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# AN INFORMATION SYSTEM MODEL FOR CONSTRUCTION PROJECT MANAGEMENT IN UNIVERSITY FACILITY DEPARTMENTS

By

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# ABSTRACT

## AN INFORMATION SYSTEM MODEL FOR CONSTRUCTION PROJECT MANAGEMENT IN UNIVERSITY FACILITY DEPARTMENTS

By

William J. Whitbeck

Information systems serve as a critical medium in many industries, providing management with information necessary to make and support decisions. This research develops an information system model for construction project management in university facility departments. The information system model is developed and documented using a data flow diagraming methodology that provides a tool to document the essential information that must be captured and stored for a system of this nature to be effective. Additionally, the information system model includes a recommended list of events that must be undertaken in order to satisfy the information needs of a typical university facility department. The information system model is validated in a case study of four construction projects and shown to reduce schedules and lower costs.

*Dedication*

*This thesis is dedicated to my wife, Dina ,my mother-in-law and*

*my wonderful children Alex and Lydia*

## ACKNOWLEDGMENTS

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# CHAPTER ONE

# OVERVIEW

**Introduction**

Many universities have facilities departments that administer, manage and inspect construction projects. The proper flow of information through these departments is critical to the effectiveness and efficiency of a typical facilities department.

This project is focused on the information needs of large facilities and property owners and their construction project management departments in particular. These departments typically perform the following services; programming, design, budgeting, administration, project management and record keeping. These functions, together with the research, define the scope of this project.

Approval of the contractor's request for payment is generally considered a function of the owner, architect and engineer. Because of this, information flow affects project funding, financing and payment. There is considerable need for an effective and efficient flow of information within any project. Information is a valuable resource to any business enterprise. Effective management of information has become important for all business enterprises. An information system consists of components that collect, process and dispense data and information. A proper information system will also provide a method of feedback for evaluation. Information systems can be automated, semi-automated or manual.

Most large universities employ architects, engineers, designers and project managers. These positions are actively involved in all phases of the construction process from conceptual estimating and design thru construction, project closeout and record keeping. These departments employ administrators, managers and clerical staff to provide support and decision making capability. Positions and departments of this nature exist in the organization for a number of reasons. The foremost reason being the financial interests of the owner. Approval of payment and construction processes are completely under the owner's control in this arrangement. All other approvals typical of an architectural function such as shop drawings and other items submitted for approval are the owner's direct responsibility. The results of this are two fold. On one hand, the owner has more control over the project. This control affects the entire construction process. This is especially true in the design, construction and final approval phases. On the other hand the owner has a great deal more responsibility in the construction process. As in any contractual arrangement, with increased responsibility goes increased culpability. When considering these facts, it becomes evident that a well designed and applied information management system can be invaluable to an owner that performs design and construction management functions.

**1.1 Problem Statement**

University facilities departments design, construct and maintain facilities for large building and land owners. These departments provide a variety of services to their organizations. Among these services are design and layout of new construction, plan review, inspection and payment approval for new construction. Additionally, a typical university facilities department provides design, construction management and inspection of remodeling and renovation projects. Facilities departments also are typically responsible for service and preventive maintenance of equipment and facilities. These departments need an effective information system to manage, store, process and retrieve information related to projects. The problems resulting from the lack of a proper information management system are inaccuracies in reports and supporting systems, duplicate efforts and duplicate information. Information systems need accurate, up to date information so that decision makers can rely on accurate and current information.

Existing information systems include a variety of electronic and manual systems to track and manage information related to projects. Typical applications include spread sheets for accounting, word processing for document management, spreadsheets or scheduling software for scheduling and job progress and project management software for project administration. These tools perform their functions very well and provide great benefit. However they are not without problems.

The problem with the use of these kinds of isolated, dis-integrated systems is that data is stored in multiple places, multiple times. This leads to data redundancy and inconsistency. This is a fundamental mistake in data and information management. Data should be stored in one place, one time. (Codd, 1972)

The information systems that exist for facility departments tend to be informal and rely on the experience and knowledge of the staff. These methods are dynamic and are rarely standardized. This causes the information inputs, processes and outputs to be dis- integrated, redundant and often inaccurate. These problems lead to construction projects with longer schedules and cost overruns.

**1.2 Objectives**

The goal of this project is to provide a standard method for managing information flow in construction projects for university facilities departments. This will enable projects to be designed, funded, constructed and turned over to operations in the most cost effective and expedient fashion.

The objectives of this project are as follows; 1) Document the information inputs, processes, and outputs of a typical facilities department; 2) Develop an information system model for facility departments that incorporates the information that must be captured, processed and accessed for construction project reporting and decision making in the organization; 3) Validate the information system model in a case study.

These objectives will lead to shorter schedules, fewer cost overruns and the return of spaces to operating status more quickly. Funding dollars will be accounted for more accurately and resources will be more effectively planned and utilized.

**1.3 Summary of Project**

This project includes a review of the existing literature in the area of information systems, information systems modeling techniques, costs associated with inappropriate information flow and other available literature related to information systems and construction project information systems.

A survey of 94 facilities officers and administrators of universities was performed in order to gather data on the information management practices of existing universities. From this initial survey, five universities were chosen for a follow up survey and interviews. The data from these instruments was used to document existing information systems and their associated problems as well as to develop the information system model. The data from the surveys was then cataloged and analyzed first to validate the problem as defined previously and then to determine problem areas within the information system of each organization.

The information system model was developed based on the survey results, combined with practices recommended by the sources cited in the literature review and the references. The information system model was developed using the data flow diagraming method as outlined in chapter three. This method was also used to document the existing information systems of the surveyed facilities departments. Following development of the information system model, a case study of four construction projects was done to validate the information system model and define the limitations.

**1.4 Output and Results**

This project provides an event list and a data flow diagram modeling information management in construction projects in university facility departments. This method will enable more effective management of the information flow within a facilities department of a university. This method documents the steps in the information and work flow processes that will provide for the most effective and efficient system of managing a project for facilities departments. This results in an information system model that facilities administrators can apply to their respective departments. When developed this information system model will yield construction projects that are more likely to be on budget as well as on time.

# CHAPTER TWO

# LITERATURE REVIEW

## Introduction

Information systems have been in place for as long as facilities have been built. The design and implementation of the system is dependent on the available technologies and the existing systems in place within the organization. As technology has advanced and technical abilities have become more common in personnel skill sets, information systems have advanced. Advancement in this area has been fragmented (Jagtap 1998) and rarely has the benefit of integration of all aspects of the information been realized.

Systems essentially have grown from the ground up in many cases as various electronic media have become available. The advent of spread sheets in the construction industry in the 1980's (Paulson 1995) , email in the 1990's (Froese 1992) and the Internet in the late 1990's ( Ziga and Vanier 1996) have provided a certain level of electronic information management and accessibility.

The literature review on information management systems provides a wide background of supporting concepts. The author also researched the current literature regarding information systems as applied to the field of Construction Management, in order to draw parallels with the topic area.

The portion of the literature review covering facility owner's project administration system needs is studied to enable development of the most effective model for managing the information flow.

Further study of the literature covers the topic of potential costs of poor information management, in an effort to identify costs and problems that could be avoided by implementing a proper information system.

The researcher also studied the existing methods of documenting information systems models .

## 2.0 Information Systems

Information systems are defined as "an interrelated set of elements that collect (input) manipulate (process), store and disseminate (output) data and information." (Stair and Reynolds 1998) Many researchers have worked on and supported the concept of information systems. An information system should consist of a consistent method of input, appropriate processes to generate needed information and a graphical user interface to support the needs of the system users. (Jagtap 1998) and (Brisbane 1995)

Data is the basic building block of information systems and is a valuable resource for any organization or business. Data is organized from the smallest piece, a bit, to the largest which is a data warehouse. One of the most basic fundamentals of effective information systems is the concept of one fact stored in one place . (Codd 1972) This concept is expressed by Codd as the theory of normalization of the database. It was developed to address problems with data management. This concept is critical to effective information management. Normalization enables records to be input, processed, stored and output in a very efficient fashion while eliminating redundancy. A database system differs from a file system in that the data is integrated into a common storage medium. File systems typically store information necessary for that application only and do not offer integrated storage. File systems have been historically easier to implement and have required less processing power. (Whitten and Bentley 1998) A database is typically organized in a tabular format with the individual records having a primary key which is a unique identifier for that record. Records are defined as a collection of fields that store business data.

A data base is a collection of files and records that are stored in such a fashion as to allow easy access to the stored data. The traditional method of managing data has been a file system. This type of system is typically implemented with paper files filled with records or with an electronic file system of records. These electronic records are generally word processing files or spread sheet file. The concept of an integrated database of electronically linked records was developed to reduce redundant data, improve consistency, make updates of data uniform and allow for standardization of data access. (Codd 1972) All of these benefits are realized in a typical implementation of an electronic data base. Additional benefits of a database approach to information management are ease of modification and updates to the information, this is because the users do not have to know or remember where data is stored. Data integrity is also greatly improved. In a file system changes are not always reflected in all copies of the files. Changes in a database are made in one location, at one time. This greatly reduces the potential for errors. Data is more accessible for all parties. Each different party can look up the necessary data via a desk top client computer in a client server computing environment . A data base approach also by nature enables better security of the data since storage is physically in one location. Security codes and passwords can insure that personnel have appropriate access to the data (Johnson 1989).

Normalization can be broken into inter-operability and integration. (Hilentzaris 1997) Inter-operability is defined as the capability to communicate and exchange information between the various parts of the system. Integration is the complete unification of the overall system where the majority of the information and functions are shared. Integration is ideal, but may be more costly and may not be cost justified.

Normalization of the database can be achieved thru electronic solutions. Research has found that the implementation of an Intranet has improved project communications (Hannah 1998). This was achieved thru normalization of the data via an Intranet.

Information systems consist essentially of input processes, processing of information and output or reporting processes. Input processes provide the backbone and support for the processing and reporting functions. Processing involves calculating, organizing, forecasting, and making decisions based on rule-based logic programmed into the system. Reports can take a number of forms and perform a variety of functions. (Stair and Reynolds 1998)

Integrated information systems provide fast, accurate and consistent information, (Liu, Syal and Spearnak 1995) . Information technology can reduce the need for bureaucracy and can improve organizational communication in an architecture, engineering, or construction organization. (Ahmad 1999).

Management information systems provide routine, daily information to managers and decision makers. These reports generally consist of information concerning the operational issues of the organization. Many of these types of reports are published on a scheduled basis. Others are published on demand or on exception to a rule or condition. Another form of management information system is a transaction processing system. A transaction processing system consists of support for business related exchanges of value. These exchanges consist of payment or receipt of funds from employees, clients, suppliers, contractors or any other party in the supply chain. Classic transaction processing functions are payroll, accounts receivable and accounts payable. These systems are very useful and are usually among the first to provide positive return on investment (Whitten and Bentley 1998).

