed, a bidder may submit bids for several trades and projects at the same time. Based on these assumptions, Bids-1 becomes as follows:

Bids-2 (ProjectID, TradeID, BidderID, Bid Pkg. Sent, Bid Received, Bid Amount)

Bidder-2 (BidderID, Bidder Name, Bidder Contact, Bidder Phone)

So, for 2NF there are five entities as follows:

Project-2 (ProjectID, Project Name)

Trade-2 (TradeID, Trade Name)

TradeDetails-2 (ProjectID, TradeID, Budget, StartDate, EndDate, Bid Due Date)

Bids-2 (ProjectID, TradeID, BidderID, Bid Pkg. Sent, Bid Received, Bid Amount)

Bidder-2 (BidderID, Bidder Name, Bidder Contact, Bidder Phone)

- *Third normal form (3NF):* All the above five relations are in 3NF, as there are no transitive dependencies. However, if it is decided to specify the type of a bidder such as Subcontractor, Supplier. Again, in Bidder-2, the attribute Bidder Contact is the name of a responsible manager of the bidding organization. The attribute Bidder Contact can be linked to a new entity People. Thus, the entity Bidder-2 would be written as follows:

Bidder-2 (BidderID, Bidder Name, Bidder Phone, People ID, Last Name, First Name, Type ID, Participant Type)

Now, the entity Bidder-2 has new attributes of People ID (responsible manager's ID), Last Name (manager's last name), First Name (manager's first name), Type ID (participant type ID) and Participant Type (name of participant type). These new attributes are unaffected by previous two stages of normalization. On considering the functional dependencies in the relation above, it is noticed that the attribute People ID uniquely defines the Last Name and First Name. Similarly, the attribute Type ID defines the Participant Type. So to transform Bidder-2 into 3NF, the new relations are as follows:

Bidder-3 (BidderID, Bidder Name, Bidder Phone, People ID, Type ID)

People-3 (People ID, Last Name, First Name)

Participant Type-3 (Type ID, Participant Type)

As each of the above relations is in 3NF, so the normalization steps are complete. Therefore, the set of 3NF relations for the Bid Summary Sheet are as follows:

Project (ProjectID, Project Name)

Trade (TradeID, Trade Name)

TradeDetails (ProjectID, TradeID, Budget, StartDate, EndDate, Bid Due Date)

Bidder (BidderID, Bidder Name, Bidder Phone, People ID, Type ID)

Bids (ProjectID, TradeID, BidderID, Bid Pkg. Sent, Bid Received, Bid Amount)

People (People ID, Last Name, First Name)

Participant Type (Type ID, Participant Type)

1.6.10 Data Dictionary

Much of the information concerning the data is specified by means of a data dictionary [Bull 90]. Data dictionary is a set of system tables that contain the data definitions of the database objects. It is independent of any database management system (DBMS). It is an important feature of a DBMS and acts as a general reference tool describing all the data held on the database. There will be a data dictionary for each file (table), with one entry in the data dictionary for each piece of data on the file.

1.7 Focus of the Thesis

The main focus of this thesis is analyzing and managing project information, particularly as a means of tracking down problems on construction projects. It builds on database software called Microsoft Access, and spreadsheet software called Microsoft Excel, where all the relevant information will be well documented and shared by all the parties involved. The system adopts the most commonly used tracking logs and other information sheets on construction sites.

1.8 Overview of the Thesis

Chapter 2 outlines the literature review which is relevant to this thesis. Chapter 3 presents the framework upon which this work is based and describes its steps. Chapter 4 describes the system analysis and design. Chapter 4 also presents entity-relationship diagrams and structural model diagrams of all the user views in the system, including entities and relationship attributes, data volume and usage, suggestions for implementation environment, and physical implementation. The last section of Chapter 4, section 4.10, deals with the prototype development. Chapter 5 presents a summary of the thesis, discusses its application, describes contributions and conclusions, outlines deficiencies in the model, and gives recommendation for future work.

Appendix-A contains matrix (M-1) of construction personnel versus functions. Appendix-B contains work breakdown structure. Appendix-C contains data dictionary. Appendix-D contains the lists of default relationships of tables. Appendix-E contains printouts of the forms. Appendix F presents reports and summaries.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

A number of authors have highlighted the importance of information systems for the construction industry. This section reviews some of the literature which is relevant to this thesis. It first looks at documents, records and reports in the construction industry; then reviews issues of information and construction management, information and information systems, and related works; and finally explores the use of matrix as an analytical tool.

2.2 Documents, Records and Reports in the Construction Industry

2.2.1 Document Classifications

[Sargent 93] classifies engineering documents as follows:

- *Item Document:* an item document is an individual piece of information which is managed as a single unit, such as a letter, an order or a particular revision of an engineering drawing. An item document is never revised. Its contents are fixed when it

comes into existence and never change. It is filed and archived with a unique reference number which, similarly, never changes.

- *Compound Document:* A compound document is a collection of information possibly from several sources, which appears to be a single document to the reader, especially when it is printed and bound as a single report. It is created from many items, updated semi-automatically as the items which they quote are revised by other people in the organization. A compound document can be issued and filed for future reference as a single item document, in which case its contents become frozen at the moment it is issued. A compound document is merely a snapshot of the current status of some set of information: it usually accesses databases to quote the most recent revision of some engineering product, automatically quoting the appropriate item document. Examples include progress reports (quoting directly from company databases), change notices (quoting from engineering drawings), field reports, failure notices and so on.

2.2.2 Project Documentation

During the construction process a variety of documents are generated, depending to some extent on the construction management procedures followed by the organization [Ganeshan et al 94]. Typical documents include submittals (shop drawings, test reports, manufacturers' data, etc.), correspondence, requests for information, change orders, and inspection reports (entered as text, voice or video recordings). Additionally, there may be

other documents generated as part of the project control process such as daily reports and photographs.

[Kangari 95] focuses on arbitrators' perception of the effects of poor project documentation on the arbitration process, and their advice to construction professionals to help them properly record project information before a dispute arises. He presents results of a survey questionnaire collected from arbitrators from seven different US cities. The paper also outlines recommendations made by the arbitrators to a hypothetical client on record keeping, organizing, storing, and securing project documentation and day-to-day job information. The important documents recommended include the following:

- Detailed daily reports outlining work force levels, trade reports, job progress, work descriptions, inspections, equipment used, material deliveries, weather, unusual conditions, and other factors.

- Jobsite log maintained at site and faxed to home office every day.

- Progress photos taken at least weekly and always of critical items, dated, signed and filed.

- Chronological files of all job activities, e.g., delivery tickets, field orders, and payment requisitions.

- All correspondence maintained and answered promptly to avoid problems later.

- Requests for information, change orders, fields directions, shop-drawing submittal log, bid tabulation forms, meeting minutes, estimates, cost records, quantity take-offs, and so on.

2.2.3 Reporting Hierarchy

In order to achieve reporting that allows management by exception, data tractability, and timely response to actual or potential problems, [Gilbreath 83] recommends a structured system of periodic reporting as depicted in Figure 2.1. The documents presented therein show a recommended arrangement of (1) source documents; (2) contractual tracking and compliance documents; (3) detailed contract reports covering schedule, claims, change orders, and backcharges; all leading to a (4) summary report for higher management.

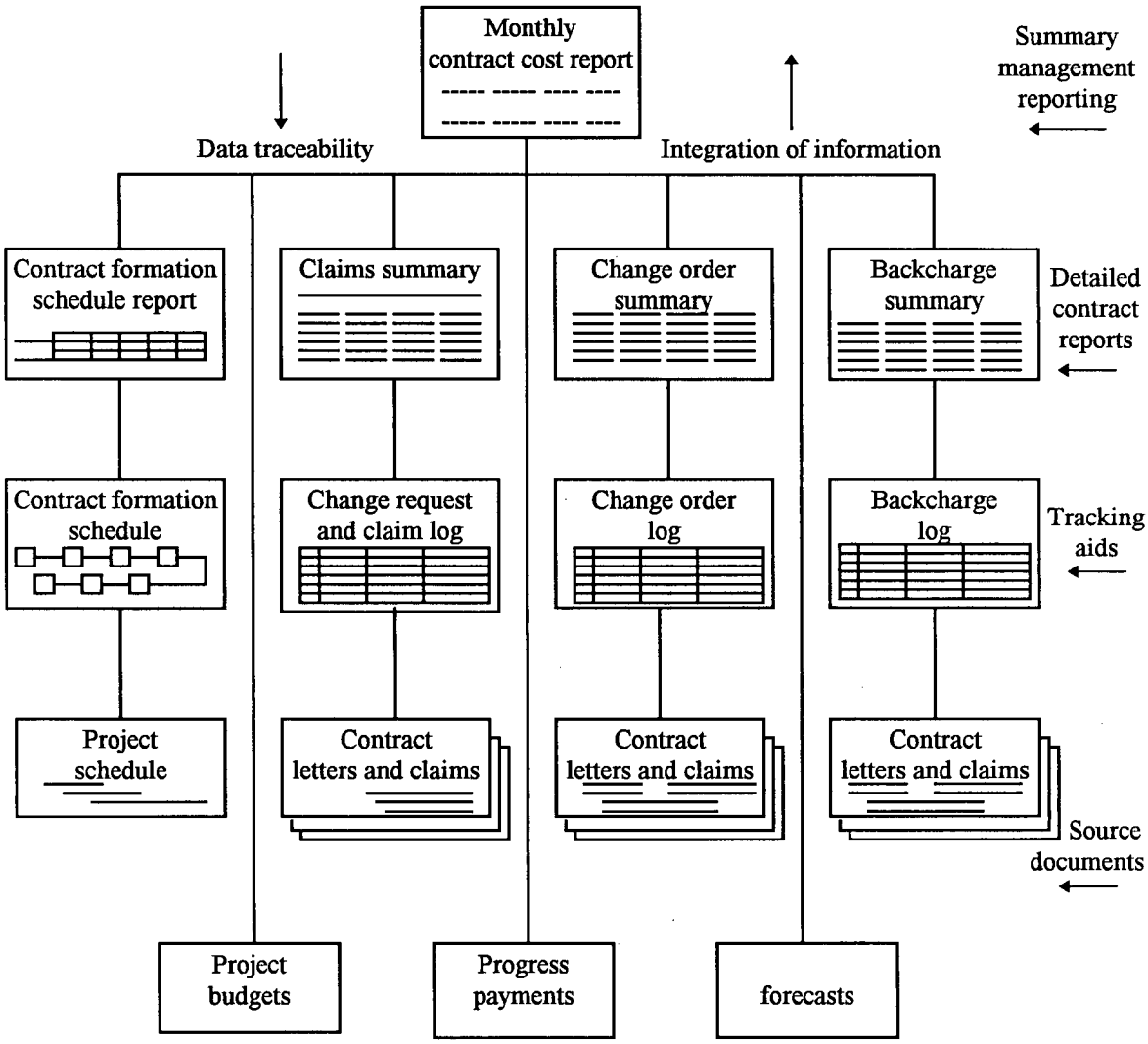


Figure 2.1 Contract Reporting Hierarchy
(Source: [Gilbreath 83], p 252)

2.2.4 Routing of Submittals

[Fisk 93] describes the general procedure of handling submittals (as shown in Figure 2.2) in order to avoid excuses for loss or delay in a submittal or transmittal among architect/engineer (A/E), general contractor, and subcontractors. Such submittals include: shop drawings, samples, certificates, or other similar items.

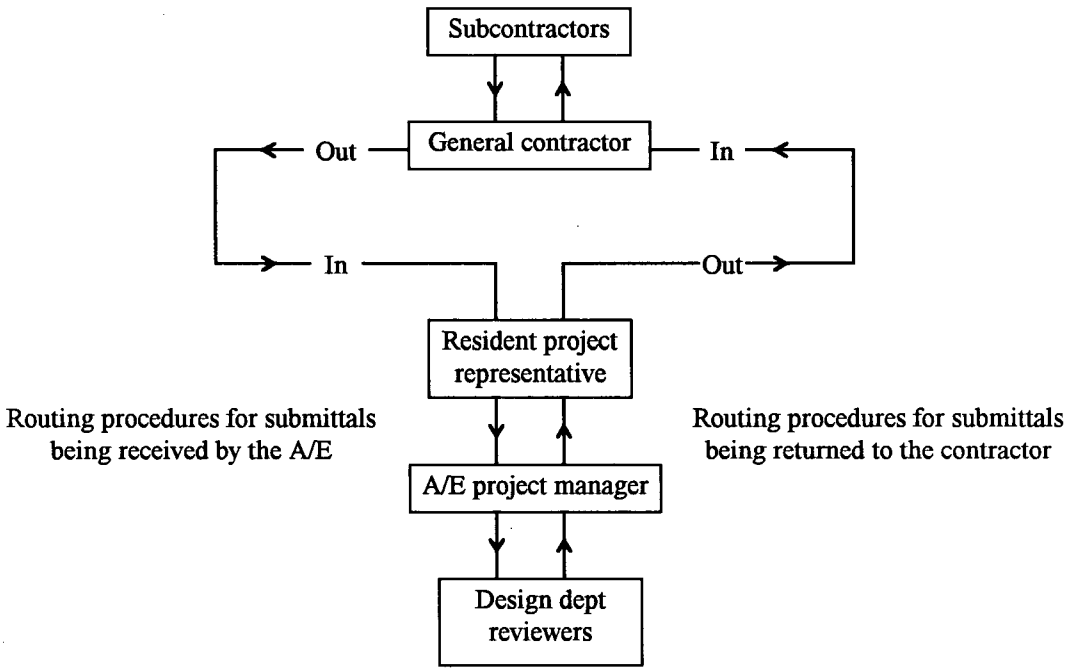


Figure 2.2 Routing of Contractor Submittals
(Source: [Fisk 93], section 17-1)

2.2.5 Computerized Daily Site Reporting

[Russell 93] describes a computerized approach for collecting and processing site information that builds on the traditional superintendent's daily site report, and claims benefit for getting current status of a project; faster response time in dealing with problems; integration of site reporting; project planning/scheduling functions; speedier updating; help in dealing with claims; and documentation of experience in a form useful for future projects.

[Rasdorf & Abudayyeh 92] quotes an example of a Daily Time Sheet and Report to describe the principles and concepts of NIAM (Nijssen's Information Analysis Methodology) modeling methodology for a relational database model.

2.2.6 Computerized Change Management

The inevitable changes on construction projects requires an administrative process, which can be streamlined with computer applications. [Krone 93] discusses the benefits of managing construction change orders with computers over manual methods. The automated method avoids management disorder by maintaining records, providing a clear and timely reminder of who is responsible for the next step in the change procedure, and providing standardized reports.

[Leymeister et al 93] describes a computer application for analyzing and managing change order work at several projects. They illustrate how a well planned database application on a personal computer (PC) proved extremely useful and versatile in processing the voluminous amount of data involved. They also discuss several types of databases which were developed for specific functions needed to analyze the data submitted for each of the contractor's claims. The types of databases used were: labor and equipment database, material database, subcontractor database, labor database, and linked labor and equipment database.

2.2.7 Claims Analysis

One of the problems associated with conducting a claims analysis is the meticulous sorting of project documentation to ascertain pertinent delay information. [Mazerolle & Alkass 93] propose a database management system in a project control process to store information on each delay when it occurs. They further outline the advantage of such system, such as: keeping track of delay information; easy retrieval; and assistance in ascertaining the type of delay, indicating which party is liable, and what actions should be taken.

2.2.8 Photo Records

[Hiroshi & Nobuoh 93] describes a filing system of construction pictures and its integration with a database. Here the proposed system is claimed to have the capability of supplying construction information through joint operation with existing databases which can perform multi-phase retrieval and index transaction.

[Maher 78] suggests that the statement, "A picture is worth a thousand words", be given practical effect by using photograph to help solve the problems occasioned by time-delays in construction projects. Acceptance of a photographic record, properly formed and used to present evidence in time delay situations, would be one method of saving time and money.

2.3 Information and Construction Projects

2.3.1 Construction Personnel Role and Information Needs

[Lock 93] states that the type of information required by an organization depends largely on its business and its people, and it is this organizational environment that determines what information must be provided, how it is to be organized, formatted, and accessed to be useful for aiding decision-making and for the general management process.

[Sanvido & Paulson 92] state that as people progress from lower levels in a site organization to higher levels, they use different information, skills, and knowledge to make new decisions. [Sanvido 88] developed a model representing the functions performed by each level in a hierarchical organization. He also defined the feedback and information required to support the control and planning functions.

[Tenah 86] acknowledges that there is a lack of information in the construction industry regarding functions, responsibilities, and information needs of construction personnel, whereas a manager or supervisor cannot perform his/her functions efficiently without proper information on which to base decisions. He further discusses how the information required by the construction personnel is organized into reports, the contents of the reports, the purpose(s) they serve, and the frequency at which they are issued. In the same paper, he presents results of a field study conducted to determine the information needs of projects and their functional managers. In his concluding remarks he says that, since management functions and management information needs are inextricably linked, there is the need to redefine personnel functions, responsibilities and information needs after revising each organizational structure.

In any project management system, the people who make up that system should be aware of their precise role. The *project responsibility matrix* is a means of achieving this. In the project responsibility matrix all functional specialists who have a role to play occupy a position in the matrix. [Tenah 86] and [Deatherage 64] describe some of the roles and

information needs of key construction personnel. As part of this thesis, Appendix-A presents matrices of construction personnel versus functions and construction personnel versus information needs.

2.3.2 Traditional Information Flow Framework

[Goldhaber et al 77] illustrate a traditional framework of information flow in a construction industry (Figure 2.3). In such a system, it is assumed that all parties and levels of management have the same information and that all must come to the same conclusion. The same reports are generated and distributed to all levels of management. These assumptions do not reflect the actual conditions and information needs of the decision makers. Different decisions are made at different levels. Unless meaningful and timely information is generated, there is no justification of an information system.

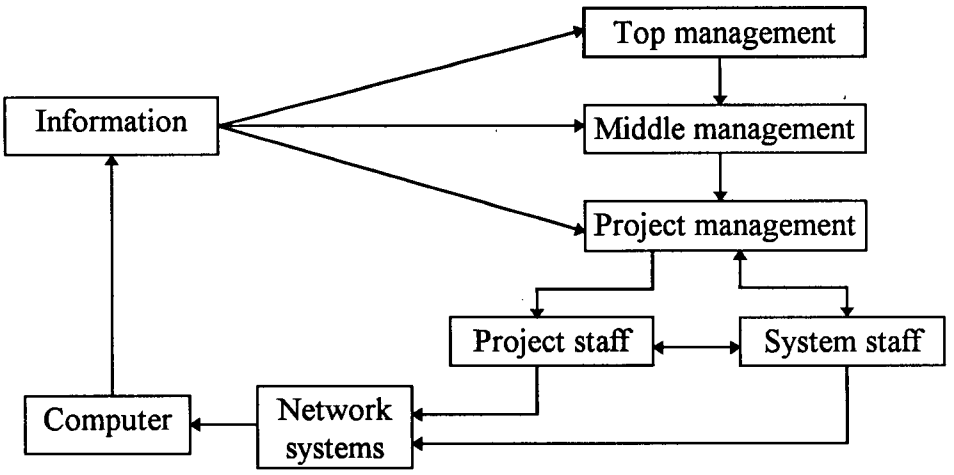


Figure 2.3 Decision makers, information, and decision making in a traditional framework
(Source: [Goldhaber et al 77], p 116)

2.3.3 Information Flow Requirements

For an organization to function properly, it is essential to encourage information to flow freely in all directions, i.e., upward, downward, and laterally [Tenah 83]. The flow of information is a necessity in order to help construction personnel carry out their duties more efficiently and effectively. This allows managers to learn projects and their problems simultaneously so that decisions and instructions can be made quickly. Reports are the key function of the information system. It must be determined who should get what and when, and not to flood the user with more data than he or she needs.

Keeping in mind the importance of information flow and providing the right information, this thesis will also focus on the different sources of information and documents used at construction sites; their purpose, origin, destination, contents, and frequency. As part of this thesis, a matrix has been developed showing the inter-relationship between project information and documents (Appendix-A).

2.4 Information and Information Systems

2.4.1 Information Definition

The concept of information is related to facts, data and knowledge. A fact is something that has happened in the real world and that can be verified [Barton 85]. Data are facts obtained through empirical research or observation. Knowledge is facts or data represented in some way (e.g., reports, lists, letters, etc.) and stored for future reference. Information represents data or knowledge evaluated for specific use. Consequently, facts or data are processed to provide meaningful information.

[Murdick & Ross 75] defines information as "the behavior-initiating stimuli between sender and receiver and in the form of signs that are coded representations of data". [Tenah 83] states that the information is a behavior-affected data. Data differ from information in a sense that data are considered signs, usually recorded observations, that do not affect the behavior of men or machines. However, data may become information if behavior becomes affected. For example, the database for computer systems consists of masses of such signs that are not affecting behavior. Until the data are properly organized for a manager so that he/she reacts to them, they are not information. Thus management information is not just the forms and reports produced. It includes all the data and intelligence—cost, financial, schedule, trend forecast, and control of a particular project or job, as well as the organization as a whole.

[Aoki et al 93] define information not only as measurement data, but also as expertise and construction data collected from previous projects.

2.4.2 Management Information and the Construction Industry

Several authors have emphasized the importance of accurate and timely information for construction project management, e.g. status of project resources [Rasdorf & Herbert 88], labor and equipment costs [Pierce 88], building product information [Çoker 85], overseas projects [Fanous & Samara 94], and project control [Liu et al 94a].

[Fischer et al 94] stress that project managers must devote a significant portion of their attention to the management of information, i.e., ensuring that information is available in a consistent and accurate form and in a timely manner. While giving a background of information systems [Riley & Sabet 94] explain that a construction project involves a large number of individuals, firms, and organizations and develops a considerable amount of information; it is the way in which this information flows between the participants in the project that has a considerable impact on the success of the project. [Fanous & Samara 94] and [Pierce 88] describe that the successful management of engineering and construction projects requires coordination, and control of many diverse activities performed by specialists assigned to the project. Successful coordination and control of these activities require the project manager and his staff to have access to accurate and

current information regarding all facets of project activities. It is also essential that the specialists in each area of the project have the information they need from other disciplines in order to perform their own work effectively and maximize their contribution to the project.

In their paper, [Couzen et al 93] explain that the day-to-day running and strategic planning of any organizations relies upon effective and efficient decision making by the organization's executive and senior management, and that the information forms the basis for such strategic decision making.

[Vanegas 94] writes that during the construction phase of a building project, the different members of the project team, namely, owner, designer, and contractors (including subcontractors and suppliers), need to communicate with each other; exchange technical and management data and information; analyze and comment on these information to resolve issues and make decisions; and, when necessary, negotiate to reach agreements among all parties. Thus, the quality of the total project team decision-making and implementation process is a direct result of the availability and reliability of information.

While introducing information technology, [Vanier et al 93] describe the importance of information in the construction industry. They state that the construction industry is information intensive, and it needs accurate, reliable, and timely information, ranging from legal requirements, building codes and standards, through scientific research, to

manufacturers' product information, and including, finally, site-specific data and past project information. They further state that the need of information is becoming more urgent and more critical as the projects are becoming more complex, and the time frame for decision-making is becoming shorter. They write that there are many reasons for these changes, including increasingly complex projects, the debilitating cost of long term project, and shifting demographic and client requirements. Further, they quote from (Mackinder et al 1982) that the task of managing the vast quantity and variety of information in a professional and timely manner represents a very considerable investment on the part of the construction industry around the world.

Information has always been an important ingredient of construction management, which relies on relevant data for effective management in all its operations [Lock 93]. What is new, however, is the increased pressure on managers to process information more effectively and to integrate them with schedules, finance, market, contractor, and operational data.

[Bhandari 78] writes that, increasingly, we depend on meaningful and relevant information for the growth and health of our endeavors, and for the smooth functioning of our institutions. Information is one of the few resources not in danger of exhaustion on the shrinking planet. It is unique because the supply is limitless. One of the primary reasons for information having proved to be such a dynamic resource is the fact that there exists a remarkable technological capacity for dealing with it rapidly and effectively.

[Burger & Halpin 77] explain that the super-projects pose new and complex logistical and management problems for project managers. The information at the project level is enormous and traditional methods of information handling are not adequate to meet the needs of new management in this environment. Managers need help in controlling information flow at the project level between the project personnel and the participating groups. Hence, new tools are required for the management of information on large construction projects.

In recent years the construction industry has started to take advantage of new developments in information technology, particularly in the field of construction management.

2.4.3 Current Information Problems

[Evt 92] states that the key features of the typical information-handling problems encountered in construction projects are the following:

- Each project tends to be unique. A lot of information is specific to the project at hand.

- Common information exists between different projects. Duplication of effort occurs for firms involved in different projects. The knowledge from one project is typically used over and over again by reassignment of the key personnel.

- Information requirements are very user dependent. Different users need different types of information about a building project.

- Information availability is time dependent. The level of detail of queries varies as the construction project proceeds from planning to design, and to construction and operation stages.

A study, conducted by [Carter 87] on information transmission systems on many construction projects in U.K , shows a considerable duplication of information flow and storage. The study highlights a number of shortcomings of the existing systems, including many files and documents containing information on more than one topic, time-consuming transmittal systems, etc.

2.4.4 Management Information Control Systems

[Kangari 95] defines management information-control systems (MICS) from a construction manager's perspective as a process of documenting transactions (project activity), communicating, and maintaining information by a consistent and ordered

method. He further states that while one use of such systems is the production of reports, the best use is the retrieval of specific, current, and accurate facts necessary for making management decisions. Kangari outlines the types of data controlled by MICS as follows:

- Raw data: basic information that furnishes factual support for technical information; e.g., building codes, test data, and topographical surveys.

- Fundamental documents: written material establishing essential criteria for the project; e.g., contract documents and agreements, project manuals, and master schedules.

- Transaction documents: documents which have as their fundamental purpose the documentation of a specific project activity; e.g., requests for proposal, requests for information, change orders, field reports, and meeting minutes.

- Transaction files: the method by which transactions are recorded through their progression with the project; e.g., RFI log, shop-drawing/submittal log, and bid tabulation forms.

- Technical products: documented results of a technical or analytical effort on the project; e.g., estimates, cost records, quantity take-off, as-built schedules, and value engineering studies.

2.4.5 Computer-Based Information Systems

The purpose of a computer-based information system for engineers is to integrate the collection, processing, and transmission of information so that engineering professionals can gain more systematic insight into the operations and functions they are managing [Lock 93]. This will minimize guess work and isolated problem solving in favor of systematic integrated problem solving. It also significantly reduces the labor cost for generating and manipulating the data for necessary documentation, reporting, ordering or just record keeping.

The computerized information system's primary function is to improve project managers' efficiency in retrieving project information from existing records [Tokar 90].

2.4.6 Information or Problem Tracking

Keeping track of information flow on a construction job site is a vital task that has a direct bearing on the timely completion of a building project [Rasdorf & Herbert 88]. The major challenge of today's project manager is tracking vast amount of details [Pierce 88]. Recording and tracking the primary categories of information: subcontractors' bidding, change orders, work progress, progress payment, labor and equipment cost, etc. are the

direct concern of the project manager or anyone else who is involved in controlling the construction process.

Responsibility tracking is a function of information systems that holds great potential for improving project management [Tokar 90]. The inclusion of a subjective coding field called "responsibility" can identify the responsible person and express a time frame for action. The data base can then be sorted and selected to produce action lists for management personnel.

The information looses its reliability, accuracy, and value when the manager receives too much or scanty information ([Bhandari 78], [Tenah 81]). The purpose of an information system is to provide the project manager with a record of each piece of data, including where they are at any time in the process [Pierce 88]. In this way, the project manager can follow up on those items that are not progressing through the process quickly enough, and take action to ensure timely delivery of material to the job. The system should also allow the project manager to find out which parties are consistently holding up the process. In the event of a claim for extension of time or other compensation, the project manager can use the tracking records to make a case concerning other causes of delays to the job.

2.4.7 Information Model

The design of a computer-based information system for the provision and interchange of information within a project implies that the real-life project can be modeled in a way that allows functionality in the computer system [Riley & Sabet 94]. This information model should cover the facts about all the products and processes needed to construct these products. But the design of such an information system represents a major task. This is due to the substantial amount and different types of information generated within a project, the variety of project type, the considerable amount of different experts involved, the vast and growing number of building materials, the complicated links and process involved in the project, variation of national and regional standards, diversity of client requirements, etc.

[Froese 93] defines an information model as a collection of information about a specific real-life object, and states that the information model should fulfill the following requirements:

- *General usefulness:* many different application will use the models for performing different functions.

- *Richness:* the model must capture significant levels of detail.

- *Comprehensiveness:* the scope must include a wide breadth of project information.

- *Flexibility:* flexibility is required both in what information can be represented (e.g., numeric parameters, graphical descriptions, logical relationships, etc.) and in how the information can be used.

[Aouad et al 93] describe the major approaches to information modeling in the construction industry, and they are: data modeling; activity modeling; and product modeling.

2.4.8 Entity-Relationship (E/R) Model

[Date 90] claims that the entity/relationship (E/R) approach is one of the best and most widely used approaches for modeling conceptual information structures. He quotes the definitions of entities, relationships, and attributes from Chen (22.10). An entity is defined as "a thing which can be distinctly identified". A relationship is identified as "an association among entities". Entities and relationships have properties (also known as attributes).

Entity-relationship diagrams are one means of formally expressing a data model [Bamford & Curran 91]. Basically, the entity-relationship data model augments a basic network model by introducing a special symbol, the diamond, to explicitly indicate each

relationship [McFadden & Hoffer 88]. Figure 2.4 illustrates the E/R data model. Each diamond represents a relationship type; this diamond exists for both 1:M and M:N (one-to-many and many-to-many) relationships between entities (rectangles). Attributes are associated with entities and represented with an ellipse.

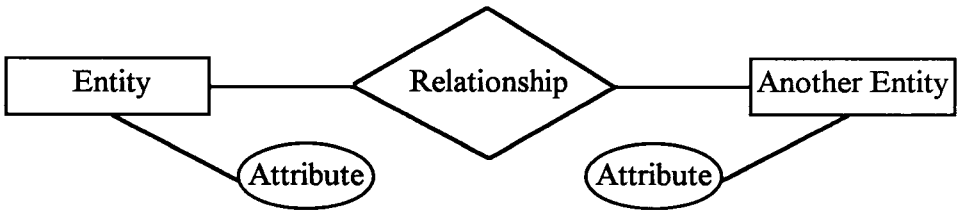


Figure 2.4 Entity-Relationship Data Model Examples

2.4.9 Structural Data Model

Choosing a good data model to represent design data and processes is a major step towards the development of an integrated system [Law & Scarponcini 91]. A data model is a collection of well-defined concepts that help the database designer to consider and express the static properties (such as objects, attributes and relationships) and the dynamic properties (such as operations and their relationships) of data intensive applications. In addition to enhancing the database design process, a data model needs to provide the integrity rules to ensure consistency among the entities.

The ultimate objective of the semantic modeling activity is to make database systems some what more intelligent [Date 90]. The goal in selecting a semantic data model is to represent directly in an easy form as many of the objects and their relationships of interest as possible. The structural data model that is used is an extension of the relational model [Law & Scarponcini 91]. Relations are used to capture the data about objects and their parts. The structural data model augments the relational model by capturing the knowledge about the constraints and dependencies among the relations in the database.

The primitives of the semantic data model are the relations (which roughly correspond to entities in the E/R model) and the connections formalizing relationships among the relations. There are three basic types of connections, namely ownership, reference, and subset connections [Law & Scarponcini 91] (Figure 2.5).

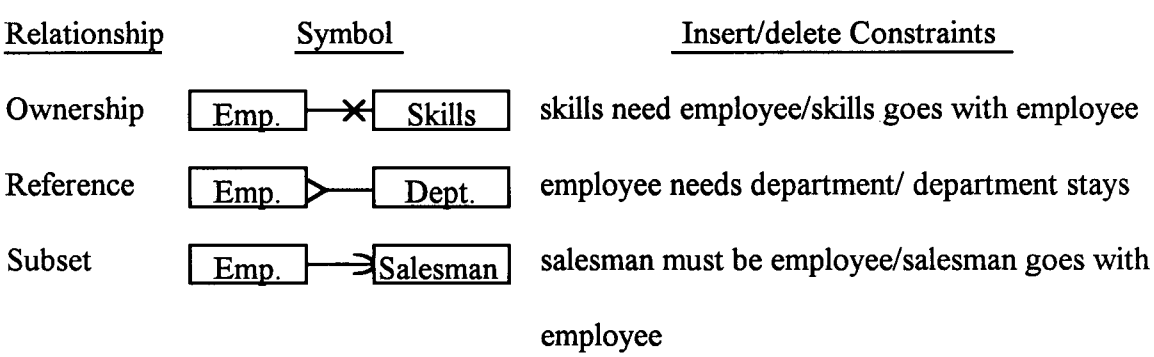


Figure 2.5 Structural Data Model Examples

In the words of [Law & Scarponcini 91], the structural data model can be explained as follows:

The connection between two relations R_1 and R_2 is defined over a subset of their attributes X_1 and X_2 with common domains. An *ownership connection* between an owner relation R_1 and an owned relation R_2 describes the dependency of the multiple owned tuples on a single owner tuple. The ownership connection implies that the owned tuples are specifically related to and dependent on a single owner tuple. As an example, a building structure may consist of structural elements, floor, foundation, roof, space, etc. The components exist if the building exists. This connection type specifies the following constraints:

- Every tuple in R_2 must be connected to an owning tuple in R_1.

- Deletion of an owning tuple in R_1 requires deletion of all tuples connected to that tuple in R_2.

- Modification of X_1 in an owning tuple of R_1 requires either propagating the modification to attributes X_2 of all tuples in R_2 or deleting those tuples.

A *reference connection* between a primary (referencing) relation R_1 and a foreign (referenced) relation R_2 describes the dependency of multiple primary tuples on the same

foreign tuple. As an example, an architectural space, which may be an office, elevator, opening, etc., locates on a floor. The floor can not be removed without first removing the spaces defined on that floor. This connection type specifies the following constraints:

- Every tuple in R_1 must either be connected to a reference tuple in R_2 or have null values for its attributes X_1.

- Deletion of a tuple in R_2 requires either deletion of its referencing tuples in R_1, assignment of null values to attributes X_1 of all the referencing tuples in R_1, or assignment of new valid values to attributes X_1 of all referencing tuples corresponding to an existing tuple in R_2.

- Modification of X_2 in a referenced tuple R_2 requires either propagating the modification to attributes X_1 of all referencing tuples in R_1, assigning null values to attributes X_1 of all referencing tuples in R_1, or deleting those tuples.

A *subset connection* between a general relation R_1 and a subset relation R_2 links general classes to their subclasses and describes the dependency of a single tuple in a subset on a single general tuple. For example, a structural element can either be a column, a beam, a wall, or a slab. Furthermore, a beam can be generalized to be either a main girder or a joist (secondary beam). Deleting a specific instance in the generic class of structural element

must delete the corresponding instance existing in the subclass. The subset connection specifies the following constraints:

- Every tuple in R_2 must be connected to one tuple in R_1.

- Deletion of a tuple in R_1 requires deletion of the connected tuple in R_2.

- Modification of X_1 in a tuple of R_1 requires either propagating the modification to attributes X_2 of its connected tuple in R_2 or deleting the tuple in R_1.

2.4.10 Users Interface

[Townsend 92] defines different interface terms as follows:

- **Interface:** The way that users communicate with a computer system. In a database, the interface consists of elements such as menus, forms, tables, reports, and queries.

- **Graphical User Interface (GUI):** A design in which a computer interacts with a user by means of graphical menus and symbols rather than a command language. Microsoft Windows, the Apple Macintosh, and GeoWorks are examples of graphical user interface.

- **Programming Interface:** A user interface based on a programming language especially suited to database applications. The first PC database packages to appear were based on programming languages.

- **Spreadsheet Interface:** This is one of the world's most popular user interfaces.

- **Form-Oriented Interface:** An approach to database design that uses paper forms as a model for building tables. This type of interface keeps programming to a minimum, and employs some of the gadgets found in the Windows operating system like fields, menus, buttons, drop down menus, and scroll bars.

2.5 Related Work

2.5.1 Expedition

One contract control software for engineering & construction, *Expedition Version 4.2* by Primavera Systems, Inc., is worth mentioning since it is developed specifically for the construction industry. Expedition can help to accomplish every task, from reviewing a submittal to making notes from a telephone call, or double-checking approvals on a change order. It helps to file, track or retrieve any contract information. Appendix-F

contains the output reports produced by the prototype of the system, PMICS, which are comparable to the samples shown in the Expedition literature [Expedition 95].

2.5.2 Resident Management System (RMS)

RMS is a DBMS developed by the U.S. Army Corps of Engineers (included in the Related Work listing [Ganeshan et al 94]) to support the 3-phase inspection process used by the Corps to administer construction projects. In this system, features of work are divided into related work activities. The contract requirements (e.g., shop drawings, test results, etc.) for each activity are maintained with that activity. It also helps to write and track modifications, manage contract finances, process progress payments, and contract correspondence.

2.5.3 Centex-Rooney's Jobsite Program

Centex-Rooney's Jobsite Program [Barnes 93] is a custom-designed proprietary program developed by Centex-Rooney of Florida. This system came into being from a long-felt need on the owner's part to have better control over the status of shop-drawing submittals, change orders, materials flow, requests for information, and the administrative status of subcontractors and suppliers.

2.5.4 MULTROL

MULTROL, a multimedia project control and documentation system [Liu et al 94], was developed for the PC platform and runs under Microsoft Windows™ operating environment. This system uses a graphical user interface for all operations, creating a user-friendly environment for construction personnel. The retrieval of project information is further assisted by user definable queries to support various needs of construction management. This system allows the storage and retrieval of project information in the format of text, image, video, and sound.

2.6 Matrix as an Analytical Tool

One of the initial tasks of an information systems design is the requirements analysis. Such task includes study of the environment, users of information and their information needs, and sources of information. To deal with these problems, some sort of analytical tool is required. The tool may be descriptive, illustrative or graphical.

[Tenah 84] presents a method of preparing and routing management reports which allows managers to receive information and take action simultaneously, information to flow in all directions, and managers to think ahead and be prepared for major commitments. The method used is a graphical reporting structure in a form of Management Recipients/Summary Reports matrix. This matrix shows the report(s) each manager or

supervisor receives to perform his role. [Lock 92] describes document/distribution matrix as a useful tool for information and documents flow. [Peters 84] recommends to use a project/responsibility matrix to define the responsibilities of projects participants.

[Benyon 90] describes a data/process matrix to verify data and process for information modeling. [Barton 85] proposes various tools for a systems design, applied to the construction industry, investigation in order to obtain a model of problem identification. These tools include hierarchy business models, personnel/functional matrices, and data flow diagrams. The personnel/functional matrix, as contained in the literature, indicates the relevant staff involvement.

[Cleveland & King 83] present some of the graphical analytical tools, and the tools are the following: tree diagram, matrix and lists. A tree diagram is a model hierarchy which is useful in organizing project entities, and is used to track deliverables remaining. It is suggested to use a matrix model to collect information concerning roles of different individuals. A matrix model is useful when two or three entities are related. A list is merely an account of items and is similar to a check list.

2.7 Summary

The literature review has identified several issues concerning information in the construction industry. Timely and accurate information is a necessity for the successful completion of a construction project. Too little information is of no use. Too much information often gets no attention. Before designing an information system for the construction industry, it is useful to identify the information needs of active project team members. Unfortunately, this area has received little attention by researchers in the construction industry. It is also revealed that information follows functions. It is discovered that one way of finding out the information needs of construction personnel is to adopt a matrix approach. A number of matrix models can be developed for this purpose, namely: personnel versus functions; personnel versus information needs; and information versus documents. It is also identified that, for managing information in a construction environment, a database approach is the most effective and desirable. This approach can reduce redundancy of data and can improve the effectiveness of an information system. This literature review also aided in the development of objectives, scope, and a framework for the development of a construction information system. Several technologies pertaining to database management systems (DBMS) have been identified. In brief, the system description in the following chapters derive from the outcome of the literature search.

Chapter 3

FRAMEWORK

3.1 Introduction

This chapter presents a framework for the development of the Project-Management Information Control Systems (PMICS). Although no single methodology or standard approach is used for this purpose, the techniques presented are representative of those proposed and suggested by various researchers and authors.

3.2 Framework for PMICS Development

As stated in the previous chapter, in order to provide an organization with an effective information system, a holistic approach toward data and information is required. A model (Figure 3.1) has been developed as a framework for PMICS development for this thesis. This model is based on the following: 'Proposed Conceptual Integrated System' model [Sadri & Kangari 93], 'Design and Implementation of a CIM Information System' description [Chadha et al 94], 'Data Base Planning' description [McFadden & Hoffer], and 'Designing Information System' outlines [Barton 85]. The basic idea behind this framework is to provide a platform for the proposed information system design and its implementation.

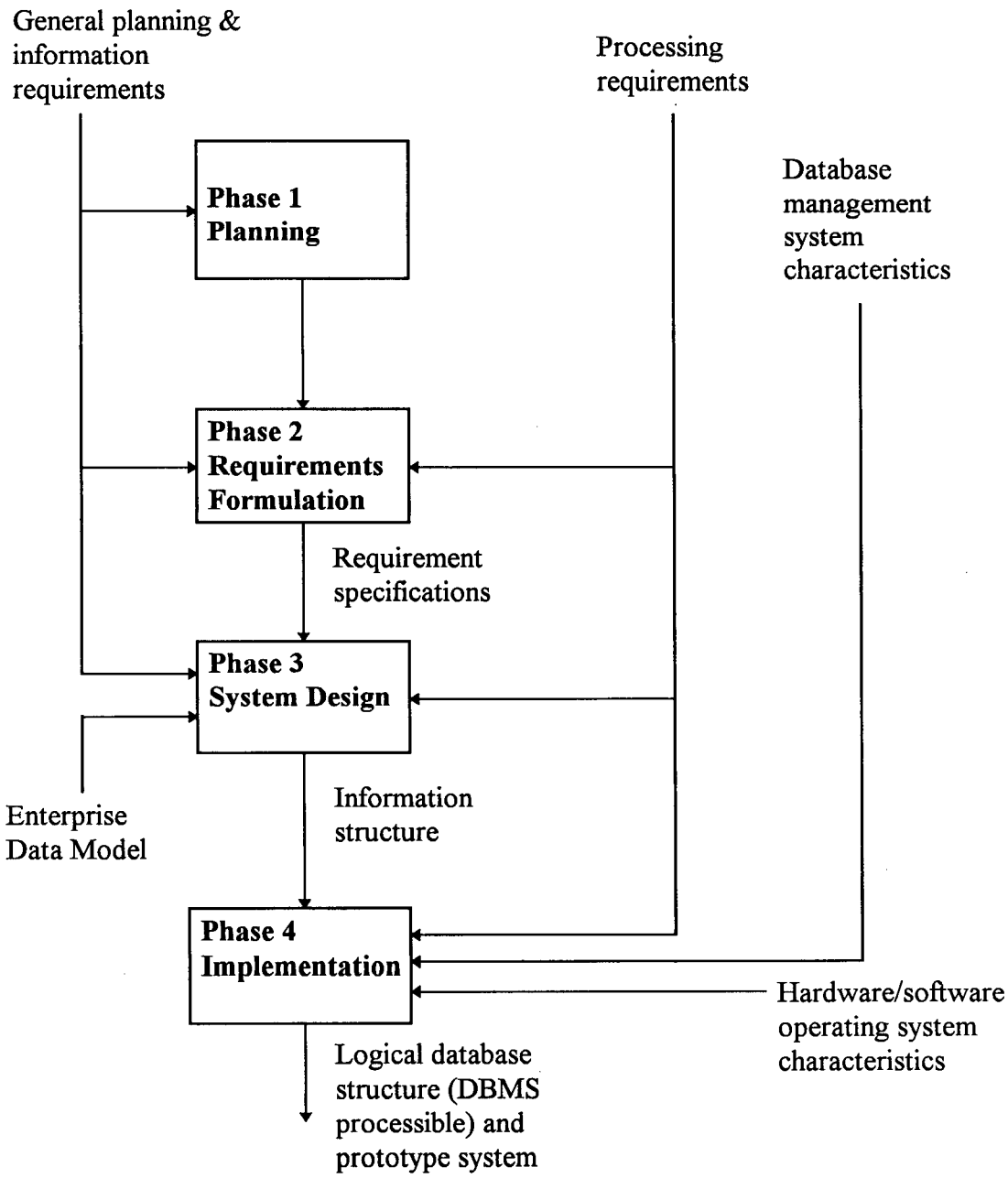


Figure 3.1 Proposed System Development Framework

The development of a potential database application for information control within a construction project environment requires a thorough understanding of all the data sources and their uses. Figure 3.1 is a graphical representation of the proposed system development framework. The model includes four phases: Planning, Requirements Formulation, System Design, and Implementation. Each phase includes different steps and procedure, and identifies its final product.