A third kind of information system is a decision support system. These systems provide excellent, problem specific tools for decision making. Effective decision making is the emphasis of these reports. This type of information is used to support the decisions of higher level executives in the organization. Typically involving large, complex projects, these kinds of decision making tools often have if/then and what/if logic statements built into them.

Beyond management information systems, transaction processing systems and decision support systems lies artificial intelligence. Artificial intelligence encompasses a variety of technologies such as neural networks, robotics, vision systems, learning systems, expert systems and natural language processors. These technologies are rapidly developing and will greatly affect information systems of the future. However, artificial intelligence is outside of the scope of this project.

Information systems successes are dependent on the personnel involved in the organization. The concept of information systems literacy (Stair and Reynolds, 1998) is the knowledge of how data and information are used by organizations. Knowledge of effective uses of information systems is critical when considering the implementation of an information system. (Graham, 1997) Examples include increasing sales, decreasing costs or increasing customer satisfaction.

Many researchers have documented the need for organizations to use technology to automate their existing processes (Forbes 1998) , instead of re-thinking and re-engineering the organizational processes. This concept has been in existence for a long period and the advent of technology has simply automated and computerized the existing processes (Hammer and Champy 1993).

**2.1 Information System Owner Needs**

Facility owners, managers and administrators have needs for an effective and efficient information system. Research in the area of construction project management information system needs has shown that timeliness, quality, integrity, value and effectiveness are critical information system needs. (Jagtap, 1998) These needs are some what generic and can be paralleled to the facility management field as system needs.

Some trade articles have documented the need for integration of "islands" of information (Johnson 1989). Industry experts have written of the need for data to be available to all parties to a facilities project for maximum success to be achievable. (Kimmel 1998). Other industry experts point out the need for a single point of access to the data (normalization) and a high level of interoperability among applications (integration). (Brisbane 1995). Facilities management systems analysts have developed requests for proposal for facilities management information systems that speak to these needs and also document additional needs of an information system for facility owners. (Michigan State University 1998) (See appendix A)

Research into the integration of the functional areas typical to a construction project has determined that most computer applications provide abundant functionality (Froese 1996). However the same research found that integration, interoperability and intelligence (historical data retrieval) were areas identified as needs.

Some researchers have broken the needs down into the typical functional areas of a construction project. As an example, in the planning stage needs arise for historical data and reduction of repetitive data exchange (Liu, Syal and Spearnak 1995). This research also identified needs in the design and specification phase as development and storage of common standards for facilities projects within a school district. Other identified needs in this research include storage of historical "as built" drawings, file organization for retrieval, and general creation of an organized system for planning, scheduling and budgeting for current and future projects.

Research has found the need for flexible and dynamic connections between software applications and product models (Ito 1995). This research has also shown that domain specific product and process models are very useful in modeling information integration.

**2.2 Costs and Problems of Poorly Designed Information Systems**

"The current practice in facility delivery is a disjointed process whereby islands of information are created and data is lost or misinterpreted when communicated" (Lawrence etall 1995)

The value of an information system increases by the data stored in it being current and available to the users. The more available the information is the more valuable the system. (Cleveland 1996)

The costs of poorly designed and developed information systems can be broken into three distinct areas. These are training and personnel costs, computing costs and project costs. The literature in each of these areas was reviewed and is summarized below.

Research has been performed in the area of increased training and personnel costs as related to poorly designed information systems. Researchers have found that poorly designed systems can cause inefficiencies and duplicate training costs (Paulson, 1995).

Some researchers have also found that personnel costs are negatively impacted by poorly designed systems. Researchers have found that benefits of proper information system design are realized as reduced costs of data capture, better use of computer storage, reduced turn around times of data processing, and increased data consistency (Ndekugir, 1986). Research has also found that computer support systems can provide several forms of assistance in employee training, particularly in information contained in relational databases. (Issa and Duvel 1996).

Some researchers have studied the savings realized when portions of an information system have been implemented. (Paulson 1995) This research has shown that implementation of estimating software in an earthwork contracting office will likely allow increased productivity. This can result in the ability to bid more work or reduce staff. Others have identified the results of computer systems that are not properly integrated as "inefficiencies resulting from inaccurate, untimely or missing information" (Russell and Froese 1996).

The researcher has observed that much research has been done on information systems in the construction field. At the same time little research has been done in facilities management information systems and into the costs of poorly designed information systems.

**2.3 Information Systems Modeling Techniques**

From this research it should be understood that integrated computer systems can provide benefit to the organization. A critical portion of this technology is information models thru which computer systems can exchange information. (Froese 1996).

Information systems are an abstract concept and as such are difficult to visualize.

The concept of modeling an information system is critical, so that the various elements are able to be documented in the systems analysis process. Systems analysis is the systematic study and breakdown of the business processes to the finest detail necessary to implement at a task level. (Stair and Reynolds 1995).

Systems analysis and information system modeling has been performed electronically since the advent of computer aided systems engineering (CASE) , attributed to John Manley, circa 1981. Case tools are based on methodologies as discussed in the following sections.

The author studied two methods of information systems modeling and systems analysis needs. These methods are entity relationship diagrams (ER diagrams) and data flow diagrams (DFD diagrams). ER diagrams rely on a resource, event and agent methodology (McCarthy 1982 and Smith-David 1997.) Data flow diagrams model the information input, storage, processes and output in the system. (Whitten and Bentley 1998)

The REA methodology models the physical entities and relationships in the system thru the use of cardinalities or occurrences between the entities and relationships. An example of REA modeling is shown in figure 2.1. Entities are modeled as resources, events or agents. The relationship between these entities is then specified as one to one, one to many or many to many. In figure 2.1 the event "request for quotation" (RFQ) is related to the event "change order" thru the approval process. Each RFQ is related to one and only one change order, however each change order may involve many RFQ's. Additionally each of these events is related to a resource (cash) and an agent (project

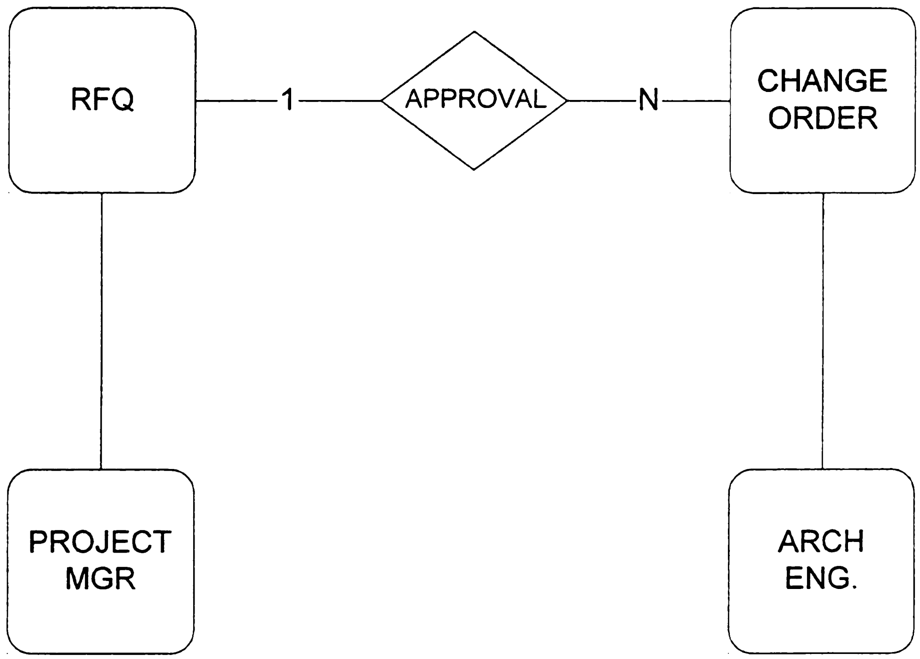



Figure 2.1

Example of Cardinality

manager or architect). The REA methodology places an emphasis on the design and use of the conceptual database for the business. The REA method is frequently referred to as data modeling. It is focused on data as opposed to process and information flow. Data flow diagraming or process modeling is used to specify the information flow of a given organization. There are a few key elements in understanding data flow diagrams. DFD's are first developed based on a list of events that must be satisfied for the system to meet the needs of the organization or its clients. These events then become high level processes. One should understand that these processes are able to occur in parallel, as opposed to the sequential occurrence modeled in a flow chart. Processes are critical in data flow diagraming, processes are where data is transformed into information and information into a format that can provide value to the organization. An example of a data flow diagram is contained in figure 2.2.

At the elementary level all processes should perform some kind of basic activity essential to the system. Examples of these kinds of activities are computations, decisions (on a limited, rule-based, basis), filtering and sorting data, organizing information into reports or other tools and performance of a process involved with stored data.

Other researchers have modeled information flow in construction management using object oriented tools. (Aoud etall 1996 and Chin etall 1995) This research models the physical objects in a construction projects and their relationships. This method has also been applied using process modeling or data flow diagraming. (Rivard, Bedard and Fazio 1995)

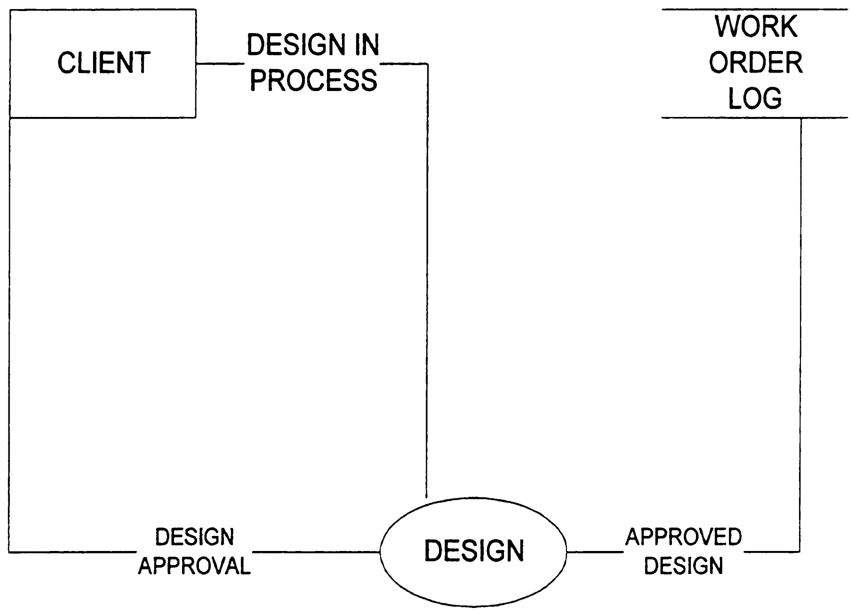



Figure 2.2

Example of Data Flow Diagram

## Summary

The literature review describes and summarizes the literature that exists relating to the scope of this thesis project. It provides support and background for the remainder of this research.