3.2.1 Planning Phase

The first phase of database system development is planning. Planning is essential if the benefits of data resource management are to be utilized. The following steps, shown in Figure 3.2, will be followed to provide necessary information for the next phase.

- ***Business Environment and Strategy Definition:*** involves the development of a model or definition reflecting the strategic plans of the organization, business environment, business planning, and critical issues. Business environment means internal and external environments in which the organization now exists and will exist over the strategic planning horizon.

- ***Existing Information System Assessment:*** involves assessment of the existing information systems of the organization based on data generating sources, data

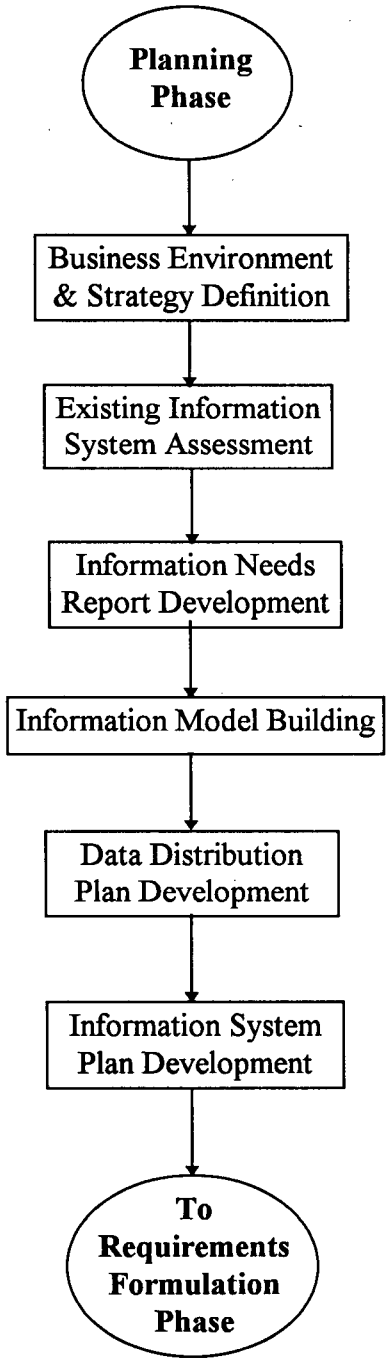


Figure 3.2 Phase I - Planning

classification and processing procedure, and the information generated as the users requirements.

- ***Information Needs Report Development:*** involves identification of the type and attributes of information needed based on the functional requirements. It is not related to the organizational structure, but based on the need report.

- ***Information Model Building:*** involves in the development of an information architecture which identifies the functions, processes, and activities for the organization. This model shows the relationships between important business entities.

- ***Data Distribution Plan Development:*** involves development of a plan of data distribution or transfer within the organization. The home office of the organization may be away from the construction job site.

- ***Information System Plan Development:*** includes the overview of the system design. Design must support the goals of each business area and satisfy user requirements.

3.2.2 Requirements Formulation Phase

The purpose of requirements formulation and analysis is to identify and describe the data

that are required by the organization. It defines the purpose of the database, the scope of information to be contained in it, and the desired functionality. The following steps, shown in Figure 3.3, will be followed to provide the necessary information for the next phase.

- ***Database Scope Definition:*** involves the definition of goals and objectives of the database for the organization. This requires establishing a scope for the database in terms of what business areas or functions are to be addressed.

- ***User Views Identification:*** involves identifying user views by reviewing tasks that are performed or decisions that are made by users and by reviewing the data required for these tasks and decisions. A user view is a description of a user's view of data in a database.

- ***Data Source Identification:*** involves an analysis of data classification (type and format), data generator and user of data and their relationship. An information flow chart for the organization is drawn. This step may be combined with conceptual model design steps.

- ***Reporting Requirements:*** involves listing the printed reports and their appearance that the system must produce, some of which may be modeled on existing reports and lists.

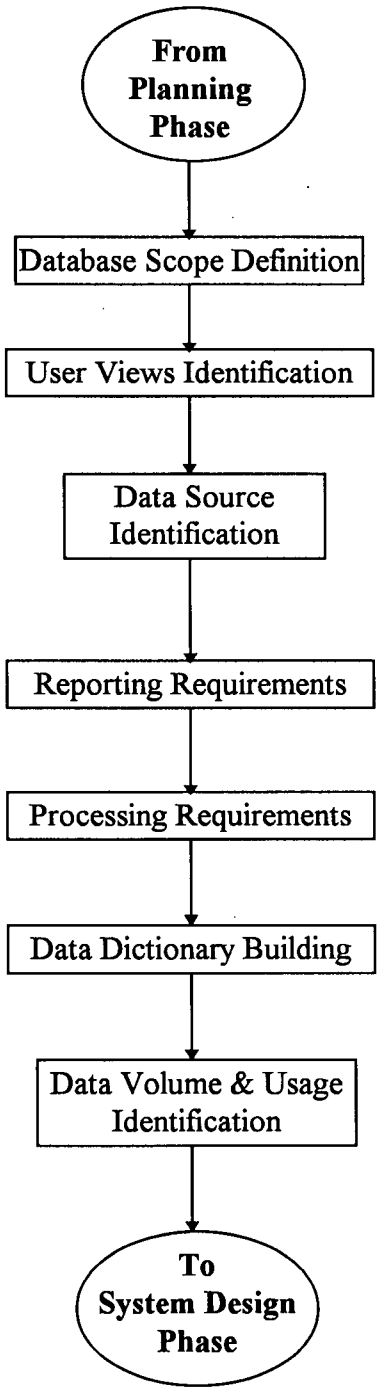


Figure 3.3 Phase II - Requirements Formulation

- ***Processing Requirements:*** involves identifying the various processing functions, e.g., calculations, posting totals, transfer of information, archiving and deleting data, etc.

- ***Data Dictionary Building:*** involves defining and describing in detail each data item type that appears in a user view. It is created by building a table containing all the fields to be used, and showing the field name, type, length, and description. It describes the objects and their functions in the system. Development of a data dictionary helps in creating standards in the system.

- ***Data Volume and Usage Identification:*** involves collecting information concerning data volume and usage patterns, including future growth. Collecting these data is another step in requirement analysis, however, it is best performed after the conceptual modeling is completed.

3.2.3 System Design Phase

This phase involves the transformation of the requirements set by the two previous phases into a system specification and design of an interface with the end user. The following steps, shown in Figure 3.4, will be followed in this phase.

- ***File Organization Scheme Development:*** involves developing an organization scheme for construction documents. Information generated during the construction process, such as specifications, estimates, drawings, submittals, change orders, correspondence, etc., need to be organized according to some standard code or in a similar fashion.

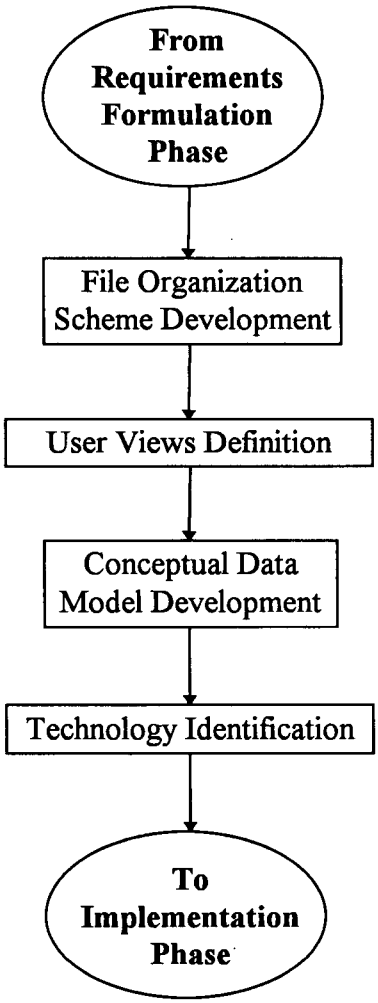


Figure 3.4 Phase III - System Design

- ***User Views Definition:*** involves reviewing and defining in detail all the information or data required as output before starting conceptual data modeling. All the main entities to be tracked in this application are listed, including the character of each entity and the required system output.

- ***Conceptual Data Model Development:*** involves identifying data items and their relationships. The conceptual design of a database starts with the definition of the requirements and produces a conceptual schema of the data. This is the most important aspect of the database design because it describes the organization and scope of the information to be stored in the implemented database and is independent of any particular Database Management System (DBMS) implementation. A conceptual model helps describe the entities to be tracked, their relationships, and the business rules that govern those entities. The steps in conceptual design include data modeling (using Entity-Relationship methodology), view integration, conceptual schema development (semantic data methodology), design review, and logical access mapping.

- ***Technology Identification:*** involves studying and identifying available technology and the incorporation of future technology into the system. At this stage the most suitable hardware and software for the proposed system is identified.

3.2.4 Implementation Phase

This phase is concerned with mapping the conceptual model to a logical database structure. This is the final phase of the system development. The important issue here is to make sure that the implementation follows design specifications and user requirements as identified in previous phases. The following steps, shown in Figure 3.5, will be followed in this phase.

- ***System Hardware and Software Selection:*** involves selecting the system hardware and software based on the previous step of technology identification. The selection of hardware will be based on two principles: first, the project participants move from one construction project to another, and second, the construction job site is the most important place to use the system. The selection of software will be based on the choice of easy-to-use data managers and compatibility for personal computers (PC's) running Windows version 3.1 or higher. The user interface will be developed with the standard Windows user interface.

- ***Prototype System Development:*** involves developing a working model of the finished application that fulfills most of the system's requirements. The purpose of prototype is to demonstrate the idea of using a PMICS for information handling

during the construction phase of a project. It will be simple but will realistically demonstrate all database functions. At this stage, all the forms, reports, menus, and queries will be designed, with frequent user-views evaluation. Following the results of evaluations of the forms and reports, the database will be refined, as required.

- ***Performance Evaluation:*** involves monitoring the performance of the system. The system performance for typical queries will be estimated.

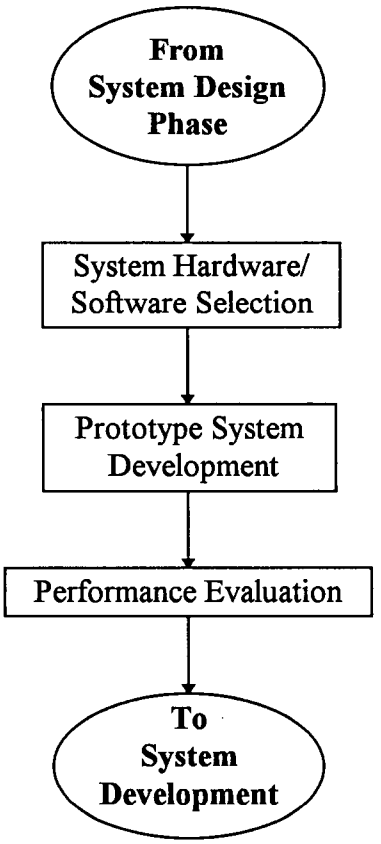


Figure 3.5 Phase IV - Implementation Phase

3.3 PMICS - Project Management Information Control System

An important part of this research is a prototype system. This section outlines the phased development methodology. This methodology is the result of methodologies present in the literature. The prototype system development and implementation involves almost all the steps mentioned in section 3.2. However, the system analysis and design (Chapter 4) does not completely follow the same sequence as outlined in section 3.2.

3.3.1 Objectives of PMICS

The main objective of this program of research is the development of a prototype information control system for a construction firm. The prototype focuses on the support of the important information requirements of one particular aspect of a construction organization, i.e., information control. The PMICS also serves, however, as a template for similar development on a wider scale, rather than focusing on the information during the construction phase only.

3.3.2 Planning for PMICS

This research uses, as a case study, an information tracking database application for an imaginary construction organization, ABC Construction Company. Although the example

is hypothetical, it does contain many of the elements of a real construction environment. Section 4.1.1 describes the business environment and strategy. Section 4.1.2 includes the description of organization's existing information system, its information needs, and data distribution plan. Section 4.1.3 presents information flow-diagrams.

3.3.3 Requirements of PMICS

Section 4.1.4 describes the database application scope. Section 4.1.5 presents the selected user views for the system. Section 4.1.2 describes the reporting requirements. Section 4.4 contains data source identification and processing requirements, in addition to conceptual data modeling. The data dictionary is listed in Appendix-C.

3.3.4 System Design of PMICS

Section 4.3 defines the file and document organization schemes. Section 4.4 describes thirteen user views. Section 4.4 through 4.9 deals with the conceptual data modeling. Section 4.10 presents the implementation and prototype development.

Chapter 4

SYSTEM ANALYSIS AND DESIGN

4.1 General Description

Construction projects progress through various life-cycle stages, for example: tender, award of contract, pre-construction, construction, and commissioning. In this thesis, the emphasis is on the pre-construction and construction stages.

After a construction contract has been executed, all the bids from suppliers and subcontractors are reviewed so that contracts can be awarded and other commitments firmed up to start the flow of labor and materials to the job site. During these stages, the project manager needs information to make important decisions. This information may include: bid summaries, subcontractor interview forms, subcontracts, purchase orders, and various tracking logs (submittal, change order, payment, field reports, site photograph, stored materials, punch lists, correspondence, etc.).

Given the bulk of information associated with construction projects, a formal organization of the information is essential so as to avoid chaos. Effectively managing this bulk of information to ensure its availability and accuracy is an important managerial task. Virtually all medium and large-size construction firms have computer-based organization

of cost accounts and other data. With the advancement in computer technology as well as in data base management systems (DBMS), it is possible to develop a computerized database for even small organizations and projects.

4.1.1 Description of Users

This system is intended to be used by managers of the fictious ABC Construction Company, a small to medium-sized construction company. Although this company is a hypothetical, it does contain many of the elements of a real construction company. The company works as a general contractor on most of its ongoing projects and employs a number of trade subcontractors.

An organizational chart for ABC Construction Company is shown in Figure 4.1. This company employs a number of managers to manage projects. Each manager is assigned specified functions and responsibilities. Every manager prepares or receives a number of periodic reports, including progress reports, daily reports, cost reports, project control reports, etc. Currently, the company has computers to do accounting, word processing, and spreadsheet procedures at their home office as well as at all project sites. Some of the information is maintained by individual managers or staff, either manually or using software less suited to database management.

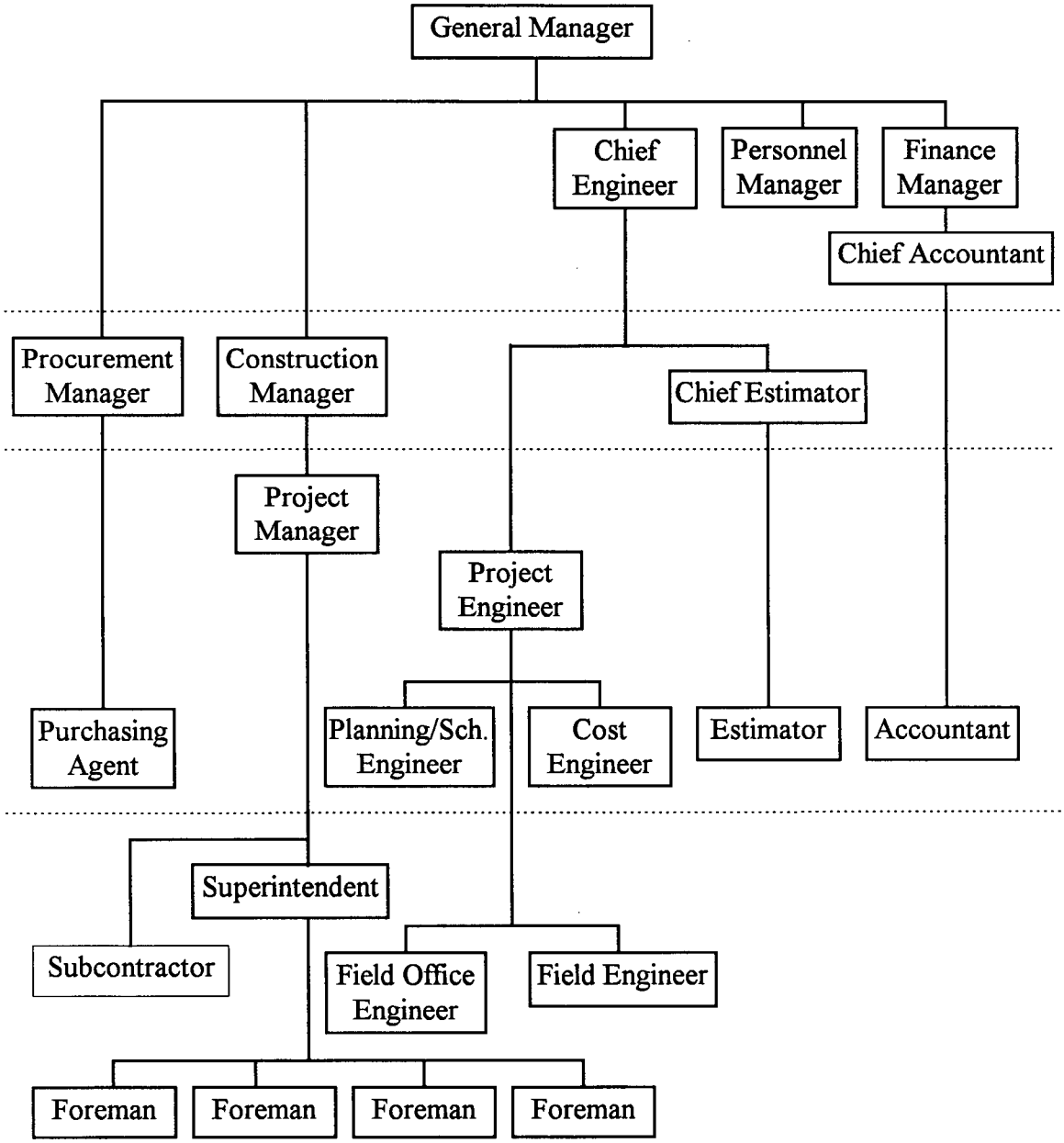


Figure 4.1 ABC Company Organization Chart

4.1.2 Background for the Application

As the number of projects is constantly growing, the company needs a project-information tracking system capable of tracking information from project sites. The project management staff normally prepare all the reports and tracking logs. Information is gathered by the project's office engineer and entered into various tracking logs, on paper or in the computer. The project manager receives information on printed forms from various sections or sites. There is a lot of duplication. The company wants to consolidate all of its project-information, eliminate duplicate information, and do more frequent expediting of work.

The most important and frequently used reports or tracking logs are the following:

- Bill-of-Quantities,
- Bid Summary Sheets,
- Change Orders Tracking Log,
- Correspondence Tracking Log,
- Daily Site Reports,
- Defective Work Notifications Tracking Log,
- Materials Stored Tracking Log,
- Monthly Progress Reports,
- Photographs Tracking Log,

- Punch Lists,
- Requests for Information Tracking Log,
- Shop Drawing Submittals Tracking Log, and
- Spare Parts Tracking Log.

Most of the above are prepared on computer (spreadsheets). As some of the information is repeated on more than one report, the idea is to integrate these information into a PMICS in order to allow the user not only to have quick access to information, but also to transfer the information to all project team members and at the same time reduce duplication. As far as possible, the appearance of reports will remain the same as that of the existing one (as shown in Appendix-B). As most of the job-sites are geographically away from the home-office, it is decided to have information distributed to managers through modem, hard copy, or printed reports.

4.1.3 Information Model Building

The information in construction environments is complex and involves numerous processes and functions. Models are therefore needed to logically break these environments into manageable pieces. Although the environments can be seen from various view points in the model, this section describes the modeling of construction environment from an information flow standpoint.

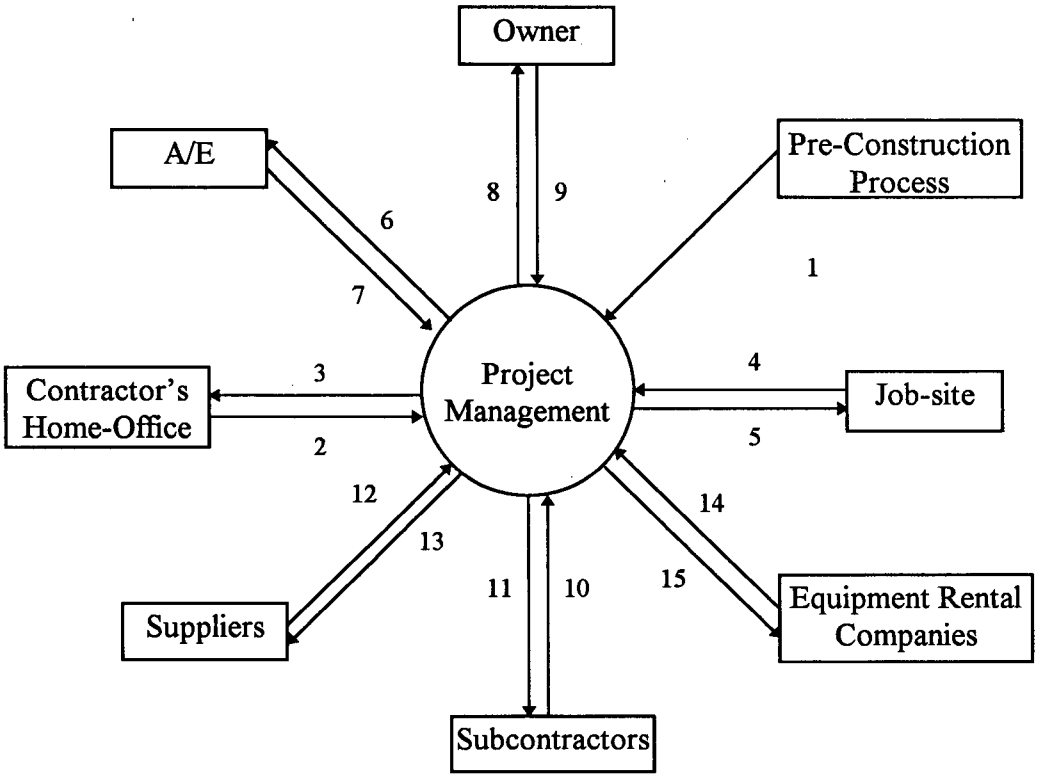
4.1.3.1 Modeling the Construction Project Environment

Figure 4.2 shows a participants/information-flow diagram. After establishing the information needs, it is necessary to model the construction environment and its information flow.

On most construction projects, the common parties who participate in the construction process are the following: project management team, contractor's home-office, owner, architects/engineers (A/E), subcontractors, suppliers, and equipment rental companies.

4.1.3.2 Modeling the Documenting/Reporting Process

The internal/external information attributes are discussed in terms of the three principal groups identified by [Skitmore 89]: (a) project related; (b) organization related (internal); and (c) market related (external). Figure 4.3 shows the data flowchart of information with the relationships established internally and externally to the program. In this figure, the circles represent job-site program activity, the rectangles denote interactive data sources, the single arrows denote the data flow, and the double-sided arrow denotes data-out as reports and logs, and data flow into the system..



Legends:

1	project information	9	payment
2	home-office information	10	quotations/sub information
3	information for head-office	11	instruction
4	checks/progress statement	12	supplier quotations
5	supervision	13	requisitions to supplier
6	inquiry/submittals	14	plant quotations
7	confirmation/inspection	15	requisitions to equipment
8	payment request		rental companies

Figure 4.2 Participants/Information-Flow Diagram

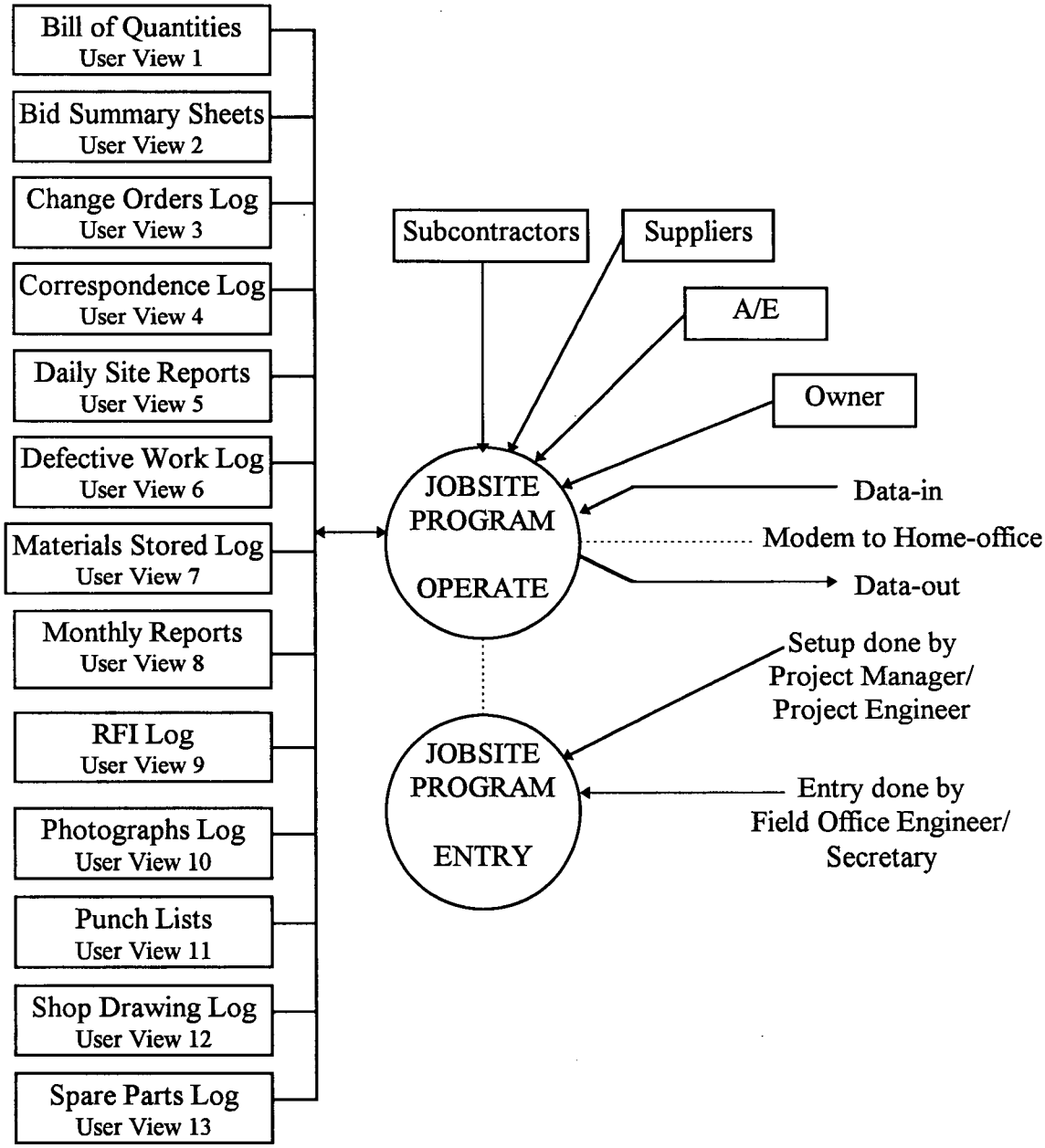


Figure 4.3 Data/Information-Flowchart

4.1.3.3 Data Entry and Updating

Most of the data from the pre-construction phase do not require any updating. However, other data need daily or periodical updating. On a daily basis, the system receives information from all project team members. Each report generated by the team members is accumulated and entered into the system, and is shared with all users as soon as it is generated.

As many default values as possible must be used to minimize the amount of information that has to be recorded by field personnel on daily basis [Russell 93].

4.1.4 Objectives and Scope of the PMICS

The PMICS is intended to be a user-friendly application that is easy to access by the different project team members. Form-oriented user interface is desired. The basic objectives are as follows:

- to understand the information needs of a construction project team;
- to develop data flow models of a construction project;
- to develop an information model for the selected user views;
- to design and implement the database and application/user interfaces; and
- to provide specifications/requirements for the future systems.

Other objectives and scopes are as follows:

- to bring the project information management function more accessible.
- to increase the frequency and efficiency of reports.
- to gain more and timely picture of project information.
- to eliminate redundancy and standardize the format used for the various reports.
- to reduce the amount of time spent recording, preparing, and posting reports.
- to track the status of project and its various activities.

4.1.5 Selected User Views

As described in section 3.2.2, requirements analysis is the process of identifying and documenting what data the users require in the data base to meet present and future information needs. Traditionally, there are two approaches for requirements analysis: process-oriented approach which focuses on data flows and process, and data-oriented approach which focuses on the data that must be included in the database to satisfy user requirements [McFadden & Hoffer 88]. The latter approach, i.e. data-oriented approach, is applied for the proposed application. The principal tools are user view analysis, data definition and description, and normalization.

A user view is defined as a subset of data required by a particular user to make a decision or carry out some action [McFadden & Hoffer 88]. User views are identified by reviewing tasks that are performed or decisions that are made by users and by reviewing the data required for these tasks and decisions. Existing reports, tracking logs, files, documents, and displays are the important sources of information of user views.

The literature review has identified functions and information needs of different construction personnel. Findings are depicted in Matrix M-1 (Figure A-1, Appendix-A). This matrix covers all the possible functions of construction personnel during construction phase of a project, including general management, accounting/financing, personnel management, engineering, estimating, planning, project management, construction management, site management, procurement, and safety.

The matrix M-1 is short listed to produce a construction personnel versus functions matrix M-2 (Figure 4.4). The matrix M-2 focuses on the project management functions. The matrix M-2 is used as a basis for the development of the third matrix M-3, construction personnel versus information needs (Figure 4.5). The next task is to identify documents which contain these information. The fourth matrix M-4, document type versus information content (Figure 4.6), serves the purpose. Based on Matrix M-4, several user views are identified. However, only thirteen distinct views will be used in the system development. The sample documents of the various user views (tracking logs, reports, and

lists) are depicted in the respective sections (section 4.4.1 to 4.4.13). The selected views are as follows:

- Bill of Quantities,
- Bid Summary Sheet,
- Change Orders Tracking Log,
- Correspondence Tracking Log,
- Daily Site Report,
- Defective Work Notifications Tracking Log,
- Materials Stored Tracking Log,
- Monthly Progress Report,
- Photographs Tracking Log,
- Punch Lists,
- Requests for Information (RFI) Tracking Log,
- Shop Drawing Submittals Tracking Log, and
- Spare Parts Tracking Log.

PERSONNEL/FUNCTIONS MATRIX (M-2)

Legends:
A=advisory/assist C=control responsibility
D=data provisions E=execution H=handle
R=review & analyze

Function/Activity	Responsibility	Construction Manager	Chief Engineer	Procurement Manager	Project Manager	Project Engineer	Planning/Sched. Engineer	Cost Engineer	Estimator / QS	Accountant	Purchasing Agent	Field Office Engineer	Field Engineer	Superintendents	Foremen
Engineering															
project's engineering & design operations					A	C,H									
field and office engineering liaison						H									
change orders, work orders, claims					C	H						E			
design, drafting & shop drawing					A	C,H						E			
drawing, papers and submittals					C	H							A		
Estimating															
project's estimating					C,A	H			E			D			
quantity survey/estimate from drawings						C			E			D,E			
subcontract estimate					C	H			E						
Planning															
project's planning and scheduling	R	A			C,A	H	E		D						
project's schedule for resources					C	H	E								
delivery schedules					C	H	E								
detail schedules						C							E		
Quantity Surveying															
work measurement & payment estimates					C	H			E						
valuations preparation					C	H			E						
cost /value preparation					C				E						
final accounts agreements					C	H			E						
Construction Management															
construction operations management	C,H														
construction methods development	C	H				D									
subcontractor selection and negotiation	C,A		A	H					D						
procurement of resources	C,H			A											
building production supervision	C			H											
architect/client liaison	C,H			A											
Procurement															
quotations requests/receipts				C,A	A		D	D	D		H				
technical assistance to subs/suppliers				C,A	A	D									
negotiation with subs/suppliers				C	A						H				
procurement contracts/specs approval				C,A	A						E				
project's purchasing/expediting/inspection				A	C						H		A		
transportation & routes arrangements				C							H				
materials order				C,A	A						E				
materials chase				C							H				
Project Management															
project completion					C,H	A									
project's progress/potential problem reports	R				C,R	H,R						E	D	D	D
project's progress & status reports	R				C,R	H	E								
progress photographs					C	H						E			
Site Management															
field work, field survey, layout, etc.					C	A							E		
subcontractors' progress check													A		
punching lists completion					C,R	R							A	E	
subcontractors organization & coordination													A	A	H

Figure 4.4 Personnel/Functions Matrix (M-2)

PERSONNEL/INFONEEDS MATRIX (M-3)														
Information Needs	**Infoneed By**	Construction Manager	Chief Engineer	Procurement Manager	Project Manager	Project Engineer	Planning/Scheduling Engineer	Cost Engineer	Estimator / QS	Accountant	Purchasing Agent	Field Office Engineer	Field Engineer	Superintendents	Foremen
Estimating / Quantity Surveying															
work item lists						x		x	x						
bill of quantities (item & quantity)		x		x	x	x	x	x	x	x	x		x	x	x
item cost		x		x	x	x		x	x	x	x				
cost summary		x	x	x	x	x		x	x	x	x				
budget for a trade				x	x				x		x				
start and end dates of trades				x	x	x	x		x				x	x	x
sub-bid due dates				x	x				x		x				
subcontractors/suppliers directory				x					x		x				
bid receipt dates				x	x				x		x				
bid amounts (individual bidder/trade)				x	x				x		x				
bid comparison or summary				x	x				x		x				
bidder ranking lists		x		x	x										
selected subcontractors/suppliers lists		x		x	x	x			x	x	x			x	x
progress measurements									x				x		
pay estimate number & date									x						
monthly work progress							x		x					x	
quantity of materials stored at sites									x		x			x	
value of materials stored at sites									x						
monthly valuation and report		x			x	x			x	x					
subcontract estimate									x	x					
Planning															
approval time for submittals					x	x	x				x				
delivery time of an item				x	x		x				x				
time impact by change orders					x	x	x								
revised completion date of project		x	x	x	x	x	x				x			x	
Engineering															
shop drawing lists					x	x					x	x		x	
shop drawing submission due dates						x						x			
shop-drawing subcontractor/supplier				x		x					x	x			
status of shop drawings					x	x					x	x		x	
lists of approved shop drawings				x	x	x					x	x		x	
shop drawing approval delay time					x	x									
requests for information (RFI) lists			x		x	x									
RFI initiator's name					x	x									
contents of RFI					x	x									
date of RFI					x	x									
status of RFI			x		x	x									
response time of RFI					x	x									
RFI responding person						x									
outstanding RFI			x		x	x									
change order lists			x	x	x	x			x	x	x			x	x
change order details			x	x	x	x			x	x	x			x	x
subcontractor affected by change order				x		x				x	x			x	
change order value				x	x	x			x	x	x				
change order contract time impact					x	x	x								
status of change orders			x	x	x	x				x				x	
revised total contract price		x			x				x	x					
revised completion date		x	x	x	x	x	x				x			x	

Figure 4.5 Personnel/InfoNeeds Matrix (M-3) ... contd...

PERSONNEL/INFONEEDS MATRIX (M-3)															
Information Needs	**Infoneed By**	Construction Manager	Chief Engineer	Procurement Manager	Project Manager	Project Engineer	Planning/Scheduling Engineer	Cost Engineer	Estimator / QS	Accountant	Purchasing Agent	Field Office Engineer	Field Engineer	Superintendents	Foremen
Procurement															
suppliers directory				x							x				
requirement dates of materials				x	x						x			x	
sample/approval requirements				x	x	x					x	x			
approval time for submittals				x	x	x					x	x			
delivery time of materials				x	x	x					x				
materials affected by change orders				x							x			x	
status of materials on job site					x		x		x				x	x	
quantity of materials required					x						x		x	x	
quantity of materials stored					x				x					x	
supplier of materials				x						x					
lists of spare parts required				x	x						x				
details of spare parts				x	x						x				
quantity of spare parts required & delivered				x	x						x				
quantity of spare parts balance				x	x						x				
location of spare parts stored											x			x	
supplier of spare parts				x							x				
Project Management															
daily work progress					x	x								x	x
equipment in use and idle on job site					x			x		x			x	x	x
daily labor force on job site					x			x		x				x	x
daily weather condition					x										
visitors on job site					x	x							x	x	
materials requirements															
lists of site photograph					x	x									
negative/roll number of photograph					x	x									
date and location of photograph					x	x									
purpose of photograph					x	x									
Site Management															
lists of defective work notice (DWN)					x	x						x		x	
details of defective work notice					x	x						x		x	
subcontractor responsible for DWN					x	x						x		x	
type of defects/rejection of DWN					x	x						x		x	
value of DWN					x				x						
punch lists and details item lists					x	x						x		x	
subcontractor responsible for punch list					x	x						x		x	
status of punch lists					x	x						x		x	
Administrative															
owners contact & phone		x			x										
architects/engineers contact & phone		x	x		x	x						x			
subcontractors contact & phone					x	x			x	x		x		x	
suppliers contact & phone				x	x	x		x			x	x		x	
correspondence in & out list		x	x	x	x	x	x	x	x	x	x	x			
contents of a correspondence		x	x	x	x	x	x	x	x	x	x	x			
origins of correspondence		x	x	x	x	x	x	x	x	x	x	x			
dates of correspondence		x	x	x	x	x	x	x	x	x	x	x			
file-location of correspondence		x	x	x	x	x	x	x		x	x	x			

... contd... Figure 4.5 Personnel/InfoNeeds Matrix (M-3)

DOCUMENT TYPE / INFORMATION CONTENTS MATRIX (M-4)															
Information Contents	**Document Type**	Bill of Quantities	Bid Summary Sheets	Change Orders TL	Correspondence TL	Daily Site Report	Defective Work TL	Materials Stored TL	Monthly Prog. Report	Photographs TL	Punch Lists TL	Requests for Info TL	Shop Drawing TL	Spare Parts TL	Company Directory
Estimating / Quantity Surveying															
work item lists		x													
bill of quantities (item & quantity)		x													
item cost		x													
cost summary		x													
budget for a trade			x												
start and end dates of trades			x												
sub-bid due dates			x												
subcontractors/suppliers directory															x
bid receipt dates			x												
bid amounts (individual bidder/trade)			x												
bid comparison or summary			x												
bidder ranking lists			x												
selected subcontractors/suppliers lists			x												
progress measurements									x						
pay estimate number & date									x						
monthly progress estimates									x						
quantity of materials stored at sites								x	x						
value of materials stored at sites								x	x						
monthly valuation and report									x						
subcontract estimate									x						
Planning															
approval time for submittals													x		
delivery time of an item													x		
time impact by change orders				x											
revised completion date of project				x											
Engineering															
shop drawing lists													x		
shop drawing submission due dates													x		
shop-drawing subcontractor/supplier													x		
status of shop drawings													x		
lists of approved shop drawings													x		
shop drawing approval delay time													x		
requests for information (RFI) lists												x			
RFI initiator's name												x			
contents & dates of RFI												x			
status ans response time of RFI												x			
RFI responding person												x			
outstanding RFIs												x			
change order lists and details				x											
subcontractor affected by change order				x											
change order value				x											
change order contract time impact				x											
status of change orders				x											
revised total contract price				x											
revised completion date				x											

Figure 4.6 Document Type/Information Contents Matrix (M-4) ... contd...

DOCUMENT TYPE / INFORMATION CONTENTS MATRIX (M-4)

Information Contents	Document Type	Bill of Quantities	Bid Summary Sheets	Change Orders TL	Correspondence TL	Daily Site Report	Defective Work TL	Materials Stored TL	Monthly Prog. Report	Photographs TL	Punch Lists TL	Requests for Info TL	Shop Drawing TL	Spare Parts TL	Company Directory
Procurement															
suppliers directory															x
requirement date of materials													x		
sample/approval requirements													x		
approval time for submittals													x		
delivery time of materials													x		
materials affected by change orders				x											
status of materials on job site								x	x						
quantity of materials required									x						
quantity of materials stored								x	x						
supplier of materials								x							
lists of spare parts required														x	
details of spare parts														x	
quantity of spare parts required/delivered														x	
quantity of spare parts balance														x	
location of spare parts stored														x	
supplier of spare parts														x	
Project Management															
daily work progress						x									
equipment in use and idle on job site						x									
daily labor force on job site						x									
daily weather condition						x									
visitors on job site						x									
materials requirements						x									
lists of site photograph										x					
negative/roll number of photograph										x					
date of photograph										x					
location of photograph										x					
purpose of photograph										x					
Site Management															
lists of defective work notice (DWN)							x								
details of defective work notice							x								
subcontractor responsible for DWN							x								
type of defects/rejection of DWN							x								
value of DWN							x								
punch lists and details item lists											x				
sub responsible for punch list											x				
status of punch lists											x				
Administrative															
owners contact & phone															x
arch./engineers contact & phone															x
subcontractors contact & phone															x
suppliers contact & phone															x
correspondence in & out list					x										
contents of a correspondence					x										
origins & dates of correspondence					x										
file-location of correspondence					x										

... contd... Figure 4.6 Document Type/Info Contents Matrix (M-4)

4.2 Database Design Overview

As discussed in section 1.6.4, the first step in designing a database is to do data modeling. Furthermore, a data modeling process involves the creation of the following three separate models: the conceptual model, the logical model and the physical model.

The conceptual data model may be expressed in several different ways, for example: an entity or table relationship model, a data structure diagram, or a semantic data model. Sections 4.3, 4.4 and 4.5 present the conceptual model development for the database of the proposed system. Section 4.3 deals with the basic files and their organization schemes. Section 4.4 covers the description of user views, identification of information requirements, identification of entities and their attributes including primary keys, description of relationships between entities, and presentation of entity-relationship diagrams. Section 4.5 presents the normalized relations and structural model diagram.

The logical modeling is carried out in sections 4.6 and 4.7. Section 4.6 presents entities and relationships, their attributes based on the conceptual models developed in sections 4.4 and 4.5, and entity cross-reference matrix. Section 4.7 defines a data dictionary.

The translation process, from the logical model to a physical model will be performed by the DBMS software. Section 4.8 assesses the space required for the database system.

Section 4.9 and section 4.10 are concerned with the implementation and prototype development.

4.3 File Organization Schemes

This section identifies some of the important and basic entities required for database of the proposed system, and highlights their organization schemes in the database. One of the most significant basic entities, as identified during the requirements analysis, is the specifications. Most of the transactions are referred to a particular specifications section. A specifications is defined as a part of the contract documents contained in the project manual consisting of technical descriptions of material, equipment, construction systems, standards, and workmanship [Jones 91]. Other basic entities are the following: work breakdown structure (WBS), project, subcontractor or company, employee or people, and trade. These basic entities are discussed as follows.

4.3.1 Core Entity - the specifications

A database of specifications related to construction industry will be required for most of the items. Classification schemes such as MASTERFORMAT are widely accepted (though not universally) in the AEC industry [Froese 93]. Project specifications are organized according to CSI Masterformat in North America [Ganeshan et al 94]. Masterformat also provides a framework for organizing all construction documents.

For the proposed PMICS, most of the files and documents are tied to a specific CSI Masterformat section number which is called a 'Specs Section' for simplicity. Estimating items are tied to work breakdown structure (WBS) of the ASPE (American Society of Professional Estimators) classification hierarchy, which is parallel to the CSI Masterformat classification hierarchy. A WBS is defined as a list or chart of work items. A work item or item of work is defined as a portion of work that can be observed, identified, and separated for purposes of estimating, cost accounting, and management [Collier 94].

The reasons for using WBS over specs section for estimating purposes are as follows [Stewart & Stewart 86]: a specs section may not go far enough down into the estimate details; a specs section number may not apply to the estimate at hand; a WBS is short and covers almost all work items of small to medium projects. A project is defined as a construction undertaking of the work of a construction contract as a whole or a part.

As discussed above, a work item constitutes a WBS. Each work item is assigned with a unique WBS number. Work items usually involve the work of only one trade. A trade may be defined as a division of work having work items of same field. For example, plumbing, HVAC, electrical. A trade may have one or more work items. Thus a WBS is tied to a trade. A WBS may cover one or many specs section, or in another words, a specs section may appear on one or many WBS. This way a specs section is tied to a WBS. The hierarchy of a trade, WBS and specs section is shown in Figure 4.7.