Information systems is a large and far ranging field of research. This literature review covers the existing literature in the area of information systems on a broad level, so that appropriate concepts could be brought into the topic area. This researcher believes that the existing research in the area of information systems, information system owner needs and costs of poorly designed systems can be applied to the subject matter of this thesis to advance the body of research.

# CHAPTER THREE

# SURVEY METHODOLOGY

**Introduction**

This chapter consists of a summary of the methods used to gather data and develop the information system model for construction project management in a typical university facilities department. The researcher used two surveys and a series of interviews as instruments to gather data. The data was analyzed in a qualitative fashion in order to draw some conclusions about the surveyed institutions. A case study of one university was selected. From this university, four projects in two separate departments were examined to explore the validity and effect of the implementation of the model information system.

**3.1 Survey and Data Gathering Methods**

An initial survey of ninety four college and university administrators was done to determine current project management technologies in place in facilities departments and to identify organizations willing to participate in a second, more in depth, survey as well as a series of follow up interviews.

The initial survey was done via electronic mail. Electronic mail was chosen as the survey medium because of the small size of the survey instrument (See appendix B) and the efficiencies of this medium. The surveyed group consisted of directors and coordinators of construction and design departments of member institutions of the Association of Higher Education Facilities Officers. (APPA). This group was selected for the survey based on similarities to the department that the author is employed in. This questionnaire consisted of the question

"Have you or your organization used any formal information system (IE software) for project management. Specifically for scheduling, estimating and

contract administration."

The data from this survey was tabulated and characterized based on the software solutions that were specified in the responses and the interest in the application of information systems in the project management field. The interest levels of the respondents were categorized by analyzing the response and categorizing them as follows; little interest, moderate interest, very interested. The software solutions specified by the respondents are tabulated in chapter four.

From the respondents that were interested in further research, five institutions were chosen for the second survey. These institutions were chosen based on their demographic similarity to the author's employer, a division one research university, their interest in information systems as determined by the initial survey and their willingness to participate. Each of these were contacted via electronic mail to explore their willingness to participate in the survey.

The follow up survey of five facilities administrators was performed via facsimile and electronic mail according to the wishes of the parties to be surveyed. These individuals were directors of construction and design departments or construction information systems departments. A survey was written with a combination of open ended questions and yes or no questions. The survey consisted of sixteen questions, three related to demographic information and thirteen related to project management processes and information systems. A complete copy of the survey is in appendix C.

This survey was done in order to gather detailed data on the information management practices of their organizations. Specific areas that were addressed in the survey were standards for project management, data storage standards, standards for historical project information storage and integration of the various functional areas of the construction management process such as estimating, scheduling and project control.

A series of telephone interviews with the same individuals discussed above were conducted as well. Telephone interviews with project managers were conducted as well in order to determine information systems needs. Telephone was chosen as the medium for convenience and scheduling. This researcher had a pre designed series of questions relating to the use and application of information systems. The researcher used the telephone interviews to question the managers and administrators of the respective organizations as to the particular information needs of their departments, particular attention was given to the precise pieces of information related to the basic construction processes previously identified. The researcher also used the telephone interviews to develop a list of processes and events each organization used to accomplish a complete construction project. The results of these telephone interviews are summarized in chapter four.

### 3.2 Decision Making and Development in the Data Flow Diagraming Process

The researcher developed the information system model, in the form of a data flow diagram, based on the survey results, telephone interviews, the author's professional experiences and the literature review. This section will explain the steps through which the data flow diagram (DFD) was developed.

The information systems of the five institutions that participated in the follow up survey were modeled as DFD's in order to provide a method of documenting existing systems. The DFD's for the existing systems were based on the essential information needs of the organizations. These needs are documented as "events" that occur in order

for the organization to have the information it needs to properly function. These events were identified thru surveys and discussions with the universities. The events (or high level processes) of each organization were documented using the selected DFD software. The steps undertaken to develop the event list are documented as a flow chart in figure 3.1.

The basic processes of each organization were analyzed and broken into needs. From these information needs a model event list was developed. The events are tabulated in chapter four. Many of these events are very basic to the project management process, these were considered as “given” events for the model. Estimating, design, and construction events were analyzed and discussed with administrators as to the need for the event and the use of the information generated by the event.

The events of all the organizations were cataloged and these events were analyzed and discussed in the course of the telephone survey because they provide the essential information needs of the surveyed organizations. The events in this list were then characterized as processes in the first level of the data flow diagram. The processes were analyzed and diagramed in an ongoing iterative fashion.

The next step in the development of the model is the assignment of appropriate information flow to the processes. These decisions were made based on the information requirements identified in the survey, interview data and the author’s observations of these systems.

The processes in the first level of the DFD were studied and analyzed to identify problems in the information flow as determined by the case studies. The processes associated with the problems as identified in the case study were further broken down

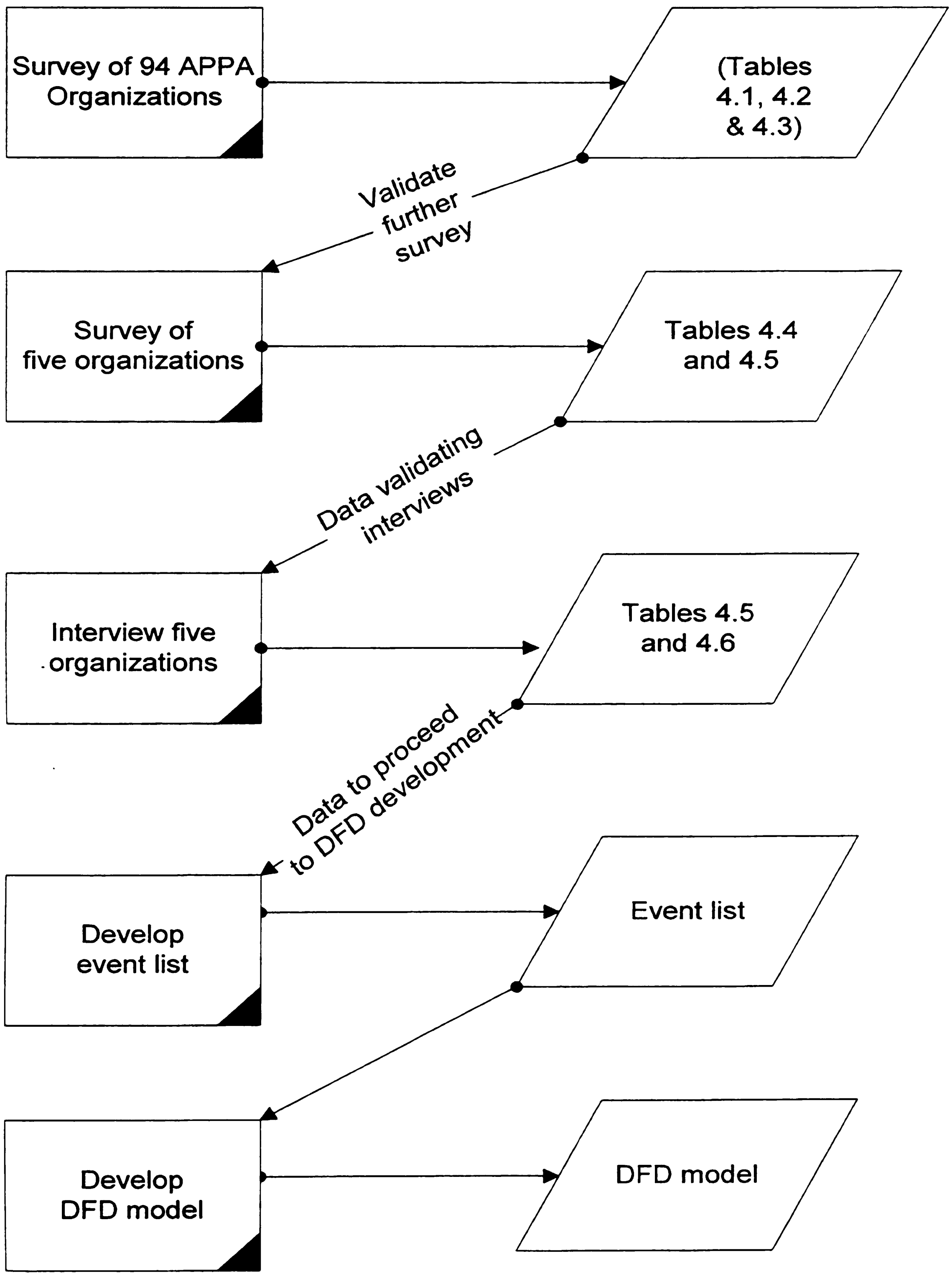



Figure 3.1 Flowchart of Event List Development

into sub processes in order to study them in more detail. This allowed the author to pinpoint the proper information flow necessary to alleviate the problems as identified in the case studies.

### 3.3 Case Study Methodology

A case study of one university was selected to examine the effectiveness of the information system model. Four construction projects from two facilities departments were studied. This section will explain the methods used in selection of these cases and the methods used to gather and analyze the data concerning the background facts of these cases.

The case study was selected based on the survey and interviews with the administrators and managers of the five organizations. A portion of the telephone interview questions were used to identify projects that the administrators had been involved with that may have had problems that could be traced to improper information flow. The method selected by the researcher to identify the problem areas consisted of an if/then question methodology, i.e. if this information had been properly recorded or processed then certain costs or time delays may have been avoided. If the project discussed met this test then it was considered for inclusion in the case study. This method was chosen to select the projects because the author wanted to select projects that had a clearly identifiable problem, that could be quantified in terms of time or dollars. At this point in the case study selection process eight projects were identified as potential projects for examination. From these eight projects, the projects to be studied were selected based on data gathered from the interviews relating to specific information flow problems with the projects studied. Although the selection method used has limitations, these projects serve to provide a degree of validation for the model.

### 3.4 Methods for Development

The information system model was developed using a structured system requirements development methodology. The methodology chosen was an iterative assurance process. (Davis and Olson 1985) There are four distinct strategies for systems requirements development. These strategies are acceptance assurance strategy, linear assurance process, iterative assurance process and experimental assurance process. The selection of the appropriate strategy is based on the following contingencies. Project size, degree of structure, user task comprehension and developer task proficiency. For this project, developer task proficiency was disregarded as systems development is outside of the project scope. The iterative assurance process was chosen because the project characteristics fit the contingencies of this strategy. These characteristics being a relatively high level of uncertainty and a large multi-user environment that requires iterative development of the system needs. The iterative, correcting nature of this strategy accounts for these characteristics.

As discussed in section 3.3 the information system model begins with the list of events that must occur in order for the basic information needs of the organization to be satisfied. The event list was developed as discussed in section 3.3 . The remainder of this section will discuss the methodology for development of the data flow diagram.