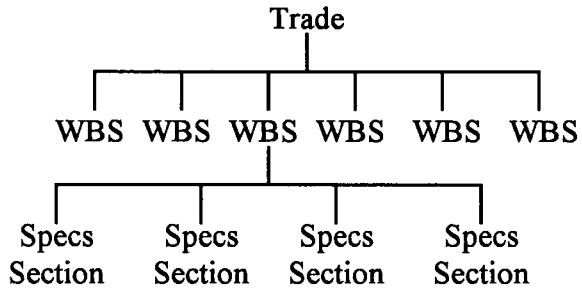


Figure 4.7 Hierarchy of Trade/WBS/Specifications

A subcontractor may work on one or more trade areas; a trade is associated with one or more WBS; a WBS is related to one or more specs sections, thus all subcontractors are tied to the specs sections. Figure 4.8 explains the scenario.

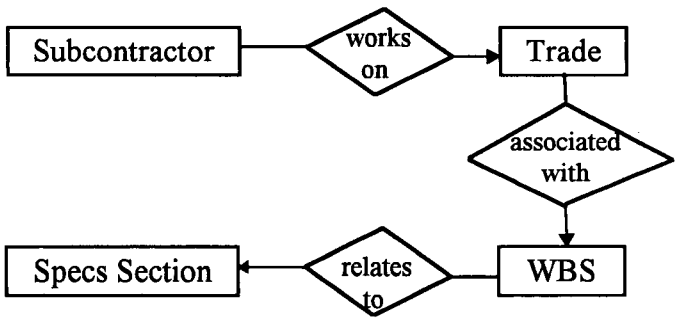


Figure 4.8 Specs Sections/Subcontractor Relationships

Under the older control systems, when RFI, shop drawing, change order, defective work notification, etc., came in, they had to be checked manually to determine the responsible subcontractor. Now, by citing a specs section, related subcontractor will be highlighted. Similarly, for materials or spare parts, related suppliers will be highlighted.

4.3.2 Other Basic Entities

As discussed earlier, other basic entities include the following: project, subcontractor or company, employee or people, and trade. A brief description of these entities are given as follows.

A construction company can have several projects running, or completed. The database of projects becomes an essential component of the information to identify different projects. Some times, it is required to get information about similar project type, architects/engineers on previous projects, responsible project manager, or projects on a particular location. To accommodate all these information under one entity, *project*, the attributes will include the following: project identification number, name, location, type (building, bridge, highways, etc.), start date, scheduled completion date, actual completion date, contract value in dollars, architects/engineers, owner, supervisor (company's project manager), and phone and fax numbers.

A database of possible subcontractors or suppliers for construction projects might be required by the cost estimator to identify subcontractors to ask to bid on parts of a project. Appropriate subcontractors or suppliers appearing in the database could be contacted to prepare bids for specific projects. Other possible contacts for business developments are the following: owners, architects, engineers and other agencies. Even on

a running project, there will be many participants associated with the project. In order to have a global look, information about the above mentioned project participants will be organized in an entity, called *company.* The entity company will include the following attributes: company identification number, name, address, phone and fax numbers, type (subcontractor, supplier, architects, engineers, owner, etc.), size (small, medium, big), and name of the contact persons. In order to identify the type of a company or the nature of a participant on a project, a separate entity is required. This will be organized into an entity, called *Participant Type*.

A database of company's employee will be required for personnel requirements, assignment to a project, or other related information. Similarly, a database of people associated with other organizations will be required in order to contact them for important matters. A common entity, *people,* is assigned to accommodate information about each person. The attributes of entity people will include the following: people identification number, name (last name and first name), address, phone and fax numbers, title, and company identification number.

A database of trades for a project will be required for information about a trade. The information required may include the following: work items included, start and end dates, estimated and actual cost, and budget. These are organized in an entity, called *project trade-details.* This entity will also help in identifying a subcontractor of a trade on a project.

4.4 System Views

This section describes the selected views as listed in section 4.1.5, identifies typical queries for each view, determines entities and their attributes referenced in each view, determines the primary key(s) for each view, defines general key terms for each view, identifies the entities and relationships that exist, explains the entities and their relationships, presents entity-relationship (E/R) diagrams for each view, and finally presents E/R diagram for the integrated view.

Reference sources for this section include the following: [Tidwell 95], [Fisk 93], [Seeley 93], [O'Brien 90], [Levy 94], [Callahan & Bramble 83], [Goldhaber et al 77], [Stewart & Stewart 86] for description of views; [McFadden & Hoffer 88], [Date 90], [El-Bibany & Froese 89], [Townsend 92], [Liskin 93], [Access 92], [Turk 95] for data modeling and system design.

The meaning of repeating groups (set/sets of attributes within inner brackets) of a relation has been explained in section 1.6.8. The concepts of data modeling and E/R diagrams have been introduced in section 1.6.4 and 2.4.8, respectively. Definitions of some of the general terms used throughout the system views are shown in Table 4.1.

Table 4.1 General Key Terms, Abbreviations and Symbols

Key Terms	Definitions
Architects/Engineers	or A/E, an individual or firm offering professional services.
Client/Owner	the agency or individual requiring the construction project.
Company	any enterprise or organization included in the database.
Contractor	the person or private organization responsible for the site construction work (ABC Construction Company, in this system).
EngineerID	company identification number of the supervising A/E.
Engr Contact	name of contact person of the A/E.
Engr Name	official name of the A/E.
Engr Phone	phone number of the A/E.
File Ref. no.	file reference number (as in the office filing system).
Item	short for item of work, or work item.
Participant Type	nature of job performed by a company participating in a project.
People	an individual included in the database or employed by a company
Project	the total construction of which the work performed under the contract documents may be the whole or a part.
ProjectID	project identification number.
Project Name	official name of the project.
Proj-company	a set of projects and companies.
Project ItemDetails	details of items included in a project.
Proj-trade	a set of projects and trades.
Project TradeDetails	details of trades included in a project.
Specs Section	CSI Masterformat specification section.
SpecsID	serial or identification number of a specs section.
Subcontractor	a person or an organization who has a contract with the contractor to perform a portion of the work at the site.
Sub ID	company identification number of a subcontractor.
Sub Name	company name of the subcontractor.
Sub Contact	name of contact person of the subcontractor.
Sub Phone	phone number of the subcontractor.
Trade	a collection of items relating to one division or discipline of work on a project, e.g., HVAC, plumbing, electrical, etc.
TradeID	identification number of a trade.
Trade Name	name of the trade.
WBS	Work Breakdown Structure, a list or chart of work items used for estimating, costing and management purposes.
WBS_ID	identification number of a WBS.
*	computed attribute.
———	one-to-one relationship.
———→	one-to-many relationship.
←——→	many-to-many relationship.

4.4.1 View 1: Bill of Quantities

A Bill of Quantities (BoQ) is a schedule which gives brief descriptions and quantities of all the items of work involved. The quantities of work are computed from contract drawings and associated documents. A BoQ is prepared in accordance with a standard method of measurement giving the quantities of each item of work to be executed. The contractor enters a unit rate against each item of work and the extended totals are added to give the tender total. Whether it is a lump sum contract or a bill of quantities contract, a contractor needs a BoQ to build up his tender. In the former case, the BoQ is prepared by the contractor, and in the latter case, the BoQ is provided by the owner. A BoQ is similar to a Bid Breakdown which is used to determine the value of work performed each month on lump-sum contracts.

The Bill of Quantities (Figure 4.9) is useful in quoting for a job, estimating the cost of developing a new site, subcontracting out, producing a site budget and cash flow forecast, preparing periodic progress payment request, providing information to enable accurate cost control during the site construction, etc.

BILL OF QUANTITIES

PROJECT: CITY WAREHOUSE BUILDING
PROJECT# 1

CONTRACTOR

XYZ Contracting
Vancouver, B.C.
Prime Contact: mnop
Second Contact: qrst
Tel: 987 6543

ENGINEER

ABC Engineers
Vancouver, B.C.
Prime Contact: abcd
Second Contact: bcde
Tel: 876 5432

Pay Item No.	ITEM DESCRIPTION	CONTRACT			
		Quantity	Unit	Unit Price	Item Total
1	Demolition	1	L.S.	$100,000	$100,000
2	General Excavation	1	L.S.	$75,000	$75,000
3	Structural Concrete	1	cum	$125,000	$125,000
4	Brick & Block Masonary Works	1700	sqm	$50	$85,000
5	Structural Steel Works	2000	ton	$200	$400,000
6	Decking & Siding	1500	sqm	$150	$225,000
7	Waterproofing & Dampproofing	1	L.S.	$45,000	$45,000
8	Roofing	1700	sqm	$35	$59,500
9	Skylights	6	ea	$1,500	$9,000
10	Wooden Doors	40	ea	$350	$14,000
11	Hollow Metal Windows	40	ea	$350	$14,000
12	Lath & Plaster	1400	sqm	$45	$63,000
13	Drywall	2500	sqm	$34	$85,000
14	Ceramic Tiles	1050	sqm	$50	$52,500
15	Plumbing and Water supply	1	L.S.	$84,000	$84,000
16	Heating, Ventilating, & Airconditio	1	L.S.	$165,000	$165,000
17	Fire Protection Works	1	L.S.	$54,000	$54,000
18	Electrical Works	1	L.S.	$135,000	$135,000
				TOTAL	$1,790,000

Figure 4.9 View-1 Bill of Quantities

This view provides bill of quantities information to the Construction Manager, Chief Estimator, Procurement Manager, Project Manager, Project Engineer, Planning and Scheduling Engineer, Cost Engineer, Estimator, Field Engineer, Superintendent, and Foremen.

The following queries are typical examples for this view of the data:

Construction Manager, Chief Estimator, Project Manager, Project Engineer, Estimator, and Accountant:

- Find the quantity of an item. The output should have the project id, project name, WBS id, and item description, quantity and unit.

- Find the item cost and cost summary. The output should have the project id, project name, WBS id, item description and cost, subtotal for a division of work or trade, and grand total.

Procurement Manager and Cost Engineer:

- Find the quantity, cost summary, and budget of an item. The output should have the project id, project name, WBS id, item (description, cost, budget, and markup), subtotal for a division of work or trade, and grand total.

Planning and Scheduling Engineer, Field Engineer, Superintendent, and Foreman:

- Find the quantity of an item. The output should have the project id, project name, WBS id, and item description, quantity and unit.

It is assumed that only one table is maintained for the Bill of Quantities of all the projects or sites executed by this organization. Also, a particular work item is identified by both ProjectID and WBS_ID.

The Bill of Quantities (BoQ) is expressed in the following relations:

BoQ (ProjectID, Project Name, (WBS_ID, Item Description, Quantity, Unit, Unit Price, Total Item Cost*, File Ref. no.*, (TradeID, Trade Name)))

Table 4.2 Key Terms of Bill of Quantities

Key Terms	Definitions
Item Description	description of a work item as in WBS
Quantity	quantity of a work item
Unit	unit of measurement of a work item
Unit Price	price per unit of measurement
Total Item Cost	= Quantity x Unit Price x % markup

The entities and relationships that apply to this view are shown in Figure 4.10. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Project ItemDetails (PID) is central to this data model. A PID can be identified by both ProjectID and WBS_ID together (Table C.15, Appendix C). A PID is related to a

single project and a single WBS. A project may appear on many PID. There may be many projects. A WBS may appear on many PID. A WBS is related to a single trade. A trade will appear on many WBS. A project may have many trades. Bill of Quantities (BoQ) is just an extension (or subset) of the PID. A BoQ will have the following foreign keys: ProjectID, WBS_ID and TradeID.

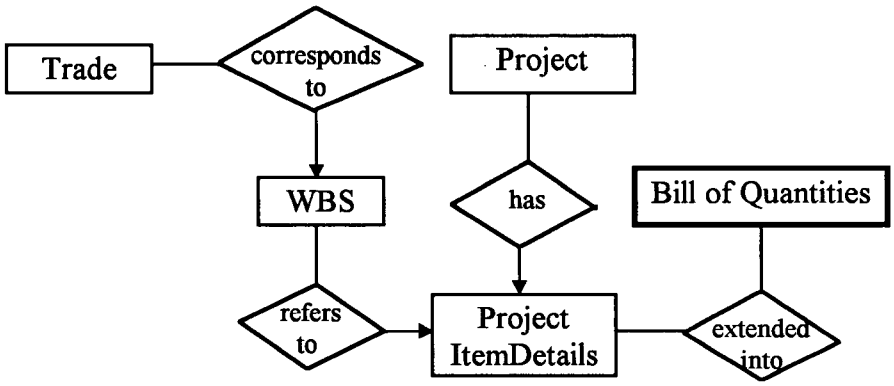


Figure 4.10 E/R Diagram for Bill of Quantities

4.4.2 View 2: Bid Summary Sheet

A bid or quotation is defined as an offer to do construction work for payment, the acceptance of which constitutes a contract between the contractor who made the bid (the bidder) and the owner who accepted it [Collier 94]. When a contract is awarded to a company, the project bidding documents and details provide the basic budget information

for a trade. A trade budget may be defined as the stipulated highest acceptable sub-bid price for a particular trade subcontract.

A sub-bid (here after referred as bid) is defined as an offer to a contractor to do a trade work for payment, the acceptance of which constitutes a contract between the subcontractor who made the bid (the bidder) and the contractor who accepted it. A bidder is not a subcontractor or supplier until a contract exists between him and the main contractor. Several bidders bid for various work packages or trades on a construction project. Before beginning any contract negotiation, all the bid information has to be organized and collated.

A Bid Summary Sheet (Figure 4.11) is useful as a collection point for information about bids submitted, bids requested and bids received on each of the trades of a project. Estimates submitted by bidders can be logged and tracked, or recorded and stored for later review. The purpose of this view is to provide a means of comparing one quotation with another to ensure sameness or to highlight differences.

This view provides bidding information to the Project Manager, Procurement Manager, and Estimator. This information relates to the bid submitted by a bidder for a trade package.

BID SUMMARY SHEET

Project: CITY WAREHOUSE BUILDING
Project# 1

Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

TRADE: Electrical
BUDGET: $ 135,000

Serial No.	Bidder Name	Phone Number	Bid Due Date	Bid Rcving Date	Bid Amount $	Difference $
1	Globe Electricals	888 9999	15-Jan-95	14-Jan-95	125,000	10,000
2	Polar Electric Co.	987 6543	15-Jan-95	15-Jan-95	128,600	6,400
3	Power & Cable Co.	876 5432	15-Jan-95	14-Jan-95	129,000	6,000
4	Light & Power Cont	765 4321	15-Jan-95	15-Jan-95	127,000	8,000
5						
6						
7						

TRADE: HVAC
BUDGET: $ 165,000

Serial No.	Bidder Name	Phone Number	Bid Due Date	Bid Rcving Date	Bid Amount $	Difference $
1	ACME	888 9999	10-Jan-95	10-Jan-95	155,500	9,500
2	Awal Engineering	987 6543	10-Jan-95	10-Jan-95	158,900	6,100
3	Super Aircond. Co.	876 5432	10-Jan-95	10-Jan-95	157,800	7,200
4						
5						
6						
7						

TRADE: Earthwork
BUDGET: $ 75,000

Serial No.	Bidder Name	Phone Number	Bid Due Date	Bid Rcving Date	Bid Amount $	Difference $
1	Ground Contracting	888 9999	5-Jan-95	5-Jan-95	70,000	5,000
2	Excavation Contracor	987 6543	5-Jan-95	5-Jan-95	68,500	6,500
3	Smith Earthwork Co.	876 5432	5-Jan-95	5-Jan-95	71,400	3,600
4	Excavation & Hauling	765 4321	5-Jan-95	5-Jan-95	64,500	10,500
5						
6						
7						

TRADE: Drywall
BUDGET: $ 85,000

Serial No.	Bidder Name	Phone Number	Bid Due Date	Bid Rcving Date	Bid Amount $	Difference $
1	A1 Finishing Co.	888 9999	25-Jan-95	25-Jan-95	79,000	6,000
2	Drywall Co.	987 6543	25-Jan-95	25-Jan-95	77,600	7,400
3	Wall & Plaster Co.	876 5432	25-Jan-95	25-Jan-95	78,100	6,900
4	Interior Const., Inc	765 4321	25-Jan-95	25-Jan-95	76,800	8,200
5						
6						
7						

Figure 4.11 View-2 Bid Summary Sheet

The following queries are typical for this view of the data:

Procurement Manager:

- Find the quotations and bidding from subcontractors and suppliers for different trades. The output should have the project name, trade or package name, bidder name, bid due date, bid package sent date, bid receiving date, and the bid amount.

- Compare the quotations with the budget. The output should have the project name, trade name, its budget and difference between budget and bid amount, including the scope of work.

- Provide a bidder ranking list or find the most competitive bidders to negotiate with. The output should have the bidder name, name of contact person, phone number, and fax number.

Project Manager:

- List the selected subcontractors and suppliers. The output should have the project name, trade name, subcontractor name, subcontract amount, and budget.

- Find the start and completion dates for a trade in order to call the selected subcontractor to start the work. The output should have the project name, trade name, start and end dates, and selected subcontractor including contact names and phone numbers.

Estimator:

- Compare the items and their quantities quoted for. The output should have the project name, trade name, bidder name, bid details and bid amount.

It is assumed that the organization has several ongoing projects, each project has several trades for which bidding is sought, and that a bidder is bidding on more than one trade. Also, it is assumed that a particular bid is identified by a combination of ProjectID, TradeID and SubID.

The user view for the Bid Summary Sheet (BSS) is expressed as the following relations:

BSS (ProjectID, Project Name, (TradeID, Trade Name, Budget, StartDate, EndDate, Bid Due Date, Lowest Bid*, (BidderID, Bidder Name, (Bidder Type), (Bidder Contact), Bidder Phone, Bid Pkg. Sent, Bid Received, Bid Amount, Remarks, Difference*, File Ref. no.*)))

Table 4.3 Key Terms for Bid Summary Sheet

Key Terms	Definitions
Budget	total planned cost of work items included in a trade package
StartDate	start date of a trade activities
EndDate	completion date of a trade activities
Bid	a proposal to do all or a part of the work for a stipulated sum
Bid Due Date	date established for the receipt of bids for a trade
Lowest Bid	the lowest bid that complies with the bidding requirements
Bidder	the company that submits a bid
BidderID	company identification number of a bidder
Bidder Contact	contact or responsible person of a bidder
Bid Pkg. Sent	date bid package sent to a bidder
Bid Received	date bid received from a bidder
Bid Amount	bid amount quoted by a bidder
Difference	difference between budget for a trade and the bid amount

The entities and relationships that apply to this view are shown in Figure 4.12. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Project TradeDetails (PTD) is central to this data model. A PTD can be identified by both ProjectID and TradeID together (Table C.16, Appendix C). A PTD may appear on many BoQ. A BoQ is related to a single PTD and a single project. A project may appear on many BoQ. A project may have many trades. A trade may be on many projects. A proj-trade is related to a single PTD.

A proj-trade may be related to a single bid. A bid can come from many bidders and a bidder can submit many bids. Thus, a bid can only be identified by all the following three together: ProjectID, TradeID and BidderID (Table C.1, Appendix C). A bidder is related to a single participant type. A participant type may appear on many bidders. Each bid will appear on the bid summary sheet. A bid summary is related to only one Proj-trade but may

include many proj-trade-bidder. Only one winning bidder is identified for a proj-trade. Wining bidder is added to the respective proj-trade in PTD as a subcontractor.

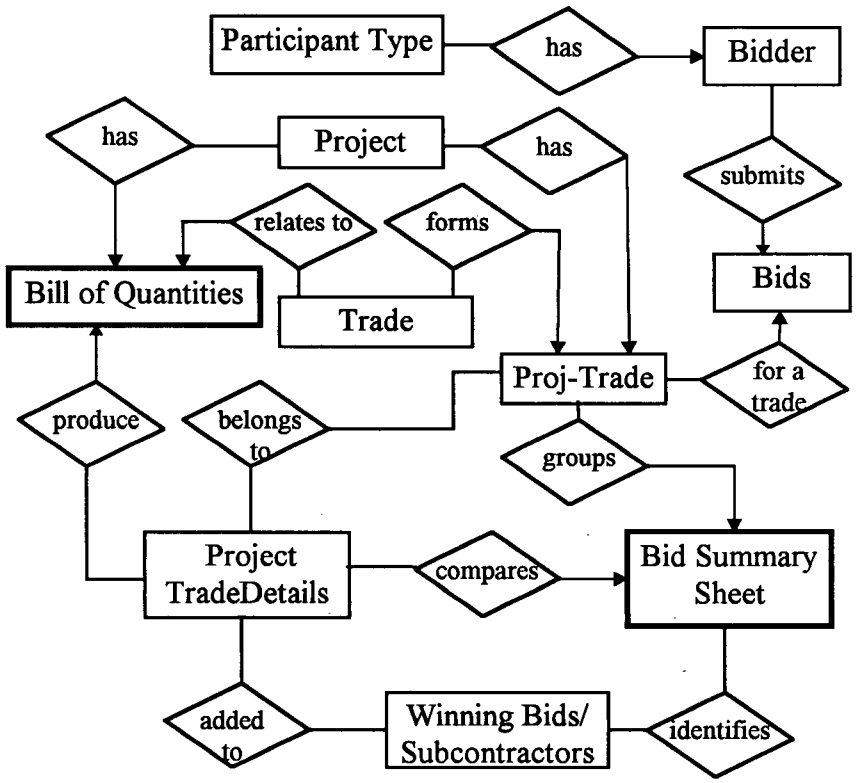


Figure 4.12 E/R Diagram for Bid Summary Sheet

4.4.3 View 3: Change Orders Tracking Log

A change order is a written agreement to modify, add to, or otherwise alter the work from that of the approved contract plans and specifications. It is the only legal means available

to change the contract provisions after the award of the contract. Although it may be initiated by either party, it is usually prepared by the owner and submitted to the contractor, signed by the contractor, and submitted to the owner for acceptance.

Most construction projects go through contract modifications or changes during their construction phase. Sometimes, change orders are the primary cause of disputes and claims because they: modify the original contracts and record changes in the contract price and the project schedule. Hence, it is a necessity to have a means of monitoring and tracking the change orders affecting the contract cost and completion time.

A Change Order Tracking Log (Figure 4.13) is useful for logging and tracking change orders. The log is also invaluable as an effective means of locating and retrieving change order documents from files.

This view provides change order information to the Project Manager, Project Engineer, Construction Manger, Procurement Manager, Planning and Scheduling Engineer, Estimator, Accountant, Superintendent, and Foreman. This information relates to the current status of a change order and its details including description, approved change order amount, time impact, revised contract price, and revised completion date.

CHANGE ORDERS TRACKING LOG

PROJECT: CITY WAREHOUSE BUILDING
PROJECT No: 1
Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

Orginal Contract Bid Price	$	5,000,000.00
Authorized Change Orders	$	15,600.00
Revised Contract Price	$	5,015,600.00
Change Order as % of Contract		0.3%

Original Contract Start	01-Jan-95
Origianl Contract Completion	31-Dec-96
Contract Days Added	2
Revised Contract Completion	01-Jan-97

				Cost/Schedule Information				Date Information						
CMR No.	Initiation Date	Current Status	DESCRIPTION	Engineers Estimate	Contractors Estimste	Final Settlement	Contract Time/Impact Days	Date Rcvd From Engr For Quote	Date Sent to Sub for Quote	Date Rcvd back from Sub	Date Sent Back to Engineer	Final Settlement Date	Total Duration CMR Days	Disposition/Comments
1	01-Feb-95	CM No. 1	Building Permit related modification	$ 2,000.00	$ 2,900.00	$ 2,900.00	0	02-Feb-95	02-Feb-95	08-Feb-95	09-Feb-95	16-Feb-95	15	Incorporated into CM No. 1
2	19-Feb-95	CM No. 2	Foundation Rock excavation	$ 5,000.00	$ 7,500.00	$ 7,000.00	1	20-Feb-95	20-Feb-95	28-Feb-95	28-Feb-95	07-Mar-95	16	Incorporated into CM No. 2
3	07-Mar-95	CM No. 2	Valve pit excavation	$ 6,000.00	$ 6,500.00	$ 6,500.00	1	09-Mar-95	09-Mar-95	16-Mar-95	15-Mar-95	21-Mar-95	14	Incorporated into CM No. 2
4	15-Apr-95	CM No. 3	Delete installation high service	$ 900.00	$ 750.00	$ (800.00)	0	16-Apr-95	16-Apr-95	23-Apr-95	23-Apr-95	30-Apr-95	15	Incorporated into CM No. 3
5														
6														
7														
8														
9														
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25														

Figure 4.13 View-3 Change Orders Tracking Log

The following queries are typical examples for this view of the data:

Project Manager, Project Engineer, Construction Manger, and Procurement Manager:

- Find the work items and trade subcontractors affected by a change order. The output should have the project id, change order number, description, status, trade name, and subcontractor id, name, contact name and phone number.

- Find the revised contract price and completion date. The output should have the project id, change order number, change order cost, original contract price, total authorized change order price, revised contract price, original completion time, contract time impact in days, and revised completion date.

Planning and Scheduling Engineer:

- Find the contract time impact in days affected by a change order, and the revised completion date. The output should have the project id, change order number, status, original completion time, contract time impact in days, and revised completion date.

Estimator, and Accountant:

- Find the change order amount and revised contract price and completion date. The output should have the project id, change order number, status, change

order cost, original contract price, total authorized change order price, revised contract price, original completion time, contract time impact in days, and revised completion date.

Superintendent, and Foreman:

- Find the status of a change order and the responsible subcontractor. The output should have the project id, change order number, description, status, trade name, and subcontractor id, name, contact name and phone number.

It is assumed that only one log is maintained to record change orders on all the projects or sites executed by this organization. Also, it is assumed that the CMR# (Contract Modification Request Number) is a unique number for a project, and that a particular Change Order is identified by both ProjectID and CMR# .

The Change Order Tracking Log (COTL) is expressed as the following relations:

COTL (ProjectID, Project Name, (EngineerID, Engr Name, (Engr Contact), Engr Phone), OCBP, ACO*, RCP*, CO%C*, OCCD, CDA*, RCCD*, (CMR#, Initiation Date, Current Status, Description, EsitmatValue, EngrEstimate, Final Value, Time Impact, D-RfAE, D-StS , D-BfS, D-RtAE, D-FS, CMR Days*, Disposition, File Ref. no.*, (SpecsID, Specs Section, (WBS_ID, Item Description, (TradeID, Trade Name, (SubID, Sub Name, Sub Contact, Sub Phone))))))

Table 4.4 Key Terms for Change Orders Tracking Log

Key Terms	Definitions
OCBP	Original contract bid price in $
ACO	authorized change orders in $
RCP	revised contract price in $
CO%C	change order as % of the contract bid price
OCCD	original contract completion date
CDA	contract days added
RCCD	revised contract completion date
CMR	Contract Modification Request
CMR#	Contract Modification Request number
Initiation Date	date CMR initiated/introduced
Description	brief description of CMR
EstimatValue	contractor's estimate of CMR
EngrEstimate	engineer's estimate of CMR
Final Value	final settlement value
Time Impact	contract time impact in days
D-RfAE	date CMR received from architect/engineer (A/E)
D-StS	date sent to subcontractor
D-BfS	date back from subcontractor
D-RtAE	date returned to A/E
D-FS	date for final settlement
CMR Days	total time taken in change order process in days

The entities and relationships that apply to this view are shown in Figure 4.14. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Change Order is the principal entity of this data model. A change orders log lists each change order. A change order can be identified by both ProjectID and CMR# (Table C.2, Appendix C). A change order will be referred to a single specs section. A specs section may appear on many change orders.

A specs section is related to a single WBS. A WBS will appear on many specs sections. A WBS is related to a single trade. A trade will appear on many WBS. A proj-trade is related to a single project and a single trade. A project may appear on many proj-trade, as could a trade. A PTD is related to a single proj-trade and a single company (subcontractor/supplier). There may be many projects. A project may have many participating companies.

A company can work on many projects. A company may appear on many people. A people is related to only one company. A company may appear on many PTD. A PTD is identified by both ProjectID and TradeID (Table C.16, Appendix C), so does a proj-trade. Thus, a proj-trade identifies a trade subcontractor or supplier for further actions. A proj-company is related to a single project and a single company. A project may appear on many proj-company, as could a company. It helps in identifying the A/E. People is related to a single company. A company may appear on many people. It helps in identifying the contact person of the A/E.

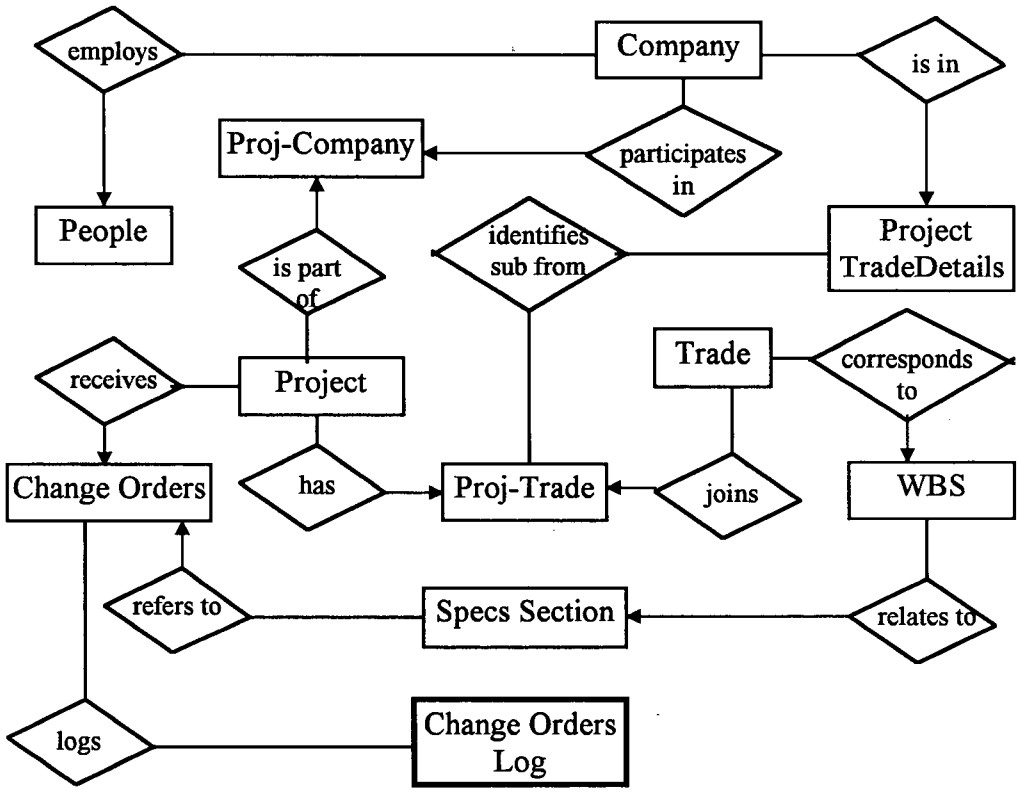

Figure 4.14 E/R Diagram for Change Orders Tracking Log

4.4.4 View 4: Correspondence Tracking Log

Most construction projects produce a large amount of paper work. Correspondence is one of the principal methods of communication between site and external organizations such as owner, engineer, subcontractors, and suppliers. It is always useful to record and log all important information of incoming as well as outgoing correspondence for future retrieval.

A Correspondence Tracking Log (Figures 4.15a and 4.15b) is useful in keeping track of all incoming and outgoing papers. It is used to record any kind of correspondence such as letters, memorandums, interoffice communications, reports, invoices, etc. The log is also invaluable as an effective means of locating and retrieving correspondence from files in case it is needed for substantiation or negotiation.

This view provides incoming and outgoing correspondence information to construction managers. This information relates to correspondence such as letters to or from project participants, change order packages, submittal records, as-built drawings, specification interpretations, finding of facts, records of negotiations, minutes of meeting, memorandums, inter-office communications, reports, invoices, etc.

The following queries are typical examples for this view of the data:

- Find a specific item of correspondence. The output should have the project id, correspondence number, correspondence date, date received, reference number, from company id, to company id, keyword or phrase. The output should be able to be sorted on the basis of any of the above attributes.

- Find the contents of a correspondence. The output should have the project id, correspondence number, reference number, description/notes.

CORRESPONDENCE IN TRACKING LOG

Project: CITY WAREHOUSE BUILDING
Project# 1

Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

Corr. in No.	Ref. No.	Date of Corresp.	Date Received	Corresp From	Name of Company	Keyword One	Keyword Two	Description/Notes
1	40.1	05-Jan-95	08-Jan-95	Smith, S.R.	A1 Quality Doors	SUPPLIER	DOORS	Ltr from supplier re: doors; wrong sizes called out; quotation
2	41.1	05-Jan-95	08-Jan-95	Wise, M.	ABC Company	SUPPLIER	WINDOWS	Ltr from supplier re: windows; window covering; sizes
3	1.1	06-Jan-95	09-Jan-95	Warner, J	Engineer	ENGINEER	AIR COND	Ltr from engineer re: air cond; will review sizing and get back ASAP
4	2.1	06-Jan-95	10-Jan-95	Yong, C.	WC Associates	ARCHITECT	ROOF	Ltr from architect re: change order necessary to add roof purlins
5	50.1	08-Jan-95	11-Jan-95	Will, T.	A1 Readymix	SUPPLIER	CONCRETE	Concrete mix design report from the supplier
6	41.2	10-Jan-95	15-Jan-95	Whitaker, K.C.	ABC Company	SUPPLIER	WINDOWS	Follow-up ltr from supplier re: windows, window covering, sizes
7	1.2	10-Jan-95	15-Jan-95	Warner, J.	Engineer	ENGINEER	INSPECTION	Ltr from engineer re: inspection schedule
8	1.3	11-Jan-95	15-Jan-95	Warner, J	Engineer	ENGINEER	DOORS	Ltr from engineer re: location of door
9	51.1	12-Jan-95	16-Jan-95	Harvey, Dennis	Quality Materials	SUPPLIER	WOOD	Ltr from supplier re: wood for formwork
10	42.1	12-Jan-95	16-Jan-95	Walter, H.	Doors & window Co.	SUPPLIER	WINDOWS	Ltr from supplier re: availability of special windows and doors
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Figure 4.15a View-4 Correspondence Tracking Log

CORRESPONDENCE OUT TRACKING LOG

Project: CITY WAREHOUSE BUILDING
Project# 1

Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

Corr. Out No.	Ref. No.	Date of Corresp.	Corresp. From	Corresp To	Name of Company	Keyword One	Keyword Two	Description/Notes
1	40.1	8-Jan-95	Brown, A	Smith, S.R.	A1 Quality Doors	SUPPLIER	DOORS	Ltr from supplier re: doors; wrong sizes called out; quotation
2	41.1	8-Jan-95	Brown, A	Wise, M.	ABC Company	SUPPLIER	WINDOWS	Ltr from supplier re: windows; window covering; sizes
3	1.1	9-Jan-95	Brown, A	Warner, J	Engineer	ENGINEER	AIR COND	Ltr from engineer re: air cond; will review sizing and get back ASAP
4	2.1	10-Jan-95	Brown, A	Yong, C.	WC Associates	ARCHITECT	ROOF	Ltr from architect re: change order necessary to add roof purlins
5	50.1	11-Jan-95	Brown, A	Will, T.	A1 Readymix	SUPPLIER	CONCRETE	Concrete mix design report from the supplier
6	41.2	15-Jan-95	Brown, A	Whitaker, K.C.	ABC Company	SUPPLIER	WINDOWS	Follow-up ltr from supplier re: windows, window covering, sizes
7	1.2	15-Jan-95	Brown, A	Warner, J.	Engineer	ENGINEER	INSPECTION	Ltr from engineer re: inspection schedule
8	1.3	15-Jan-95	Brown, A	Warner, J	Engineer	ENGINEER	DOORS	Ltr from engineer re: location of door
9	51.1	16-Jan-95	Brown, A	Harvey, Dennis	Quality Materials	SUPPLIER	WOOD	Ltr from supplier re: wood for formwork
10	42.1	16-Jan-95	Brown, A	Walter, H.	Doors & window Co.	SUPPLIER	WINDOWS	Ltr from supplier re: availability of special windows and doors
11								
12								
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20								

Figure 4.15b View-4 Correspondence Tracking Log

- Find the originator or receiver name. The output should have the project id, correspondence number, reference number, from people id, to people id.

- Find the original date and receiving date. The output should have the project id, correspondence number and date, reference number, receiving date.

- Locate a filed correspondence or submittal. The output should have the project id, correspondence number, reference number, file reference no.

To simplify the presentation it is assumed that the organization has several ongoing projects, and only one Correspondence Tracking Log is maintained to record all incoming or outgoing correspondence. Also, it assumed that the Corr# (correspondence identifier) is a unique serial number of correspondence for a project (including both incoming or outgoing). A particular correspondence is identified by both ProjectID and Corr# .

The user view for the Correspondence Tracking Log (CTL) is expressed as follows:

CTL (ProjectID, Project Name, (Corr#, Reference#, CorrDate, Date Sent, DateRcvd, Follow up, (From People, To People, (From Company, To Company, (From Participant Type, To Participant Type))), Keyword1, Keyword2, Notes, File Ref. no.*))

Table 4.5 Key Terms for Correspondence Tracking Log

Key Terms	Definitions
Corr#	project's correspondence entry serial number
Reference#	reference number of a correspondence (i.e. sender's reference number as appears on the correspondence)
CorrDate	original date of a correspondence
Date Sent	date of mailing
DateRcvd	date correspondence received
Follow-up	follow up required?
Participant Type	type of the project participant, e.g., engineers, supplier
Keyword1	first keyword describing the subject
Keyword2	second keyword describing the subject

The entities and relationships that apply to this view are shown in Figure 4.16. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Correspondence is the principal entity of this data model. A correspondence log lists each correspondence. A correspondence is identified by both ProjectID and Corr# (Table C.4, Appendix C).

There may be many projects. A correspondence can come from many People and vise versa. A people is related to only one company. A company may appear on many people. A company is related to a single participant type. A participant type may appear on many companies. These help in identifying the people, company and participant type.

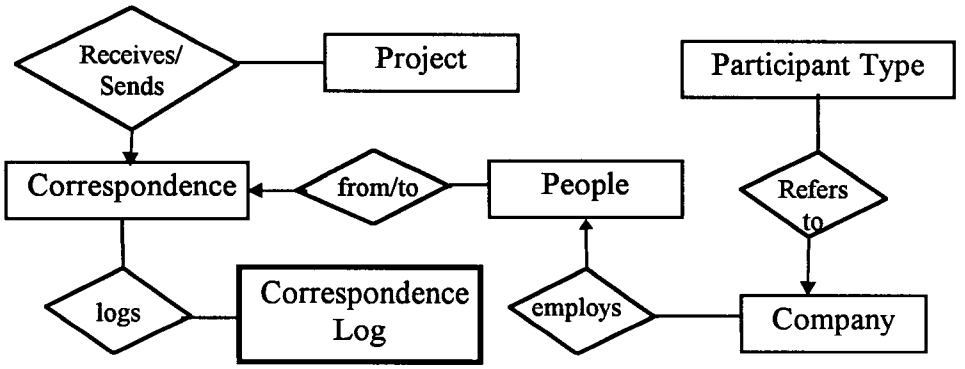

Figure 4.16 E/R Diagram for Correspondence Tracking Log

4.4.5 View 5: Daily Site Report (Daily Report)

Almost every construction project has a Daily Report. A daily report is an important part of site communications. It is primarily a summary of information and the principal method of conveying information on site matters to home office, the owner and other parties.

A daily report (Figure 4.17) traditionally records the number of equipment working, the names of the subcontractor working, amount of labor present for both the general contractor and his subcontractors, and a description of the work accomplished during the day, weather conditions, visitors to the site, problems encountered during the day, additional men, equipment, or materials necessary for near future work, and requests to the home office. This document becomes a part of the permanent file and is a most useful source of information in the event of a dispute.

DAILY SITE REPORT

Report No. 12
Date: 15-Jan-95
Day: M T W T F S S

Project: CITY WAREHOUSE BUILDING
Project# 1

Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

Weather	Sunny	Cloudy	Rain	Snowy
Temp.	0-5	5-15	15-20	20-30
Wind	Still	Moder.	High	
Humidity	Dry	Moder.	Humid	

AVERAGE FIELD FORCE

Name of Contractor	Non-manual	Manual	Remarks
ABC Contracting	3	5	Supervision & Q.C.
Awal Engineering	2	10	HVAC & Ducts
Ready Mix Supply	1	12	Forms & Concrete
Smith Steel	1	8	Steel Erection
Total Force	7	35	

VISITORS

Time	Name	Representing	Remarks
9:30 AM	Ferguson, R.	XYZ	Jobsite visitation
11:00 AM	Brannon, W.	XYZ	Jobsite visitation

EQUIPMENT AT THE SITE:

CONSTRUCTION ACTIVITIES:

MATERIAL NEEDS:

Prepared By: **Signature:**

Figure 4.17 View-5 Daily Site Report

This view provides project managers information about daily work progress, equipment in use and idle, personnel at the site, material needs, visitors and weather conditions on that day. This information relates to the reports of the field engineer or superintendent.

The following queries are typical examples for this view of the data:

- Find the details of subcontractors force account (number of people working on the job-site). The output should have the project id, date and day, name of subcontractors and their field labor force.

- Find the details of work progress and equipment. The output should have the project id, date and day, equipment in use, idle equipment, work in progress, new work activities, and work completed.

- Find the details of weather conditions. The output should have the project id, date and day, and weather conditions, including temperature, humidity, and wind.

- Find the names of visitors and their purpose of visit. The output should have the project id, date and day, name of visitors, name of representing organization, time of visits, and purpose of visits.

- Prepare and print the daily report. The output should have all the above attributes, e.g., the project id, project name, date and day, engineer and owner name, weather conditions, listing of job-site visitors, recording of field force, reporting of work progress, recording of delivered and stored materials, and safety related matters.

It is assumed that only one system is used to input Daily Report data of all the projects or sites executed by this organization. A particular Daily Report is identified by both ProjectID and Date .

The Daily Site Report (DSR) may be expressed as the following relations:

DSR (ProjectID, Project Name, (EngineerID, Engr Name, (PeopleID, People Name), (TypeID, Participant Type)), (Date, (Day ID, Day), (Weather (sunny, cloudy, rainy, snowy), Temperature, Wind (still, moderate, high), Humidity (dry, mod, high)), (Prepared by ID, Prepared by), (FFC1, FFC2, FFC3, FFC4, NMFF1, NMFF2, NMFF3, NMFF4, MFF1, MFF2, MFF3, MFF4, Job1, Job2, Job3, Job4), (Daily Report#, Visitor1, Visitor2, VisitTime1, VisitTime2, Company1, Company2, Purpose1, Purpose2, EquipUse, EquipIdle, Activities, New Act, Act Compl, Material Needs))

Table 4.6 Key Terms for Daily Site Report

Key Terms	Definitions
Date	date of a report
Report#	project's serial number of a report
Prepared by ID	PeopleID of the person making report
Day ID	same as Day ID in Day table
FFC1	field force contractor-1 Co_ID
FFC2	field force contractor-2 Co_ID
FFC3	field force contractor-3 Co_ID
FFC4	field force contractor-4 Co_ID
NMFF1	non-manual field force of FFC1
NMFF2	non-manual field force of FFC2
NMFF3	non-manual field force of FFC3
NMFF4	non-manual field force of FFC4
MFF1	manual field force of FFC1
MFF2	manual field force of FFC2
MFF3	manual field force of FFC3
MFF4	manual field force of FFC4
Job1	job/trade name of FFC1
Job2	job/trade name of FFC2
Job3	job/trade name of FFC3
Job4	job/trade name of FFC4
Visitor1	name of visitor-1
Visitor2	name of visitor-2
VisitTime1	time of visit of visitor-1
VisitTime2	time of visit of visitor-2
Company1	name of the visitor-1's company
Company2	name of the visitor-2's company
Purpose1	purpose of the visitor-1's visit
Purpose2	purpose of the visitor-2's visit
EquipUse	equipment in use at the project
EquipIdle	equipment idle at the project
Activities	activities in progress at the site
New Act	new activities started at the site
Act Compl	activities completed at the site
Material Needs	future material needs

The entities and relationships that apply to this view are shown in Figure 4.18. This figure is in accordance with the typical queries of the user view as discussed earlier in this

section. Daily report is central to this data model. A daily report combines daily events and daily weather. A daily report can be identified by both ProjectID and Date together, and as could a daily events (Table C.5, Appendix C) and daily weather (Table C.6, Appendix C).

Both the daily events and daily weather relate to a single project. There may be many projects. A project may have many participating companies. A company can work on many projects. A company may appear on many people. A people is related to only one company. A company is related to a single participant type. A participant type may appear on many companies. These help in identifying people, company and participant type.

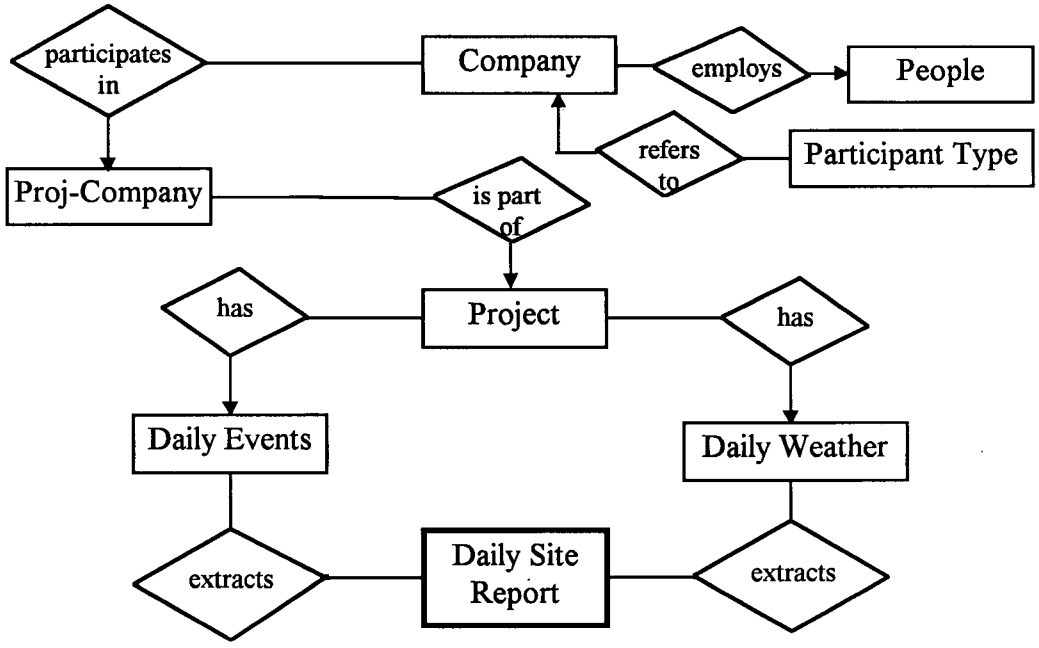

Figure 4.18 E/R Diagram for Daily Site Report

4.4.6 View 6: Defective Work Notifications (DWN) Tracking Log

A Defective Work Notice is a written notice of deficiency and a formal demand for corrective action by the contractor. The term Defective Work refers to work that does not meet the contract requirements. These notices are received from time to time during the course of any project. A work may be rejected by the engineer or owner's representative on the basis of non-complying work, material, or tests of material.

A Defective Work Notification Tracking Log (Figure 4.19) is helpful in tracking down the defective-work notices received and the subsequent related actions taken for correction. As any non-complying work is subject to removal and reconstruction, corrective action, or acceptance by the owner upon consideration of a price discount, this log is very useful in tracking down rejected work and its nature of rejection, corrective action needed, and estimated value.

This view provides information about defective-work notices or non-compliance work notice to the Project Manager, Project Engineer, Field Engineer, and Superintendent. This information relates to the notices issued by architect/engineer of a project, and their corrective action needed.

DEFECTIVE WORK NOTIFICATION (DWN) LOG

Project: CITY WAREHOUSE BUILDING
Project# 1

Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

Notice No.	Notification Date	Specs. Section	Description/Location	Date Notice Received	Engineer's Estimated Value	Date Reinspected	Reinspected By	Notification of Correction Received	Total Days For Correction	Comments
1	6-Jun-95	03200	Concrete reinforcement in F5 footing not proper	7-Jun-95	$ 150	8-Jun-95	Engineer	9-Jun-95	1	
2	12-Jun-95	03370	Concrete curing not carried out on grade beams	12-Jun-95	$ 100	13-Jun-95	Engineer	14-Jun-95	1	
3	15-Jun-95	15400	Piping installed in wrong position in washroom	16-Jun-95	$ 250	20-Jun-95	Engineer	20-Jun-95	4	
4	25-Jun-95	03300	Concrete side walk not level	25-Jun-95	$ 200	5-Jul-95	Engineer	6-Jul-95	10	
5	30-Jun-95	05500	Metal fabrications cracking at weld joint	30-Jun-95	$ 500	5-Jul-95	Engineer	6-Jul-95	5	
6	3-Jul-95	15400	Piping tests not performed correctly	4-Jul-95	$ 750	10-Jul-95	Engineer	11-Jul-95	6	
7	5-Jul-95	02700	Swerage and drainage bedding not proper	5-Jul-95	$ 350	7-Jul-95	Engineer	8-Jul-95	2	
8	6-Jul-95	02760	Existing underground pipe damaged	7-Jul-95	$ 450	15-Jul-95	Engineer	15-Jul-95	8	
9	10-Jul-95	03100	Concrete formwork for level-1 wall out of level	10-Jul-95	$ 350	11-Jul-95	Engineer	12-Jul-95	1	
10	15-Jul-95	07150	Dampproofing not provided on ext. wall footing	16-Jul-95	$ 400	25-Jul-95	Engineer	26-Jul-95	9	
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Figure 4.19 View-6 Defective Work Notification (DWN) Tracking Log

The following queries are typical examples for this view of the data:

Project Manager, Project Engineer:

- Find the details of non-compliance notices. The output should have the project id, notice number, description and type of rejection, notice date, receiving date, estimated value, subcontractor id, and correction status.

Field Engineer and Superintendent:

- Find the list of outstanding rejected work and its status for field inspection. The output should have the project id, notice number, area or location, subcontractor id, inspection date, and status.

It is assumed that only one log is maintained to record Defective Work Notifications of all the projects or sites executed by this organization. Also, it assumed that the DWN# (Defective Work Notification number) is a unique serial number of Defective Work Notifications for a project, and that a particular Defective Work Notification is identified by both ProjectID and DWN# .

The Defective Work Notifications Tracking Log (DWNTL) may be expressed as follows:

DWNTL (ProjectID, Project Name, (EngineerID, Engr Name, (Engr Contact), Engr Phone), (DWN#, NoticeDate, Description, DateRcvd, EstimatValue, Date Reinspected, Reinspected By, D-NoCR, TDfC*, Comments, File Ref.

no.*, (SpecsID, Specs Section, (WBS_ID, Item Description, (TradeID, Trade Name, (SubID, Sub Name, Sub Contact, Sub Phone))))))

Table 4.7 Key Terms for DWN Tracking Log

Key Terms	Definitions
DWN#	project's DWN entry serial number
NoticeDate	DWN issue date
DateRcvd	date DWN received
EstimatValue	estimated value of the DWN item
DateReinsp	date the DWN item reinspected
D-NoCR	date no-objection certificate received
TDfC	total days for correction

The entities and relationships that apply to this view are shown in Figure 4.20. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Defective work notification (DWN) is the principal entity of this data model. A defective work notifications log lists each DWN. A DWN can be identified by both ProjectID and DWN# (Table C.8, Appendix C). A DWN will be referred to a single specs section. A specs section may appear on many DWN.

As the Figure 4.20 is similar to the Figure 4.14., the relationships of entities specs section, WBS, trade, proj-trade, project, PTD, company and people are the same as explained in the last paragraph of section 4.2.3.

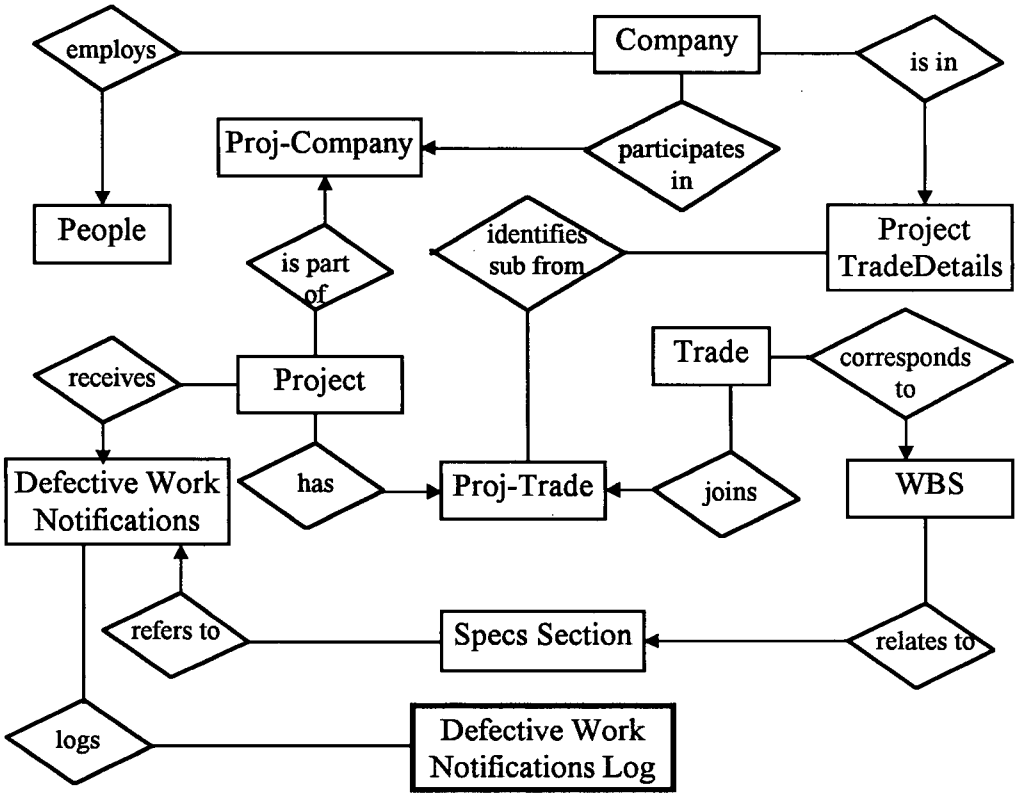

Figure 4.20 E/R Diagram for Defective Work Notifications Tracking Log

4.4.7 View 7: Materials Stored Tracking Log

This view describes materials delivered to the site but not yet incorporated. Most construction projects have construction materials stored at site or at another predetermined locations. Information about the availability of materials is always helpful in order for construction to proceed smoothly. Some contracts even allow for partial or full

payment of materials stored. When costly items requiring long lead times to fabricate are delivered to the site, it is often customary to ask for partial payment for such items while they are stored at the site. The remaining value is then paid only after they have finally been installed in the work.

A Materials Stored Tracking Log (Figure 4.21) is useful in tracking down stored materials, their location and value.

This view provides the Project Manager, Project Engineer, Purchasing Agent, Estimator, and Superintendent information about materials delivered but not yet incorporated into the work.

The following queries are typical examples for this view of the data:

Project Manager, Project Engineer, Purchasing Agent, and Superintendent:

- Find the status of materials on the site. To get materials if required. The output should have the project id, material description, supplier id, supplier name, supplier phone number, stored location, original quantity stored, quantity installed to-date, location installed, quantity currently stored.

MATERIALS STORED TRACKING LOG

Project: WAREHOUSE BUILDING
Project# 1
Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

PREVIOUSLY STORED:	$ 274,000
CONSUMED:	$ 59,350
CURRENTLY STORED:	$ 214,650

ITEM NO.	SUPPLIER	DESCRIPTION	LOCATION STORED	LOCATION INSTALLED	PAY EST NO.	EST Date	% used	ORIGINAL VALUE STORED	AMOUNT CONSUMED TO DATE	AMOUNT CURRENTLY STORED
1	Material Corp.	HVAC ductwork and fittings	Site stoage area	Office area	1	2/1/95	30	$ 45,000	$ 13,500	$ 31,500
2	Steel Supply	Various Shapes and frames for grating	Site Storage area	Office area	1	2/1/95	25	$ 32,000	$ 8,000	$ 24,000
3	ABC Products	Roofing, felt, nails, equipment	Contractor's warehouse off site	Operation building	1	2/1/95	20	$ 49,000	$ 9,800	$ 39,200
4	XYZ Materials	Fiberglass ductwork and fittings	NE corner of site	Kitchen area	2	3/1/95	30	$ 10,000	$ 3,000	$ 7,000
5	Wood Products	Wooden trusses	Fenced storage area	Office area	2	3/1/95	25	$ 24,000	$ 6,000	$ 18,000
6	Equipment Mart	Fittings for HVAC equipments	Site storage area	Office area	2	3/1/95	15	$ 27,000	$ 4,050	$ 22,950
7	Material Corp.	Ductile iron pipe	Fenced storage area	Opreation building	3	4/1/95	15	$ 37,000	$ 5,550	$ 31,450
8	Steel, Inc.	Metal bracing for tank	Fenced storage area		2	3/1/95	20	$ 15,000	$ 3,000	$ 12,000
9	Material Corp.	Threaded rods and fasteners	Site atorage area	Kitchen area	3	4/1/95	25	$ 12,000	$ 3,000	$ 9,000
10	Wood Products	Wooden Trusses	Fenced storage area	Office area	3	4/1/95	15	$ 23,000	$ 3,450	$ 19,550
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Figure 4.21 View-7 Materials Stored Tracking Log

Estimator:

- Find the value of material stored and installed. The output should have the project id, material description, stored location, original quantity stored, original value stored, % installed, installed quantity to-date, amount installed to-date, location installed, quantity currently stored, amount currently stored.

It is assumed that only one tracking log is maintained to record materials of all the projects or sites executed by this organization, and a supplier is the same as the subcontractor of that trade. Also, it assumed that the Mat# (material number) is a unique serial number of material stored at a project, and that a particular stored-material is identified by both ProjectID and Mat#.

The user view of Materials Stored Tracking Log (MSTL) in expressed as follows:

MSTL (ProjectID, Project Name, (EngineerID, Engr Name, (Engr Contact), Engr Phone), (Mat#, Item Description, (Loc_ID, Location Stored), Loc-Installed, Original Value, Pay Est#, Pay Est Date, % Installed, Amount Consumed To-date*, Amount Currently Stored*, File Ref. no.*, (SpecsID, Specs Section, (WBS_ID, Item Description, (TradeID, Trade Name, (SupplierID, Supplier Name, Supplier Contact, Supplier Phone)))

Table 4.8 Key Terms for Materials Stored Tracking Log

Key Terms	Definitions
Mat#	project's materials stored entry serial number
Item Description	description of the materials stored as in the WBS
Location Stored	location where the materials stored
Loc-Installed	location where the materials installed
Original Value	total value of the materials when initially stored
Pay Est#	monthly payment estimate number
Pay Est Date	monthly payment estimate date
% Installed	estimated % quantity installed to-date

The entities and relationships that apply to this view are shown in Figure 4.22. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Materials stored list (MS) is the principal entity of this data model. A materials stored log lists each material which is stored. An MS can be identified by both ProjectID and Mat# (Table C.9, Appendix C). An MS is related to a single storage location. A storage location may appear on many MSL. An MS will be referred to a single specs section. A specs section may appear on many MS.

As the Figure 4.22 is similar to the Figure 4.14., the relationships of entities specs section, WBS, trade, proj-trade, project, PTD, company and people are the same as explained in the last paragraph of section 4.2.3.

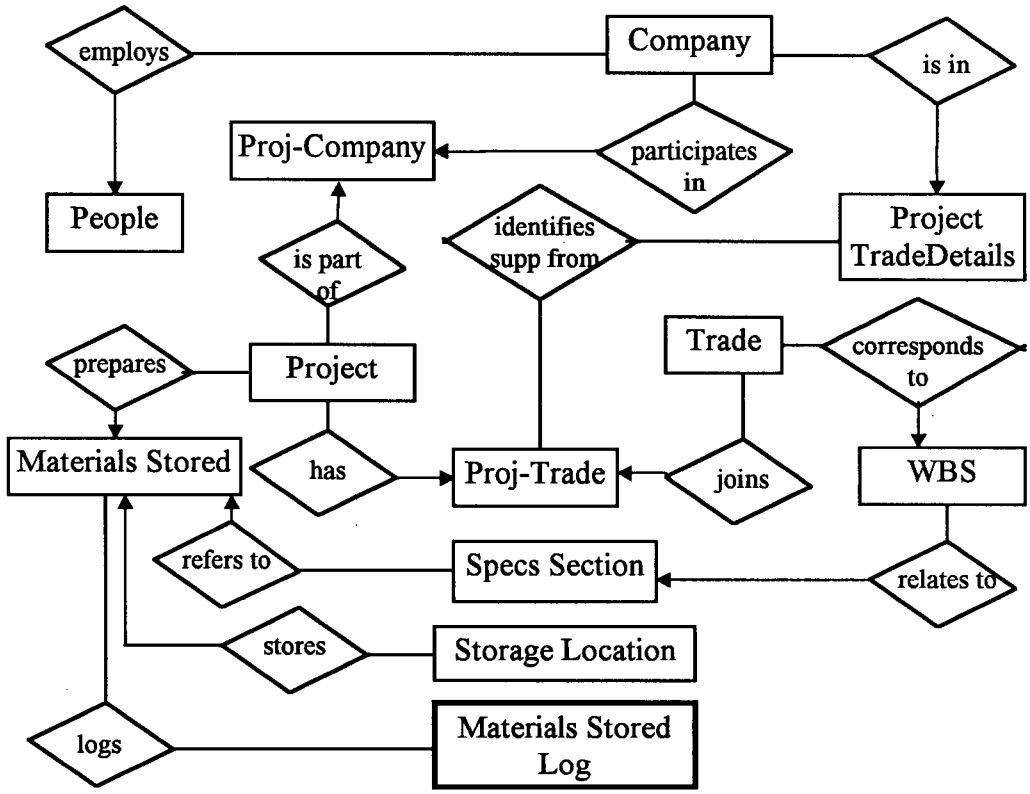

Figure 4.22 E/R Diagram for Materials Stored Tracking Log

4.4.8 View 8: Monthly Progress Report

A contractor is required to submit to the engineer a monthly progress report or a monthly statement showing the estimated quantity of work done up to the end of each month for the progress payment. It is a very important part of the contractor's operation since it provides the cash flow to progress through the job smoothly.

A Monthly Progress Report (Figure 4.23) is a means of itemizing work completed to-date and extending the amount during the current pay period. This report includes all the items on the Bill of Quantities and further columns to show the current month's progress (quantity or percentage, and earnings), and to-date progress (quantity or percentage, and earnings). This view also provides total monthly value of work done for a particular trade for an interim payment to subcontractors.

This view provides monthly and up-to-date progress information to the Construction Manager, Project Manager, Project Engineer, Estimator, Planning and Scheduling Engineer, and Field Engineer.

The following queries are typical examples for this view of the data:

Construction Manager, Project Manager, Project Engineer:

- Find the progress of work. The output should have the project id, pay estimate number and date, work done and earnings (for the month and to-date).

Planning and Scheduling Engineer:

- Find the work remaining for updating the monthly schedule. The output should have the project id, pay estimate number and date, and work done (to-date).

MONTHLY PROGRESS REPORT

PROJECT: CITY WAREHOUSE BUILDING
PROJECT# 1

Payment Estimate # 2
Estimate Date: 01 Mar 1995

CONTRACTOR
XYZ Contracting
Vancouver, B.C.
Tel:
Prime Contact:
Second Contact:

ENGINEER
ABC Engineers
Vancouver, B.C.
Prime Contact:
Second Contact:
Tel:

Pay Item No.	ITEM DESCRIPTION	CONTRACT				THIS MONTH		TO DATE	
		Quantity	Unit	Unit Price	Item Total	% Quantity	Earnings	% Quantity	Earnings
1	Demolition	1	L.S.	$100,000	$100,000	20	$20,000	60	$60,000
2	General Excavation	1	L.S.	$75,000	$75,000	25	$18,750	40	$30,000
3	Structural Concrete	1	cum	$125,000	$125,000	15	$18,750	20	$25,000
4	Brick & Block Masonary Works	1700	sqm	$50	$85,000	20	$17,000	25	$21,250
5	Structural Steel Works	2000	ton	$200	$400,000	10	$40,000	20	$80,000
6	Decking & Siding	1500	sqm	$150	$225,000	25	$56,250	30	$67,500
7	Waterproofing & Dampproofing	1	L.S.	$45,000	$45,000	15	$6,750	20	$9,000
8	Roofing	1700	sqm	$35	$59,500	20	$11,900	20	$11,900
9	Skylights	6	ea	$1,500	$9,000				
10	Wooden Doors	40	ea	$350	$14,000				
11	Hollow Metal Windows	40	ea	$350	$14,000				
12	Lath & Plaster	1400	sqm	$45	$63,000				
13	Drywall	2500	sqm	$34	$85,000				
14	Ceramic Tiles	1050	sqm	$50	$52,500				
15	Plumbing and Water supply	1	L.S.	$84,000	$84,000	15	$12,600	15	$12,600
16	Heating, Ventilating, & Airconditioning	1	L.S.	$165,000	$165,000	15	$24,750	15	$24,750
17	Fire Protection Works	1	L.S.	$54,000	$54,000				
18	Electrical Works	1	L.S.	$135,000	$135,000	15	$20,250	15	$20,250
				TOTAL	$1,790,000		$247,000		$362,250

Figure 4.23 View-8 Monthly Work Progress Report

Estimator, Field Engineer, Accountant:

- Determine the monthly progress. The output should have the project id, pay estimate number, pay estimate date, itemized work with total quantity, unit, unit price, work done and earnings (for the month and to-date), work done for a trade (for the month and to-date).

It is assumed that only one progress payment tracking log is maintained to record monthly progress of all the projects or sites executed by this organization. Also, it assumed that the Pay Est# (Payment Estimate number) is a unique serial number of the Monthly Progress reports for a project, and that a particular monthly progress is identified by both ProjectID and Pay Est#.

The user view for Monthly Progress Report (MPR) is expressed as the following relations:

MPR (ProjectID, Project Name, (EngineerID, Engr Name, (Engr Contact), Engr Phone), (Pay Est#, PayEst Date, This Qntty, This Earnings*, To-date Qntty, To-date Earnings*, (WBS_ID, Item Description, Quantity, Unit, Unit Price, Item Total*, (TradeID, Trade Name, (SubID, Sub Name, Sub Contact)))))

Table 4.9 Key Terms for Monthly Progress Report

Key Terms	Definitions
Pay Est#	project's sequential payment estimate number
PayEst Date	date of the payment estimate
Item Description	item description as in WBS
Quantity	total quantity of the item
Unit	measurement unit of the item as in WBS
Unit Price	unit price of the item in $
Item Total	Quantity x Unit Price
This Qntty	percentage of the work item done for the month
This Earnings	Quantity x Unit Price x This Qntty
To-date Qntty	percentage of the work item done to-date
To-date Earnings	Quantity x Unit Price x To-date Qntty.

The entities and relationships that apply to this view are shown in Figure 4.24. This figure is in accordance with the purpose of the user view as discussed earlier in this section. Monthly progress is central to this data model. A monthly progress can be identified by both ProjectID and Pay Est# together (Table C.10, Appendix C). A monthly progress report is an extension of a monthly progress. A monthly progress is related to a single project and a single BoQ. A project may appear on many monthly progress, as could a BoQ. There may be many projects. A BoQ is just an extension of PID. A PID is related to a single WBS. A WBS may appear on many PID. A WBS is related to a single trade. A trade will appear on many WBS. A proj-trade is related to a single project and a single trade. A project may appear on many proj-trade, as could a trade. A proj-trade is related to a single PTD. Thus a proj-trade identifies a trade subcontractor for a progress payment.

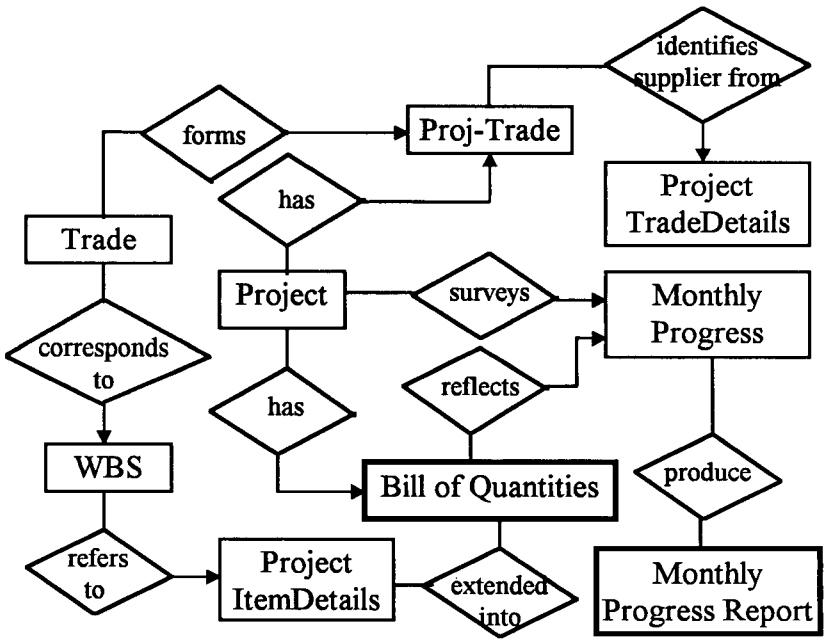

Figure 4.24 E/R Diagram for Monthly Progress Report

4.4.9 View 9: Photographs Tracking Log

Photographs of job progress or construction details are a very valuable part of the project documentation. Some specifications require a general contractor to take progress photographs on a regular basis. This leads to a considerable amount of work in photograph and negative-handling alone. Even if it is not a project requirement, many contractors take job photographs for a variety of reasons, for example: to record the

uncovering of unusual conditions; to act as a further substantiation of a change-order request; to record a complex construction process to show compliance with the contract documents; to record the condition of materials, and environments; etc. The type of photographs are related to their purpose: progress photographs, public relation photographs, time-lapse photographs, claims-exhibit photographs, etc.

A Photographs Tracking Log (Figure 4.25) is a useful means for tracking down photographs by either roll number, negative number, facility or area, date, or keywords. This log is maintained as a permanent record of all construction photographs taken. It is an orderly means of photograph indexing and retrieval for any purpose. In addition, it establishes the date and sequence of photographs intended for claims exhibits.

This view provides project's photographs information to the Project Manager, Project Engineer, Planning and Scheduling Engineer, and Field Engineer.

The following queries are typical examples for this view of the data:

- Find the details of a photograph. The output should have the project id, photo number, roll number, negative number, facility/location, date taken, time of day, name of photographer, direction of camera, position of photographer, photo type, keywords, and caption.

PHOTO TRACKING LOG

Project: CITY WAREHOUSE BUILDING
Project# 1

Owner: City Warehouse '
Engineer: XYZ Engineering; Inc.
Contractor: ABC Contracting

FACILITY LEGEND	
1=Main Bldg.	5=Level 1
2=Operation Area	6=Level 2
3=Generator Room	7=Conveyor
4=Compactor	8=other

Photo No.	Facility No.	Roll No.	Negative No.	Photogr. Name	Camera Direction	Photogr. Position	Date Taken	Time of day	Keyword ONE	Kyword TWO	CAPTION
1	8	1	2	AM	NE	Sidewalk	25-Jan-95	10:00 AM	STREET	TRAFFIC	Traffic routing during setup
2	5	1	4	AM	Front	Front	25-Jan-95	10:30 AM	CASING	CASING	Pump No. 1 casing cracked
3	6	1	7	AM	Top	Rim of Well	26-Jan-95	9:00 AM	WET WELL	DEBRIS	Floating debris in well
4	3	1	9	AM	Front	Front	29-Jan-95	10:00 AM	ELECTRICAL	MCC	Starters damaged
5	4	1	11	AM	Back	Corner of roo	29-Jan-95	11:00 AM	EQUIPMENT	GEAR RED.	Gear reducer leaking oil
6	5	1	14	AM	Front	Front	29-Jan-95	11:30 AM	PUMP	DRIVE COUPLIN	Coupling loose
7	3	1	15	AM	Front	entrance	30-Jan-95	2:00 PM	ELECTRICAL	MCC	MCC 3 during setup
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Figure 4.25 View-9 Photograph Tracking Log

It is assumed that only one tracking log is maintained to record photographs of all the projects or sites executed by this organization. Also, it assumed that the Photo# (photograph number) is a unique serial number of photographs for a project, and that a particular photograph is identified by both ProjectID and Photo#.

The user view for Photo Tracking Log (PTL) is expressed as the following relations:

PTL (ProjectID, Project Name, (EngineerID, Engr Name, (Engr Contact), Engr Phone), (Photo#, Roll#, Negative#, Date Taken, Time of day, (Photogr ID, Photogr Name), Camera direction, Photogr position, Facility/Location, Keyword1, Keyword2, Caption, File Ref. no.*, (Photo TypeID, Photo Type)))

Table 4.10 Key Terms for Photographs Tracking Log

Key Terms	Definitions
Photo#	project's photograph entry serial number
Roll#	serial number of the film roll
Negative#	negative-number in the film roll
Date Taken	date of photograph
Time of day	time of the day when the photograph taken
Photogr ID	PeopleID of the photographer
Camera direction	direction of camera while taking photograph
Facility/Location	name of the location photo taken for
Photgr Position	position of the photographer
Keyword1	first keyword describing the photograph
Keyword2	second keyword describing the photograph
Caption	caption or title of the photograph
Photo Type	purpose of a photograph

The entities and relationships that apply to this view are shown in Figure 4.26. This figure is in accordance with the purpose of the user view as discussed earlier in this section. Photograph is the principal entity of this data model. A photographs log lists each photographs taken on a project. A photograph is related to a single project and a single photo type. A project may appear on many photographs, as could a photo type. There will be many photo types. There may be many projects. A photograph can be identified by both ProjectID and Photo# together (Table C.13, Appendix C). A proj-company is related to a single project and a single company. A project may appear on many proj-company, as could a company. It helps in identifying the A/E. People is related to a single company. A company may appear on many people. It helps in identifying the contact person of A/E.

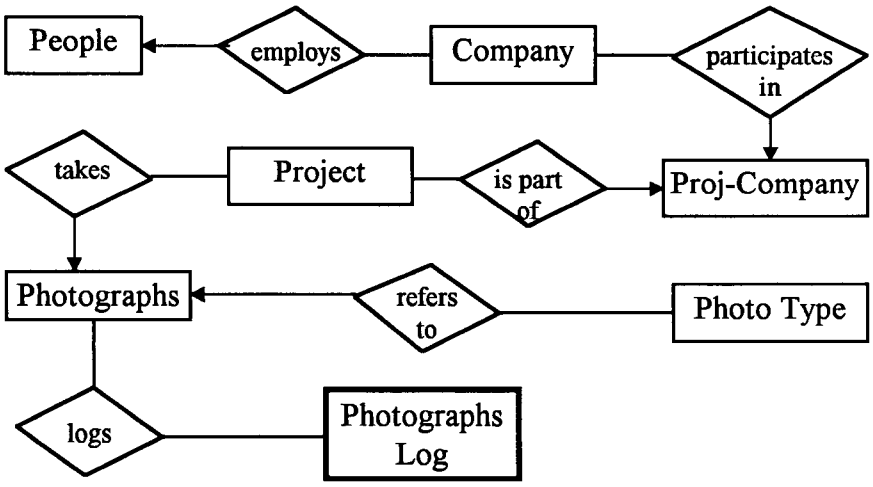

Figure 4.26 E/R Diagram for Photographs Tracking Log

4.4.10 View 10: Punch Lists

A Punch List is a list of items, usually minor, prepared by the owner or engineer, that must be completed by the contractor before a project is finally accepted. In other words, it is a guide list during finishing stages of a contract to indicate all work or corrective action remaining before acceptance of the work. The quantity of punch list items may vary from project to project. From a contractor's standpoint, the punch list is the final doorway to project completion and acceptance. In order to ensure prompt completion of this critical close-out requirement, a definitive method of recording, tracking and reporting punch list items is a necessity of the project.

A Punch List (Figure B-10, Appendix-B) is a useful means of recording, tracking and reporting punch list items. It contains the date each punch list item originated, an accurate description of the work to be done, the person generating the item, an estimated dollar value of the work, the date each punch list item was rechecked, and the person rechecking the item.

This view provides punch list information to the Project Manager, Project Engineer, Field Engineer, and Superintendent.

PUNCH LIST

Project: CITY WAREHOUSE BUILDING
Project# 1

Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

Work Type Legend	
G=General	I=Instrument
C=Civil	M=Mechanical
E=electrical	H=HVAC

Item #	Facility	Work Type	Punch List Item/location	Subcontractor	Date Idenfied	Identified By	Work Completed		
							Date Compl	Date Checked	Checked by
1	Operation Area	C	Paint touchup inside operation area	ABCContracting	25-Apr-95	Engineer	5-May-95	6-May-95	Engineer
2	Operation Area	E	Light in control room not operating properly	Globe Electricals	25-Apr-95	Engineer	5-May-95	6-May-95	Engineer
3	Operation Area	E	Tighten electrical outlet wall panel	Globe Electricals	25-Apr-95	Engineer	6-May-95	8-May-95	Engineer
4	Operation Area	H	Grill bent in main control room	Awal Engineering	25-Apr-95	Engineer	6-May-95	8-May-95	Engineer
5	Operation Area	C	Clean out construction debris	ABCContracting	25-Apr-95	Engineer	6-May-95	8-May-95	Engineer
6	Operation Area	E	Submit load test report	Globe Electricals	25-Apr-95	Engineer	7-May-95	8-May-95	Engineer
7	Operation Area	C	Clean out entrance area	ABCContracting	25-Apr-95	Engineer	7-May-95	8-May-95	Engineer
8	Operation Area	E	Ceiling lights not mounted properly	Globe Electricals	25-Apr-95	Engineer	7-May-95	8-May-95	Engineer
9	Operation Area	M	Adjust speed of conveyor belt	Awal Engineering	25-Apr-95	Engineer	8-May-95	10-May-95	Engineer
10	Operation Area	H	Balance HVAC system	Awal Engineering	25-Apr-95	Engineer	8-May-95	10-May-95	Engineer
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Figure 4.27 View-10 Punch List

The following queries are typical examples for this view of the data:

Project Manager and Project Engineer:

- Find the status of remaining work items, and the name of the responsible subcontractors. The output should have the project id, item description, status, Engineer Name, Engineer Contact, Engineer phone, subcontractor name, contact name, and phone number.

Field Engineer and Superintendent:

- Find the remaining work items and their details. The output should have the project id, item description, facility/area, date identified, date completed, date checked, subcontractor name, contact name, and phone number.

It is assumed that only one tracking log is maintained to record punch list items of all the projects or sites executed by this organization. Also, it assumed that the PL# (punch list number) is a unique serial number of Punch List Item for a project, and that a particular Punch List item is identified by both ProjectID and PL# .

The Punch List (PL) may be expressed in relational form as follows:

PL (ProjectID, Project Name, (EngineerID, Engr Name, (Engr Contact), Engr Phone), (PL#, Punch List Item, Facility/Area, Date Identified, Identified By, Date Completed, Date Checked, Checked By, File Ref. no.*, (SpecsID, Specs

Section, (WBS_ID, Item Description, (TradeID, Trade Name, (SubID, Sub Name, Sub Contact, Sub Phone))))

Table 4.11 Key Terms for Punch Lists

Key Terms	Definitions
PL#	project's punch list entry serial number
Punch List Item	item description of the punch list
Facility/Area	facility or area of the punch list item
Date Identified	date noticed or identified by the A/E
Date Completed	date the item completed for re-inspection
Date Checked	date rechecked or inspected by the A/E
Checked By	PeopleID of the inspector

The entities and relationships that apply to this view are shown in Figure 4.28. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Punch lists is the principal entity of this data model. A punch lists log enters each punch list item. A punch list can be identified by both ProjectID and PL# (Table C.18, Appendix C). A punch list item is related to a single project and a single specs section. A project may appear on many punch list, as could a specs section.

As the Figure 4.28 is similar to the Figure 4.14., the relationships of entities specs section, WBS, trade, proj-trade, project, PTD, company and people are the same as explained in the last paragraph of section 4.2.3.

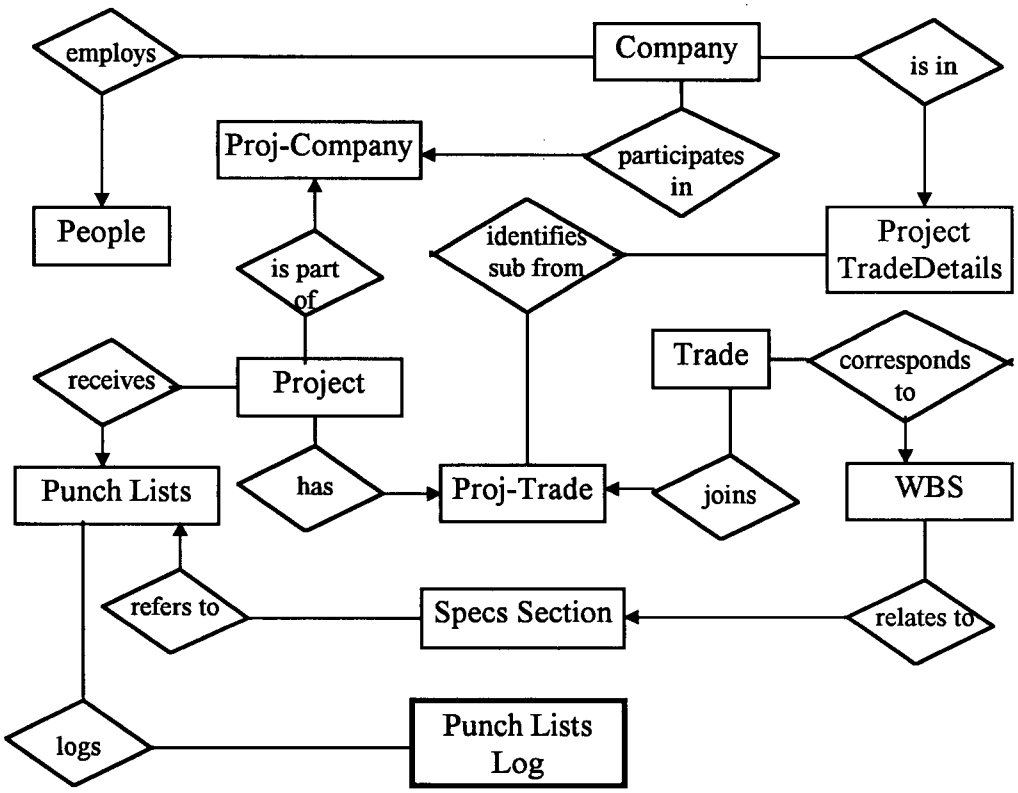

Figure 4.28 E/R Diagram for Punch Lists

4.4.11 View 11: Requests for Information (RFI) Tracking Log

During the bidding and construction phases, a number of questions arise regarding interpretation of those portions of the plans and specifications that are unclear, vague, or in conflict with the contract documents. These field questions are often termed Requests for Information (RFI) or Request for Clarification (RFC). In most construction contracts,

the engineers are obliged to provide answers to the questions in a reasonable amount of time. Sometimes, late clarification is a basis for claims. Hence a system is required for filing, locating and retrieving both questions and answers throughout the life of a project.

An RFI Tracking Log (Figure 4.29) is a means of logging and tracking field clarification questions, critical items and their dates. This log is used when questions arise from subcontractors and require answers from the general contractor or from the design consultants, or when the general contractor needs to obtain information or clarification from a subcontractor or owner/architect/engineer.

This view enables the Project Manager, Chief Engineer, and Project Engineer to control information about RFI or clarification from different project participants.

The following queries are typical examples for this view of the data:

- Retrieve a particular RFI. The output should have the project id, initiation date, initiator id, and RFI# and description.

- Find details of a particular RFI. The output should have the project id, initiation date, initiator id, , RFI# and description, related specs section and drawing number, dates of transaction, response, response by, and comments.

REQUESTS FOR INFORMATION (RFI) TRACKING LOG

Project: City Warehouse Building
Project#: 1

Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

						Status Dates/Review Time					
RFI #	Initiation Date	Initiated By	Specs. Section	Drwg No.	DESCRIPTION	Date Sent to Engineer	Date Received Back	Date snet back to sub	Resp by	Total Time Days	Comments
1	05-Jan-95	Estimator	03300	-	Is the aggregate gradation complete?	05-Jan-95	13-Jan-95	13-Jan-95	AKB	8	
2	05-Jan-95	Estimator	03300	C-2	Can site concrete be used for ditches?	05-Jan-95	13-Jan-95	13-Jan-95	AKB	8	
3	06-Jan-95	Estimator	03320	M-5	Can manholes be sealed with mastic?	06-Jan-95	15-Jan-95	15-Jan-95	AKB	9	
4	06-Jan-95	Estimator	16100	G-4	Do all electric handholes require drainage?	06-Jan-95	16-Jan-95	16-Jan-95	CKJ	10	
5	09-Jan-95	Estimator	16200	M-24	Do DB conduits require coating?	10-Jan-95	19-Jan-95	19-Jan-95	CKJ	9	
6	10-Jan-95	Estimator	-	H-12	Clarify Detail	10-Jan-95	20-Jan-95	20-Jan-95	AKB	10	
7	10-Jan-95	Estimator	-	C-23	Clarify setion A	10-Jan-95	20-Jan-95	20-Jan-95	AKB	10	
8	12-Jan-95	Estimator	-	C-12	Clarify Details 4,5,and 6	12-Jan-95	25-Jan-95	25-Jan-95	AKB	13	
9	12-Jan-95	Estimator	09900	M-19	Do all metal boxes get paint?	12-Jan-95	22-Jan-95	22-Jan-95	CKJ	10	
10	15-Jan-95	Estimator	00400	C-1	What are requirement for dust control?	16-Jan-95	24-Jan-95	24-Jan-95	CKJ	8	
11	17-Jan-95	Estimator	16450	M-7	Do all buried pipes recive cathodic protection?	17-Jan-95	28-Jan-95	28-Jan-95	CKJ	11	
12											
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14											
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Figure4.29 View-11 Request for Information (RFI) Tracking Log

- Find the total response time. The output should have the project id, initiation date, RFI# and description, response date, and response time.

- List the outstanding RFIs. The output should have the project id, RFI#, initiation date, and response date.

- Find the contact numbers of engineer and subcontractor. The output should have the project id, RFI#, engineer name, engineer contact, engineer phone, sub name, sub contact, and sub phone number.

It is assumed that only one tracking log is maintained to record RFIs of all the projects or sites executed by this organization. Also, it assumed that the RFI# (requests for information number) is a unique serial number of RFI for a project, and that a particular RFI item is identified by both ProjectID and RFI# .

The user view for the RFI Tracking Log (RFITL) is expressed as the following relations:

RFITL (ProjectID, Project Name, (EngineerID, Engr Name, (Engr Contact), Engr Phone), (RFI#, Initiation Date, (Initiated By, (Initiator ID, (Initiator Type))), Drawing#, RFI Description, D-RfS, D-StAE, D-RBfAE, D-SBtS, (Response by), Total Days*, Comments, File Ref. no.*))

Table 4.12 Key Terms for RFI Tracking Log

Key Terms	Definitions
RFI#	project's RFI entry serial number
Initiated By	PeopleID of the initiator
Initiator ID	Company identification number of the initiator
Initiator Type	Participant Type of the initiator company
Initiation Date	date of RFI initiation
Drawing#	drawing number for reference
RFI Description	short description of the RFI
D-RfS	date received from subcontractor
D-StAE	date sent to architect/engineer (A/E)
D-RBfAE	date returned back from A/E
D-SBtS	date sent back to subcontractor
Response By	PeopleID of the person who responded the RFI
Total Days	total time taken for a response in days

The entities and relationships that apply to this view are shown in Figure 4.30. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Requests for Information (RFI) is the principal entity of this data model. An RFI log lists each RFI. An RFI can be identified by both ProjectID and RFI# (Table C.19, Appendix C). An RFI is related to a single project and a single people. There may be many projects. A project may appear on many RFI, as could a people.

A people is related to a single company. A company may appear on many people. A company is related to a single participant type. A participant type may appear on many company. These help to identify initiator company and participant type. Proj-company is related to a single project and a single company. A project may appear on many proj-company, as could a company. These help in identifying the A/E and their contact persons.