The data flow diagram for the information system model was first developed on the context level, as recommended by the DFD methodology as discussed in the literature review. The context level diagram was developed by consideration of the necessary information flow to satisfy the events in the model event list.

The specific pieces of information were identified and then validated thru the interviews and surveys as discussed previously. Most of this information consists of common information in the industry such as contract documents, estimates, schedules, designs, invoices and approvals for these documents. The need for information of this nature is inherent in the construction project management process. The needs of each entity (client, supplier, accounting and the organization) for the particular information inputs and outputs was determined thru the literature review, surveys, interviews, course work and the author's professional work experience in the industry.

In order to properly document the needed information, the author first developed a list of all processes performed throughout a construction project by systematically working thru the model event list. The author then logged all necessary information and attributed it to each respective event. This is shown in figures 3.2 and 3.3. A number of iterations of this process were performed by the author to enable the particular information flow and its relationship with each event to become clearly associated with that event.

After the relationship between each piece of information and the related events was established, the context level data flow diagram was generated. From the context level diagram, the zero level diagram was developed. This portion of the information system model was developed thru the data flow diagraming methodology as outlined in the literature review. Each of the events in the event list was modeled as a process with corresponding information inputs and outputs as discussed previously in this section. Each process was then broken down further into sub processes in order to identify problem areas with the information flow as determined by the case studies. Each process

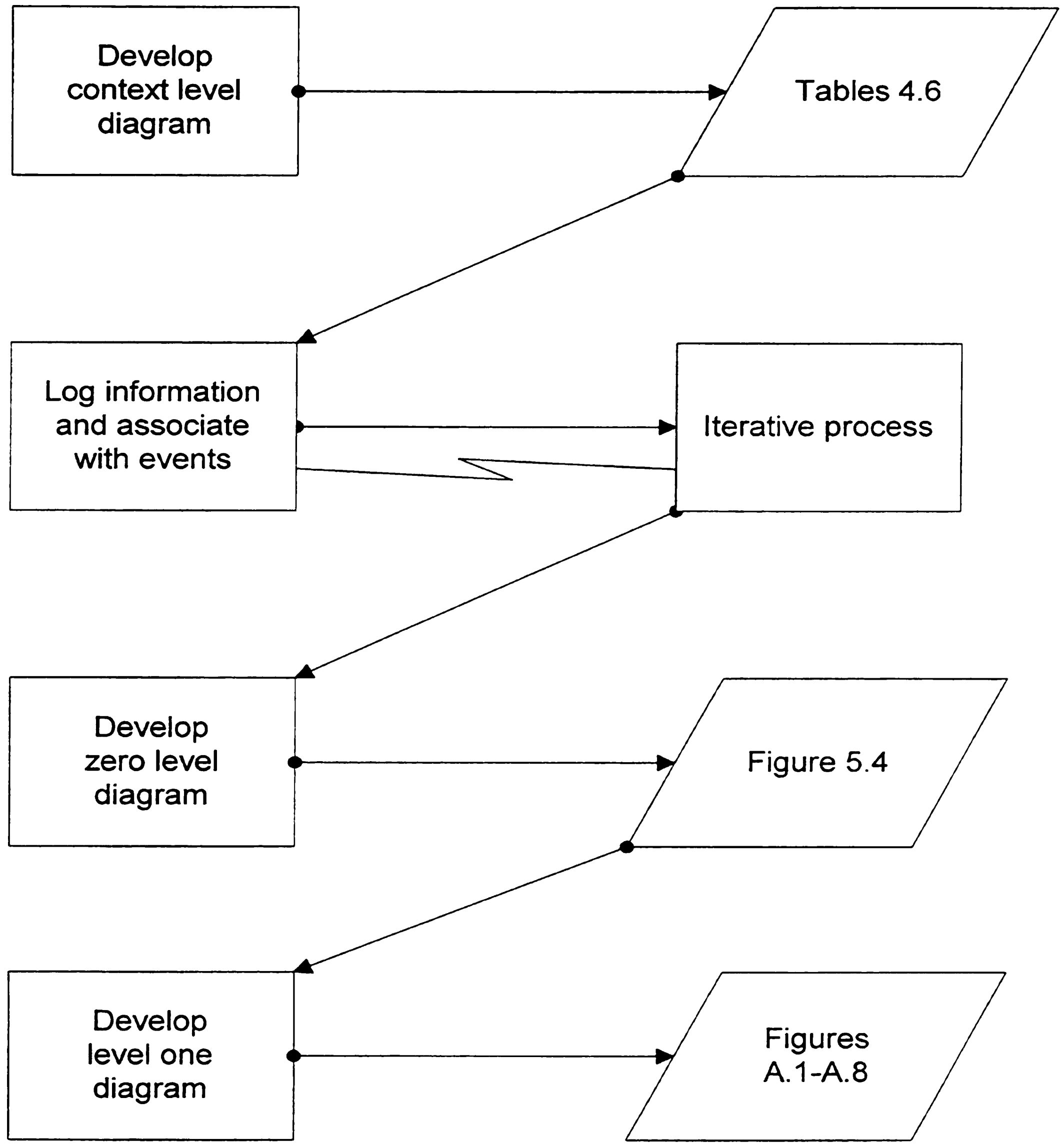



Figure 3.2 Detail of DFD Development

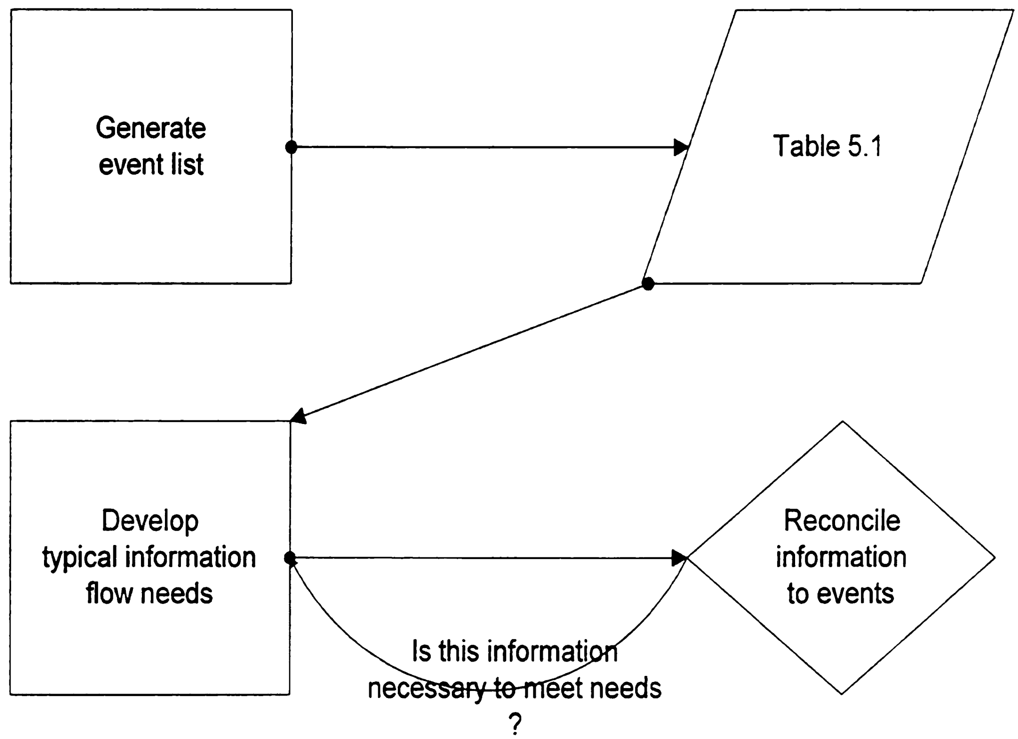



Figure 3.3 Information and event relationship attribution

was treated separately and analyzed for discrepancies as related to the proper information management practices found in the literature review.

**3.5 Methods for Predicting the Effectiveness of the Model**

The effectiveness of the information system model was explored thru the application of the model to the existing information systems used in the construction projects referenced in the case study. This section will explain the methods used to predict the effectiveness of the information system model as applied to the case study.

The researcher documented the existing information systems of the organizations involved in the case study using the DFD methodology as discussed previously. The existing information systems were analyzed to determine areas where potential information flow problems occurred. These problem areas were identified by comparison with the information system model as initially developed. The specific information flow and information management practices that were divergent from the model system were identified. These practices were then analyzed and compared to the shortcomings associated with the project, as determined thru the interviews. The appropriate practices were then selected based on the model and applied to the existing information system of the organization. The information practices that affected the problems as identified in the case studies were implemented. Due to the nature of the case studies as historical projects, it becomes difficult to predict with absolute accuracy the results of the implementation of the information system model. The author believes that the method of applying the information system model practices where there are identified shortcomings in the existing system is the best method for a project of this nature. This method was chosen to explore the effect of the model because of the dynamic and unique nature of construction projects. This provided a necessary measure of control, in that all other concerns and issues with the case studies were unchanged. This allowed the author to speculate that differing project outcomes in terms of time and costs were reflected by the application of the information system model.

### 3.6 Summary

This chapter provides the reader with background information as to the methods used in data gathering, development of the information system model and methods for conducting the case study.

The researcher used two surveys and a series of interviews as instruments to gather data for development of the information system model. The data flow diagram method was discussed as the tool used to develop the information system model. The case study was selected based on the data gathered in the survey. The application of the information system model to the case study was also discussed, relative to the study of construction projects with shortcomings that were identified in the data gathering process.

# CHAPTER FOUR

# RESULTS OF THE SURVEYS

## Introduction

This chapter will report the results of the surveys and interviews as discussed in the previous chapter. The results of these data gathering exercises will contribute to the design and exploration of the affect of the information system model developed in chapter five.

### 4.1 Survey of APPA administrators and managers

This survey consisted of an electronic mail survey of ninety four college and University administrators. The surveyed group consisted of member institutions of the Association of Higher Education Facilities Officers. (APPA). Thirty four responses were received from the survey. The general tone of the response is characterized in table 4.1

**Table 4.1**

**Interest level in Facility Management Information Systems**

**from Initial Survey October 1998**

| Little interest | Moderate Interest | Very Interested |
|---|---|---|
| 9 | 18 | 8 |

Twenty six of the thirty five survey respondents were categorized as "moderately interested" or "very interested" in the subject matter. The respondents categorized as "very interested" responded by offering additional information or offering to discuss the topic personally via a phone call or meeting. Many of the respondents were also interested in the integration of all project information as well. Table 4.2 provides comments taken from the survey that address this topic. This survey was undertaken to investigate the need for research and development of a information system model for owners. This survey particularly addressed the need for an integrated construction project management system.