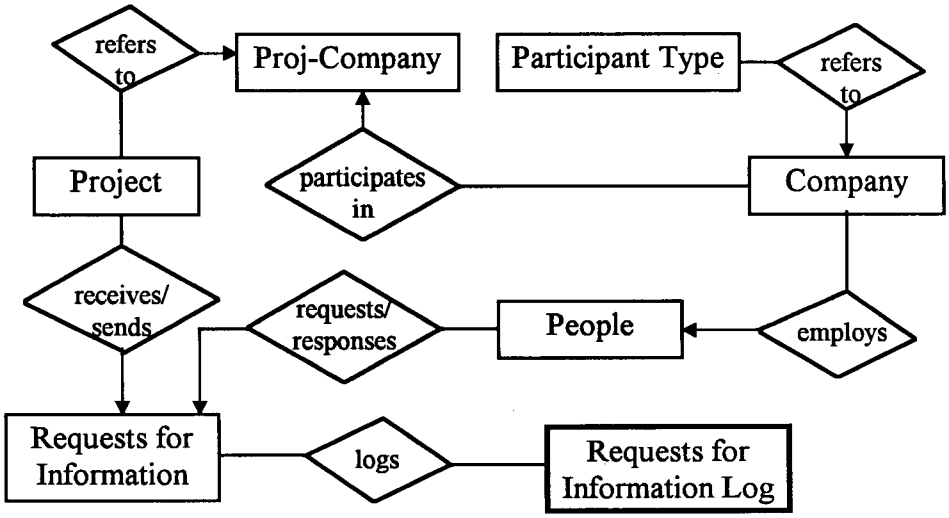

Figure 4.30 E/R Diagram for Requests for Information (RFI) Tracking Log

4.4.12 View 12: Shop Drawing Submittals Tracking Log

Submittals are an ordinary part of just about every construction project. The contractor and his subcontractors submit shop drawings, samples, certificates, test results, etc., for review by the owner or engineer. These submittals contain detailed information concerning relationships, quantities, construction methods, locations, sizes, and other information about equipment or materials to be incorporated into the construction project. A review of the specifications establishes the procedures for shop drawing or any other submissions.

Contractors often base equipment/material orders on timely review and return of the shop-drawing submittals. Most construction contracts require the engineer to review, comment on, and return shop-drawing submittals to the contractor within a certain time frame. Any shop drawings that are returned late can be a basis for a claim for time extension or have other impacts on the project. It is also important to note when a particular submittal is due from the subcontractors and suppliers, so that they can be reminded.

A shop drawing submittals log is a documentation of all shop drawing transmittals received from the subcontractors or sent to the engineer, and a record of the action taken in each case.

A Shop Drawing Submittals Tracking Log (Figure 4.31) is a means of logging, tracking, and following up on submitted shop drawings. Not only does such a tracking log allow a project manager to keep track of what drawings have been received; it also shows where the drawings have been sent and how long they have been there.

This view provides shop drawing submittals information to the Project Manager, Project Engineer, Purchasing Agent, and Superintendent. This information relates to the status of a shop drawing submittal which is submitted by a subcontractor or supplier and reviewed by the architect/engineer.

SHOP DRAWING SUBMITTAL TRACKING LOG

PROJECT: CITY WAREHOUSE BUILDING
PROJECT# 1

DISPOSITION LEGEND
1. Approved
2. Make Corrections Noted
3. Rejected
4. Revise and Resubmit
5. Submit Specified Item

CONTRACTOR
XYZ Contracting
Vancouver, B.C.
Prime Contact: mnop
Second Contact: qrst
Tel: 987 6543

ENGINEER
ABC Engineers
Vancouver, B.C.
Prime Contact: abcd
Second Contact: bcde
Tel: 876 5432

Shop Drawing Information								Submittal/Review Status Dates					Submittal Summary	
Submittal No.	Specs. Section	Disposition	KEYWORD DESCRIPTION	Name of Subs/Supp	Scheduled Date	Date Rcvd from Sub	No. of Copies	Date Sent to Engineer	Date Back from Engineer	Date Sent back to Sub/Supp	Copies back fr Engr.	Copies back to Sub	Total days to Process	Review Status/ Comments
1	03300	1	Cast-in-Place Concrete Mix Design	A1 Readymix	07-Jan-95	07-Jan-95	6	08-Jan-95	15-Jan-95	16-Jan-95	4	2	7	
2	03200	2	Concrete Reinforcement	Smith Steel	09-Jan-95	09-Jan-95	8	10-Jan-95	18-Jan-95	19-Jan-95	6	4	8	
3	02140	1	Dewatering Plan	Dewat Co.	10-Jan-95	10-Jan-95	6	10-Jan-95	18-Jan-95	19-Jan-95	4	2	8	
4	03370	5	Concrete Curing Compound	City Materials	15-Jan-95	15-Jan-95	6	15-Jan-95					#VALUE!	.... Being Reviewed ...
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Figure 4.31 View-12 Shop Drawing Submittals Tracking Log

The following queries are typical examples for this view of the data:

Project Manager and Project Engineer:

- Find shop-drawing due for submission. The output should have the project id, shop-drawing number, keyword description, scheduled date of submission, trade name, sub id, name, contact name and phone number.

- Find the details of a particular shop-drawing. The output should have the project id, shop-drawing number, keyword description, scheduled submission date, specs section, submission and review dates, disposition, and comments.

- Find the status of a shop drawing approval. The output should have the project id, shop-drawing number, dates of submission and reviews, disposition, comments, engineer name, contact and phone number.

- Find the time-lapse for shop-drawing review. The output should have the project id, drawing number, submission and approval dates, and total days to process.

Purchasing Agent and Superintendent:

- Find the status of a shop drawing. The output should have the project id, shop-drawing number, dates of submission and reviews, disposition, and comments.

It is assumed that only one tracking log is maintained to record Shop Drawing Submittals of all the projects or sites executed by this organization. Also, it assumed that the Shop Drwg# (shop drawing number) is a unique number (computed through query expression) for a project, and that a particular Shop-Drawing Submittal is identified by both ProjectID and Shop Drwg#.

The Shop Drawing Submittals Tracking Log (SDSTL) is expressed as follows:

SDSTL (ProjectID, Project Name, (EngineerID, Engr Name, (Engr Contact), Engr Phone), (Shop Drwg#, Scheduled Date*, Description, Disposition, D-RfS, D-StAE-I, D-StAE-R, D-StAE-F, D-RBfAE, D-SBtS, C-RfS, C-StAE, C-RBfAE, C-SBtS, TDP*, Comments, File Ref. no.*, (WBS_ID, (TradeID, Trade Name, (Sub ID, Sub Name, Sub Contact, Sub Phone)))))

Table 4.13 Key Terms for Shop Drawing Submittals Tracking Log

Key Terms	Definitions
Shop Drwg#	shop drawing number
Scheduled Date	scheduled date of shop-drawing submission
Description	keyword or title of the shop drawing
Disposition	disposition or comments
D-RfS	date received from subcontractor
D-StAE-I	date sent to architect/engineer (A/E), initial
D-StAE-R	date sent to A/E, re-submission
D-StAE-F	date sent to A/E, final
D-RBfAE	date returned back from A/E
D-SBtS	date sent back to subcontractor
C-RfS	copies received from subcontractor
C-StAE	copies sent to A/E
C-RBfAE	copies received back from A/E
C-SBtS	copies sent back to subcontractor
TDP	total days to process (from submittal to approval)

The entities and relationships that apply to this view are shown in Figure 4.32. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Shop drawing submittals (SDS) is central to this data model. A SDS can be identified by both ProjectID and WBS_ID together (Table C.20, Appendix C), as could a PID (Table C.14, Appendix C). A SDS is related to a single PID, and vise versa. A shop drawing log lists each SDS.

As part of the Figure 4.32 is similar to the Figure 4.14., the relationships of entities specs section, WBS, trade, proj-trade, project, PTD, company and people are the same as explained in the last paragraph of section 4.2.3.

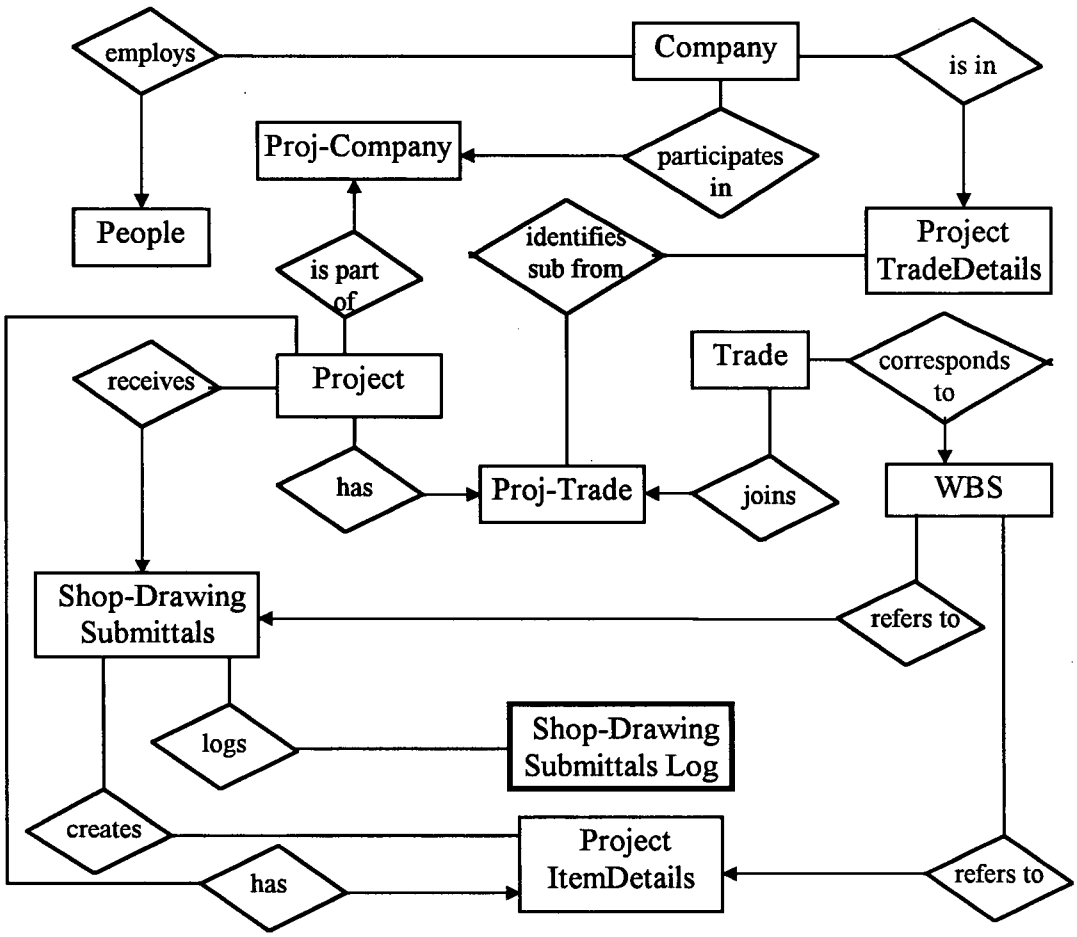


Figure 4.32 E/R Diagram for Shop Drawing Submittals Tracking Log

4.4.13 View 13: Spare Parts Tracking Log

Some construction contracts require installation of different types of equipment and sometimes also require a large inventory of spare parts to be handed over to the owner at the end of the contract. A record of spare parts becomes an important part of a project. A Spare Parts Tracking Log (Figure 4.33) is a means of tracking down spare parts that have or have not been delivered to the owner.

SPARE PARTS LOG

Project: CITY WAREHOUSE BUILDING
Project# 1

Owner: City Warehouse
Engineer: XYZ Engineering, Inc.
Contractor: ABC Contracting

= Spare Parts Still Needed

Specs. Section	Equipment Description	Spare Part Description	Location Stored	Quantity Required		Quantity Delivered			STATUS
05300	Metal decking	Metal decking corrugated sheets	Site storage yard	1000	sqm	600	sqm	#	Still need 400 sqm of Metal decking corrugated sheets
07800	Skylights	Skylight domes, size 2 m x 2m	Site stores	10	no.	12	no.		Provided 2 no. More than required of Skylight domes, size 2 m x 2m
08100	Metal Doors and Frames	Metal doors, size 2.4 m x 1.2 m	Site stores	20	no.	20	no.		
08500	Metal windows	Metal windows, size 1.2 m (H) x 1.5 m (w)	Site stores	30	no.	25	no.	#	Still need 5 no. of Metal windows, size 1.2 m (H) x 1.5 m (w)
09250	Gypsum board	Gypsum board, size 1.2 m x 2.4 m	Site stores	500	sqm	400	sqm	#	Still need 100 sqm of Gypsum board, size 1.2 m x 2.4 m
09300	Tile	Glazed wall tiles 150 mm x 150 mm	Site stores	350	sqm	400	sqm		Provided 50 sqm More than required of Glazed wall tiles 150 mm x 150 mm
09680	Carpet	Carpet flooring Scotchguard	Site stores	750	sqm	750	sqm		
11170	Solid waste handling equip	Heavy duty compressor	Site storage yard	2	no.	1	no.	#	Still need 1 no. of Heavy duty compressor
14200	Elevators	Three-floor-rise elevator	Site stores	2	no.		no	#	Still need 2 no of Three-floor-rise elevator
14500	Material Handling systems	Conveyor-belt and accessories	Site storage yard	2	units		units	#	Still need 2 units of Conveyor-belt and accessories
15650	Refrigeration	Food-Refrigeration units	Site stores	2	units	1	units	#	Still need 1 units of Food-Refrigeration units

Figure 4.33 View-13 Spare Parts Tracking Log

This view provides spare parts information to the Project Manger, Procurement Manager, Purchasing Agent, and Superintendents. This information relates to the listing of various spare parts to be delivered to the owner and their status.

The following queries are typical examples for this view of the data:

Project Manger and Procurement Manager:

- Find the status of spare parts delivery. The output should have the project id, spare part number, spare part description, equipment description, quantity required, quantity delivered, balance quantity to be delivered, supplier id, contact and phone number, and Owner/engineer contact and phone number.

Purchasing Agent and Superintendent:

- Find the list of spare parts to prepare a purchase order. The output should have the project id, spare part number, spare part description, equipment description, specs section, quantity required, quantity delivered, balance quantity to delivered, location stored, supplier id, contact and phone number.

It is assumed that only one tracking log is maintained to record the Spare Parts of all the projects or sites executed by this organization. Also, it assumed that the SP# (spare part number) is a unique serial number of Spare Part for a project, and that a particular Spare Part item is identified by both ProjectID and SP#.

The user view of Spare Parts Log (SPL) is expressed as the following relations:

SPL (ProjectID, Project Name, (EngineerID, Engr Name, (Engr Contact), Engr Phone), (SP#, SP Description, Eq Description, Qntty Required, Qntty Dlvd, Unit, (Loc_ID, Location Stored), Status*, File Ref. no.*, (SpecsID, Specs Section, (WBS_ID, (TradeID, Trade Name, (SupplierID, Supplier Name, Supplier Contact, Supplier Phone))))))

Table 4.14 Key Terms for Spare Parts Tracking Log

Key Terms	Definitions
SP#	project's spare parts entry serial number
SP Description	description of the spare parts
Eq Description	which equipment the spare part is for
Qntty Required	total quantity required to be delivered
Qntty Dlvd	actual quantity delivered to-date
Unit	unit of the spare parts
Location Stored	storage location of the spare parts
Status	balance spare parts to be delivered

The entities and relationships that apply to this view are shown in Figure 4.34. This figure is in accordance with the typical queries of the user view as discussed earlier in this section. Spare Parts (SP) is the principal entity of this data model. A spare parts log lists each spare part which is stored. A SP can be identified by both ProjectID and SP# (Table C.21, Appendix C). A SP is related to a single storage location. A storage location may appear on many SP. A SP will be referred to a single specs section. A specs section may appear on many SP.

As the Figure 4.34 is similar to the Figure 4.14., the relationships of entities specs section, WBS, trade, proj-trade, project, PTD, company and people are the same as explained in the last paragraph of section 4.2.3.

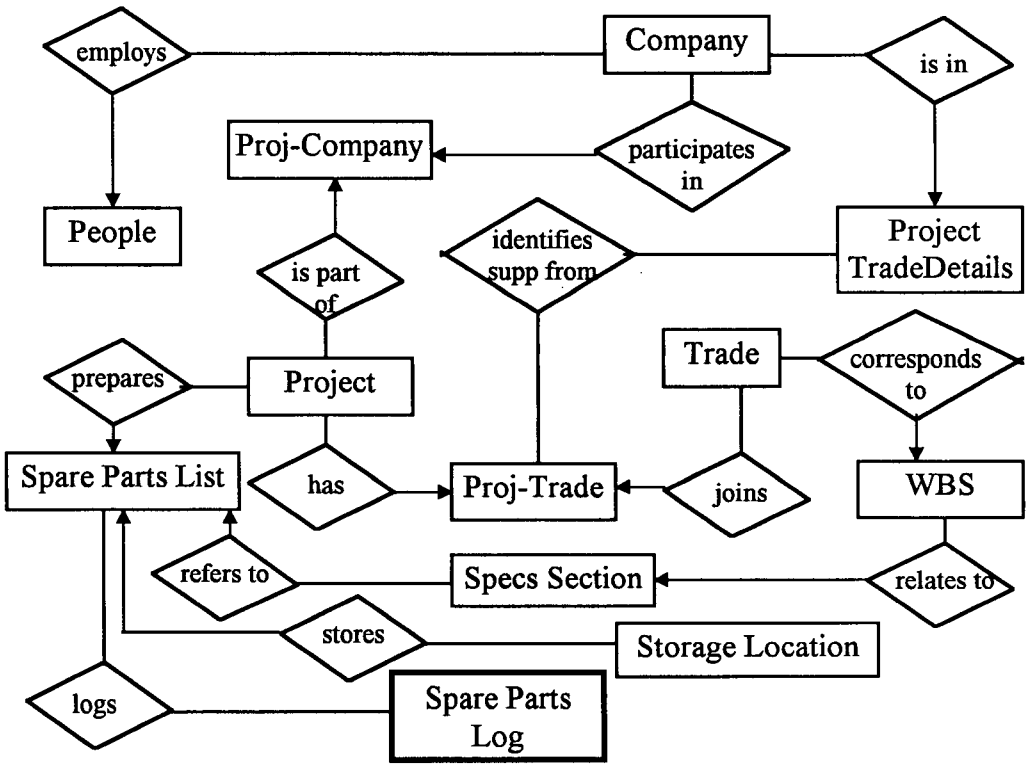


Figure 4.34 E/R Diagram for Spare Parts Tracking Log

4.4.14 Integrated View

The E/R diagram of the integrated view is shown in Figures 4.35a and 4.35b.

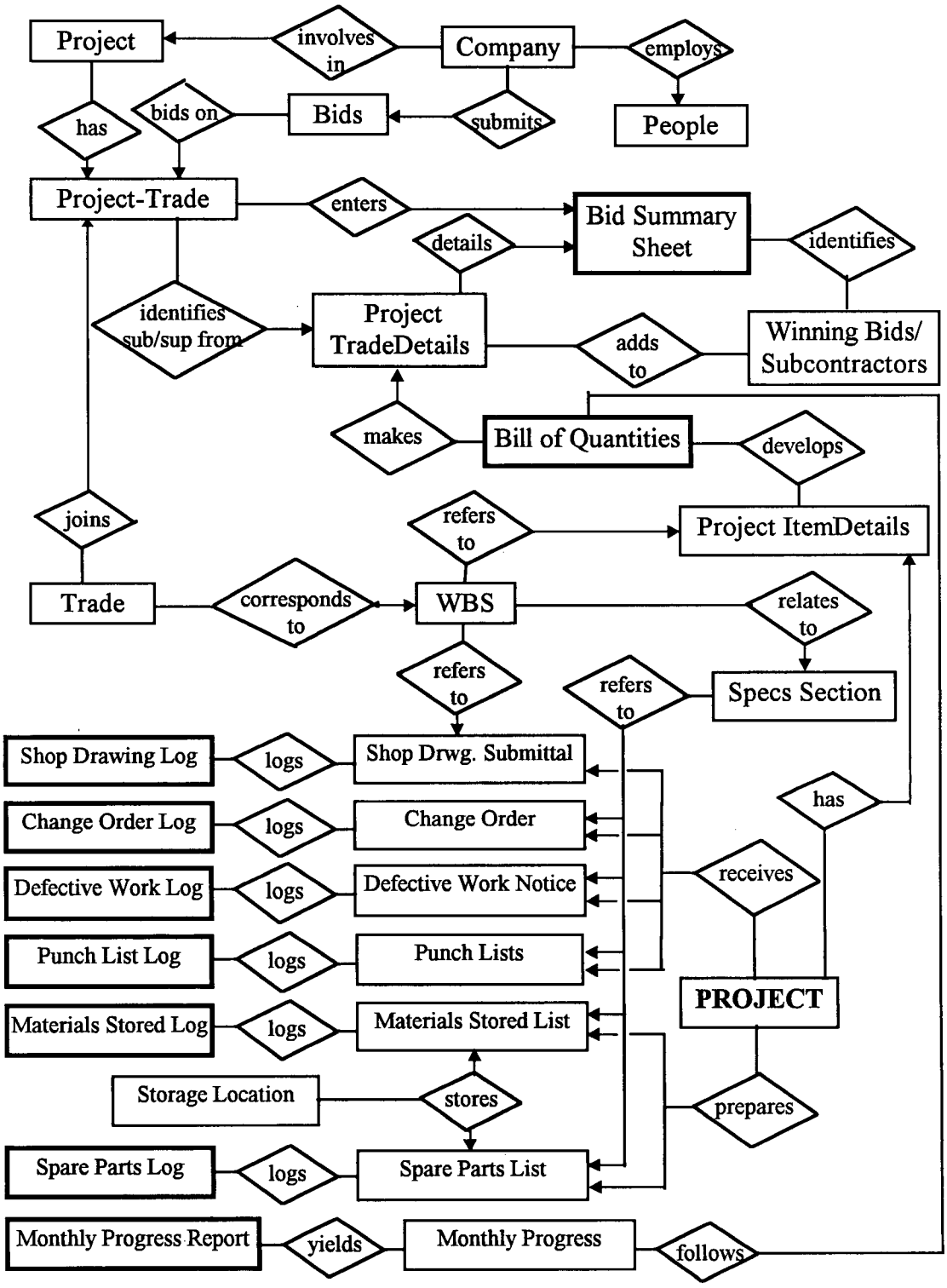


Figure 4.35a E/R Diagram for Integrated View (Part A)

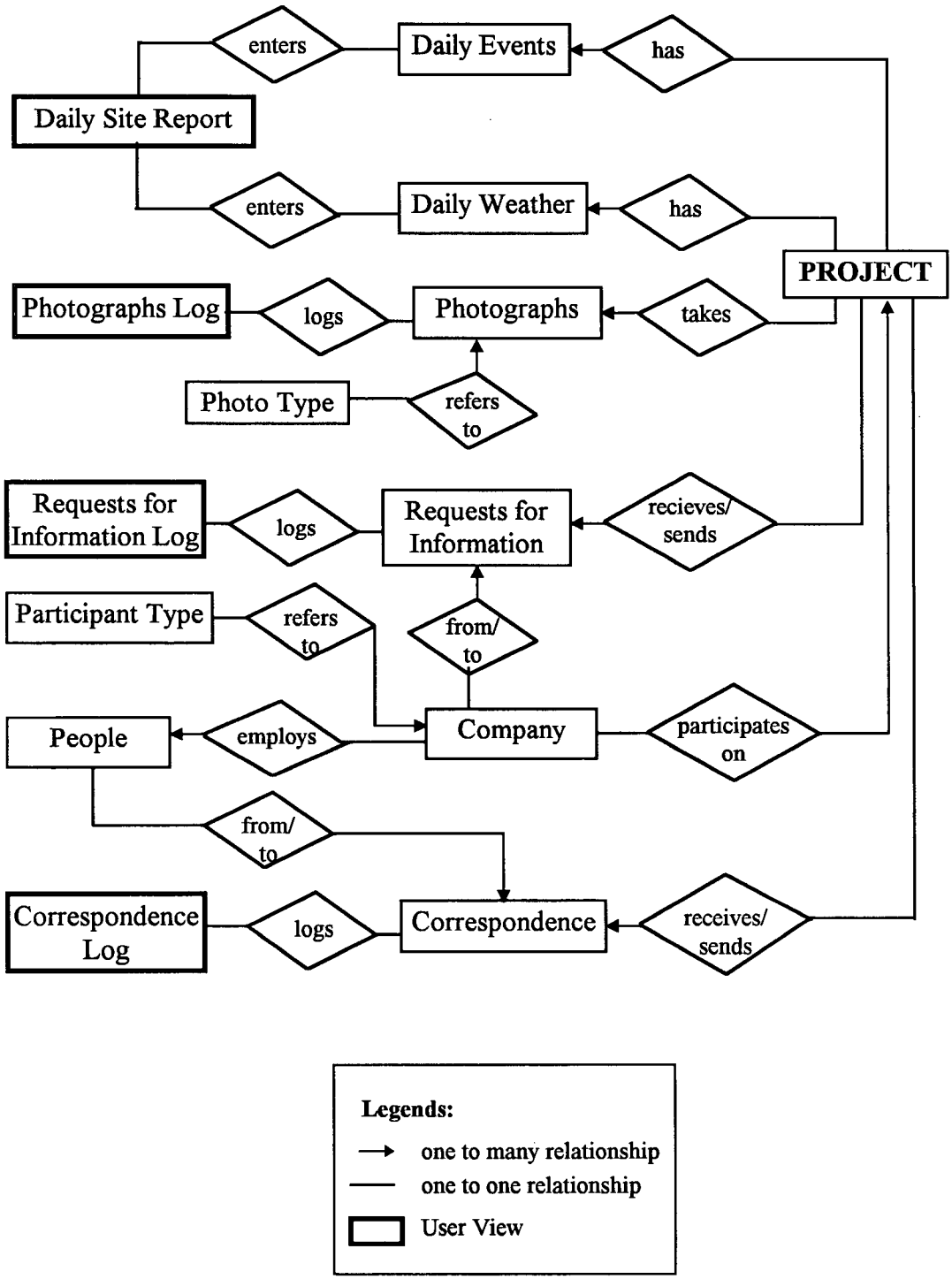
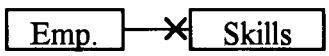
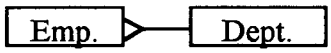
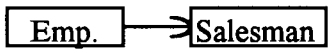


Figure 4.35b E/R Diagram for Integrated View (Part B)

4.5 Structural Data Model

The conceptual models of the database for each user view is presented in the previous section. The conceptual model, so far presented, are in the form of relations and entity-relationship (E/R) diagrams. This section continues with the conceptual modeling, and includes normalization and development of structural data models.

The main purpose of using the tool of E/R diagrams is to show the pictorial views of the entities, their relationships and degree of relationships; and the SDM diagrams is to show database structures (tables) joined by table relationships. Figure 2.5 is reproduced, below, from section 2.4.9, for a reference in this section.

Relationship	Symbol	Insert/delete Constraints
Ownership		skills need employee/skills goes with employee
Reference		employee needs department/ department stays
Subset		salesman must be employee/salesman goes with employee

The basic difference between an entity-relationship model (ERM) and SDM is the data models they represent. Although, both the models are regarded as semantic or meaning associated with data, and can be used as the basis for a systematic database design methodology.

The main differences between ERM and SDM can be explained as follows:

- ERM emphasizes the relationships between entities. SDM formalizes the relationships between entities.

- ERM is expressed as a degree of relationship between entities (1:1, 1:M, or M:1). SDM is expressed as a connection between entities (ownership, reference, or subset).

- ERM distinguishes between entities and relationships. SDM does not make any major distinctions between entities and relationships; a relationship is regarded as an entity.

- ERM does not provide constraints and integrity details precisely. SDM provides constraints and the integrity rules.

- ERM provides a map of the information system, and also acts like a process model. In SDM, relations are used to capture data about objects and their parts.

- ERM is more flexible. It allows to create entities for M:M relationships, and uses normalized relations.

- E/R diagrams for an organization may become voluminous. SDM diagrams require less space.

The following sections, 4.5.1 to 4.5.13, present the normalized relations in third normal form (3NF) or local data model and structural data model diagram for each user view. Section 4.5.14 presents the structural data model diagram for an integrated (user) view. The underlined attributes are prime keys.

Each sub-section is divided into three parts. The first part presents a set of entities or relations derived from the relations, as expressed in sections 4.4.1 to 4.4.13, for each user view. Each entity is assigned a unique name. The second part presents the entities in their third normal form (3NF). Normalization process is based on the normalization example as described in section 1.6.9. The part shows a structural data model (SDM) diagram.

4.5.1 View 1: Bill of Quantities

The initial relations derived from the entity-relationship model, as shown in section 4.4.1, are as follows:

Project (ProjectID, Project Name)

Bill of Quantities (ProjectID, WBS_ID, Item Description, Quantity, Unit, Unit Price)

Project ItemDetails (ProjectID, WBS_ID, TradeID, Trade Name)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name)

WBS (WBS_ID, Item Description, Unit, TradeID)

Trade (TradeID, Trade Name)

Project ItemDetails (ProjectID, WBS_ID, Quantity, Unit Price)

The system control derived from the semantics required by the users is shown in Fig. 4.36.

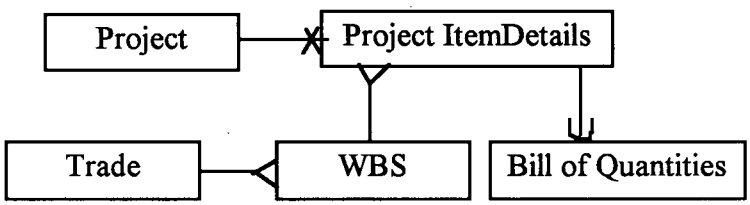


Figure 4.36 Structural Model Diagram for Bill of Quantities

4.5.2 View 2: Bid Summary Sheet

The initial relations derived from the entity-relationship model, as shown in section 4.4.2, are as follows:

Project (ProjectID, Project Name)

Project TradeDetails (ProjectID, TradeID, Trade Name, Budget, StartDate, EndDate, Bid Due Date)

Bids (ProjectID, TradeID, BidderID, Bidder Name, Bidder Phone, Bid Pkg. Sent, Bid Received, Bid Amount, Remarks)

Bidder Type (ProjectID, TradeID, BidderID, Bidder Type)

Bidder Contact (ProjectID, TradeID, BidderID, Bidder Contact (=PeopleID))

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name)

Trade (TradeID, Trade Name)

Project TradeDetails (ProjectID, TradeID, Budget, StartDate, EndDate, Bid Due Date, SubID (Co_ID), Subcontract Amount)

Bids (ProjectID, TradeID, BidderID (=Co_ID), Bid Pkg. Sent, Bid Received, Bid Amount, Remarks)

Bidder (BidderID, Bidder Name, TypeID, PeopleID, Phone), **or**

Company (Co_ID, Co_Name, TypeID, Contact (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.37.

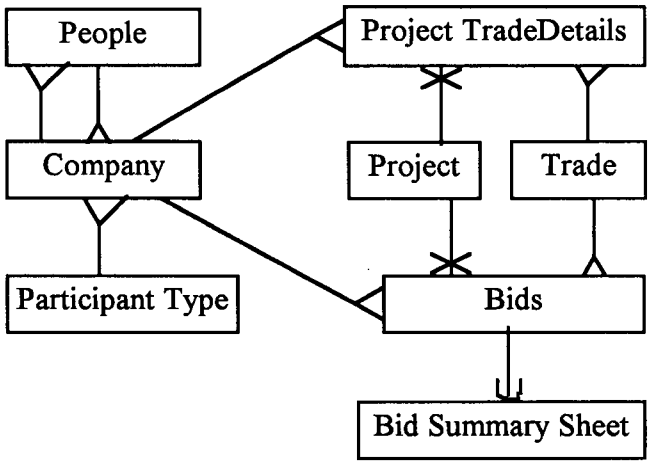


Figure 4.37 Structural Model Diagram for Bid Summary Sheet

4.5.3 View 3: Change Orders Tracking Log

The initial relations derived from the entity-relationship model, as shown in section 4.4.3, are as follows:

Project (ProjectID, Project Name, OCBP, OCCD)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (EngineerID, Engr Contact (=PeopleID))

Change Order (ProjectID, CMR#, Initiation Date, Current Status, Description, EsitmatValue, EngrEstimate, Final Value, Time Impact, D-RfAE, D-StS, D-BfS, D-RtAE, D-FS, Disposition)

CMRspecs (ProjectID, CMR#, SpecsID, Specs Section)

CMRitem (ProjectID, CMR#, SpecsID, WBS_ID)

CMRtrade (ProjectID, CMR#, SpecsID, WBS_ID, TradeID, Trade Name)

CMRsub (ProjectID, CMR#, SpecsID, WBS_ID, TradeID, SubID, Sub Name, Sub Contact, Sub Phone)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID), OCBP, OCCD)

Change Order (ProjectID, CMR#, SpecsID, Initiation Date, Current Status, Description, EsitmatValue, EngrEstimate, Final Value, Time Impact, D-RfAE, D-StS , D-BfS, D-RtAE, D-FS, Disposition)

Specs Section (SpecsID, Specs Section, WBS_ID)

WBS (WBS_ID, Item Description, TradeID)

Trade (TradeID, Trade Name)

Project TradeDetails (ProjectID, TradeID, SubID (=Co_ID))

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.38.

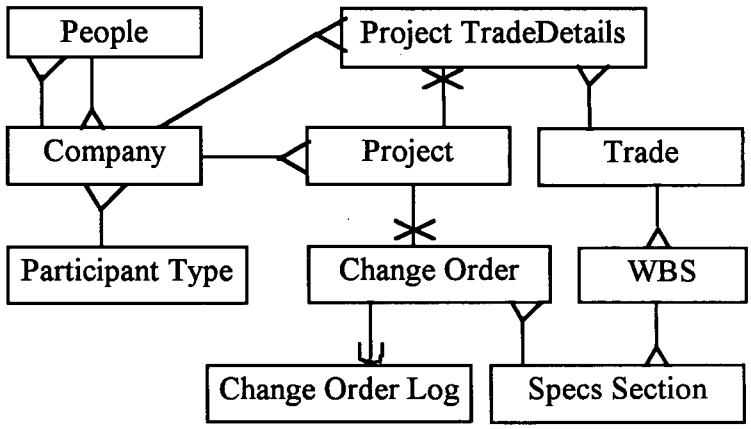


Figure 4.38 Structural Model Diagram for Change Orders Tracking Log

4.5.4 View 4: Correspondence Tracking Log

The initial relations derived from the entity-relationship model, as shown in section 4.4.4, are as follows:

Project (ProjectID, Project Name, Address)

Correspondence (ProjectID, Corr#, Reference#, CorrDate, Date Sent, DateRcvd, Follow up, Keyword1, Keyword2, Notes)

From/toPeople (ProjectID, Corr#, From People (=ID), To People (=ID))

From/toCompany (ProjectID, Corr#, From Company (=ID), To Company (=ID))

From/toType (ProjectID, Corr#, From Type (=ID), To Type (=ID))

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name)

Correspondence (ProjectID, Corr#, From People (=PeopleID), To People (=PeopleID), Reference#, CorrDate, Date Sent, Date Rcvd, Keyword One, Keyword Two, Follow up, Notes)

People (PeopleID, Name, Co_ID, Phone)

Company (Co_ID, Co_Name, TypeID, Contact1(=PeopleID), Contact2 (=PeopleID), Phone)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.39.

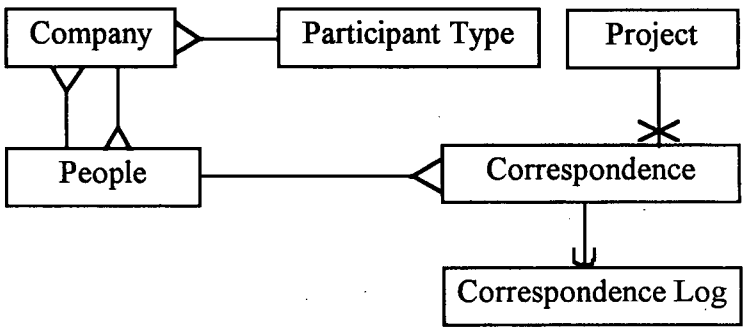


Figure 4.39 Structural Model Diagram for Correspondence Tracking Log

4.5.5 View 5: Daily Site Report

The initial relations derived from the entity-relationship model, as shown in section 4.4.5, are as follows:

Project (ProjectID, Project Name)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (ProjectID, EngineerID, Engr Contact (=PeopleID), Contact Name)

EngrType (ProjectID, EngineerID, TypeID, Participant Type)

ReportDay (ProjectID, Date, Day ID, Day)

Weather (ProjectID, Date, Temperature, Sunny (yes/no), Cloudy (yes/no), Rainy (yes/no), Snowy (yes/no), Still Wind (yes/no), Moderate Wind (yes/no), High Wind (yes/no), Humid-dry (yes/no), Humid-mod (yes/no), Humid-high (yes/no))

Daily Events (ProjectID, Date, Daily Report#, Visitor1, Visitor2, VisitTime1, VisitTime2, Company1, Company2, Purpose1, Purpose2, EquipUse, EquipIdle, Activities, New Act, Act Compl, Material Needs)

DailySub (ProjectID, Date, FFC1, FFC2, FFC3, FFC4, NMFF1, NMFF2, NMFF3, NMFF4, MFF1, MFF2, MFF3, MFF4, Job1, Job2, Job3, Job4)

DailyReporter (ProjectID, Date, Prepared by ID, Prepared by)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID), OwnerID (=Co_ID))

Weather (ProjectID, Date, Day ID, Temperature, Sunny (yes/no), Cloudy (yes/no), Rainy (yes/no), Snowy (yes/no), Still Wind (yes/no), Moderate Wind (yes/no), High Wind (yes/no), Humid-dry (yes/no), Humid-mod (yes/no), Humid-high (yes/no))

Day (Day ID, Day Name)

Daily Events (ProjectID, Date, Day ID, Daily Report#, Prepared by ID, FFC1, FFC2, FFC3, FFC4), NMFF1, NMFF2, NMFF3, NMFF4, MFF1, MFF2, MFF3, MFF4, Job1, Job2, Job3, Job4, Visitor1, Visitor2, VisitTime1, VisitTime2, Company1, Company2, Purpose1, Purpose2, EquipUse, EquipIdle, Activities, New Act, Act Compl, Material Needs)

People (PeopleID, Name, Co_ID, Phone)

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Phone)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.40.

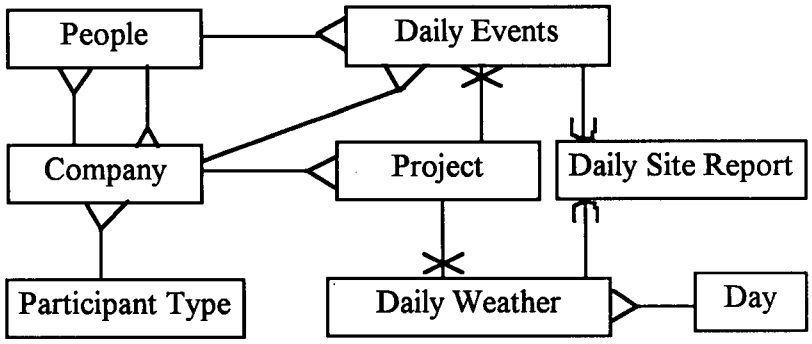


Figure 4.40 Structural Model Diagram for Daily Site Report

4.5.6 View 6: Defective Work Notifications Tracking log

The initial relations derived from the entity-relationship model, as shown in section 4.4.6, are as follows:

Project (ProjectID, Project Name)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (EngineerID, Engr Contact (=PeopleID))

Defective Work (ProjectID, DWN#, NoticeDate, Description, DateRcvd, EstimatValue, Date Reinspected, Reinspected By, D-NoCR, Comments)

DWNspecs (ProjectID, DWN#, SpecsID, Specs Section)

DWNitem (ProjectID, DWN#, SpecsID, WBS_ID)

DWNtrade (ProjectID, DWN#, SpecsID, WBS_ID, TradeID, Trade Name)

DWNsub (ProjectID, DWN#, SpecsID, WBS_ID, TradeID, SubID, Sub Name, Sub Contact, Sub Phone)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID)

DefectiveWork (ProjectID, DWN#, SpecsID, Notice Date, Description, Date Rcvd, EstimatValue, Date Reinspected, Reinspected By, D-NoCR, Comments)

Specs Section (SpecsID, Specs Section, WBS_ID)

WBS (WBS_ID, Item Description, TradeID)

Trade (TradeID, Trade Name)

Project TradeDetails (ProjectID, TradeID, SubID (=Co_ID))

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.41.

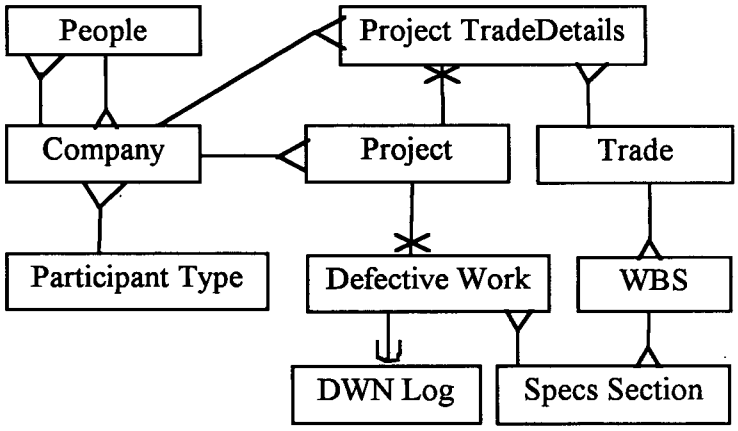


Figure 4.41 Structural Model Diagram for DWN Tracking log

4.5.7 View 7: Materials Stored Tracking Log

The initial relations derived from the entity-relationship model, as shown in section 4.4.7, are as follows:

Project (ProjectID, Project Name)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (EngineerID, Engr Contact (=PeopleID))

MaterialsStored (ProjectID, Mat#, Item Description, Loc-Installed, Original Value, Pay Est#, Pay Est Date, % Installed)

MatStorage (ProjectID, Mat#, Loc_ID, Location Stored)

MatSpecs (ProjectID, Mat#, SpecsID, Specs Section)

MatItem (ProjectID, Mat#, SpecsID, WBS_ID)

MatTrade (ProjectID, Mat#, SpecsID, WBS_ID, TradeID, Trade Name)

MatSub (ProjectID, Mat#, SpecsID, WBS_ID, TradeID, SubID, Supplier Name, Sub Contact, Sub Phone)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID)

MaterialsStored (ProjectID, Mat#, SpecsID, Loc_ID, Item Description, Loc-Installed, Original Value, Pay Est#, Pay Est Date, % Installed)

Storage Location (Loc_ID, Location name, Address)

Specs Section (SpecsID, Specs Section, WBS_ID)

WBS (WBS_ID, Item Description, TradeID)

Trade (TradeID, Trade Name)

Project TradeDetails (ProjectID, TradeID, SubID (=Co_ID))

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.42.

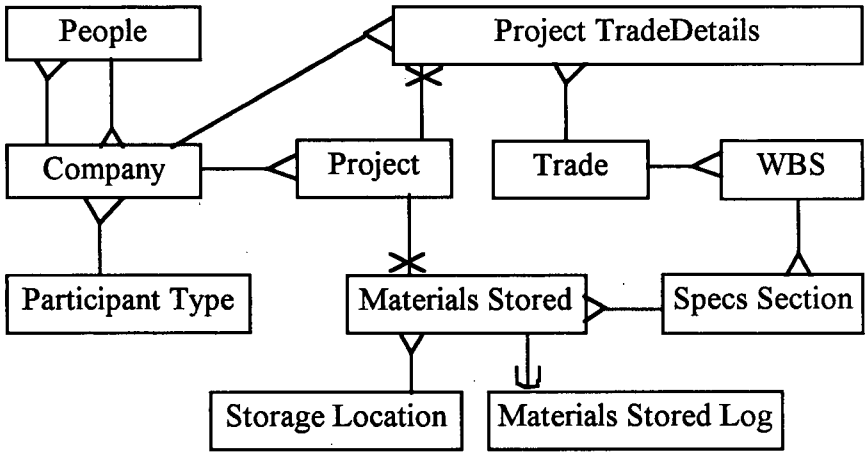


Figure 4.42 Structural Model Diagram for Materials Stored Tracking Log

4.5.8 View 8: Monthly Progress Report

The initial relations derived from the entity-relationship model, as shown in section 4.4.8, are as follows:

Project (ProjectID, Project Name)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (EngineerID, Engr Contact (=PeopleID))

Monthly Progress (ProjectID, Pay Est#, PayEst Date, This Qntty, To-date Qntty)

ProgressItem (ProjectID, Pay Est#, WBS_ID, Item Description, Quantity, Unit, Unit Price)

ProgressTrade (ProjectID, Pay Est#, WBS_ID, TradeID, Trade Name)

ProgressSub (ProjectID, Pay Est#, WBS_ID, TradeID, SubID, Sub Name, Sub Contact, Sub Phone)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID)

Monthly Progress (ProjectID, Pay Est#, WBS_ID, PayEst Date, This Qntty, To-date Qntty)

Project ItemDetails (ProjectID, WBS_ID, Quantity, Unit Price)

WBS (WBS_ID, Item Description, Unit, TradeID)

Trade (TradeID, Trade Name)

Project TradeDetails (ProjectID, TradeID, SubID (=Co_ID))

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.43.