**Table 4.2**
**Comments Regarding Integration of Facilities Project Management Information**

**"We are looking at various types of software to integrate these kinds of functions"**

**"There exists a facilities information systems committee which has been investigating integration of all ... facilities data"**

**"We recently purchased and are implementing a software program that will integrate"**

**"Each area is separate, however we would love integrated project information"**

**"We are currently looking at ... to integrate the areas you addressed"**

**"The value of integrated information would be well worth the cost, I believe"**

**"We are studying this topic, in an effort to cost justify integration"**

**"To interface our internal scheduling effort with the PM software, we had to switch to the same manufacturer's scheduling software. This was necessary to integrate the two"**

The author believes that the results as depicted in tables 4.1 and 4.2 reflect this need and also prove the willingness of a percentage of the respondents to participate in an additional survey as well as interviews.

The survey also addresses the topic of particular types of software used for the basic activities in the construction management process. The results of this portion of the survey are tabulated in table 4.3 . The results of the survey categorized in table 4.3 reflect the differing solutions and dis-integrated nature of applications to perform the basic construction management functions of estimating, scheduling and project management. This survey revealed that the respondents used seven different software solutions for scheduling, four different software solutions for estimating and six different software solutions for project management. This researcher believes that these results point to the need for an information system model for construction project management for facilities owners.

From this survey one can conclude that facilities owners are performing estimating, scheduling and project management processes electronically. One can also conclude that owners are using a variety of systems to perform these functions. The researcher developed a second, follow up survey based on these conclusions.

**4.2 Follow up Survey Results**

The researcher conducted a follow up survey of administrators and managers of five selected universities as discussed in the methodology section. The results of this survey are tabulated in table 4.4. The results of this survey were used by the researcher to further validate the need for an information system model, to develop interview questions that pinpoint precise information flow needs, and to identify

**Table 4.3**

**Software Solutions for Essential Project Functions**

**from Initial Survey October 1998**

| APPLICATION SOFTWARE | SCHEDULING | ESTIMATING | PROJECT MANAGEMENT |
|---|---|---|---|
| PRIMAVERA | 4 | | |
| TIMBERLINE | | 4 | |
| MS PROJECT | 9 | | 2 |
| MS ACCESS | 4 | 4 | 2 |
| FAMIS | | | 2 |
| EXCEL | | 6 | |
| CUSTOM DEVELOP | 2 | | |
| NO SOFTWARE | 6 | 8 | 6 |
| TMA | | | 2 |
| EXPEDITION | 2 | | 2 |
| SURETRAC | 2 | | |
| **TOTALS** | **23** | **16** | **10** |
| **DIFFERENT SOLUTIONS** | **7** | **4** | **6** |

**Table 4.4 Panel A**
**Survey results of five Universities**

| Question | Yes | No | Comments |
|---|---|---|---|
| Is there a documented method of project mgt? | 3 | 2 | None |
| Is there a standard method of project mgt? | 5 | 0 | None |
| Are there standard forms for PM process? | 5 | 0 | None |
| Are these forms always used? | 4 | 1 | Depends on Project scope |

| | Yes | No | Comments |
|---|---|---|---|
| Is past project info stored? | 5 | 0 | None |
| Is past info used on future projects? | 5 | 0 | Used to generate rules of thumb |
| Is past project info stored electronically? | 2 | 3 | Plans are in place benefit is realized |
| Would electronic integration of the above be of value? | 5 | 0 | **Very much** |
| Has the Internet been considered or implemented? | 5 | 0 | **4 considered 1 implemented** |

**Table 4.4 Panel B**
**Estimate and Schedule development**

| | In house | Others | Both |
|---|---|---|---|
| Are estimates developed in house or by others? | 0 | 0 | 5 |
| Are schedules developed in house or by others? | 0 | 0 | 5 |

fundamental project management processes. See figure 3.1, a flow chart outlining the development process.

The first issue that this survey addresses is the question of whether facilities owners see a need for electronic integration of the basic construction project management functions. The author believes that the response to the two questions on this topic validates the need for an information system model in facilities construction management organizations.

The first four questions on the survey determine the need for a standard method of project management. The strong affirmative response to the questions regarding standardization of methods and forms points toward a legitimate need for a standard system. This type of standard system lends itself to a normalized database.

The survey next indicates the number of organizations that are performing the estimating and scheduling processes in house as opposed to using information prepared by others. (Typically contractors and suppliers) All organizations are using in house and outside services for these areas. One should understand that these results further the need for integration of this information due to the strong possibility of redundant information.

Finally the survey addresses storage of submittal and historical data in an effort to further validate the need for an information system model. The survey data reflects the need for integrated storage. Particularly in the area of historical information and records.

**4.3 Telephone Survey and Interview Results**

The researcher used the telephone interviews to discuss in detail with managers and administrators of the respective organizations the particular information needs of

their departments, specifically how precise pieces of information were related to the basic construction processes previously identified. The researcher also used the telephone interviews to develop a list of processes and events each organization used to accomplish a complete construction project.

Table 4.5 summarizes the comments taken from discussions of the various functional areas with facilities administrators as they relate to the context of this project. The data from the above table further indicates the need for an information system model. It also provides the background for the researcher to begin development of the event list, which is the initial step in the development of the model system.

**4.4 Further Discussions with Facilities Administrators**

Beyond the structured telephone survey, the researcher had numerous discussions with the administrators at the five surveyed institutions regarding information systems and information flow within their organizations. The following section relates these conversations to the scope of this project.

The second portion of the telephone survey specifically asked the question "which event(s) or process(es) are performed by the respective institutions in the construction management process. A matrix of the respective events and which organizations they are attributed to is contained in table 4.6. This data was used to develop the model event list. Each process or event that any organization performed was studied and integrated into the model system, either in the event list or as a child process.

The construction project manager for one of the organizations surveyed told of a recent complete systems implementation. This individual believes very strongly in the concept of an electronic repository of information related to a particular project.

**Table 4.5**
**Comments from Administrators of Five Universities Surveyed Broken up by Topic Area for Analysis.**

**1-Project Management**

"We are developing our administrative information system to be more user friendly"
"Our project managers are using an intranet effectively to store and retrieve information"
"It would be useful to have PM notes integrated with AE notes electronically"
"We have a PM manual, however it rarely gets used"
"We have a PM manual on our intranet that flowcharts the PM process"
"All major projects are scheduled using MS Project"
"Our system is under development and study currently, considering many items addressed"
"It would be beneficial to have communications, eg bulletins and RFI's electronically linked"

**2-Estimating**

"Not currently integrated with cost accounting, would like to perform variance analysis"
"Estimates are done on Excel, not linked to other systems"
"Some estimates are manually developed"

**3-Scheduling**

"We use Primavera for client displays only"
"Contractors are required to furnish graphical schedules"
"All scheduling is not performed electronically in our system"
"We develop schedules using MS Project, no integration with other functions, however"

**4-Integration of all functions**

"We currently are using a web client to access our intranet. This technology has been in place for about one year and has proven very beneficial. Only certain items are integrated"
"It would be very useful to have all functions integrated, so information would be updated accurately on an ongoing basis"
"We realize the value of integrated storage and update of project data"
"Our department is currently in the process of evaluating proposals to provide an integrated facilities management system that will do this".

**TABLE 4.6**

**Matrix of Functions of Five Surveyed Universities**

| **FUNCTIONS** | #1 | #2 | #3 | #4 | #5 |
|---|---|---|---|---|---|
| CUSTOMER REQUEST | X | X | | X | X |
| PROGRAMMING | | X | | X | |
| DESIGN | X | X | X | X | X |
| DESIGN APPROVAL | | X | | | |
| ESTIMATING | X | | X | X | X |
| ESTIMATE APPROVAL | | | | | X |
| PROCUREMENT | | X | | | |
| SCHEDULING | X | X | X | | X |
| CONSTRUCTION/PM | X | X | X | X | X |
| EXPEDITING | | | | X | |
| PAYMENT APPROVAL | X | X | X | | X |
| CLOSEOUT | X | X | X | | |
| RECORDS | X | X | X | X | X |
| AFTER ACTION REVIEW | | X | | | |

The system at this institution was implemented as a relational data base with a series of report modes and other interface features to provide the necessary functionality for the department. A number of the essential processes were analyzed and restructured to best take advantage of the existing technology available. These changes resulted in less physical file space, less time spent tracking, finding, sorting, organizing and retrieving files, better coordination of information and an overall more efficient document management process. One of the organizations interviewed recently undertook an information systems project and implemented an information system via a web client and TCP/IP Internet technology. Project files are stored electronically and accessed by any party to the project via a web browser. Technology is in place to control access via a password system. The department also implemented an Intranet to provide further security. An Intranet allows access to a web site or series of web sites only to those with the proper permissions. This is typically performed via the Internet Protocol address number for the network interface device. The department has a substantial database of information available via this technology about any project currently in construction as well as information about completed projects. The information systems manager believes very strongly in the benefits of this technology. He claims it has saved his department time and reduced duplication of documents and redundant information.

Another university surveyed undertook a full scale implementation of an information system for the facilities department. This information system contains standard procedures and methods for documenting the information inputs for their system. This has enabled the department to standardize the format of the information input which provides a successful platform for the remainder of the information system.

Standardized formats and inputs allow the development of standard processes that in turn yield consistent and meaningful reports and outputs.

One university interviewed undertook a systems analysis project. This project produced a request for proposal, soliciting vendors to propose software solutions for the specified needs. The functional needs portion of the request for proposal in contained in the appendix of this paper. This document provides very specific documentation of the functional needs of the department. These needs relate very closely to the fundamental input, processes and output necessary to satisfy them. The information contained in this document together with the information generated from the interviews and the authors experience was used to formulate the information flows and their relation to processes.

**4.5 Summary**

The data gathered and summarized in this chapter provide the necessary information to validate the need for an integrated information system for facilities owners. The data also provides insight into the basic processes that most facilities organizations perform to accomplish construction projects. These fundamental processes are critical in the first stage of development of an information system model. This is the development of the event list. The data gathered and reported in this chapter will be used in the following chapter to develop the event list and to attribute information flow to the processes dictated by the event list. This will form the first level of the information system model, using the data flow diagraming methodology.

# CHAPTER FIVE

# DEVELOPMENT OF THE INFORMATION SYSTEM MODEL

**Introduction**

This chapter will develop the information system model and will document the model thru the data flow diagraming method discussed in chapter three. This information system model will provide a method of planning and managing the information in a university facilities department.. This information systems model will increase the likelihood of reduced project costs and shortened project schedules.

The information system model will be broken into sub processes as discussed in the previous chapters. This chapter will discuss each process and its associated sub processes. The parent process will first be described, then the child processes, then the recommended information flow for each process.

**5.1 System Background**

One must first understand the organization and the construction management system functions of a typical university facilities management department in order to develop and fully understand the information system model for such a department.

Figure 5.1 represents a typical organizational chart for a university facilities department. The organization consists of a layer of management staff to administer the departmental functions and provide oversight. Staff positions consist of designers, architects, project managers and clerical staff necessary to accomplish the functions of the organization. The staff positions provide information and data input into the system and rely on output from the information system for decision making and control purposes thru out the construction project. The management staff generally rely on information produced by the system to support decision making needs. The management staff may also use information for monitoring and controlling projects.

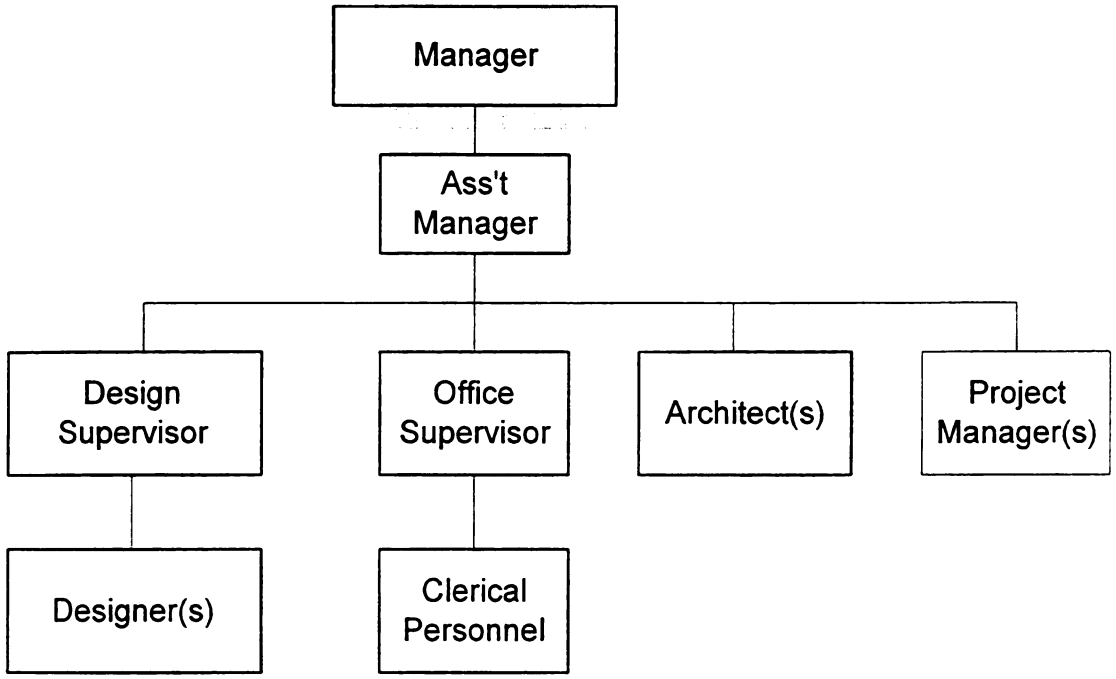



Figure 5.1 Organization chart for typical facilities department

A typical University facility department will provide design, construction management and other services such as maintenance and planning for physical facilities. Most Universities have design staff (architects and engineers), construction managers and administrative and clerical staff to support them. Projects can range in size from relatively minor interior renovation projects up to construction of new buildings. These organizations generally provide review and oversight of functional areas such as estimating and scheduling as opposed to detailed development of estimates and schedules. The facilities organization usually provides review of outside design and architectural services as well. The typical facilities department approves shops drawings and other submittal items. These departments generally provide complete inspection, payment approval, closeout and record keeping functions for the client.

These organizations are structured such that the department is able to provide programming and design, conceptual cost estimating, project management, construction project oversight, accounting and record keeping services. These services are usually provided upon receipt of an initial request for services from the client department. This request triggers the system. Such a system is represented in figure 5.2. The request for services triggers the facilities department that a client has requested the services of the department. At this point a designer or architect is assigned to the project and a design is developed. The design can be generated by the departmental staff or let to an outside firm. After completion of the design, an estimate is produced. The project budget is generally developed based on this estimate. The estimate may be developed in house or by an outside firm. After the estimate has been produced, a budget is developed and forwarded to the client for financial approval. After this approval is received the project is

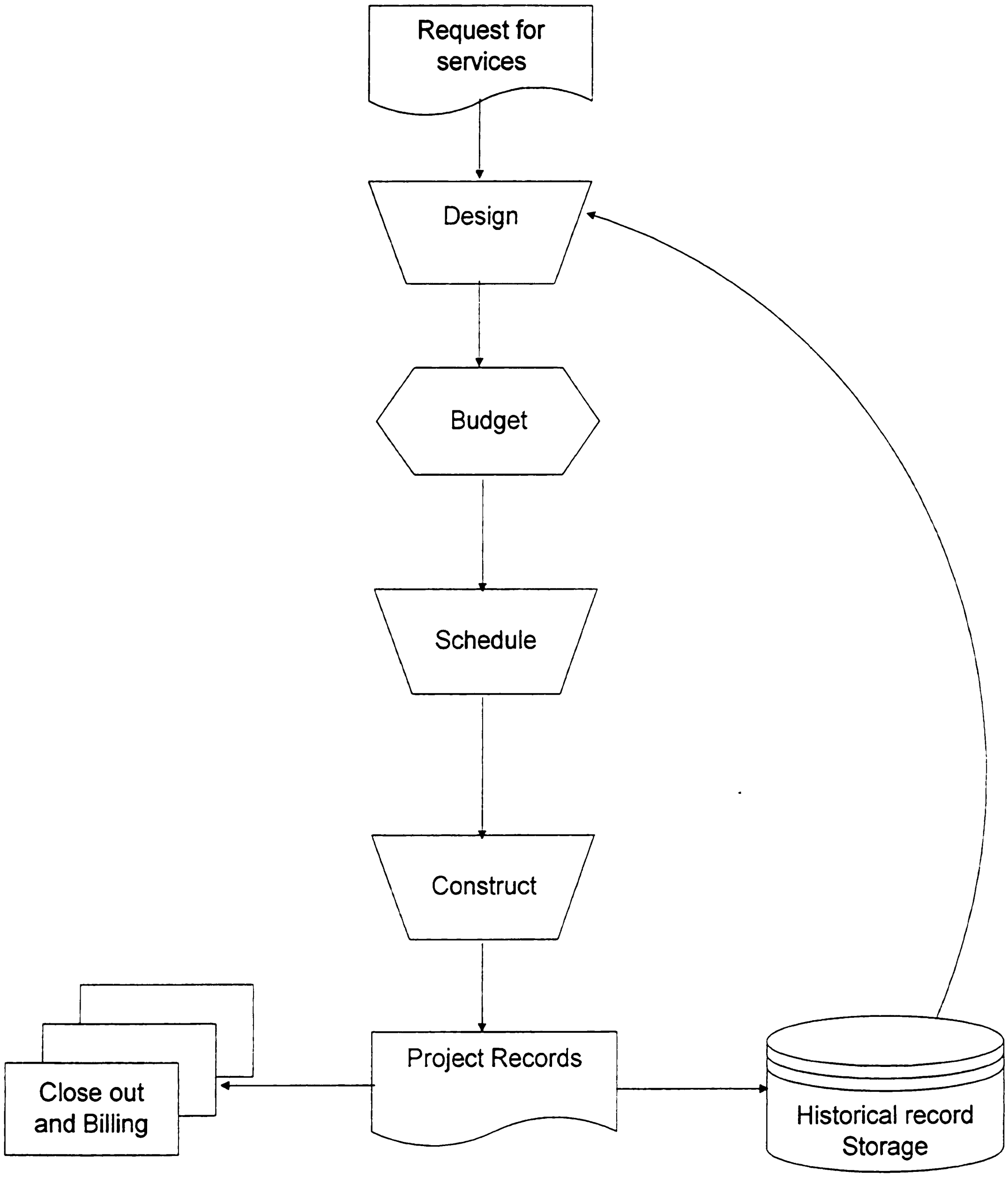



Figure 5.2 Typical construction process flow

let out for bid and contracts are generated. This function is typically performed by a separate department from the facilities department. The system in this paper is based on this model of project procurement. After a contract is awarded the startup functions take place and appropriate information is exchanged amongst all parties to the project. At this point the construction phase begins. This portion of the project is critical in that decision making needs arise almost daily, these decisions can have great affect on costs and schedules (Paulson 1995). As the project matures thru the construction phase, accounting and record keeping needs arise and these functions occur. As the project nears completion, records are compiled, the closeout activities are undertaken and input is solicited for final approval of the completed project. After the project is completed, this author recommends a review of all the activities of the project with the contractor(s), suppliers, client and project management team. This review serves the purpose of documenting the successful and less than successful practices for the benefit of future projects. Documentation of the existing information systems of the surveyed universities, in the form of data flow diagrams is contained in appendix F.

**5.2 Development of the event list**

The event list for the information system model provides a list of events or functions that must take place in order for the essential needs of the organization to be satisfied. In the case of the system discussed in this paper the needs to be met are those of a facilities management department of a large university. The first step in the identification of these needs is a survey of the system users. The author performed this survey as a subset of the follow up survey and interviews discussed previously.

The event list was generated from this research and is documented in table 5.1

TABLE 5.1
**Recommended List of Events**
**for Facility Owners Information Systems**

1) **Submission of request for service from client.**
2) **Produce design for project.**
3) **Produce budget estimate for project**
4) **Perform project administration**
5) **Perform start up activities**
6) **Manage the construction of the project**
7) **Closeout and review the project**
8) **Obtain all necessary approvals for the project.**

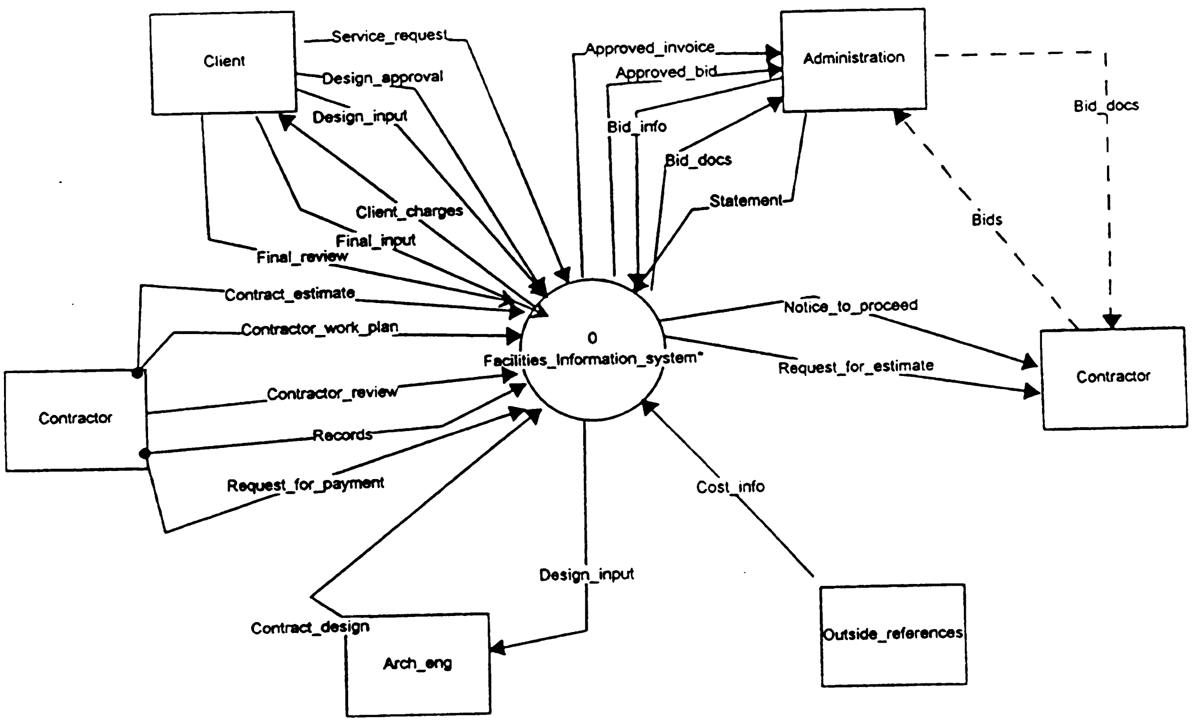
These events become the parent processes from which all sub processes and information input and output are generated in the development of the model system.