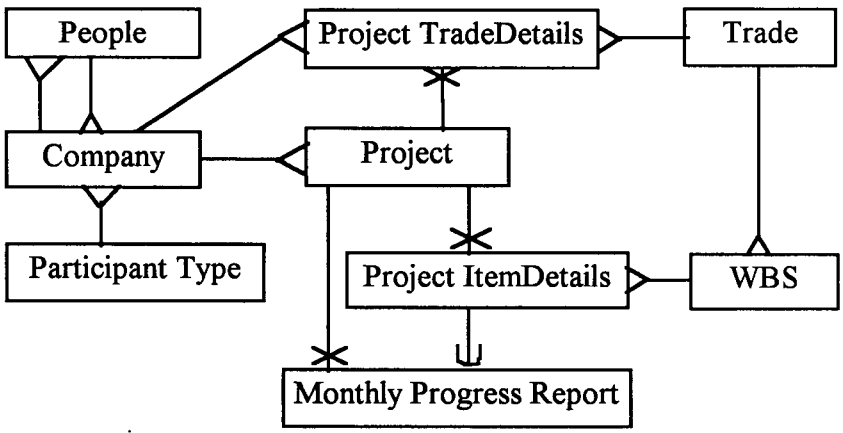


Figure 4.43 Structural Model Diagram for Monthly Progress Report

4.5.9 View 9: Photographs Tracking Log

The initial relations derived from the entity-relationship model, as shown in section 4.4.9, are as follows:

Project (ProjectID, Project Name)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (EngineerID, Engr Contact (=PeopleID))

Photographs (ProjectID, Photo#, Roll#, Negative#, Date Taken, Time of day, Camera direction, Photogr position, Facility/Location, Keyword1, Keyword2, Caption)

Photographer (ProjectID, Photo#, Photogr ID (=PeopleID), Photogr Name)

PhotoType (ProjectID, Photo#, Photo TypeID, Photo Type)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID))

Photograph (ProjectID, Photo#, Photo TypeID, Photgr ID (=PeopleID), Roll#, Negative#, Date Taken, Time of day, Camera direction, Photogr position, Facility/Location, Keyword1, Keyword2, Caption)

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

Photo Type (Photo TypeID, Photo Type)

The system control derived from the semantics required by the users is shown in Fig. 4.44.

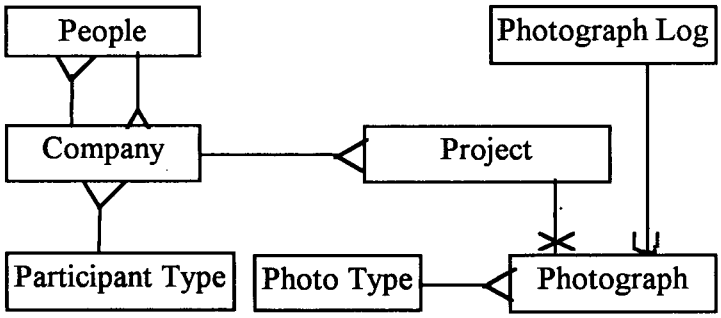


Figure 4.44 Structural Model Diagram for Photographs Tracking Log

4.5.10 View 10: Punch Lists

The initial relations derived from the entity-relationship model, as shown in section 4.4.10, are as follows:

Project (ProjectID, Project Name)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (EngineerID, Engr Contact (=PeopleID))

Punch Lists (ProjectID, PL#, Punch List Item, Facility/Area, Date Identified, Identified By, Date Completed, Date Checked, Checked By)

PLspecs (ProjectID, PL#, SpecsID, Specs Section)

PLitem (ProjectID, PL#, SpecsID, WBS_ID)

PLtrade (ProjectID, PL#, SpecsID, WBS_ID, TradeID, Trade Name)

PLsub (ProjectID, PL#, SpecsID, WBS_ID, TradeID, SubID, Sub Name, Sub Contact, Sub Phone)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID)

Punch Lists (ProjectID, PL#, SpecsID, PunchList Items, Facility/Area, Date Identified, Identified By, Date Completed, Date Checked, Checked By)

Specs Section (SpecsID, Specs Section, WBS_ID)

WBS (WBS_ID, Item Description, TradeID)

Trade (TradeID, Trade Name)

Project TradeDetails (ProjectID, TradeID, SubID (=Co_ID))

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.45.

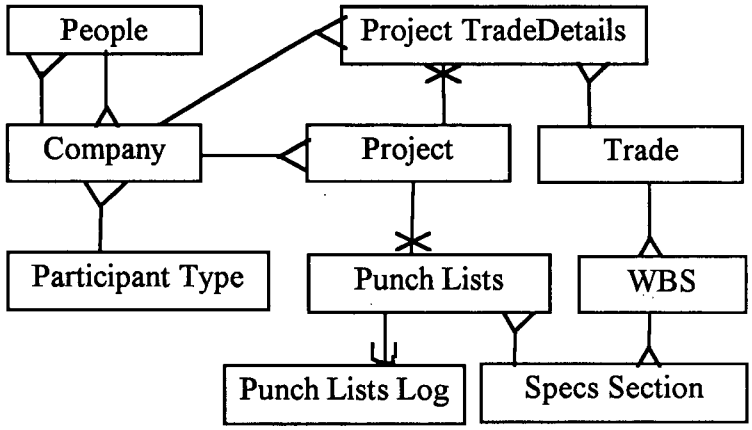


Figure 4.45 Structural Model Diagram for Punch Lists

4.5.11 View 11: Requests for Information (RFI) Tracking Log

The initial relations derived from the entity-relationship model, as shown in section 4.4.11, are as follows:

Project (ProjectID, Project Name)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (EngineerID, Engr Contact (=PeopleID))

RFI (ProjectID, RFI#, Initiation Date, Drawing#, RFI Description, D-RfS, D-StAE, D-RBfAE, D-SBtS)

RFIpeople (ProjectID, RFI#, Initiated By (=PeopleID), Name)

RFIcompany (ProjectID, RFI#, Initiated By (=PeopleID), Initiator ID (=Co_ID))

RFIcompanyType (ProjectID, RFI#, Initiated By (=Co_ID), Initiator Type)

RFIresponse (ProjectID, RFI#, Response by (=PeopleID))

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID)

RFI (ProjectID, RFI#, Initiated By(=PeopleID), Response by(=PeopleID), Initiation Date, Drawing#, RFI Description, D-RfS, D-StAE, D-RBfAE, D-SBtS)

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.46.

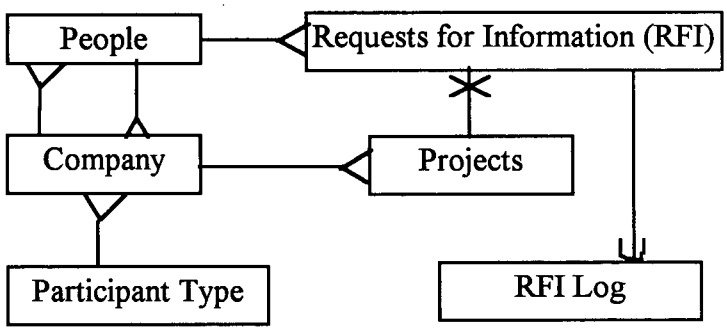


Figure 4.46 Structural Model Diagram for RFI Tracking Log

4.5.12 View 12: Shop Drawing Submittals Tracking Log

The initial relations derived from the entity-relationship model, as shown in section 4.4.12, are as follows:

Project (ProjectID, Project Name)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (EngineerID, Engr Contact (=PeopleID))

Shop Drawing (ProjectID, Shop Drwg#, Description, Disposition, D-RfS, D-StAE-I, D-StAE-R, D-StAE-F, D-RBfAE, D-SBtS, C-RfS, C-StAE, C-RBfAE, C-SBtS, Comments)

SDitem (ProjectID, Shop Drwg#, WBS_ID, Shop Drawing (yes/no))

SDtrade (ProjectID, Shop Drwg#, WBS_ID, TradeID, Trade Name)

SDsub (ProjectID, Shop Drwg#, WBS_ID, TradeID, SubID, Sub Name, Sub Contact, Sub Phone)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID)

Shop Drawing (ProjectID, Shop Drwg#, WBS_ID, Description, Disposition, D-RfS, D-StAE-I, D-StAE-R, D-StAE-F, D-RBfAE, D-SBtS, C-RfS, C-StAE, C-RBfAE, C-SBtS, Comments)

WBS (WBS_ID, Item Description, TradeID)

Trade (TradeID, Trade Name)

Project ItemDetails (ProjectID, WBS_ID, Shop Drawing (yes/no))

Project TradeDetails (ProjectID, TradeID, SubID (=Co_ID))

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

The system control derived from the semantics required by the users is shown in Fig. 4.47.

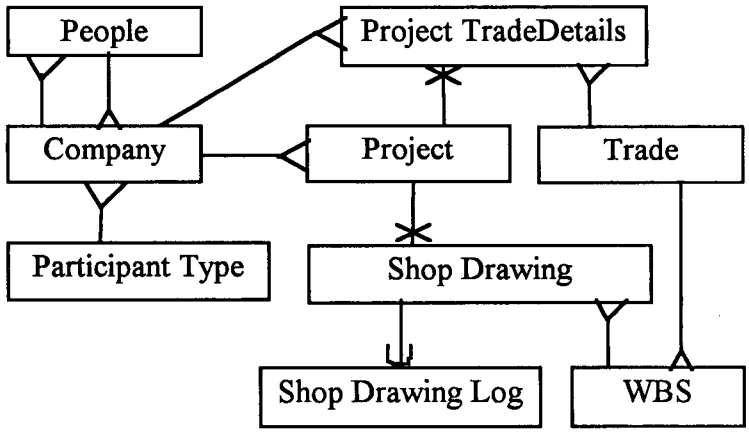


Figure 4.47 Structural Model Diagram for Shop Drawing Submittals Tracking Log

4.5.13 View 13: Spare Parts Tracking Log

The initial relations derived from the entity-relationship model, as shown in section 4.4.13, are as follows:

Project (ProjectID, Project Name)

ProjectEngr (ProjectID, EngineerID, Engr Name, Engr Phone)

EngrContact (EngineerID, Engr Contact (=PeopleID))

Spare Parts (ProjectID, SP#, SP Description, Eq Description, Qntty Required, Qntty Dlvd, Unit)

SPstorage (ProjectID, SP#, Loc_ID, Location Stored)

SPspecs (ProjectID, SP#, SpecsID, Specs Section)

SPitem (ProjectID, SP#, SpecsID, WBS_ID)

SPtrade (ProjectID, SP#, SpecsID, WBS_ID, TradeID, Trade Name)

SPsub (ProjectID, SP#, SpecsID, WBS_ID, TradeID, SubID, Supplier Name, Sub Contact, Sub Phone)

The local data model or normalized relations for the above view are as follows:

Project (ProjectID, Project Name, EngineerID (=Co_ID)

Spare Parts (ProjectID, SP#, SpecsID, Loc_ID, SP Description, Eq Description, Qntty Required, Qntty Dlvd, Unit, Status)

Specs Section (SpecsID, Specs Section, WBS_ID)

WBS (WBS_ID, Item Description, TradeID)

Trade (TradeID, Trade Name)

Project TradeDetails (ProjectID, TradeID, SubID (=Co_ID))

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Phone)

People (PeopleID, Name, Co_ID)

Participant Type (TypeID, Participant Type)

Storage Location (Loc_ID, Location name, Address)

The system control derived from the semantics required by the users is shown in Fig. 4.48.

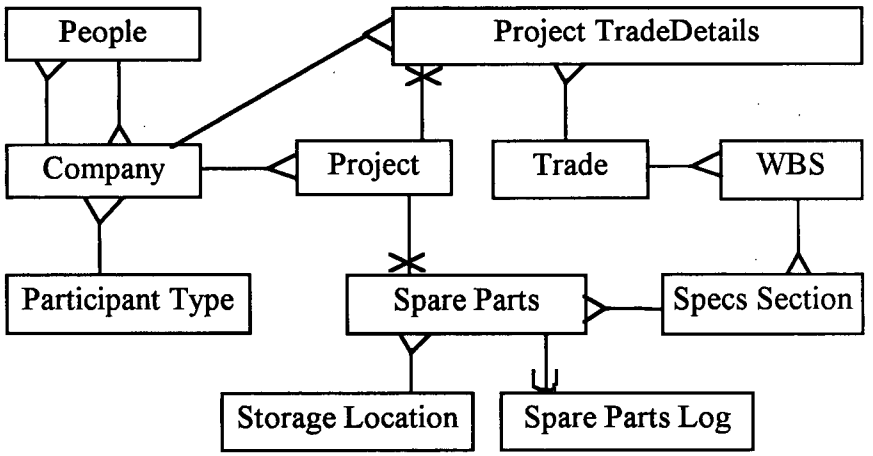


Figure 4.48 Structural Model Diagram for Spare Parts Tracking Log

4.5.14 Integrated Structural Model

The integrated structural model for all the above thirteen views, combined and simplified, is shown in Figure 4.49.

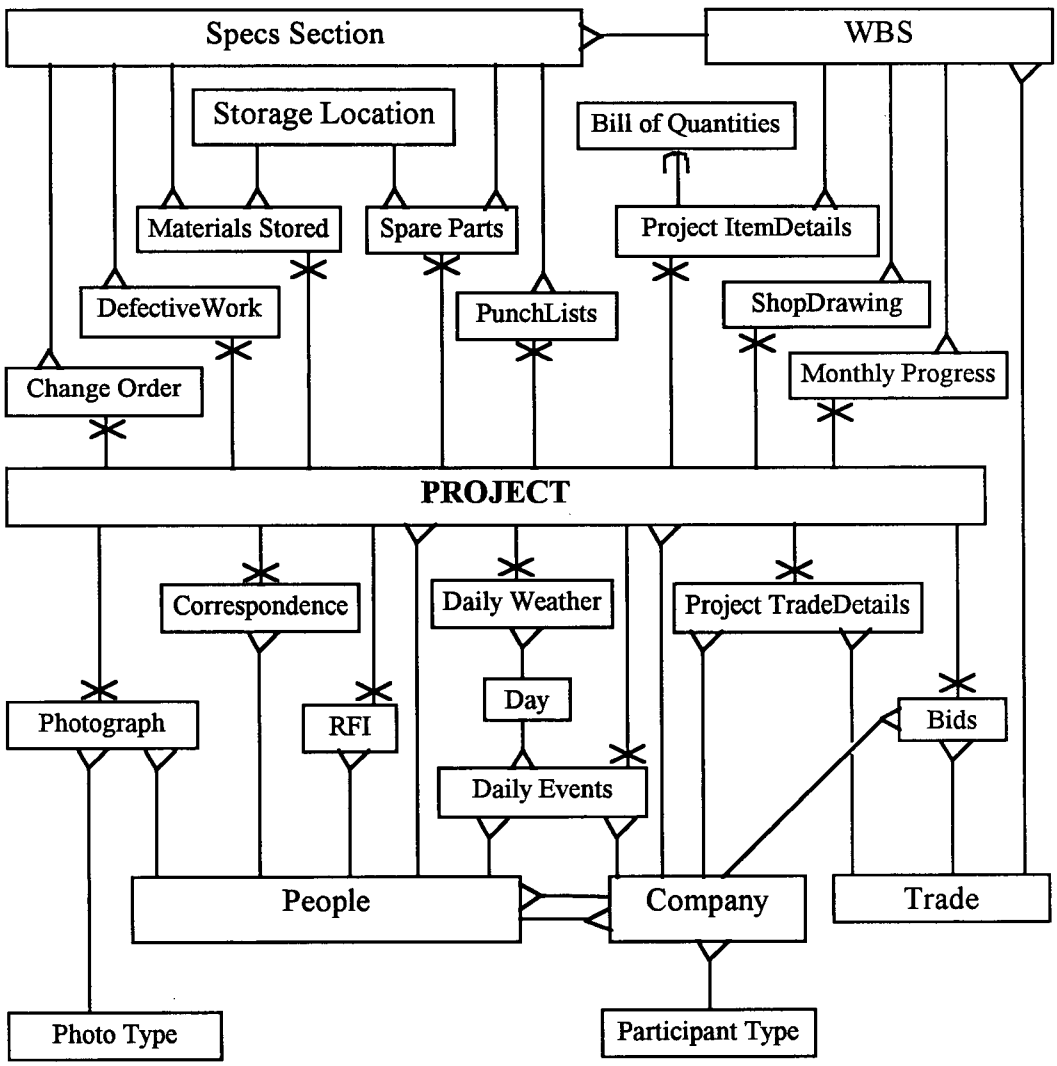


Figure 4.49 Integrated Structural Model Diagram

4.6 Entity and Relationship Attributes

This section deals with the translation of the conceptual model to a logical model. Earlier in Chapter 1, section 1.6.4 explains the data modeling stages and the data model environment of the commercial database management systems (DBMS). Although the DBMS is not a factor in designing a conceptual model, but designing a logical model is dependent on the DBMS to be used. Considering a DBMS based on a relational data model, such as Microsoft Access, this section will help in the translation of a conceptual model to a logical relational model.

This section lists the attributes associated with each entity and relationship as illustrated in Figures 4.20 to 4.32., which in fact is a global data model of the system. These relations are the results of normalization procedures carried out in section 4.5. An attribute, or a number of attributes from these relations will represent the primary key(s). The primary keys for a relation are underlined. Additional attributes have been added to some of the entities and relationships (Company, People, Project, Specs Section and Project ItemDetails) to fulfill the data information requirements, as discussed in section 4.3. These new attributes are unaffected by all the normalization stages. That is, they are not a repeating group (1NF), attributes of entity with more than one identifying attribute (2NF) or functionally dependent on the non-identifying attributes of an entity. They are in their third normal form (3NF).

As discussed in section 1.6.6 (Relational Database Terminology), the relational logical model uses two-dimensional tables to present the database. The entities and relationships, as presented in sections 4.6.1 and 4.6.2, will be termed as tables in section 4.7 onwards. When these relations will be mapped into physical models in a real DBMS environment, the tables will have the same title as that of the relations presented in this section. The attributes of these relations will be termed as fields.

The local data models of sections 4.4.4 to 4.4.13 have been combined and consolidated to arrive at the following global data model. For convenience sake, each of these tables is still presented in the relations form instead of a tabular form.

4.6.1 Entities

Bids (ProjectID, TradeID, BidderID (=Co_ID), Bid Pkg. sent, Bid Received, Bid Amount, Remarks)

Change Order ((ProjectID, CMR#, SpecsID, Initiation Date, Current Status, Description, EsitmatValue, EngrEstimate, Final Value, Time Impact, D-RfAE, D-StS, D-BfS, D-RtAE, D-FS, Disposition)

Company (Co_ID, Co_Name, TypeID, Contact1 (=PeopleID), Contact2 (=PeopleID), Address, City, Province, Postal Code, Phone, Fax, Size)

Correspondence (ProjectID, Corr#, From People (=PeopleID), To People (=PeopleID), Reference#, CorrDate, Date Sent, Date Rcvd, Keyword1, Keyword2, Follow up, Notes)

Daily Events (ProjectID, Date, Day ID, Daily Report#, Prepared by ID, FFC1, FFC2, FFC3, FFC4), NMFF1, NMFF2, NMFF3, NMFF4, MFF1, MFF2, MFF3, MFF4, Job1, Job2, Job3, Job4, Visitor1, Visitor2, VisitTime1, VisitTime2, Company1, Company2, Purpose1, Purpose2, EquipUse, EquipIdle, Activities, New Act, Act Compl, Material Needs)

Daily Weather (ProjectID, Date, Day ID, Temperature, Sunny (yes/no), Cloudy (yes/no), Rainy (yes/no), Snowy (yes/no), Still Wind (yes/no), Moderate Wind (yes/no), High Wind (yes/no), Humid-dry (yes/no), Humid-mod (yes/no), Humid-high (yes/no))

Day (Day ID, Day Name)

DefectiveWork (ProjectID, DWN#, SpecsID, Notice Date, Description, Date Rcvd, EsitmatValue, Date Reinspected, Reinspected By, D-NoCR, Comments)

Materials Stored (ProjectID, Mat#, SpecsID, Loc_ID, Item Description, Loc-Installed, Original Value, Pay Est#, Pay Est Date, % Installed)

Monthly Progress (ProjectID, Pay Est#, WBS_ID, PayEst Date, This Qntty, To-date Qntty)

Participant Type (TypeID, Participant Type)

People (PeopleID, Last Name, First Name, Co_ID, Title, Address, City, Province, Postal Code, Phone, Fax)

Photograph (ProjectID, Photo#, Photo TypeID, Photgr ID (=PeopleID), Roll#, Negative#, Date Taken, Time of Day, Camera Direction, Photogr Position, Facility/Location, Keyword1, Keyword2, Caption)

Photo Type (Photo TypeID, Photo Type)

Project (ProjectID, Project Name, Project Type, EngineerID (=Co_ID), OwnerID (=Co_ID), ManagerID (=PeopleID), OCBP, OCCD, StartDate, EndDate, Address, Phone, Fax)

Punch Lists (ProjectID, PL#, SpecsID, PunchList Items, Facility/Area, Date Identified, Identified By, Date Completed, Date Checked, Checked By)

RFI (ProjectID, RFI#, Initiated By (=PeopleID), Response by (=PeopleID), Initiation Date, Drawing#, RFI Description, D-RfS, D-StAE, D-RBfAE, D-SBtS, Comments)

Shop Drawing (ProjectID, Shop Drwg#, WBS_ID, Description, Disposition, D-RfS, D-StAE-I, D-StAE-R, D-StAE-F, D-RBfAE, D-SBtS, C-RfS, C-StAE, C-RBfAE, C-SBtS, Comments)

Spare Parts (ProjectID, SP#, SpecsID, Loc_ID, SP Description, Eq Description, Qntty Required, Qntty Dlvd, Unit, Status)

Specs Section (SpecsID, WBS_ID, Specs Section, Section Title, Division, Division Title)

Storage Location (Loc_ID, Location Name, Address)

Trade (TradeID, Trade Name, Description)

WBS (WBS_ID, Item Description, TradeID, Unit)

4.6.2 Relationships

The common relationships, in third normal form, from sections 4.4.1 to 4.4.13, are the following:

Project ItemDetails (ProjectID, WBS_ID, Quantity, Unit Price, % Markup, Delivery/Action Date, Delivery Days, Approval Days, ShopDrawing (Yes/No), MatSample (Yes/No), Catalog (Yes/No), Misc. (Yes/No), Misc Submittals, As-Built Drawing (Yes/No))

Project TradeDetails (ProjectID, TradeID, Budget, StartDate, EndDate, Bid Due Date, SubID (Co_ID), Subcontract Amount)

Proj-Company(ProjectID, Co_ID)

Proj-Trade (ProjectID, TradeID)

4.6.3 Entity Cross-Reference Matrix

As a preliminary to preparing the integrated structural data model in the preceding section, as shown in Figure 4.49, it is useful to record the entities and their relationships on an entity cross-reference matrix. This is a table in which each entity will appear as a row-heading and each basic entity, as described in section 4.3, will appear as a column-heading. At the intersection of the row and the column, any of the letters O, R, or S (corresponding

to ownership, reference, or subset) will be placed if there is a structural relationship between the entity at the head of the column and the entity at the head of the row.

The cross-reference matrix is shown in Table 4.15. The column-headings show E1 to E10, as an abbreviation for each entity. The abbreviated headings are as follows: E1 is for company, E2 for Day, E3 for participant type, E4 for people, E5 for photo type, E6 for project, E7 for specs section, E8 for storage location, E9 for trade, and E10 for WBS.

Table 4.15 Entity Cross-Reference Matrix

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
Bids	R					O			R	
Change Order						O	R			
Company			R	R						
Correspondence				R		O				
Daily Events	R	R		R		O				
Daily Weather		R				O				
Day										
DefectiveWork						O	R			
Materials Stored						O	R	R		
Monthly Progress						O				R
Participant Type										
People	R									
Photograph				R	R	O				
Photo Type										
Project	R			R						
Punch Lists						O	R			
RFI				R		O				
Shop Drawing						O				R
Spare Parts						O	R	R		
Specs Section										R
Storage Location										
Trade										
WBS									R	
Project ItemDetails						O				R
Project TradeDetails	R					O			R	

4.7 Data Dictionary

A data dictionary is defined as a set of system tables that contain the data definitions of database objects [Jennings 93]. Much of the information concerning the data is specified by means of a data dictionary. It is an important feature of DBMS and acts as a general reference tool describing all the data held on the database.

Appendix C contains the data dictionary of the proposed system. It provides information about each attribute (field) as described in sections 4.6.1 and 4.6.2. Typically, each entry in the data dictionary includes the following:

- the name of the field,
- the data type,
- the length or width of the field,
- indexing requirements, and
- brief description of the field.

4.8 Data Volume and Usage

As discussed in section 1.6.6, the number of tuples (rows) in a table is a measure of cardinality of a relation. This section outlines the assumptions employed to evaluate cardinality of entities, and evaluates the maximum cardinality and the expected entity sizes.

4.8.1 Assumptions

Based on the requirements analysis, the cardinalities of entities in the preceding section will be governed by the following assumptions:

- duration of a project will be one to two years.
- records will be kept for two years.
- there will be approximately 3 projects per year.
- there will be approximately 10 companies involved per project.
- there will be approximately 10 trades per project.
- there will be approximately 20 employees per project.
- there will be approximately 100 Bill of Items per project.
- there will be approximately 10 x 3 =30 bidders per project.
- there will be approximately 100 change orders per project.
- there will be approximately 150 correspondence per month per project.
- there will be approximately one daily report per day per project.
- there will be approximately 100 defective work notifications per project.
- there will be approximately 50 materials stored items per project.
- there will be approximately two storage locations per project.
- there will be approximately one monthly progress report per month per project.
- there will be approximately 30 photographs per month per project.

- there will be approximately 100 punch list items per project.
- there will be approximately 100 requests for information (RFI) per project.
- there will be approximately 30 shop drawings per project.
- there will be approximately 50 spare part items per project.

4.8.2 Entity Cardinality

Table 4.16 shows the entities and their maximum cardinalities.

Table 4.16 Entity Cardinality

Entity	Max. Cardinality
Projects	6
Companies	60
Employees	120
Specs Sections	250
Project Trade	60
Project Items	600
Bidders	180
Change Orders	600
Correspondence	10,800
Daily Reports	2,190
Defective Work Notices	600
Materials Stored	300
Storage Locations	12
Monthly Project Reports	72
Photographs	2,160
Punch Lists	600
Requests for Information	600
Shop Drawings	180
Spare Parts	300

4.8.3 Expected Entity Size

Table 4.17 evaluates the expected entity size in terms of bytes. Record size is the sum of field length of all the fields in a file, as recorded in the data dictionary in Appendix-C. As shown in the total column, the total storage requirement is approximately one megabyte.

Table 4.17 Expected Entity Sizes

No.	File Name	Frequency	No. of Records	Record Size (bytes)	Total Size (bytes)
1	Bill of Quantities	Monthly	72	150	10,800
2	Bid Summary Sheet	1/project	180	360	64,800
3	Change Orders Log	100/project	600	510	306,000
4	Correspondence Log	5/day/project	10,800	450	4,860,000
5	Daily Site Report	1/day/project	2,190	1,100	2,409,000
6	DWN Log	100/project	600	520	312,000
7	Materials Stored Log	Monthly	72	500	36,000
8	Monthly Progress	Monthly	72	300	21,600
9	Photograph Log	30/month/project	2,160	400	864,000
10	Punch List	100/project	600	500	300,000
11	RFI Log	100/project	600	500	300,000
12	Shop Drawing Log	30/project	180	540	97,200
13	Spare Parts Log	50/project	300	670	201,000
				Total	9,782,400

4.9 Suggestions for Implementation Environment

This section describes suggestions and recommendations for implementation environment of the proposed system.

4.9.1 System Hardware and Software Options

Technology is changing, and there is always a tendency to want what is perceived as the newest or the best. But the criteria for evaluating project management system hardware and software should be based on what is important for the company [Tidwell 92]. So, the selection of hardware is based on the following needs of the company: speed of a personal computer (PC) for processing and updating data, size of the hard disk for storage of data, RAM (random access memory) for file sizes and new software requirements (database, spreadsheets, and graphics capabilities), expandability of computer system, type of printer for faster printouts, and costs. Anticipating that other project management applications will be used on the same PC, it is suggested that the PC be an IBM-compatible with an 80386 or higher processor (486/66 is recommended); 2 MB (megabyte) of RAM (4 MB or more is recommended); 240 MB or higher hard drive; EGA or VGA monitor (VGA is recommended); compatible mouse; and a laser printer (2 MB memory or higher). The PC system will have MS-DOS® version 3.1 or later, and Microsoft Windows™ version 3.0 or later.

It is further recommended that a commercial database management software package, such as Microsoft Access, be used because this application does not require programming. Microsoft access is designed around database objects that enable to do most of the work without programming. However, it also allows programming to create custom functions.

4.9.2 Sources of Data Input

The Microsoft Access macro will be used to automate the data editing and viewing operations, as shown in Figure 4.50, as well as to aid the process of database maintenance. As per the company's requirements, the data input to the system will be through the following documents:

- Project and storage location data will be obtained from existing company project description reports.
- Employee and company data will be obtained from existing company address book.
- Specs Section data will be obtained from any literature outlining CSI (Construction Specifications Institute) Masterformat, such as [O'Brien 90].
- Bill of Quantity (BoQ) data will be obtained from the project's work item details (estimated or extracted from contract drawings) and WBS (work

breakdown structure). WBS will be based on either CSI Masterformat or ASPE (American Society of Professional Estimators) format.

- Bid data will be obtained from the bid documents as submitted by bidders.
- Change order and defective work notification data will be obtained from the respective documents and the project log book.
- Correspondence data will be obtained from company correspondence log books.
- Daily site report data will be obtained from daily events and weather reports from job sites.
- Monthly progress report and materials stored data will be obtained from BoQ and progress measurement reports from job sites.
- Photograph data will be obtained from photo log of job sites.
- Punch list data will be obtained from punch lists forwarded by architects/engineers (A/E)
- Requests for Information (RFI) data will be obtained from the RFI log of job sites and home office.
- Shop drawing data will be obtained from project's specification, schedule, and shop drawing submittals log from job sites.
- Spare parts data will be obtained from project's specifications and contracts, and spare part records from job sites.

4.9.3 System Data Output

Figure 4.50 illustrates a data output organization. The system output will be on screen (forms) as well as on printout reports. Data output on screen will be form-oriented and the user interface will employ some of the gadgets of the window operating system like fields, menus, buttons, dropdown menus, scroll bars, etc.

As required by the company, the following forms and reports will be created:

- Bill-of-Quantities,
- Bid Summary Sheets,
- Change Orders Tracking Log,
- Correspondence Tracking Log,
- Daily Site Reports,
- Defective Work Notifications Tracking Log,
- Materials Stored Tracking Log,
- Monthly Progress Reports,
- Photographs Tracking Log,
- Punch Lists,
- Requests for Information Tracking Log,
- Shop Drawing Submittals Tracking Log, and
- Spare Parts Tracking Log.

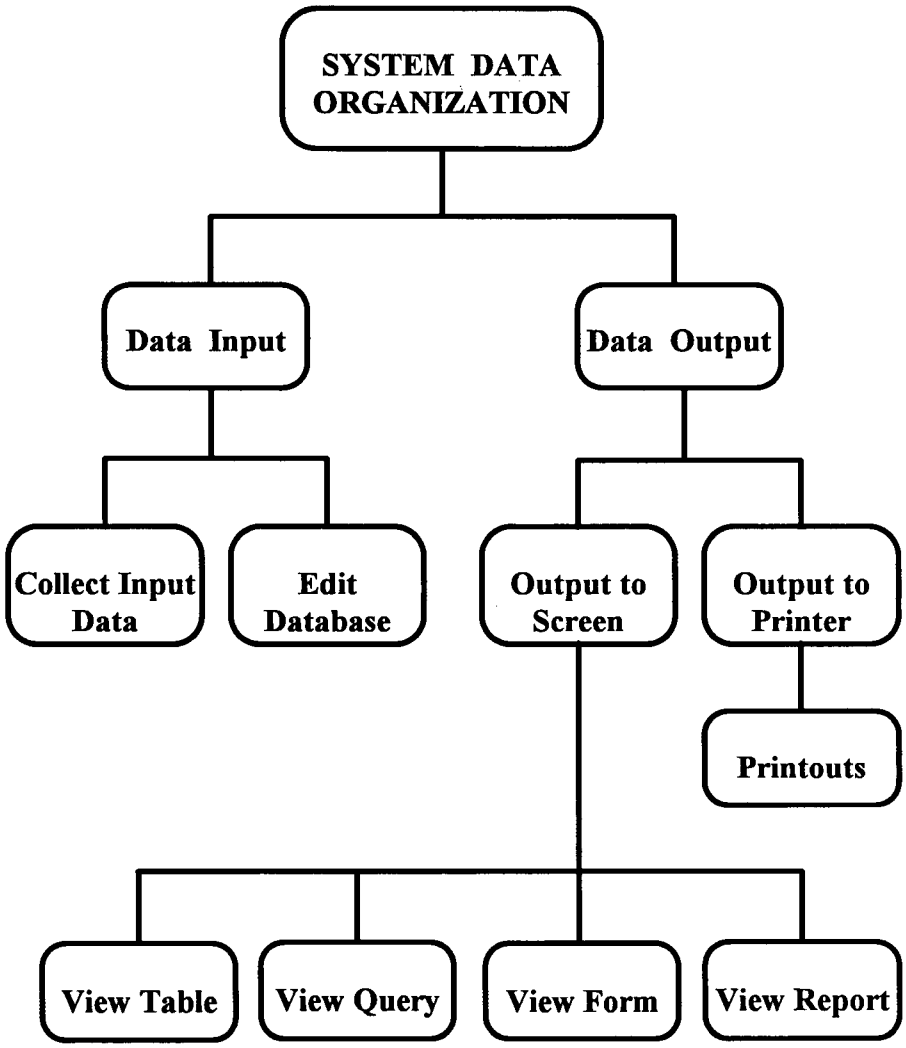


Figure 4.50 System Data Organization Diagram

4.10 Physical Implementation

This section describes the physical development of the system. Section 4.10.1 presents the Microsoft Access terminology, and section 4.10.2 presents the prototype development.

4.10.1 Microsoft Access Terminology

Some of the key terms, as used in Microsoft Access, are defined as follows:

- *Microsoft Access*: As mentioned earlier, Microsoft Access is a relational database management system (RDBMS) for Microsoft Windows™.

- *Table:* A table is a Microsoft Access object that stores data in rows (records) and columns (fields). The data is usually about a particular subject such as project or people. All data in a table describe the subject of the table. The entities and relationships, as listed in section 4.6, will be termed as tables.

- *Query:* A query is a Microsoft Access object that asks a question or defines a set of criteria about data from tables. The data that answers the questions can be from one table or from more than one table. A query brings requested questions together. A number of selected tables, the tables which contain the desired data,

are added to the Query window. The Query window is a graphical query-by-example (QBE) tool. The tables in a query are joined by a line that connects one of the fields of a table. The *join line* tells Microsoft Access how the data in the tables are related. A QBE grid is used to accomplish a variety of tasks in a database, such as the following:

- Combining and displaying records from related tables.
- Producing columns of calculated data from existing fields in a table.
- Retrieving subsets of records that match specific selection criteria.
- Updating fields of data according to updated expressions.

- *Form:* A form is a Microsoft Access object that is used to enter, change and view records of data. It is used to display data, from one or more tables and/or queries, on the screen or in print using a custom layout. A well-designed form provides a familiar, consistent, and reliable visual tool for performing a variety of database tasks, such as the following:

  - Viewing data one record at a time.
  - Viewing existing records in a table.
  - Entering new records into the table, often in a format designed to resemble a familiar paper form.
  - Printing individual records as forms.

- *Report:* A report is a Microsoft Access object that is used to print records in a custom layout. A report can be used to group records and show totals for groups and grand totals for the entire report. A report is the ultimate presentation from a database. A report often provides summaries of data, listings of records, and information gathered together in meaningful groups and subgroups.

- *Macro:* A macro automatically carries out a task for a user. Each task that a Microsoft Access is asked to perform is called an action. Microsoft Access provides a list of actions to select from to create a macro. When a macro is run, Microsoft Access carries out actions in the sequence they are listed, using the specified objects or data. Macros can automate routine or repetitive tasks, such as entering, viewing and printing data.

- *Field:* A field is a column of data contained in a table. The attributes of the entities and relationships, as described in section 4.6, will become fields of a particular table.

- *Type:* The term 'type' used in tables of Appendix-D denotes the degree of relationships between the tables. For example, one-to-one (1-1), one-to-many (1-M), etc.

- *Enforce:* The term 'enforce' used in tables of Appendix-D shows the referential integrity requirements. This column shows 'yes' if referential integrity is required. Referential integrity are the rules that govern the relationships between primary keys and foreign keys of a tables within a relational database and determine data consistency. Referential integrity requires that the values of every foreign key in every table be matched by the value of a primary key in another table. The rules help ensure that a data is related in a valid way, and that the data is not accidentally deleted.

- *Default Relationships:* Because Microsoft Access is a relational database, data can be used from more than one table at a time. If a database contains tables with related data, the data can be related in queries, forms and reports. It is always useful to create a default relationship between the related data of two tables to allow the DBMS to automatically associate data from different tables.

4.10.2 Prototype Development

This section discusses the various steps followed to produce a prototype of the system. The steps followed were in the following sequence: developing tables, setting default relationships, designing queries, creating forms and subforms, producing reports, and creating applications with macros. The following sections present a short description of each of the steps as discussed above.

4.10.2.1 Developing Tables

All the twenty five (25) tables, as listed on the left column of Table 4.15, were included in prototype database. Each table was developed by adding all the fields and their data types, as listed in the data dictionary (Appendix-C). Setting of primary key(s) for each table was performed, simultaneously, during the course of individual table development. Roughly, it took ten man-hours to create all the tables.

4.10.2.2 Setting Default Relationships between Tables

As the purpose of the database is to create queries, forms, and reports that successfully retrieve data from more than one table — setting of default relationships between table became a priority over other database actions. Default relationships between tables, as listed in Table D-1 (Appendix-D), were set before designing queries, forms and reports. It took approximately four hours to set default relationships.

4.10.2.3 Designing Queries

After considering carefully, a list of thirty one (31) queries was developed for the database. Each query was intended for a particular form, subform or report. Fields containing data required to appear on a form or report were selected, and their tables were

identified. A set of tables joined by their relationships, as listed in Table D-2 (Appendix-D), were used to create QBE grids. A slightly different naming convention, than that of a table, was used for each query in order to differentiate them while designing a form or report. Roughly, it took 10 man-hours each for designing and creating all the queries.

4.10.2.4 Creating Forms

Three different types of forms were created for each user view. The first type of forms was intended for data-entry/editing a table, the second type was for viewing information on screen, and the third one was for using as a subform in the design of a form. For the prototype, the following forms were created: twenty five data-entry forms (one for each table), thirteen on-screen view forms (one for each user view), and thirteen subforms (one for each user view). Some of the other forms created are the following: startup, data-entry form switchboard, data-table view switchboard, form view switchboard, main switchboard, and print-report switchboard. All together, fifty seven (57) forms were created and designed. Some of the forms are depicted in Appendix-E. It took approximately forty man-hours to create and design all the forms.

4.10.2.5 Producing Reports

As mentioned earlier, a report is the ultimate presentation for the database. On construction projects, it is often required to distribute a report to various people. In the

prototype, the intended reports are the same as those of the user views as listed in section 4.9.3, and some of the reports as displayed in the Expedition literature [Expedition 95]. Each report provides summaries of data and information as contained in its respective user view. Fourteen (14) reports were created and designed (thirteen for different user views, and one for company listings). Some of the reports are depicted in Appendix-F. It took approximately twenty man-hours to create and design all the reports.

4.10.2.6 Creating Applications with Macros

In order to produce a form-view or report, a number of actions would be required. As the PMICS contains quite a large number of user views, automation of actions was considered a necessity. Macros were used to create a database application, such as opening and closing a form, printing a report, exiting the Microsoft Access window. The following macros (6 nos.) were created for the prototype: AutoExec, DataEntry form switchboard, Form switchboard, Main switchboard, PrintReport switchboard, and TableData switchboard. It took approximately four man-hours to create all the macros.

Chapter 5

CONCLUSIONS

5.1 Thesis Review

The first objective of this work was to collect and review literature to determine the use and purpose of different documents on construction projects. The desired result was to identify documents which contain information that are used by construction personnel for solving problems, pursuing claims, providing instructions to site personnel, etc.

The second objective of the work was to develop a data model based on the above findings for a computer-based project-management information control system (PMICS). The expected use of the system was to handle all the problem solving and management information quickly and efficiently.

The first part of the research was based on the common condition of methodologies for designing databases for construction industry, as proposed by [Scarponcini 89], that *information follows function*. The functions executed by these by construction personnel dictate the information that these personnel need and provide. The functions must be understood before the information can be identified and efficiently modeled.

A matrix approach was adopted to determine the information needs and the documents that contain them. A set of four matrices was developed for this purpose. The first matrix, personnel versus functions (M-1), was developed wherein each component of the functions of construction site personnel was defined. This matrix included all the generic functions of various departments on a construction project, e.g., general management, financial/accounting, engineering, estimating, planning, construction management, project management and site management. The matrix M-1 was short listed to produce a matrix, construction personnel versus functions (M-2), containing functions related to project and site management. The matrix M-2 was used as a basis for the development of the third matrix, construction personnel versus information needs (M-3). The fourth matrix, document type versus information content (M-4), was then developed to identify the documents containing information that identified in M-3. Section 4.1.5 lists the documents identified as user views.

A framework was developed for designing the information system. Chapter 3 describes the framework. Based on the information requirements, each of the user view was presented as a relation. A conceptual data model was developed for each relation of the user views. The tools used for data modeling were entity-relationship (E/R) diagram and structural data model (SDM) diagram. A global data model, one each for E/R and SDM, was developed by integrating all the individual models. These models helped in identifying the various entities, including their attributes, and their relationships. A data dictionary was

developed in order to define all the attributes, and to use for future references and amendments.

After the project information environment had been modeled and understood, a prototype design was started. The global model was mapped to a relational database model. The entities became tables, and attributes their fields. The global model also helped in establishing default relationships between tables to improve query performance. Indexes were identified to simplify and speed up the queries. The database was implemented on a commercial relational database management systems (RDBMS), called Microsoft Access.

After the database was implemented, interfaces to the users were developed. Like other RDBMS, Microsoft Access allows multiple views on the data. This property was exploited in generating these interfaces. The interfaces consisted of graphical front ends (forms) for the users to manipulate/query data. All the interfaces were given a similar look and feel.

5.2 Benefits and Applications of PMICS

PMICS is a prototype project-management information control system aimed at supporting the information control requirements of the project managers. The following benefits can be achieved from the PMICS:

- PMICS can provide the project managers with a project information storage and retrieval database to facilitate the task of job site information control management.

- PMICS can provide the project managers with an expanded means of problem identification and tracking which includes transaction management.

- PMICS can generate a wide variety of periodical reports, e.g., daily site report, monthly progress report, outstanding shop-drawing report, etc.

- PMICS can be used for the purpose of claims analysis, e.g., by calculating time impacts on change order approval, shop-drawing approval, etc.

- PMICS is a user friendly and easy to use system.

5.3 Experiences and Observations

The development of PMICS prototype raised several issues and posed problems concerning the development of a system which would work in the real world. Although only a small number of construction-site documents were considered and only the project management related information was captured, the analysis turned out to be fairly large. It currently consists of thirteen user screen views and an equal number of printout reports. Some of the experiences and observations are given as following:

- A global conceptual data would be very useful for an integrated information system. Two global conceptual models, one each for entity-relationship and structural data model, were developed as depicted in Figures 4.19 and 4.33.

- Sufficient analysis and design in the early stages is very important for smooth implementation.

- Sometimes it is difficult to update the design during implementation, pointing to the need for an integrated data dictionary.

- Prototyping is very efficient in pointing out deficiencies in the design.

5.4 Contributions

The contributions of this research work include the following:

- Exhaustive literature search and survey of information management for construction projects.