The next portion of development of the model system is the creation of the context level diagram. The context level diagram defines the scope of the system and also provides an overview of the entire system, including entities within the system, external entities and documentation of information flow into the system and information flow out of the system.

**5.3 The Context Level Diagram**

The context level diagram provides documentation of the scope of the system. This diagram provides an overview of the entire system, necessary information input and output. The context model contains, by definition, one process which represents the scope of the entire information system. This is represented in figure 5.3 as " Facilities Construction System." The context model contains entities which are typical to a system of this nature. These entities consist of clients, contractors, architects, engineers, administrative areas and outside references. Each of these entities interact with the system and provide input as well as receive output. The final piece to the context level diagram is the representation of the information flow at this level of the system. The information flow at this level is modeled as a series of arrows with the description of the information listed near the arrow. The Data Flow Dictionary (see appendix D) provides a definition of all data flow items in the information system model.

Figure 5.3 Context Level Data Flow Diagram



## 5.4 The Zero Level and One Level Diagrams

The zero level diagram represents the major subsystems of the information system model and is contained in figure 5.4 This diagram reflects the events listed in table 5.1 as processes in the data flow diagram. The zero level diagram also depicts the information flow of each process. Each process in the zero level diagram is known as a parent process with child processes "beneath" the parent process, providing the detail of the information flow model which are modeled in the level one diagram. The level one diagrams and the information flows attributed to them are discussed in the subsequent sections, along with the zero level diagrams. This is done for clarity. The data flow diagrams for levels below the zero level are contained in appendix E.

### 5.4.1 Client Service Request Process

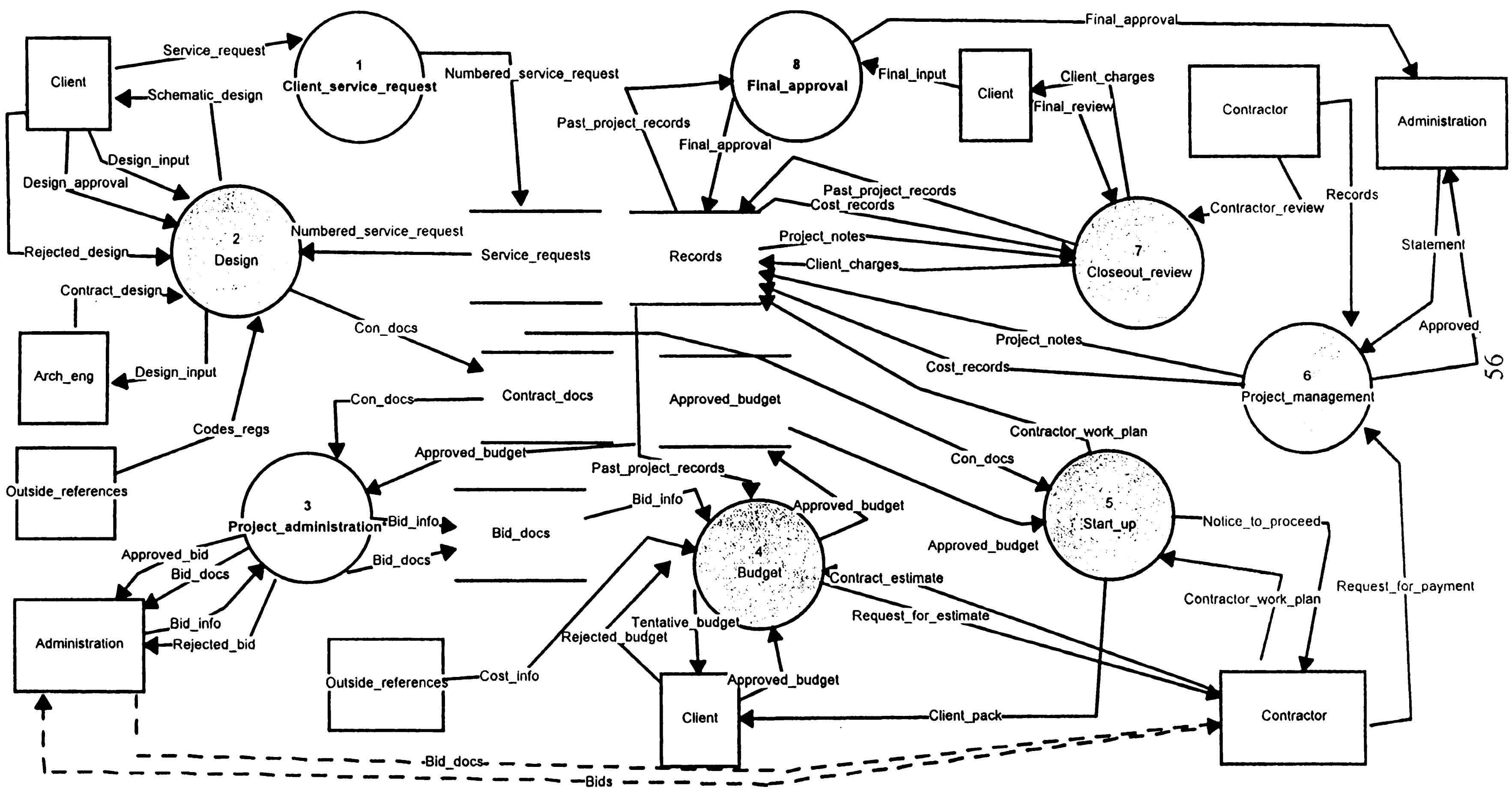
This process is critical to the system and triggers the beginning of each project. The information flow "client service request" provides a tremendous amount of information for the system. Typical data items for this information flow are account numbers, building identifiers, signatures for approval, dates and contact information.

After the client has requested services, the facilities department should assign a unique non redundant number, to the project. This task is critical in a database application because it assures that the information associated with any project has an identifier electronically "attached" to it. This unique, non redundant, identifier is then used to organize the information in a data base format.

### 5.4.2 The Design Process

The design process for the information system model consists of two sub processes. These sub processes are the production of the design, labeled as con docs, and

Figure 5.4 Zero Level Data Flow Diagram



the approval of the design, by the client.

The approval process generates the client approval of the design, which is necessary before proceeding with the project. This process requires as input, a schematic design, contract design, rejected design(s) and approved designs. The corresponding output then becomes the approved design.

The process labeled "produce design" is further broken into two child processes. These consist of in house design which is the generation of a complete design by staff of the facilities organization, and outside design, which is the submittal and review of a design by an outside architectural or engineering firm. The design process produces a design (con docs) which is stored in the system. In order to produce this design, information inputs are required. Design input consists of client input into the project as well as codes and regulations.

Within the in house design process lie two child processes. These are architectural design and interior design. Architectural design consists of that portion of the design containing demolition plans, architectural plans, electrical plans, mechanical plans and other technical plans. Interior design is that portion of the design consisting of finish selections and typical interior design elements. Because these design processes are often performed by separate staff, the common storage of the client design input becomes critical. With this procedure in place information is available to each designer working on the project. Each of these processes produce designs which are stored in the design data store. The information in puts for these processes are similar to the parent in house design process.

The critical output of the design process is labeled "con docs". This information

consists of drawings, specifications and other typical contract documents. It also includes all information related to the change order process. This flow of information consists of all necessary information to prepare bidding documents for a hard bid project.

### 5.4.3 The Budget Process

The process of preparing the budget estimate provides an estimated cost of constructing the project, given the approved design. This estimate is used to set up project budgets and to control the project, cost wise, from the owner's perspective. As seen by the research, facilities departments utilize their own staff to generate estimates and also request estimates from outside firms. For this reason the information system model separates the estimating process into in house estimates and outside estimates.

Estimates prepared by the facilities department staff are used to develop project budgets as discussed in the previous section. Estimates are developed based on the project design. The project design provides the background to develop material and labor quantities. The next phase of this process is the assignment of costs to these material and labor quantities. This cost information comes from historical project cost information and from outside references sources. The historical information can be very valuable in this phase of the estimating process. The output of this process is the tentative budget.

The outside estimate is prepared by a contractor or architect. The purpose of the outside estimate is to provide cost information regarding the designed project and to set up budgets. The facilities department generates a request for estimate based on the design and transmits this to the contractor or architect. The contractor or architect then returns the outside estimate. This estimate is reviewed and if necessary combined with other outside estimates to develop the tentative budget. It is the sum total of all estimates

from outside entities plus overhead and fees.

The final phase of the budget process is the approval of the budget. This function is typically performed at a high level in the organization. The input necessary to produce the approval include the tentative budget and the contract documents.

### 5.4.4 Project Administration

This process consists of the preparation of the appropriate authorizations and documents to release the project for bidding as well as administrative approval of the successful bidder. The contract documents are a necessary input as well as information relating to account number and signatures of approval. The outputs of this process are the bid docs and approved bid which are transmitted to administration and are stored in the bid docs data store. The transmission of the bid documents to the contractor is not modeled as part of this information system, however it is shown as a dashed line on the zero level diagram, so that this relationship is understood by the reader. Additional information flows in this process are the bid information input and the rejected bid output. These items are defined in the data dictionary in appendix B.

### 5.4.5 Project Startup

The process of starting the construction of the project requires three sub processes that are necessary in order to provide the information for the appropriate decision to made, triggering the beginning of the project.