- Development of various matrices, namely, personnel versus functions, personnel versus information needs, and document type versus information contents.

- Development of global data models for documents in the construction industry.

- Development of methodologies for designing a system that might be applicable to the development of such a system within most organizations.

- And last, but not the least, the PMICS itself.

5.5 Extensions and Future Research

In terms of future development and research work, the next logical steps would be to redefine and expand the prototype to serve as a template for a more general information system for construction organizations. Other research work may include the following: to redefine the information needs for the whole organization, and to integrate PMICS with the information systems of all the project participants.

More remote extensions include filing of construction photographs linked with PMICS database, and using pen-based computer to enter daily and site report data.

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APPENDIX A

Matrix

This appendix contains matrix M-1 (personnel versus functions) only. Other matrices (M-2, M-3 and M-4) are depicted in Chapter 4. Matrix M-1 is produced through a exhaustive literature search. The main purpose of producing this matrix is to identify the construction documents which contain information required by construction personnel. The matrix M-1 presents functions of various construction personnel. The functions included in the matrix are in the following areas: general management, financial/accounting, engineering, estimating, planning, construction management, project management and site management. This matrix has helped to produce matrices M-2, M-3 and M-4. Matrix M-2 (Figure 4.4) is a short-listed version of matrix M-1, and shows only project and site management functions. Matrix M-3 (Figure 4.5) presents information needs of various construction personnel. Matrix M-4 (Figure 4.6) identifies the construction documents which contain information as listed in matrix M-3. Matrix M-1 runs through page number 237 to 240.

PERSONNEL/FUNCTIONS MATRIX (M-1)

MANAGEMENT LEVEL		Top					Construction					Project								Functional					
Legends: A= advisory/assist C= control responsibility D= data provisions E= execution H= handle R= review & analyze	Responsibility	President	General Manager	Finance Manager	Chief Accountant	Chief Engineer	Construction Manager	Asst. Chief Engineer	Chief Estimator	Procurement Manager	Personnel Manager	Project Manager	Project Engineer	Planning/Scheduling Engineer	Cost Engineer	Estimator / QS	Safety Engineer	Accountant	Purchasing Agent	General Supdt.	Field Office Engineer	Field Engineer	Superintendents	Foremen	Subcontractor
Function/Activity																									
1. GENERAL MANAGEMENT																									
set out company objective		C,E																							
formulate company plans & strategies		C,E																							
responsible for company growth		C																							
determine company policy			C,E																						
marketing		A	C,E																						
decide to tender			C			H	A		E																
tender adjudication		R,A	E			H	A		D																
analyze status of projects		R	R	R		R	R																		
review business forecast & legislation		R	R	R			R																		
advise and assist key personnel		A	A																						
2. FINANCING/ACCOUNTING																									
financial planning, admin. & control		A	A	C,E																					
advise key personnel on financial matters				A																					
project's budgeting				A			A					C				E									
issue project's financial statement		R	R	R	R		R					C,R						E							
develop accounting procedures					C,H																				
direct accounting functions					C,H																				
company accounts					C,H																				
administration					C																				
project accounts/records/costs												C						E							
supervise timekeeping, payroll											A	C						E		A		D		D	
receive/process invoices and vouchers																		E							
record money committed/apprvd												C						E							
3. ADMIN. & PERSONNEL MANAGEMENT																									
hiring personnel, general											C,E														
hiring & training personnel, engineering						H		A			C,E														
hiring & training personnel, construction							H				C,E	A													
arrange training for personnel											C,H														
arrange safety facilities											A						H								
leveling project's labor and manpower												C								A					
perform labor relations such as interpreting																	A								

Figure A.1 Personnel/Function Matrix (M-1)

PERSONNEL/FUNCTIONS MATRIX (M-1)

MANAGEMENT LEVEL		Top					Construction					Project								Functional					
Legends: A= advisory/assist C= control responsibility D= data provisions E= execution H= handle R= review & analyze	Responsibility	President	General Manager	Finance Manager	Chief Accountant	Chief Engineer	Construction Manager	Asst. Chief Engineer	Chief Estimator	Procurement Manager	Personnel Manager	Project Manager	Project Engineer	Planning/Scheduling Engineer	Cost Engineer	Estimator / QS	Safety Engineer	Accountant	Purchasing Agent	General Supdt.	Field Office Engineer	Field Engineer	Superintendents	Foremen	Subcontractor
Function/Activity																									
union regulations, settling dispute, etc.																									
4. ENGINEERING																									
Engineering																									
engineering & design operations, home office						C,H		A																	
advise key personnel on technical matters						A		A																	
engineering & design operations, project's												A	C,H												
liaise field and office engineering													H												
handle change orders, work orders, claims								R,A				C	H								E				
handle design, drafting & shop drawing												A	C,H								E				
coordinate drawing, papers and submittals												C	H									A			
Estimating																									
analyze tender documents						C	R	A	R,H																
calculate required rates									C,A							E									
prepare net cost estimate									C,H							E									
analyze post-bid rates									C,R							E									
advise clients on cost reduction measures						C			A																
project's estimating									A			C,A	H			E					D				
make quantity survey from drawings													C			E					D,E				
subcontract estimate												C	H			E									
Planning																									
prepare pre-tender programs						C	R,A							E											
prepare contract programs						C	R,A							E											
prepare method statements						C	R,A						H	E											
project's planning and scheduling						A	R					C,A	H	E		D									
prepare project's schedule for resources												C	H	E											
develop delivery schedules												C	H	E											
prepare project's weekly/monthly schedule												C	H	E											
expand/monitor preliminary schedules into detail schedules													C							A		E			
Cost Control																									
find economical men/machines/materials												C	A		E				*						
prepare all cost reports							R					C,R	A		E										

Figure A.1 Personnel/Function Matrix (M-1)

PERSONNEL/FUNCTIONS MATRIX (M-1)

Legends:
A= advisory/assist **C**= control responsibility
D= data provisions **E**= execution **H**= handle **R**= review & analyze

MANAGEMENT LEVEL		Top					Construction					Project								Functional					
Function/Activity	**Responsibility**	President	General Manager	Finance Manager	Chief Accountant	Chief Engineer	Construction Manager	Asst. Chief Engineer	Chief Estimator	Procurement Manager	Personnel Manager	Project Manager	Project Engineer	Planning/Scheduling Engineer	Cost Engineer	Estimator / QS	Safety Engineer	Accountant	Purchasing Agent	General Supdt.	Field Office Engineer	Field Engineer	Superintendents	Foremen	Subcontractor
prepare cost engineering procedure												C	H		E										
prepare accounts/cost codes classifications					C								A		E										
cost distribution of labor/equipment/material													C		E										
analyze & control cost												C,R	A		R,E										
maintain cost records & reports												C	H		E										
forecast project's financial outcome			R	R	R		R					C,R			E										
monitor project's weekly labor, material, & equipment cost												C,R	A		E	D									
Quantity Surveying																									
measure work & payment estimate												C	H			E									
prepare/agree valuations												C	H			E									
prepare cost /value reconciliation												C				E									
agree final accounts												C	H			E									
Safety																									
implement safety programs on the project																	C,E								
make accident reports																	E								
take charge of explosive/blasting/safety												C					H								
administer safety enforcement																	H							E	
5. CONSTRUCTION/OPERATIONS																									
Construction Management																									
manage construction operations							C,H																		
develop construction methods						H	C						D												
supervise subs selection and negotiation							C,A			A		H				D									
procurement of resources							C,H					A													
supervise building production, all projects							C					H													
liaise with architect/client, all projects							C,H					A													
Procurement																									
obtain quotations										C,A		A		D	D	D			H						
assist supplier/subs on technical matters										C,A		A	D												
negotiate with sub-contractors/suppliers										C		A							H						
prepare/approve procurement contracts										C,A		A							E						
project's purchasing/expediting/inspection										A		C							H	A		A			

Figure A.1 Personnel/Function Matrix (M-1)

PERSONNEL/FUNCTIONS MATRIX (M-1)

MANAGEMENT LEVEL		Top					Construction					Project								Functional					
Legends: A= advisory/assist C= control responsibility D= data provisions E= execution H= handle R= review & analyze	Responsibility	President	General Manager	Finance Manager	Chief Accountant	Chief Engineer	Construction Manager	Asst. Chief Engineer	Chief Estimator	Procurement Manager	Personnel Manager	Project Manager	Project Engineer	Planning/Scheduling Engineer	Cost Engineer	Estimator / QS	Safety Engineer	Accountant	Purchasing Agent	General Supdt.	Field Office Enginee	Field Engineer	Superintendents	Foremen	Subcontractor
Function/Activity																									
coordinate project's volume purchases										C,A		A							H	A					
maintain project's source files												C							E						
arrange transportation & routes										C									H						
order materials										C,A		A							E						
chase materials										C									H						
Project Management																									
project completion												C,H	A							E					
coordination (field, engineering, client, union)												C,E													
report project's progress/potential problems							R					C,R	H,R								E	D	D	D	
prepare project's progress & status reports							R					C,R	H	E											
job records, periodical reports, subs records													C,A								E	D	D	D	
progress photographs												C	H								E				
Site Management																									
field work, field survey, layout, etc.												C	A							H		E			
check progress of subcontractor																				H		A			
organize/supervise supdt./foremen/subs												C								H					
implement management decisions, like												C								E					
constr. methods, schedules, safety, etc.																									
monitor preconstruction activities like												C,A								A					
preparing preliminary schedule, obtaining																									
permits, job staffing, insurance, etc..																									
supervise & organize the work of foremen, and												C,A								C,A			H		
equipment, materials, and services																									
direct all pre-construction activities												C,A								C,A			H		
direct inspection												C										H	A		
concrete pours & quality control												C	A									H		E	
complete punching lists/operating data												C,R	R							A		A	E		
organize employee engaged in a craft																						A	A	H	
read/interpret drawing, blueprints, & specifics																						A		E	
allocate, assign and inspect work																						A		E	

Figure A.1 Personnel/Function Matrix (M-1)

APPENDIX B

Work Breakdown Structure

This appendix lists a work breakdown structure (or work element structure) developed and promoted by the American Society of Professional Estimators (ASPE). Figure B.1 shows the 17-division construction estimating classification system recommended by the ASPE (source: [Stewart & Stewart 86], p36). The Construction Specifications Institute (CSI) recommends a 16-division work breakout (used in the prototype as specs sections) that closely parallels that of the ASPE at the division level but deviates substantially thereafter. The ASPE breakout contains divisional classifications, which are subdivided into discipline classifications, which are, in turn, subdivided into definitive classifications. As the list of CSI breakout is very long, it is not presented in this thesis.

1.00 GENERAL DISCIPLINES
- 1.10 BUILDING
- 1.20 TRANSPORTATION
- 1.30 INDUSTRIAL
- 1.40 HEAVY/UTILITIES
- 1.50 POWER

2.00 SITE WORK DISCIPLINES
- 2.10 SITE PREPARATION - TYPE I (DEMOLITION)
  - 2.11 Mechanical Demolition
  - 2.13 Explosive Demolition
  - 2.15 Salvaging
- 2.20 SITE PREPARATION - TYPE II (EARTHWORK)
  - 2.21 Site Grading
  - 2.22 Rock Excavation
  - 2.23 Trench Excavation
  - 2.24 Hauling
  - 2.26 Finish Grading
  - 2.27 Soil Stabilization
  - 2.29 Dewatering
- 2.30 SITE PREPARATION - TYPE III (PILES, CAISSONS & SHORING)
  - 2.31 Pile Foundations
  - 2.35 Pier Foundations
  - 2.37 Drilled Caissons
  - 2.38 Sheet Piling & Cribbing
  - 2.39 Underpinning
- 2.40 SITE DEVELOPMENT - TYPE I (UTILITIES)
  - 2.41 Permanent Site Drainage
  - 2.43 Water Utilities
  - 2.44 Sanitary Utilities
  - 2.45 Gas Utilities
  - 2.46 Oil Utilities
  - 2.47 Electrical Power Utilities
  - 2.48 Telecommunication Utilities
- 2.50 SITE DEVELOPMENT - TYPE II (PAVING, SPECIALTIES, LANDSCAPE)
  - 2.51 Curb and Gutter Specialist
  - 2.52 Mudjacking Specialist
  - 2.53 Bituminous Paving
  - 2.54 Concrete Paving
  - 2.55 Fencing
  - 2.56 Site Specialties
  - 2.57 Irrigation
  - 2.58 Landscaping
- 2.60 RAILROAD WORK
- 2.70 MARINE WORK
- 2.80 TUNNELING

3.00 CONCRETE DISCIPLINE
- 3.10 CAST-IN-PLACE
- 3.20 REINFORCING STEEL
- 3.30 PRECAST
- 3.40 SPECIALIZED DECKS & FINISHES

4.00 MASONRY DISCIPLINE
- 4.10 BRICK & BLOCK MASONRY
- 4.20 STONE MASONRY

5.00 METAL DISCIPLINES
- 5.10 STRUCTURAL (FAB & ERECT)
  - 5.11 Fabrication only
  - 5.15 Erection only
- 5.20 MISCELLANEOUS ((FAB & ERECT)
- 5.30 ORNAMENTAL ((FAB & ERECT)
- 5.40 DECKING & SIDING
- 5.50 PRE-ENGINEERED BUILDING

6.00 WOOD & PLASTIC DISCIPLINES
- 6.10 ROUGH CARPENTRY
  - 6.11 Light Framing
  - 6.13 Heavy Timber Framing
  - 6.15 Trestle Framing
  - 6.17 Laminated framing
- 6.20 FINISH CARPENTRY

7.00 THERMAL & MOISTURE DISC.
- 7.10 WATERPROOFING & DAMP.
- 7.20 INSULATION
- 7.30 ROOFING
  - 7.31 Shingle & Tile
  - 7.35 Membrane
- 7.40 ARCHITEC. SHEET METAL
- 7.50 SKYLIGHTS
- 7.60 CAULKING & SEALANT

8.00 DOOR & WINDOW DISCIPLINE
- 8.10 HOLLOW METAL
- 8.20 WOOD & PLASTIC DOORS
- 8.30 SPECIAL DOORS
- 8.40 STOREFRONT & GLASS
  - 8.41 Storefront & Curtain Wall
  - 8.45 Glass & Glazing only
- 8.50 FINISH HARDWARE

9.00 FINISH DISCIPLINES
- 9.10 FINISHES - TYPE I
  - 9.11 Lath & Plaster
  - 9.13 Metal & Stud Framing
  - 9.14 Drywall
  - 9.15 Acoustical System
  - 9.17 Special Coatings
  - 9.19 Painting & Wall Covering
- 9.20 FINISHES - TYPE II
  - 9.21 Ceramic & Quarry Tile
  - 9.23 Terrazzo
  - 9.25 Resilient Flooring
  - 9.27 Carpeting
  - 9.29 Special Flooring

10.00 SPECIALTY DISCIPLINES
- 10.10 BUILDING SPECIALTIES
- 10.20 PARTITION SYSTEMS

11.00 EQUIPMENT DISCIPLINES

12.00 FURNISHING DISCIPLINES

13.00 SPECIAL CONSTRUCTION DISC.

14.00 CONVEYING SYSTEM DISC.
- 14.10 ELEVATORS & ESCALATORS
- 14.20 HOISTS & CRANES
- 14.30 MATERIAL CONVEYING SYSTEM

15.00 MECHANICAL DISCIPLINES
- 15.10 PLUMBING
- 15.20 PIPING
- 15.30 HVAC
- 15.40 FIRE PROTECTION

16.00 ELECTRICAL DISCIPLINES
- 16.10 RESIDENTIAL
- 16.20 COMMERCIAL/IND.
- 16.30 POWER TRANSMISSION
- 16.40 COMMUNICATION SYSTEMS

17.00 ENVIRONMENTAL DISCIPLINES

Figure B.1 Work Breakdown Structure

APPENDIX C

Data Dictionary

This appendix contains the tables describing the attributes of each entities and relationships as presented in Section 4.6. Each attribute contains the following categories of information: field name, data type, length, index and comments. Field name is same as the attribute name. Data type is the type of data the field will store, e.g., text, number, date/time, yes/no, currency. The number data-type is further categorized into byte, integer, long integer, single and double. Length is the storage space required for the values stored in the field. Index shows the settings required for the indexed property. Comments shows a brief description of the field.

The term 'data element list' is used as a title for all the tables in this appendix. The following abbreviations and legends have been used through out the tables: DOK = Duplicate OK; NOD = No Duplicate; Long = Long integer; Bold field name(s) = key-field(s).

Table C.1 Data Element List for Bids

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
TradeID	Integer	2	Yes (DOK)	same as TradeID in Trades table
BidderID	Long	4	Yes (DOK)	same as Co_ID in Company table
Bid Pkg Sent	Date/Time	8	No	date bid package sent to a bidder
Bid Received	Date/Time	8	No	date bid received from a bidder
Bid Amount	Currency	8	No	bid amount quoted by a bidder
Remarks	Text	50	No	special comments or remarks

Table C.2 Data Element List for Change Orders

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
CMR#	Integer	2	Yes (DOK)	Contract Modification Request no.
SpecsID	Integer	2	No	same as SpecsID in Specs Section table
Initiation Date	Date/Time	8	No	date the CMR initiated/introduced
Current Status	Text	20	No	current status of the CMR
Description	Text	50	No	brief description of the CMR
EstimatValue	Currency	8	No	contractor's estimate of the CMR
EngrEstimate	Currency	8	No	engineer's estimate of the CMR
Final Value	Currency	8	No	final settlement value
Time Impact	Byte	1	No	contract time impact (CTI) in days
D-RfAE	Date/Time	8	No	date CMR received from the A/E
D-StS	Date/Time	8	No	date CMR sent to subcontractor
D-BfS	Date/Time	8	No	date back from the subcontractor
D-RtAE	Date/Time	8	No	date returned to the A/E
D-FS	Date/Time	8	No	date of final settlement
Disposition	Text	50	No	disposition or comments

Table C.3 Data Element List for Company

Field Name	Data Type	Length	Index	Comments
Co_ID	Counter	4	Yes (NOD)	company identification number
Co_Name	Text	40	Yes (DOK)	name of the company
TypeID	Integer	2	Yes (DOK)	same as TypeID in Participant Type
Contact1	Long	4	No	PeopleID of primary contact person
Contact2	Long	4	No	PeopleID of second contact person
Address	Text	30	No	address of the company
City	Text	20	Yes (DOK)	name of the city
Province	Text	20	No	province abbreviated name
Postal Code	Text	7	No	postal code of the area
Phone	Text	20	No	company's phone number
Fax	Text	20	No	company's fax number
Size	Text	6	No	company size: big, medium or small

Table C.4 Data Element List for Correspondence

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
Corr#	Integer	2	No	project's correspondence entry serial number
From People	Long	4	No	PeopleID of the sender
To People	Long	4	No	PeopleID of the addressee
Reference#	Text	20	Yes (DOK)	reference no. on a correspondence
Corr Date	Date/Time	8	Yes (DOK)	original date of a correspondence
Date Sent	Date/Time	8	No	date of mailing
DateRcvd	Date/Time	8	No	date correspondence received
Follow-up	Yes/No	1/8	Yes (DOK)	follow up required?
Keyword1	Text	20	Yes (DOK)	first keyword describing the subject
Keyword2	Text	20	Yes (DOK)	2nd keyword describing the subject
Notes	Text	75	No	notes or comments

Table C.5 Data Element List for Daily Events

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
Date	Date/Time	8	Yes (DOK)	date of a report
Day ID	Integer	2	No	same as Day ID in Day table
Daily Report#	Integer	2	Yes (DOK)	project's serial number of a report
Prepared by ID	Long	4	No	PeopleID of person making report
FFC1	Long	4	No	field force contractor-1 Co_ID
FFC2	Long	4	No	field force contractor-2 Co_ID
FFC3	Long	4	No	field force contractor-3 Co_ID
FFC4	Long	4	No	field force contractor-4 Co_ID
NMFF1	Byte	1	No	non-manual field force of FFC1
NMFF2	Byte	1	No	non-manual field force of FFC2
NMFF3	Byte	1	No	non-manual field force of FFC3
NMFF4	Byte	1	No	non-manual field force of FFC4
MFF1	Byte	1	No	manual field force of FFC1
MFF2	Byte	1	No	manual field force of FFC2
MFF3	Byte	1	No	manual field force of FFC3
MFF4	Byte	1	No	manual field force of FFC4
Job1	Text	20	No	job/trade name of FFC1
Job2	Text	20	No	job/trade name of FFC2
Job3	Text	20	No	job/trade name of FFC3
Job4	Text	20	No	job/trade name of FFC4
Visitor1	Text	30	No	name of visitor-1
Visitor2	Text	30	No	name of visitor-2
VisitTime1	Date/Time	8	No	time of visit of visitor-1
VisitTime2	Date/Time	8	No	time of visit of visitor-2
Company1	Text	30	No	name of the visitor-1's company
Company2	Text	30	No	name of the visitor-2's company
Purpose1	Text	30	No	purpose of the visitor-1'S visit
Purpose2	Text	30	No	purpose of the visitor-2'S visit
EquipUse	Memo	N/A		equipment in use at the project
EquipIdle	Memo	N/A		equipment idle at the project
Activities	Memo	N/A		activities in progress at the site
New Act	Memo	N/A		New activities started at the site
Act Compl	Memo	N/A		activities completed at the site
Material Needs	Memo	N/A		future material needs

Table C.6 Data Element List for Daily Weather (Weather)

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
Date	Date/Time	8	Yes (DOK)	date of a report
Day ID	Integer	2	No	same as Day ID in Day table
Temperature	Integer	2	No	recorded average temperature
Sunny	Yes/No	1/8	No	sunny weather?
Cloudy	Yes/No	1/8	No	cloudy weather?
Rainy	Yes/No	1/8	No	rainy weather?
Snowy	Yes/No	1/8	No	snowy weather?
Still Wind	Yes/No	1/8	No	wind is still?
Moderate Wind	Yes/No	1/8	No	wind is moderate?
High Wind	Yes/No	1/8	No	wind is high?
Humid-dry	Yes/No	1/8	No	humidity: dry?
Humid-mod	Yes/No	1/8	No	humidity: moderate?
Humid-high	Yes/No	1/8	No	humidity: high?

Table C.7 Data Element List for Days

Field Name	Data Type	Length	Index	Comments
Day ID	Integer	2	Yes (DOK)	day's identity number
Day Name	Text	9	No	name of the day

Table C.8 Data Element List for Defective Work Notice (DWN)

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
DWN#	Integer	2	Yes (DOK)	project's DWN entry serial number
SpecsID	Integer	2	No	same as SpecsID in Specs Section
NoticeDate	Date/Time	8	No	DWN issue date
Description	Text	50	No	brief description of the DWN
DateRcvd	Date/Time	8	No	date the DWN received
EstimatValue	Currency	8	No	estimated value of the DWN item
DateReinsp	Date/Time	8	No	date the DWN item re-inspected
Reinspected by	Long	4	No	name of the inspector
D-NoCR	Date/Time	8	No	date no-objection received
Comments	Text	50	No	special comments, if any

Table C.9 Data Element List for Materials Stored

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
Mat#	Integer	2	Yes (DOK)	project's materials serial number
SpecsID	Long	4	No	same as SpecsID in Specs Section table
Loc_ID	Long	4	No	same as Loc_ID in Storage Location table
ItemDescription	Text	50	No	item description of the materials
Loc-Installed	Text	30	No	location of materials installed
Original Value	Currency	8	No	original value of materials stored
% Installed	Single	4	No	estimated % quantity installed to-date
Pay Est#	Byte	1	No	payment estimate number
Pay Est Date	Date/Time	8	No	monthly payment estimate date

Table C.10 Data Element List for Monthly Progress

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
Pay Est#	Byte	1	Yes (DOK)	project's pay estimate serial number
WBS_ID	Double	8	No	same as WBS_ID in WBS table
PayEst Date	Date/Time	8	Yes (DOK)	date of payment estimate
This Qntty	Single	4	No	% of the work item done this month
Todate Qntty	Single	4	No	% of the work item done to-date

Table C.11 Data Element List for Participant Type

Field Name	Data Type	Length	Index	Comments
TypeID	Integer	2	Yes (NOD)	identity number of participant type
Participant Type	Text	15	No	name of the participant type

Table C.12 Data Element List for People

Field Name	Data Type	Length	Index	Comments
PeopleID	Counter	4	Yes (NOD)	people identification number
Last Name	Text	20	Yes (DOK)	last name of the people
First Name	Text	10	No	last name of the people
Co_ID	Long	4	Yes (DOK)	same as Co_ID in Company table
Title	Text	20	No	title of the person in the company
Address	Text	30	No	address of the people
City	Text	20	No	name of the city
Province	Text	5	No	province abbreviated name
Postal Code	Text	7	No	postal code of the area
Phone	Text	20	No	phone number including area code
Fax	Text	20	No	fax number including area code

Table C.13 Data Element List for Photograph

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
Photo#	Integer	2	Yes (DOK)	project's photograph serial no.
Photo TypeID	Long	4	Yes (DOK)	same as in Photo Type table
Photgr ID	Long	4	No	PeopleID of the photographer
Roll#	Integer	2	No	serial number of the film roll
Negative#	Integer	2	No	negative-number in the film roll
Date Taken	Date/Time	8	No	date of photography
Time of Day	Date/Time	8	No	day time when photo taken
Camera Direction	Text	25	No	direction of camera when taking
Photgr Position	Text	25	No	position of the photographer
Facility/Location	Text	20	Yes (DOK)	name of location where photo taken
Keyword1	Text	20	Yes (DOK)	first keyword describing the photo
Keyword2	Text	20	Yes (DOK)	second keyword describing the photo
Caption	Text	30	No	caption or title of the photograph

Table C.14 Data Element List for Photo Type

Field Name	Data Type	Length	Index	Comments
Photo TypeID	Integer	2	Yes (NOD)	identity number of photo type
Photo Type	Text	15	No	name of the photo type

Table C.15 Data Element List for Project ItemDetails

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
WBS_ID	Double	8	Yes (DOK)	same as WBS_ID in WBS table
Quantity	Single	4	No	quantity of the WBS item
Unit Price	Currency	8	No	unit cost of the item
% Markup	Single	4	No	% markup to be added
Delivery Date	Date/Time	8	Yes (DOK)	scheduled delivery or action date
Delivery days	Integer	2	No	number of days required for delivery
Approval Days	Integer	2	No	number of days required for approval
ShopDrawing	Yes/No	1/8	Yes (DOK)	shop drawing required?
MatSample	Yes/No	1/8	No	materials sample required?
Catalog	Yes/No	1/8	No	catalog or brochure required?
Misc	Yes/No	1/8	No	other submittals required?
Misc Submittals	Text	20	No	calculation method statement etc.
As-built Drawing	Yes/No	1/8	No	as-built drawing required?

Table C.16 Data Element List for Project TradeDetails

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
TradeID	Integer	2	Yes (DOK)	same as TradeID in Trades table
Budget	Currency	8	No	estimated budget for the trade
StartDate	Date/Time	8	Yes (DOK)	start date of the trade activities
EndDate	Date/Time	8	No	end date of the trade activities
Bid Due Date	Date/Time	8	Yes (DOK)	bid due date from bidders
SubID	Long	4	No	Co_ID of the trade subcontractor
Sub Amount	Currency	8	No	subcontract amount

Table C.17 Data Element List for Project

Field Name	Data Type	Length	Index	Comments
ProjectID	Counter	4	Yes (NOD)	project identification number
Project Name	Text	30	Yes (DOK)	official name of the project
Project Type	Text	10	Yes (DOK)	type of project (building, bridge, etc.)
EngineerID	Long	4	No	Co_ID of the architects/engineers
OwnerID	Long	4	No	Co_ID of the owner
ManagerID	Long	4	No	PeopleID of contractor's project manager
OCBP	Currency	8	No	original contract bid price
OCCD	Date/Time	8	Yes (DOK)	original contract completion date
Start Date	Date/Time	8	Yes (DOK)	start date of the project
End Date	Date/Time	8	No	actual completion date
Address	Text	50	No	address or location of the project
Phone	Text	20	No	site office phone number
Fax	Text	20	No	site office fax number

Table C.18 Data Element List for Punch Lists

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
PL#	Integer	2	Yes (DOK)	project's punch list serial number
SpecsID	Integer	2	No	same as SpecsID in Specs Section table
Punch List Item	Text	50	No	item description of the punch list
Facility/Area	Text	20	No	location of the punch list item
Date Identified	Date/Time	8	No	date identified by the engineer
Identified by	Long	4	No	PeopleID of the engineer
Date Completed	Date/Time	8	No	date punch list item completed
Date Checked	Date/Time	8	No	date rechecked by the engineer
Checked by	Long	4	No	PeopleID of the engineer

Table C.19 Data Element List for RFI

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
RFI#	Integer	2	Yes (DOK)	project's RFI entry serial number
Initiated By	Long	4	No	PeopleID of the initiator
Initiation Date	Date/Time	8	No	date of RFI initiation
Drawing#	Text	10	No	drawing number, for reference
RFI Description	Text	50	No	short description of the RFI
D-StAE	Date/Time	8	No	date sent to the architect/engineer
D-RBfAE	Date/Time	8	No	date returned back from the A/E
D-SBtS	Date/Time	8	No	date sent back to subcontractor
Response By	Long	4	No	PeopleID of the person who responded
Comments	Text	50	No	comments or remarks

Table C.20 Data Element List for Shop Drawing

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
ShopDrwg#	Integer	2	Yes (DOK)	shop drawing number
WBS_ID	Double	8	No	same as WBS_ID in WBS table
Description	Text	40	No	keyword or title of the shop drawing
Disposition	Text	10	No	disposition or comments
D-RfS	Date/Time	8	No	date received from the subcontractor
D-StAE-I	Date/Time	8	No	date sent to A/E (initial)
D-StAE-R	Date/Time	8	No	date sent to A/E (resubmission), if any
D-StAE-F	Date/Time	8	No	date sent to A/E (Final), if any
D-RBfAE	Date/Time	8	No	date received back from the A/E
D-SBtS	Date/Time	8	No	date sent back to the subcontractor
C-RfS	Byte	1	No	copies received from the subcont.
C-StAE	Byte	1	No	copies sent to the A/E
C-RBfAE	Byte	1	No	copies received back from the A/E
C-SBtS	Byte	1	No	copies sent back to subcontractor
Comments	Text	50	No	comments or remarks

Table C.21 Data Element List for Spare Parts

Field Name	Data Type	Length	Index	Comments
ProjectID	Long	4	Yes (DOK)	same as ProjectID in Project table
SP#	Integer	2	No	project's spare parts entry serial number
Specs ID	Integer	2	No	same as Specs ID in Specs Section
Loc_ID	Long	4	No	same as Loc_ID in Storage Location table
SP Description	Text	40	No	description of the spare parts
Eq Description	Text	40	No	equipment the spare part is for
Qntty Required	Integer	2	No	total quantity required to be delivered
Qntty Dlvd	Integer	2	No	actual quantity delivered to-date
Unit	Text	4	No	unit of the spare parts
Status	Text	50	No	balance spare parts to be delivered

Table C.22 Data Element List for Specs Section

Field Name	Data Type	Length	Index	Comments
SpecsID	Integer	2	Yes (NOD)	identity number of a specification section
WBS_ID	Long	4	No	same as WBS_ID in WBS table
Specs Section	Text	5	Yes (NOD)	CSI Masterformat section number
Section Title	Text	50	No	CSI Masterformat section title
Division	Text	12	No	CSI Masterformat specs division
Division Title	Text	40	No	CSI Masterformat Division Title

Table C.23 Data Element List for Storage Location

Field Name	Data Type	Length	Index	Comments
Loc_ID	Counter	4	Yes (NOD)	identity number of storage location
Location Name	Text	30	No	name of the storage location
Address	Text	50	No	address of the storage location

Table C.24 Data Element List for Trades

Field Name	Data Type	Length	Index	Comments
TradeID	Integer	2	Yes(NOD)	identity number of construction trade
Trade Name	Text	25	Yes (NOD)	name of the trade
Description	Memo	N/A	No	short description or scope of the trade

Table C.25 Data Element List for WBS

Field Name	Data Type	Length	Index	Comments
WBS_ID	Double	8	Yes (NOD)	identity number of Work Breakdown Structure element
Item Description	Text	45	No	WBS item description
TradeID	Integer	2	No	same as TradeID in Trade table
Unit	Text	5	No	unit of the WBS item

Table C.26 Space Estimate for Tables

View No.	View Name	Frequency	No. of Records	Record Size (bytes)	Total Size (bytes)
1	Bill of Quantities	Monthly	24	150	3,600
2	Bid Summary Sheet	1/project	1	360	360
3	Change Orders Log	5/month	120	510	61,200
4	Correspondence Log	5/day	3600	450	1,620,000
5	Daily Site Report	1/day	730	1100	803,000
6	DWN Log	5/month	120	520	62,400
7	Materials Stored Log	Monthly	24	500	12,000
8	Monthly Progress	Monthly	24	300	7,200
9	Photograph Log	20/month	480	400	192,000
10	Punch List	100/project	100	500	50,000
11	RFI Log	100/project	100	500	50,000
12	Shop Drawing Log	30/project	30	540	16,200
13	Spare Parts Log	50/project	50	670	33,500
				Total	2,911,460

APPENDIX D

Default Relationships

Table D-1 presents the default relationships of table in the database of the system. Primary table denotes the one-end of the one-to-many (1-M) relationship. The related table denotes the many-end of the relationship. The fields column contains the attributes as described in section 4.6 for a particular entities or relationships (here referred to primary table or related table). The type column contains the relationships between entities as shows in Sections 4.4.1 to 4.4.13. The enforce column shows if referential integrity is required or not.

Table D-2 can be used as a list of tables required for a query, and as a guide lines for joining line between two tables and setting their relationships. The bold-faced titles are the name of the different queries to be used in the database.

Table D.1 Default Relationships

Primary Table	Related Table	Fields	Type	Enforce
Company	Bids	Co_ID/BidderID	1-M	Yes
Company	Daily Events	Co_ID/FFC1	1-M	Yes
Company	Daily Events	Co_ID/FFC2	1-M	Yes
Company	Daily Events	Co_ID/FFC3	1-M	Yes
Company	Daily Events	Co_ID /FFC4	1-M	Yes
Company	People	Co_ID	1-M	Yes
Company	Project	Co_ID/Engineer	1-M	Yes
Company	Proj-Company	Co_ID	1-M	Yes
Company	Project TradeDetails	Co_ID/SubID	1-M	Yes
Day	Daily Events	Day ID	1-M	Yes
Day	Daily Weather	Day ID	1-M	Yes
Participant Type	Company	TypeID	1-M	Yes
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID/Contact2	1-M	Yes
People	Correspondence	PeopleID/From	1-M	Yes

Primary Table	Related Table	Fields	Type	Enforce
People	Correspondence	PeopleID/To	1-M	Yes
People	Daily Events	PeopleID/Prep by ID	1-M	Yes
People	Photograph	PeopleID/Photgr ID	1-M	Yes
People	Project	PeopleID/ManagerID	1-M	Yes
People	RFI	PeopleID/Initiated By	1-M	Yes
People	RFI	PeopleID/ResponseBy	1-M	Yes
Photo Type	Photograph	Photo TypeID	1-M	Yes
Project	Bids	ProjectID	1-M	Yes
Project	Change Order	ProjectID	1-M	Yes
Project	Correspondence	ProjectID	1-M	Yes
Project	Daily Events	ProjectID	1-M	Yes
Project	Daily Weather	ProjectID	1-M	Yes
Project	Defective Work	ProjectID	1-M	Yes
Project	Materials Stored	ProjectID	1-M	Yes
Project	Monthly Progress	ProjectID	1-M	Yes
Project	Photograph	ProjectID	1-M	Yes
Project	Project ItemDetails	ProjectID	1-M	Yes
Project	Proj-Company	Project	1-M	Yes
Project	Proj-Trade	Project	1-M	Yes
Project	Project TradeDetails	Project	1-M	Yes
Project	Punch List	ProjectID	1-M	Yes
Project	RFI	ProjectID	1-M	Yes
Project	Shop Drawing	ProjectID	1-M	Yes
Project	Spare Parts	ProjectID	1-M	Yes
Specs Section	Change Order	SpecsID	1-M	Yes
Specs Section	Defective Work	SpecsID	1-M	Yes
Specs Section	Materials Stored	SpecsID	1-M	Yes
Specs Section	Punch Lists	SpecsID	1-M	Yes
Specs Section	Spare Parts	SpecsID	1-M	Yes
Storage Location	Materials Stored	Loc_ID	1-M	Yes
Storage Location	Spare Parts	Loc_ID	1-M	Yes
Trade	Bids	TradeID	1-M	Yes
Trade	Proj-Trade	TradeID	1-M	Yes
Trade	Project TradeDetails	TradeID	1-M	Yes
Trade	WBS	TradeID	1-M	Yes
WBS	Monthly Progress	WBS_ID	1-M	Yes
WBS	Project ItemDetails	WBS_ID	1-M	Yes
WBS	Shop Drawing	WBS_ID	1-M	Yes
WBS	Specs Section	WBS_ID	1-M	Yes

Table D.2 Queries and Join Tables

Primary Table	Related Table	Fields	Type	Enforce
BidSummary				
Company	Bids	Co_ID/BidderID	1-M	Yes
Company	Project TradeDetails	Co_ID/SubID	1-M	Yes
Project	Bids	ProjectID	1-M	Yes
Project	Project TradeDetails	ProjectID	1-M	Yes
Trade	Bids	TradeID	1-M	Yes
Trade	Project TradeDetails	TradeID	1-M	Yes
Bill of Quantities				
Project	Project ItemDetails	ProjectID	1-M	Yes
Trade	WBS	TradeID	1-M	Yes
WBS	Project ItemDetails	WBS_ID	1-M	Yes
Change Orders				
Company	People	Co_ID	1-M	Yes
Company	Project	Co_ID/EngineerID	1-M	Yes
Company	Project TradeDetails	Co_ID/SubID	1-M	Yes
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID/Contact2	1-M	Yes
Project	Change Order	ProjectID	1-M	Yes
Project	Project TradeDetails	ProjectID	1-M	Yes
Specs Section	Change Order	SpecsID	1-M	Yes
Trade	Project TradeDetails	TradeID	1-M	Yes
WBS	Specs Section	WBS_ID	1-M	Yes
Correspondence				
Company	People	Co_ID	1-M	Yes
Participant Type	Company	TypeID	1-M	Yes
People	Company	PeopleID/ Contact1	1-M	Yes
People	Company	PeopleID/ Contact2	1-M	Yes
People	Correspondence	PeopleID/From People	1-M	Yes
People	Correspondence	PeopleID/To People	1-M	Yes
Project	Correspondence	ProjectID	1-M	Yes
Daily Report				
Company	People	Co_ID	1-M	Yes
Company	Project	Co_ID/EngineerID	1-M	Yes
Company	Project	Co_ID/OwnerID	1-M	Yes
Company	Daily Events	Co_ID/FFC1	1-M	Yes
Company	Daily Events	Co_ID/FFC2	1-M	Yes
Company	Daily Events	Co_ID/FFC3	1-M	Yes
Company	Daily Events	Co_ID/FFC4	1-M	Yes

Primary Table	Related Table	Fields	Type	Enforce
Day	Weather	Day ID	1-M	Yes
People	Daily Events	PeopleID/Prep by ID	1-M	Yes
Project	Daily Events	ProjectID	1-M	Yes
Project	Weather	ProjectID	1-M	Yes
Defective Work				
Company	People	Co_ID	1-M	Yes
Company	Project TradeDetails	Co_ID/SubID	1-M	Yes
Company	Project	Co_ID/EngineerID	1-M	Yes
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID/Contact2	1-M	Yes
Project	Defective Work	ProjectID	1-M	Yes
Project	Project TradeDetails	ProjectID	1-M	Yes
Specs Section	Defective Work	SpecsID	1-M	Yes
Trade	Project TradeDetails	TradeID	1-M	Yes
WBS	Specs Section	WBS_ID	1-M	Yes
Materials Stored				
Company	People	Co_ID	1-M	Yes
Company	Project	Co_ID/EngineerID	1-M	Yes
Company	Project TradeDetails	Co_ID/SubID	1-M	Yes
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID/Contact2	1-M	Yes
Project	Materials Stored	ProjectID	1-M	Yes
Project	Project TradeDetails	ProjectID	1-M	Yes
Specs Section	Materials Stored	SpecsID	1-M	Yes
Storage Location	Materials Stored	Loc_ID	1-M	Yes
Trade	Project TradeDetails	TradeID	1-M	Yes
WBS	Specs Section	WBS_ID	1-M	Yes
Monthly Progres				
Company	People	Co_ID	1-M	Yes
Company	Project	Co_ID/EngineerID	1-M	Yes
Company	Project TradeDetails	Co_ID/SubID	1-M	1-M
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID/Contact2	1-M	Yes
Project	Monthly Progress	ProjectID	1-M	Yes
Project	Project ItemDetails	ProjectID	1-M	Yes
Project	Project TradeDetails	ProjectID	1-M	Yes
Trade	Project TradeDetails	TradeID	1-M	Yes
WBS	Monthly Progress	WBS_ID	1-M	Yes
WBS	Project ItemDetails	WBS_ID	1-M	Yes

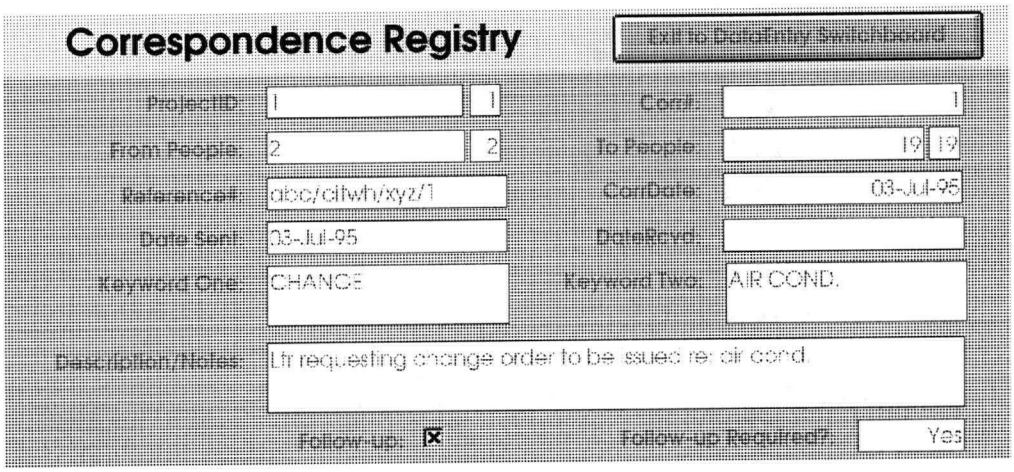
Primary Table	Related Table	Fields	Type	Enforce
Photographs				
Company	People	Co_ID	1-M	Yes
Company	Project	Co_ID/Engineer	1-M	Yes
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID/Contact2	1-M	Yes
People	Photograph	PeopleID/Photgr ID	1-M	Yes
Photo Type	Photograph	Photo TypeID	1-M	Yes
Project	Photograph	ProjectID	1-M	Yes
Punch Lists				
Company	People	Co_ID	1-M	Yes
Company	Project TradeDetails	Co_ID/SubID	1-M	Yes
Company	Project	Co_ID/EngineerID	1-M	Yes
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID/Contact2	1-M	Yes
Project	Punch Lists	ProjectID	1-M	Yes
Project	Project TradeDetails	ProjectID	1-M	Yes
Specs Section	Punch Lists	SpecsID	1-M	Yes
Trade	Project TradeDetails	TradeID	1-M	Yes
WBS	Specs Section	WBS_ID	1-M	Yes
RFIs				
Company	People	Co_ID	1-M	Yes
Company	Project	Co_ID/EngineerID	1-M	Yes
Participant Type	Company	TypeID	1-M	Yes
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID /Contact2	1-M	Yes
People	RFI	PeopleID/Initiated By	1-M	Yes
People	RFI	PeopleID/Response by	1-M	Yes
Project	RFI	ProjectID	1-M	Yes
Shop Drawing				
Company	People	Co_ID	1-M	Yes
Company	Project TradeDetails	Co_ID/SubID	1-M	Yes
Company	Project	Co_ID/EngineerID	1-M	Yes
Participant Type	Company	TypeID	1-M	Yes
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID/Contact2	1-M	Yes
Project	Shop Drawing	ProjectID	1-M	Yes
Project	Project ItemDetails	ProjectID	1-M	Yes
Project	Project TradeDetails	ProjectID	1-M	Yes
Specs Section	WBS	SpecsID	1-M	Yes
Trade	Project TradeDetails	TradeID	1-M	Yes
Trade	WBS	TradeID	1-M	Yes

Primary Table	Related Table	Fields	Type	Enforce
WBS	Project ItemDetails	WBS_ID	1-M	Yes
WBS	Shop Drawing	WBS_ID	1-M	Yes
Spare Parts				
Company	People	Co_ID	1-M	Yes
Company	Project	Co_ID/EngineerID	1-M	Yes
Company	Project TradeDetails	Co_ID/SubID	1-M	Yes
Participant Type	Company	TypeID	1-M	Yes
People	Company	PeopleID/Contact1	1-M	Yes
People	Company	PeopleID/Contact2	1-M	Yes
Project	Project TradeDetails	ProjectID	1-M	Yes
Project	Spare Parts	ProjectID	1-M	Yes
Specs Section	Spare Parts	SpecsID	1-M	Yes
Storage Location	Spare Parts	Loc_ID	1-M	Yes
Trade	Project TradeDetails	TradeID	1-M	Yes
WBS	Specs Section	WBS_ID	1-M	Yes

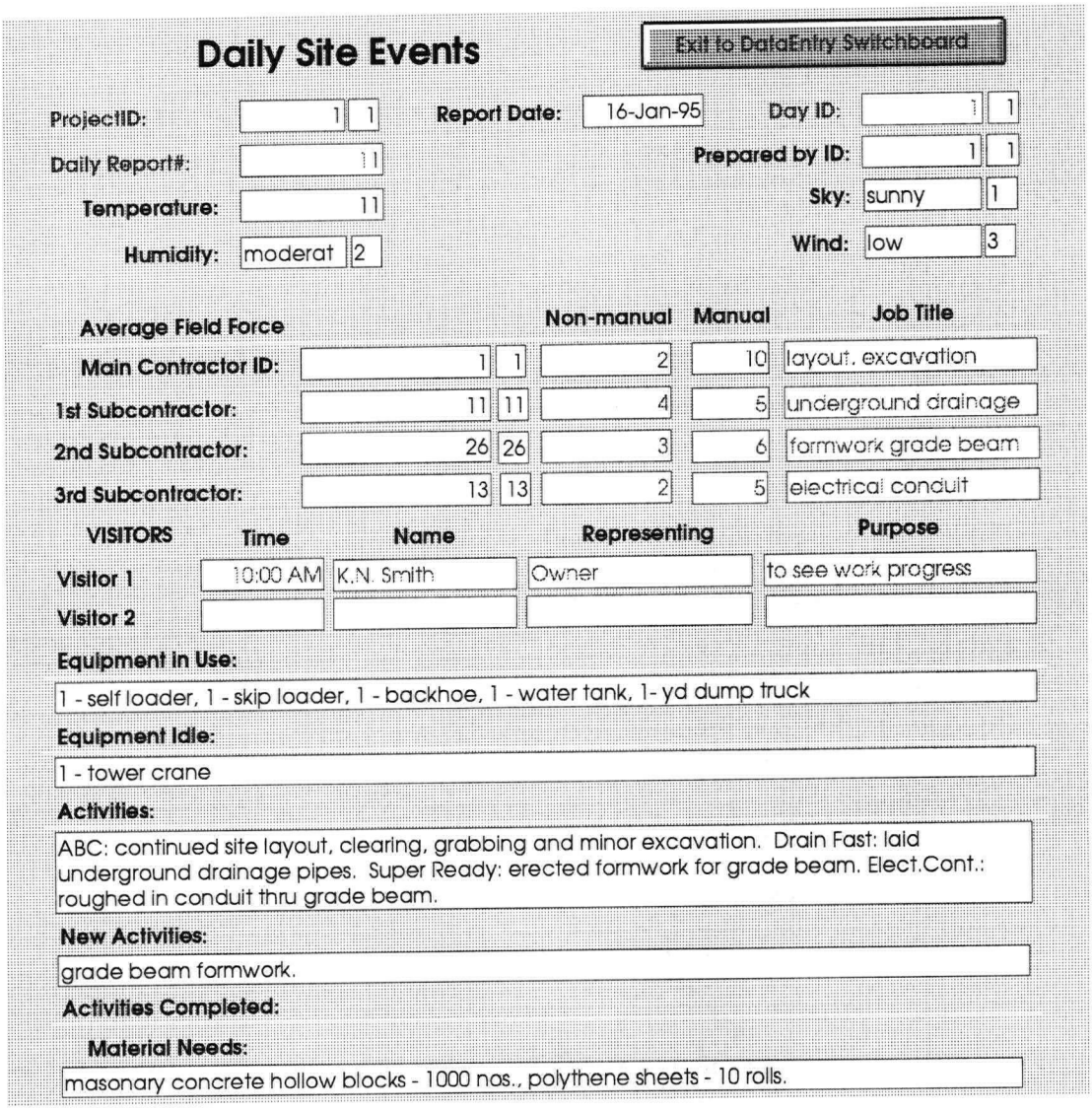
APPENDIX E

Form Printouts

This appendix presents some of the form views as they appear on the screen. As stated in section 4.10.2.4, fifty seven forms were created for the prototype. This appendix contains only six of them, as rest of the forms are more or less similar to these forms in their respective categories. The form categories are the following: data entry form, view form, and switchboard form. This appendix includes the following figures:



E.1 Data Entry Form: Correspondence Registry



Daily Site Events

Exit to DataEntry Switchboard

ProjectID: 1 1 | Report Date: 16-Jan-95 | Day ID: 1 1

Daily Report#: 11 | Prepared by ID: 1 1

Temperature: 11 | Sky: sunny 1

Humidity: moderat 2 | Wind: low 3

Average Field Force		Non-manual	Manual	Job Title
Main Contractor ID:	1 1	2	10	layout, excavation
1st Subcontractor:	11 11	4	5	underground drainage
2nd Subcontractor:	26 26	3	6	formwork grade beam
3rd Subcontractor:	13 13	2	5	electrical conduit

VISITORS	Time	Name	Representing	Purpose
Visitor 1	10:00 AM	K.N. Smith	Owner	to see work progress
Visitor 2				

Equipment in Use:

1 - self loader, 1 - skip loader, 1 - backhoe, 1 - water tank, 1- yd dump truck

Equipment Idle:

1 - tower crane

Activities:

ABC: continued site layout, clearing, grabbing and minor excavation. Drain Fast: laid underground drainage pipes. Super Ready: erected formwork for grade beam. Elect.Cont.: roughed in conduit thru grade beam.

New Activities:

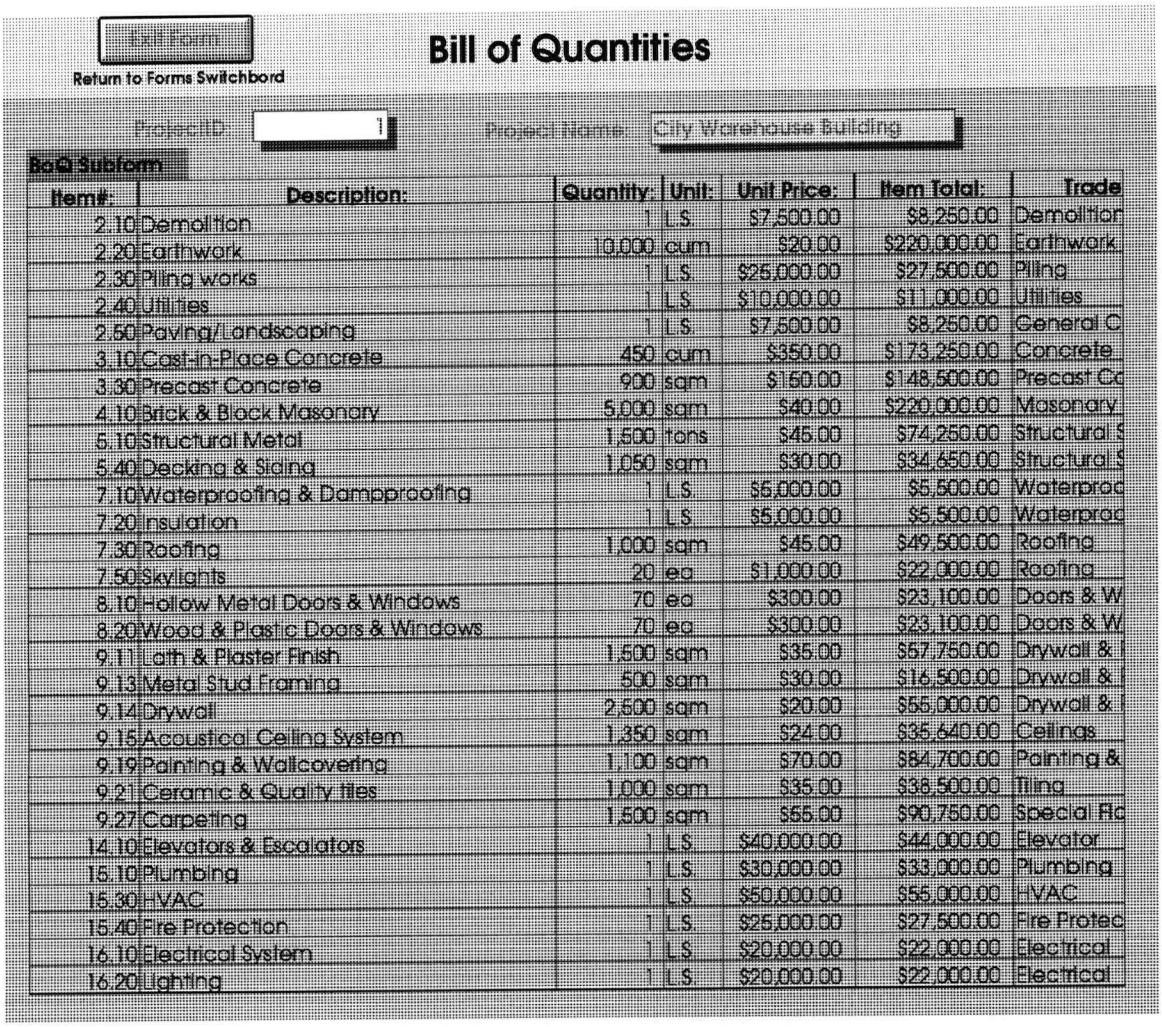
grade beam formwork.

Activities Completed:

Material Needs:

masonary concrete hollow blocks - 1000 nos., polythene sheets - 10 rolls.

E.2 Data Entry Form: Daily Site Activity



Exit Form

Return to Forms Switchboard

Bill of Quantities

Project ID: 1 Project Name: City Warehouse Building

BoQ Subform:

Item#:	Description:	Quantity:	Unit:	Unit Price:	Item Total:	Trade
2.10	Demolition	1	L.S.	$7,500.00	$8,250.00	Demolition
2.20	Earthwork	10,000	cum	$20.00	$220,000.00	Earthwork
2.30	Piling works	1	L.S.	$25,000.00	$27,500.00	Piling
2.40	Utilities	1	L.S.	$10,000.00	$11,000.00	Utilities
2.50	Paving/Landscaping	1	L.S.	$7,500.00	$8,250.00	General C
3.10	Cast-in-Place Concrete	450	cum	$350.00	$173,250.00	Concrete
3.30	Precast Concrete	900	sqm	$150.00	$148,500.00	Precast Co
4.10	Brick & Block Masonary	5,000	sqm	$40.00	$220,000.00	Masonary
5.10	Structural Metal	1,500	tons	$45.00	$74,250.00	Structural S
5.40	Decking & Siding	1,050	sqm	$30.00	$34,650.00	Structural S
7.10	Waterproofing & Dampproofing	1	L.S.	$5,000.00	$5,500.00	Waterproc
7.20	Insulation	1	L.S.	$5,000.00	$5,500.00	Waterproc
7.30	Roofing	1,000	sqm	$45.00	$49,500.00	Roofing
7.50	Skylights	20	ea	$1,000.00	$22,000.00	Roofing
8.10	Hollow Metal Doors & Windows	70	ea	$300.00	$23,100.00	Doors & W
8.20	Wood & Plastic Doors & Windows	70	ea	$300.00	$23,100.00	Doors & W
9.11	Lath & Plaster Finish	1,500	sqm	$35.00	$57,750.00	Drywall &
9.13	Metal Stud Framing	500	sqm	$30.00	$16,500.00	Drywall &
9.14	Drywall	2,500	sqm	$20.00	$55,000.00	Drywall &
9.15	Acoustical Ceiling System	1,350	sqm	$24.00	$35,640.00	Ceilings
9.19	Painting & Wallcovering	1,100	sqm	$70.00	$84,700.00	Painting &
9.21	Ceramic & Quality tiles	1,000	sqm	$35.00	$38,500.00	Tiling
9.27	Carpeting	1,500	sqm	$55.00	$90,750.00	Special Flo
14.10	Elevators & Escalators	1	L.S.	$40,000.00	$44,000.00	Elevator
15.10	Plumbing	1	L.S.	$30,000.00	$33,000.00	Plumbing
15.30	HVAC	1	L.S.	$50,000.00	$55,000.00	HVAC
15.40	Fire Protection	1	L.S.	$25,000.00	$27,500.00	Fire Protec
16.10	Electrical System	1	L.S.	$20,000.00	$22,000.00	Electrical
16.20	Lighting	1	L.S.	$20,000.00	$22,000.00	Electrical

E.3 View Form: Bill of Quantities

Exit Form

Return to Forms Switchboard

Shop Drawing Submittals Tracking Log

ProjectID: 1

Project Name: City Warehouse Building

Engineer: XYZ Engineering, Inc.

Contact1: Allan Woo

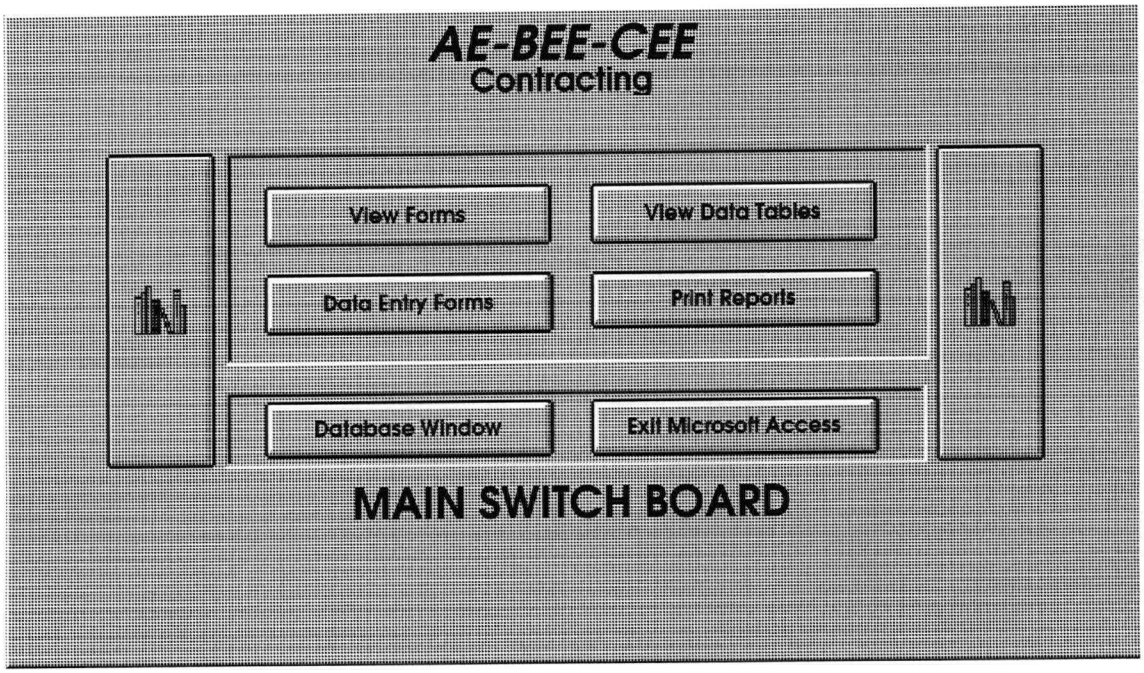
Contact2: Lam Wonder

Phone: (604) 555-2211

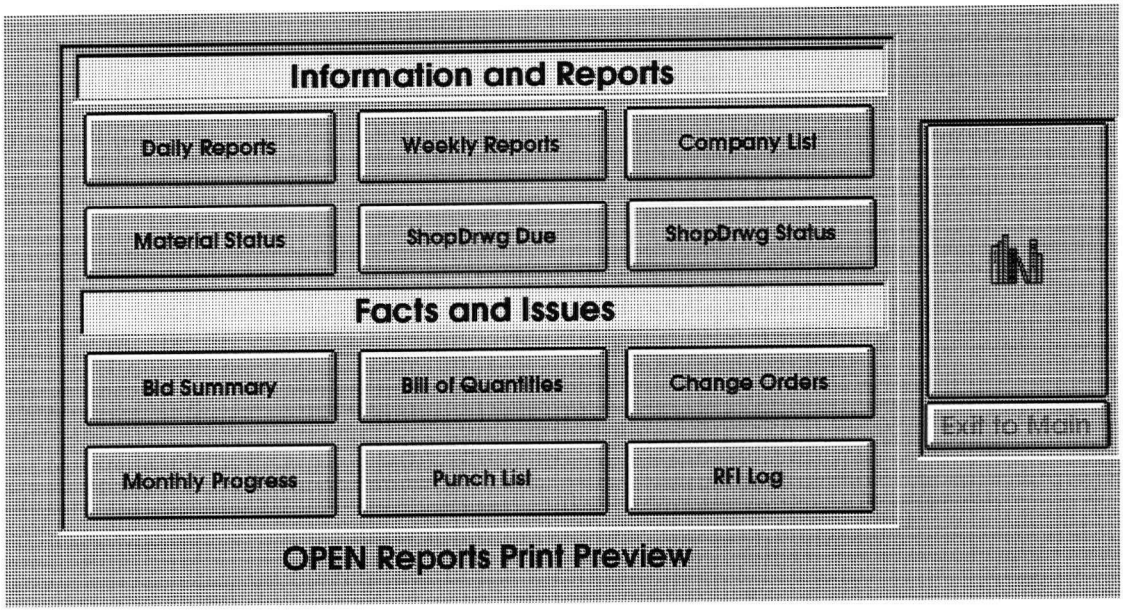
Shop Drawing Subform

WBS_ID:	Shop Drawing#:	Scheduled Date:	Status:	Keyword Description:	D-Rf
2.10	1-SD-2.1	22-Jan-95	Approved	plan & location for detonator	25-Jar
2.30	1-SD-2.3	11-Feb-95	Make correction not	plan and section of piles	11-Feb
2.40	1-SD-2.4	14-Feb-95	Submit specified item	details	14-Feb
2.50	1-SD-2.5	06-Mar-95	Approved	plan and section	06-Mc
3.30	1-SD-3.3	14-Feb-95	Approved	layout plan and sections	13-Feb
5.10	1-SD-5.1	14-Feb-95	Submit specified item	plan and elevation details	14-Feb
5.40	1-SD-5.4	14-Feb-95	Approved	plan and elevation details	14-Feb
7.30	1-SD-7.3	16-Feb-96	Approved	plan and sections	14-Feb
7.50	1-SD-7.5	02-Feb-96	Approved	plan and sections	02-Feb
8.10	1-SD-8.1	25-Mar-96	Revise and resubmit	plan and elevation details	25-Mc
8.20	1-SD-8.2	30-Mar-96	New	plan and elevation details	01-Ap
9.11	1-SD-9.11	11-Apr-96	Due	layout details	
9.13	1-SD-9.13	01-Apr-96	Due	plan and sections	
9.14	1-SD-9.14	04-Apr-96	Due		
9.15	1-SD-9.15	01-Apr-96	Due	plan and sections	
9.21	1-SD-9.21	01-Apr-96	Due	plan and elevation details	
9.27	1-SD-9.27	01-May-96	Due	layout details	
14.10	1-SD-14.1	02-May-96	Due	sections and details	
15.10	1-SD-15.1	10-Apr-96	Due	plan and sections	
15.30	1-SD-15.3	20-Apr-96	Due	plan and sections	
15.40	1-SD-15.4	27-Apr-96	Due	details	
16.10	1-SD-16.1	11-May-96	Due	plan and sections	
16.20	1-SD-16.2	11-May-96	Due	conduit layout plan and detail	

E.4 View Form: Shop Drawing Submittals Log



E.5 Switchboard Form: Main Switchboard



E.6 Switchboard Form: Print Reports Switchboard

APPENDIX F

Reports

Appendix F contains some of the reports/summaries/listings printouts that the prototype of PMICS can produce. The PMICS can be used as an administrative tool box, choosing what is needed from this system to perform specific tasks. It can be used to manage changes, to track submittals and other information, to produce reports and summaries, and so on. All the reports presented in this appendix are comparable to the reports displayed in the Expedition literature [Expedition 95}. This appendix includes the following figures:

- Figure F.1 Bid Summary Sheet.
- Figure F.2 Bill of Quantities.
- Figure F.3 Change Orders Status Reports.
- Figure F.4 Company Listings.
- Figure F.5 Daily Site Reports.
- Figure F.6 Weekly Activity Reports.
- Figure F.7 Monthly Progress Reports.
- Figure F.8 Punch Lists.
- Figure F.9 Requests for Information Reports.
- Figure F.10 Shop Drawing Submittals Due Lists.
- Figure F.11 Shop Drawing Submittals Status reports.

Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook
Engineer: XYZ Engineering, Inc.

PMICS

Bid Summary Sheet by Trade or Package

Print Date: 4/10/96
Project #: 1
Project Name: City Warehouse Building
Page #: 1

Bidder Name	Contact Phone	Bid Due Date	Package Sent on	Bid Received	Bid Amount	Budget	Difference
Trade: *Concrete*							
ABC Concrete	Paul Nandi (604) 666-423	4/13/95	3/25/95	4/13/95	$135,500	$157,500	$22,000
			Remarks: Price includes formwork, rebar, placing and curing.				
Concrete Pouring & Contr	Comil Dey (604) 777-445	4/13/95	3/25/95	4/13/95	$134,000	$157,500	$23,500
			Remarks: Price includes formwork, rebar, placing and curing.				
Quick Concrete Supply	Tahir Ahmad (604) 555-668	4/13/95	3/25/95	4/12/95	$135,000	$157,500	$22,500
			Remarks: Price includes formwork, rebar, placing and curing.				
Super Readymix Co.	Abdul Kareem (604) 444-222	4/13/95	3/25/95	4/13/95	$133,500	$157,500	$24,000
			Remarks: Price includes formwork, rebar, placing and curing.				
Trade: *Doors & Windows*							
City Doors & Windows	Nigel Ho (604) 555-668	4/23/95	4/3/95	4/23/95	$33,100	$42,000	$8,900
			Remarks: Price includes labor, materials and installation only.				
Grade One Doors & Win	Mike Noble (604) 666-332	4/23/95	4/3/95	4/23/95	$32,900	$42,000	$9,100
			Remarks: Price includes labor, materials and installation. Scaffolding not included.				
Insta Doors, Inc.	Laloo Tipnis (604) 555-112	4/23/95	4/3/95	4/24/95	$34,000	$42,000	$8,000
			Remarks: Price includes labor, materials and installation only.				

Figure F.1 Bid Summary Sheet

Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook
Engineer: XYZ Engineering, Inc.

PMICS

Bill of Quantities by Project

Print Date: 4/11/96
Project #: 1
Project Name: City Warehouse Building
Page #: 1

Item#/WBS-ID	Description	Quantity	Unit	Unit Price	Item Total
2.10	Demolition	1	L.S.	$7,500	$7,500
2.20	Earthwork	10,000	cum	$20	$200,000
2.30	Piling works	1	L.S.	$25,000	$25,000
2.40	Utilities	1	L.S.	$10,000	$10,000
2.50	Paving/Landscaping	1	L.S.	$7,500	$7,500
3.10	Cast-in-Place Concrete	450	cum	$350	$157,500
3.30	Precast Concrete	900	sqm	$150	$135,000
4.10	Brick & Block Masonary	5,000	sqm	$40	$200,000
5.10	Structural Metal	1,500	tons	$45	$67,500
5.40	Decking & Siding	1,050	sqm	$30	$31,500
7.10	Waterproofing & Dampproofing	1	L.S.	$5,000	$5,000
7.20	Insulation	1	L.S.	$5,000	$5,000
7.30	Roofing	1,000	sqm	$45	$45,000
7.50	Skylights	20	ea	$1,000	$20,000
8.10	Hollow Metal Doors & Windows	70	ea	$300	$21,000
8.20	Wood & Plastic Doors & Windows	70	ea	$300	$21,000
9.11	Lath & Plaster Finish	1,500	sqm	$35	$52,500
9.13	Metal Stud Framing	500	sqm	$30	$15,000
9.14	Drywall	2,500	sqm	$20	$50,000
9.15	Acoustical Ceiling System	1,350	sqm	$24	$32,400
9.19	Painting & Wallcovering	1,100	sqm	$70	$77,000
9.21	Ceramic & Quality tiles	1,000	sqm	$35	$35,000
9.27	Carpeting	1,500	sqm	$55	$82,500
14.10	Elevators & Escalators	1	L.S.	$40,000	$40,000
15.10	Plumbing	1	L.S.	$30,000	$30,000
15.30	HVAC	1	L.S.	$50,000	$50,000
15.40	Fire Protection	1	L.S.	$25,000	$25,000
16.10	Electrical System	1	L.S.	$20,000	$20,000
16.20	Lighting	1	L.S.	$20,000	$20,000
				Page Total:	$1,487,900

Figure F.2 Bill of Quantities

Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook
Engineer: XYZ Engineering, Inc.

PMICS

Requests and Changes Log by Trade or Package

Print Date: 4/10/96
Project #: 1
Project Name: City Warehouse Building
Page #: 1

CMR #	To Vendor	Value	.....Initiated..... Vendor	Date	.....Responded..... Vendor	Date	Date Approved	Current Status
Trade: ***Concrete***								
5	XYZ Engineer	$1,675	Ae Bee Cee Co	02-Aug-95	XYZ Engineerin	03-Aug-95	15-Aug-95	CO No. 4
			Comments:		Incorporated into CO No. 4			
7	XYZ Engineer	$0	Ae Bee Cee Co	22-Aug-95	XYZ Engineerin	23-Aug-95	03-Sep-95	Not incorporated
			Comments:		Not incorporated			
Trade: ***Electrical***								
4	Ae Bee Cee	$550	Globe Electrical	25-Jul-95	XYZ Engineerin	26-Jul-95	04-Aug-95	CO No. 3
			Comments:		Incorporated into CO No. 3			
10	Ae Bee Cee	$2,000	Globe Electrical	06-Sep-95	XYZ Engineerin	07-Sep-95	18-Sep-95	CO No. 7
			Comments:		Incorporated into CO No.7			
Trade: ***HVAC***								
8	Ae Bee Cee	$1,200	Aeros Mechanic	27-Aug-95	XYZ Engineerin	28-Aug-95	07-Sep-95	CO No. 5
			Comments:		Incorporated into CO No. 5			
9	Ae Bee Cee	$1,250	Aeros Mechanic	02-Sep-95	XYZ Engineerin	02-Sep-95	15-Sep-95	CO No. 6
			Comments:		Incorporated into CO No. 6			
12	Ae Bee Cee	$1,250	Aeros Mechanic	15-Sep-95	XYZ Engineerin	16-Sep-95	28-Sep-95	CO No. 9
			Comments:		Incorporated into CO No. 9			
Trade: ***Masonary***								
6	XYZ Engineer	$0	Ae Bee Cee Co	15-Aug-95	XYZ Engineerin	15-Aug-95	29-Aug-95	Time & material
			Comments:		To be done time & material			
11	XYZ Engineer	$1,550	Ae Bee Cee Co	11-Sep-95	XYZ Engineerin	12-Sep-95	25-Sep-95	CO No. 8
			Comments:		Incorporated into CO No. 8			

Figure F.3 Change Orders Status Report

Contractor: Ae Bee Cee Contracting

Proj. Manager: John Cook

Print Date: 4/10/96

PMICS

Company Listing With Contacts

Project #: 1

Project Name: City Warehouse Building

Page #: 1

Contacts	Title	Adress	City	Province	Postal Code	Phone	Fax
Company:	***ABC Concrete***		**Participant Type:**	**Subcontractor**			
Paul Nandi	Technical Manager	303 Green Ave.	Vancouver	B.C.	V6A 3K3	(604) 666-423	(604) 666-4235
Ratan Mahi	Asst. Manager						
Company:	***Ae Bee Cee Contracting***		**Participant Type:**	**Home-office**			
Allan Maxwell	Construction Mana	123 Green Avenue	Vancouver	B.C.	V5R 4W8	(604) 666-223	604) 666-2234
Dick Wise	Chief Engineer						
Company:	***Aeros Mechanical Contracting***		**Participant Type:**	**Subcontractor**			
Anu Bo	Engineering Mana	707 Plum Street	Vancouver	B.C.	V6N 4X8	(604) 666-224	(604) 666-2245
Safdar Alam	Site Representativ						
Company:	***City Warehouse***		**Participant Type:**	**Owner**			
Ajay Peter	Warehouse Manag	123 Dead End Street	Vancouver	B.C.	V6M 5W9	(604) 888-556	604) 888-5567
Andrew Wael	Asst. Manager						
Company:	***Civil Contracting Co.***		**Participant Type:**	**Subcontractor**			
Don Holland	Sales Agent	879 Nariman Point	Vancouver	B.C.	V6B 3B3	(604) 444-123	(604) 444-1233
Brian Whisker	Sales Agent						
Company:	***Constructive Steel***		**Participant Type:**	**Subcontractor**			
Lotte Green	Business Manager	404 Alps Street	Vancouver	B.C.	V5T 6M7	(604) 666-599	(604) 666-5996
Saad Cho	Asst. Manger						
Company:	***Globe Electricals, Inc.***		**Participant Type:**	**Subcontractor**			
Mahmood Hassa	Manger	555 Avon Street	Vancouver	B.C.	V6A 4M3	(604) 888-665	(604) 888-6656
Allan Jo	Sales Agent						
Company:	***Grade One Doors & Windows***		**Participant Type:**	**Subcontractor**			
Mike Noble	Business Manager	333 Fonton Avenue	Vancouver	B.C.	V5R 6H3	(604) 666-332	(604) 666-3323
Mike Noble	Business Manager						

Figure F.4 Company Listing

Daily Site Report — PMICS — Page #: 1

Project #: 1
Project Name: **City Warehouse Building**

Engineer: XYZ Engineering, Inc.
Owner: City Warehouse
Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook

Daily Report#: 11
Date: **16-Jan-95**
Day: Monday

Weather: sunny
Temperature: 11
Wind: low
Humidity: moderate

AVERAGE FIELD FORCE

Name of Contractor	Non-manual	Manual	Remarks / Job Type
Ae Bee Cee Contracting	2	10	layout, excavation
Drain Fast Co.	4	5	underground drainage
Super Readymix Co.	3	6	formwork grade beam
Electrical Contracting Est.	2	5	electrical conduit
Total Force:	11	26	= 37

VISITORS

Time	Visitors' Name	Representing	Remarks / Purpose
10:00 AM	K.N. Smith	Owner	to see work progress

Equipments in Use

1 - self loader, 1 - skip loader, 1 - backhoe, 1 - water tank, 1- yd dump truck

Equipments Idle

1 - tower crane

Construction Activities

ABC: continued site layout, clearing, grabbing and minor excavation. Drain Fast: laid underground drainage pipes. Super Ready: erected formwork for grade beam. Elect.Cont.: roughed in conduit thru grade beam.

New Activities

grade beam formwork.

Activities Completed

Material Needs

masonary concrete hollow blocks - 1000 nos., polythene sheets - 10 rolls.

Prepared By: Allan Maxwell Signature:

Figure F.5 Daily Site Report

Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook
Engineer: XYZ Engineering, Inc.
Owner: City Warehouse

PMICS

Weekly Site Activity

Print Date: 4/10/96
Project #: 1
Project Name: City Warehouse Building
Page #: 1

Report #	Temp c	Sky	Wind	Humidity	Contractors on site	Construction Activities
16-Jan-95	**Monday**				Ae Bee Cee Contracting Drain Fast Co. Super Readymix Co. Electrical Contracting Est.	ABC: continued site layout, clearing, grabbing and minor excavation. Drain Fast: laid underground drainage pipes. Super Ready: erected formwork for grade beam. Elect.Cont.: roughed in conduit thru grade beam.
11	11	sunny	low	moderate		
17-Jan-95	**Tuesday**				Ae Bee Cee Contracting Drain Fast Co. Super Readymix Co. Electrical Contracting Est.	ABC: continued site layout, clearing, grabbing and minor excavation. Drain Fast: alligned and tested underground drainage pipes. Super Ready: placed rebar for grade beam. Elect.Cont.: continued roughing in conduit thru grade beam.
12	13	sunny	low	moderate		
18-Jan-95	**Wednesday**				Ae Bee Cee Contracting Drain Fast Co. Super Readymix Co. Electrical Contracting Est.	ABC: continued site layout & suevey, and minor excavation. Drain Fast: backfilled and compacted, underground drainage pipes. Super Ready: continued rebar and formwork for grade beam. Elect.Cont.: dug hole for earthen pit.
13	4	snowy	high	low		
19-Jan-95	**Thursday**				Ae Bee Cee Contracting Drain Fast Co. Super Readymix Co. Civil Contracting Co.	ABC: continued site survey, clearing, grabbing and minor excavation. Drain Fast: dug hole and poured bilnding concrete for drainage manholes. Super Ready: closed formwork for grade beam. Elect.Cont.: checked conduit thru grade beam.
14	3	cloudy	high	moderate		
20-Jan-95	**Friday**				Ae Bee Cee Contracting Drain Fast Co. Super Readymix Co. Civil Contracting Co.	ABC: continued site survey and minor excavation. Drain Fast: erected manhole and fixed underground pipe accessories. Super Ready: poured concrete for grade beam. CCC.: started masonary work for site office.
15	4	sunny	moderat	low		
21-Jan-95	**Saturday**				Ae Bee Cee Contracting Drain Fast Co. Super Readymix Co. Civil Contracting Co.	ABC: checked concrete quality. Drain Fast: continued manhole erection and underground pipe fixing. Super Ready: continued concrete pouring for grade beam. CCC.: continued masonary work for site office.
16	7	rainy	low	moderate		
22-Jan-95	**Sunday**				Ae Bee Cee Contracting Ae Bee Cee Contracting Ae Bee Cee Contracting Ae Bee Cee Contracting	No work done today.
17	6	cloudy	high	moderate		

Figure F.6 Weekly Activity Report

Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook
Engineer: XYZ Engineering, Inc.

PMICS

Monthly Progress Report by Project

Print Date: 4/11/96
Project #: 1
Project Name: City Warehouse Building
Page #: 1

Item #	Description	Quantity Unit	Unit Price	Item Total	This Amount	Todate Amount
Pay Est#:	**1** PayEst Date:	**15-Feb-95**				
2.10	Demolition	1	$7,500	$7,500	$24,750	$24,750
		L.S.		**% Progress:**	20	20
2.20	Earthwork	10,000	$20	$200,000	$66,000	$66,000
		cum		**% Progress:**	15	15
2.30	Piling works	1	$25,000	$25,000	$8,250	$8,250
		L.S.		**% Progress:**	15	15
2.40	Utilities	1	$10,000	$10,000	$2,200	$2,200
		L.S.		**% Progress:**	10	10
2.50	Paving/Landscaping	1	$7,500	$7,500	$12,375	$12,375
		L.S.		**% Progress:**	10	10
3.10	Cast-in-Place Concrete	450	$350	$157,500	$51,976	$51,976
		cum		**% Progress:**	15	15
3.30	Precast Concrete	900	$150	$135,000	$29,700	$29,700
		sqm		**% Progress:**	10	10
4.10	Brick & Block Masonary	5,000	$40	$200,000	$44,000	$44,000
		sqm		**% Progress:**	10	10
5.10	Structural Metal	1,500	$45	$67,500	$14,850	$14,850
		tons		**% Progress:**	10	10
5.40	Decking & Siding	1,050	$30	$31,500	$10,396	$10,396
		sqm		**% Progress:**	15	15
7.10	Waterproofing & Dampproofing	1	$5,000	$5,000	$1,100	$1,100
		L.S.		**% Progress:**	10	10
7.20	Insulation	1	$5,000	$5,000	$1,100	$1,100
		L.S.		**% Progress:**	10	10
7.30	Roofing	1,000	$45	$45,000	$14,850	$14,850
		sqm		**% Progress:**	15	15
7.50	Skylights	20	$1,000	$20,000	$4,400	$4,400
		ea		**% Progress:**	10	10
8.10	Hollow Metal Doors & Windows	70	$300	$21,000	$6,930	$6,930
		ea		**% Progress:**	15	15
8.20	Wood & Plastic Doors & Windo	70	$300	$21,000	$4,620	$4,620
		ea		**% Progress:**	10	10

Figure F.7 Monthly Progress Report

Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook
Engineer: XYZ Engineering, Inc.

PMICS

Print Date: 4/10/96
Project #: 1
Project Name: City Warehouse Building
Page #: 1

Punch List by Contractor

Item #	Status	Trade	Date	Location	Description	Value	Checked
Company:		***Ae Bee Cee Contracting***					
		Contact: Allan Maxwell	or	Dick Wise	Phone: (604) 666-223		
5	New	General Constru	31-Mar-96	Admin Bldg	Clean debris from around building	$450	
Company:		***Aeros Mechanical Contracting***					
		Contact: Anu Bo	or	Safdar Alam	Phone: (604) 666-224		
1	Approved	HVAC	11-Mar-96	Admin Bldg	Balance HVAC system	$2,500	28-Mar-96
Company:		***Civil Contracting Co.***					
		Contact: Don Holland	or	Brian Whisker	Phone: (604) 444-123		
4	New	Utilities	30-Mar-96	OP Bldg	Clean out storm inlet box	$400	
Company:		***Globe Electricals, Inc.***					
		Contact: Mahmood Hassa	or	Allan Jo	Phone: (604) 888-665		
2	Approved	Electrical	19-Mar-96	OP Bldg	Light in control room not operating correctly	$1,500	31-Mar-96
3	New	Electrical	30-Mar-96	Admin Bldg	Tighten electrical outlet wall plates	$250	
6	New	Electrical	01-Apr-96	OP Bldg	Submit load test reports	$1,000	
Company:		***Aeros Mechanical Contracting***					
		Contact: Anu Bo	or	Safdar Alam	Phone: (604) 666-224		
2	New	HVAC	02-Apr-96	Level 1	Grill bent in room 122	$475	

Figure F.8 Punch Lists

Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook
Engineer: XYZ Engineering, Inc.

PMICS

Requests for Information By Participant

Print Date: 4/10/96
Project #: 1
Project Name: City Warehouse Building
Page #: 1

RFI #	Title / RFI Description	From Vendor / Phone	To Vendor / Phone	Initiation Date	Response Date	Days Taken	File Location	Status
Responsible Dept:	***Civil***							
2	Painting	Ae Bee Cee Contrac (604) 666-2233	City Warehouse (604) 555-8122	5/7/95	5/12/95	5	1-RFI-2	Done
	Do all metal boxes get paint?			Yes, all metal boxes get paint.				
6	Concrete	Super Readymix Co. (604) 444-2222	City Warehouse (604) 555-8122	5/23/95	5/29/95	6	1-RFI-6	Done
	Can manholes be sealed with mastic?			No, appropriate sealing method to be employed.				
7	Demolition methods	Destruction Co. (604) 666-2240	City Warehouse (604) 555-8122	5/25/95	5/31/95	6	1-RFI-7	Done
	Questions on demolition methods.			Refer to the method statements attached.				
Responsible Dept:	***Electrical***							
1	Electrical service	Electrical Contractin (604) 444-1111	City Roads Dept. (604) 555-8122	5/10/95	5/16/95	6	2-RFI-1	Done
	Do all buried pipe receive cathodic protection?			Yes, they do. Follow the specifications for cathodic				
3	Elecetrical handhole	Globe Electricals, In (604) 888-6655	City Warehouse (604) 555-8122	5/7/95	5/13/95	6	1-RFI-3	Done
	Do all electrical handholes require drainage?			Yes, all electrical handholes require drainage.				
4	Electrical systems	Globe Electricals, In (604) 888-6655	City Warehouse (604) 555-8122	5/12/95	5/18/95	6	1-RFI-4	Done
	Do DB conduits require coating?			Not necessarily.				

Figure F.9 Requests for Information Report

Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook
Engineer: XYZ Engineering, Inc.

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Print Date: 4/10/96
Project #: 1
Project Name: City Warehouse Building
Page #: 1

Shop Drawing Sumittals Due

Trade	Subcontractor	Contacts	Phone	Scheduled Date Activity	Scheduled Date Submission	Remaining Days	Status
Shop Drawing#: **1-SD-9.15**		Description: plan and sections					
Ceilings	Civil Contracting Co.	Don Holland Brian Whisker	(604) 444-1234	15-Apr-96	01-Apr-96	-9	Due
Shop Drawing#: **1-SD-9.13**		Description: plan and sections					
Drywall & Partition	Civil Contracting Co.	Don Holland Brian Whisker	(604) 444-1234	15-Apr-96	01-Apr-96	-9	Due
Shop Drawing#: **1-SD-9.21**		Description: plan and elevation details					
Tiling	Civil Contracting Co.	Don Holland Brian Whisker	(604) 444-1234	15-Apr-96	01-Apr-96	-9	Due
Shop Drawing#: **1-SD-9.14**		Description:					
Drywall & Partition	Civil Contracting Co.	Don Holland Brian Whisker	(604) 444-1234	18-Apr-96	04-Apr-96	-6	Due
Shop Drawing#: **1-SD-15.1**		Description: plan and sections					
Plumbing	Aeros Mechanical Cont	Anu Bo Safdar Alam	(604) 666-2244	15-May-96	10-Apr-96	0	Due
Shop Drawing#: **1-SD-9.11**		Description: layout details					
Drywall & Partition	Civil Contracting Co.	Don Holland Brian Whisker	(604) 444-1234	25-Apr-96	11-Apr-96	1	Due
Shop Drawing#: **1-SD-15.3**		Description: plan and sections					
HVAC	Aeros Mechanical Cont	Anu Bo Safdar Alam	(604) 666-2244	25-May-96	20-Apr-96	10	Due
Shop Drawing#: **1-SD-15.4**		Description: details					
Fire Protection	Aeros Mechanical Cont	Anu Bo Safdar Alam	(604) 666-2244	01-Jun-96	27-Apr-96	17	Due
Shop Drawing#: **1-SD-9.27**		Description: layout details					
Special Flooring	Civil Contracting Co.	Don Holland Brian Whisker	(604) 444-1234	15-May-96	01-May-96	21	Due

Figure F.10 Shop Drawing Submittals Due Lists

Contractor: Ae Bee Cee Contracting
Proj. Manager: John Cook
Engineer: XYZ Engineering, Inc.

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Shop Drawing Sumittals Status By Trade or Package

Print Date: 4/10/96
Project #: 1
Project Name: City Warehouse Building
Page #: 1

Subcontractor	Shop Drwg #	Keyword Description	Scheduled Date Start	Submission	Remaining Days	Status
Trade Name: ***Ceilings***						
Civil Contracting Co.		Contact: Don Holland or Brian Whisker (604) 444-1234				
	1-SD-9.15	plan and sections	15-Apr-96	01-Apr-96	-9	Due
Trade Name: ***Demolition***						
Ae Bee Cee Contracting		Contact: Allan Maxwell or Dick Wise (604) 666-2233				
	1-SD-2.1	plan & location for detonator	05-Feb-95	22-Jan-95	-444	Approved
Trade Name: ***Doors & Windows***						
Grade One Doors & Windows		Contact: Mike Noble or Mike Noble (604) 666-3322				
	1-SD-8.1	plan and elevation details	15-Apr-96	25-Mar-96	-16	Revise and resubmit
	1-SD-8.2	plan and elevation details	20-Apr-96	30-Mar-96	-11	New
Trade Name: ***Drywall & Partition***						
Civil Contracting Co.		Contact: Don Holland or Brian Whisker (604) 444-1234				
	1-SD-9.11	layout details	25-Apr-96	11-Apr-96	1	Due
	1-SD-9.13	plan and sections	15-Apr-96	01-Apr-96	-9	Due
	1-SD-9.14		18-Apr-96	04-Apr-96	-6	Due
Trade Name: ***Electrical***						
Globe Electricals, Inc.		Contact: Mahmood Has or Allan Jo (604) 888-6655				
	1-SD-16.1	plan and sections	15-Jun-96	11-May-96	31	Due
	1-SD-16.2	conduit layout plan and details	15-Jun-96	11-May-96	31	Due

Figure F.11 Shop Drawing Submittals Status Report