The first process is labeled as the procurement summary and consists of the transmission of the contractor name and the contractor plan into the system. This information is used to generate the client pack and is also transmitted to the data store labeled plans. The contractor name includes basic data such as addresses, telephone

numbers, fax numbers, email addresses and other background information. The information flow "plan" consists of a list of the contractor staff that will manage the project, the schedule for the project, the schedule of values, the list of sub contractors and suppliers, minority owned businesses, women owned businesses and other pertinent data required of the contractor by the facility owner. The information flow labeled as client pack consist of that set of information taken from the plan and relayed to the client. The data in this information would likely consist of a sub set of the plan. The level of detail transmitted to the client may depend on internal policies and procedures. It is recommended by the author that the maximum amount of information be included, this would serve to open communications and may provide benefit over the course of the project.

A second sub process of the start up function is the recording of the plan. The plan is appropriately documented and recorded in the records data store.

The third sub process is the generation of the notice to proceed. This item is critical to the commencement of the project. After receipt and review of the plan and contractor information, the facility department generates a notice to proceed which is transmitted to the contractor, providing written documentation of the owner's order to begin construction.

### 5.4.6 The Project Management Process

This process consists of the reporting, control and payment approval functions of the project. The construction of the project requires record keeping and reporting in order to properly control the project from a time and cost view point. There are two sub processes of the parent construction process. These are project reporting and payment

approval. Each of these processes has a critical role in the control of the project.

The process of project reporting consists of the gathering and storage of information relating to the project is being constructed. This information enters the system as records, which are the contractor and supplier project notes and other information, submitted to the owner. Additionally the approved payment is an input of this process. This information leaves the system as cost records which is the record of all costs of the project to date. The project notes are also generated within this process. This information is documentation of the various and on going activities of the project as prepared by the owner's staff. This item is stored in the records data store.

The payment approval process is triggered by the receipt of the request for payment from an outside entity. This entity could be a contractor, supplier or architectural firm. In order to approve the invoice, certain information is necessary. The contract documents are necessary to review the labor or construction that payment is requested for. Project notes are necessary to validate that the work that is being invoiced has been completed and the approved budget is necessary to verify the funding for the payment. The approved payment is the output of this process. This information is forwarded to administration for processing and stored in the records data store. The actual payment function is outside of the scope of the system discussed in this paper. There is further discussion of this area in chapter seven.

### 5.4.7 The Closeout and Review Process

After the contractor has achieved substantial completion of the project as defined in the contract documents, three needs are triggered.

First the need to charge back the appropriate items to proper accounts, per the

service request and approved budget is realized. The cost records are necessary to provide the amounts paid out on the project, information regrading the overhead to be applied to the charge is necessary and the approved budget is necessary to validate the charges. These charges are labeled as client charges and are transmitted to the client as well as stored in the records data store.

Secondly the need to properly prepare all of the project notes and cost records for storage and retrieval also arises at this point in the project life cycle. These items are inputs into the process, the information item labeled as past project records is the output and is stored in the records data store.

Thirdly the need to review the project after completion and document the successful and less successful practices performed over the course of the project occurs at this stage. In order for this process to produce useful output, information from the contractor (contractor review) and the client (client review) is required as well as the project notes. These items are combined and the resulting review documents are stored in the records data store.

### 5.4.8 Final Approval

After the project has achieved one hundred percent completion, it is necessary to obtain final approval of the completed project from the client, prior to turning the structure over for operations. Past project records are required as well as final input of the client. This information should provide the impetus for the client to submit the final approval of the project.

## 5 Summary

The information system model is developed through generation of a list of events ıat trigger the system to produce appropriate information that satisfies these events. 'hese events are represented as processes in the zero level diagram of the model. These ›rocesses are in turn broken down into sub processes. This allows for the identification ›f information input necessary to provide output as dictated by the processes. Each process is broken down until a level is reached where the process becomes a task that can be performed in an understandable fashion

# CHAPTER SIX

# CASE STUDY

## ·oduction

This chapter will explore a case study of four projects from one of the universities ·yed. These projects were analyzed with regard to the flow, storage and access of mation. The information system model was applied to these specific problems to ate the information system model.

The case study university is a large division one, public research university with ·ximately forty four thousand students. Within the university are two departments h perform facilities management functions. The author selected projects from each · departments for this case study. In order to understand the scope of the case study ıthor will first describe each department. After the background of the two tments is understood by the reader, the author will describe each of the projects and ›plication of the model to the problems in the cases.

## hysical Plant Engineering and Architecture Services

This department (physical plant) provides construction and engineering services ch of the one hundred twenty plus buildings on the campus. Included among these es are programming, design, estimating, project management and record keeping. ›nstruction management process for this department follows the basic flow as ı in chapter five. The department consists of architects, engineers, project ;ers and administrators. Figure 6.1 is an organizational chart for this department. epartment constructs approximately fifty projects annually with a budget of one ·d seventy million dollars. These projects range in scope from entire buildings to r renovations and build out projects.

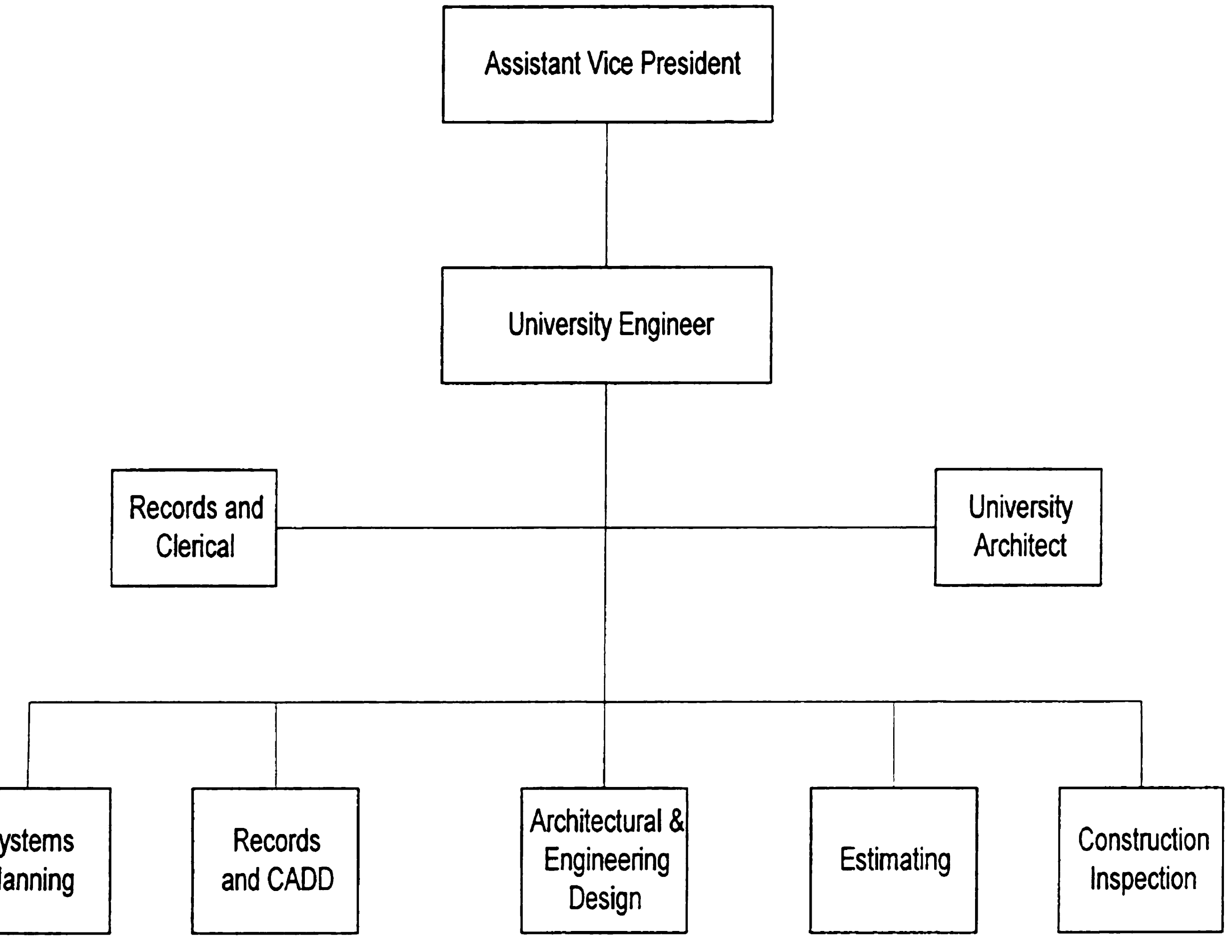



Figure 6.1 Physical Plant organizational chart

Design work is done in house or contracted to outside architects and engineers.

projects are assigned a project manager. This person coordinates and communicates

the architect, appropriate engineers, the contractor(s) and the owner. Physical Plant

a variety of software systems in place to perform the various project management

tions. Spread sheets are used for scheduling and estimating as well as job costing.

d processing is used for document management and tracking, email, facsimile,

hone, US mail and other private courier services are used for communications .

ad sheets are used for local, departmental accounting. The university has a

ralized accounting system, in the administration building, that serves the accounting

tion for the overall project budget. This system is beyond the scope of this case

y.

Beyond the functions discussed above, a mixture of software is used to

nplish the daily tasks. Spread sheets and word processing software accounts for a

percentage of the project related information. The office staff has networked

op computers. However the critical project information such as budgets and

nting information, payment histories and schedules are not implemented as a

alized database. Each person largely keeps the information they need to do their

nformation that is commonly known as essential for a given subset of personnel is

l. However, it is not stored in a centrally located, normalized database.

**ne Department of Construction, Maintenance and Interior Design**

This department (CMID) exists within the division of Housing and Food services.

D provides renovation and remodeling services for the forty buildings within the

on. The department annually completes approximately one hundred fifty projects

h a total budget of twelve million dollars. Projects consist of predominantly ovation and remodeling of interior spaces within the division of Housing and Food vices. A small percentage of projects are performed outside of the division. CMID is fed and organized in a similar fashion as physical plant. Figure 6.2 represents the anizational chart for CMID. The basic project functions and processes of CMID are same as those presented in chapter five.

The existing information system in CMID consists of a series of decentralized rmation storage centers. These consist of file cabinets, word processing files, spread t files and electronic mail storage files. Typically each staff member working on a ect will have their own folder with information that they have decided is necessary hem to accomplish their responsibilities for that project. As an example, if a project ager needs information on the budget for a particular project, they will request a tally e costs incurred and forecasted for the project. If a designer needs information ng to the clients needs, they will look up their notes from the meeting with the . This is done both manually and with word processing systems.

Estimating is performed manually and with spread sheet software. There is no ated database of past project cost information. A system of stand alone files of past t information is used to provide historical cost information. Data for the estimate s is taken from these files or from outside reference sources. Scheduling is med manually, via a calendar and word processing software. Project management ons are done manually. Payment approval is performed manually as well.

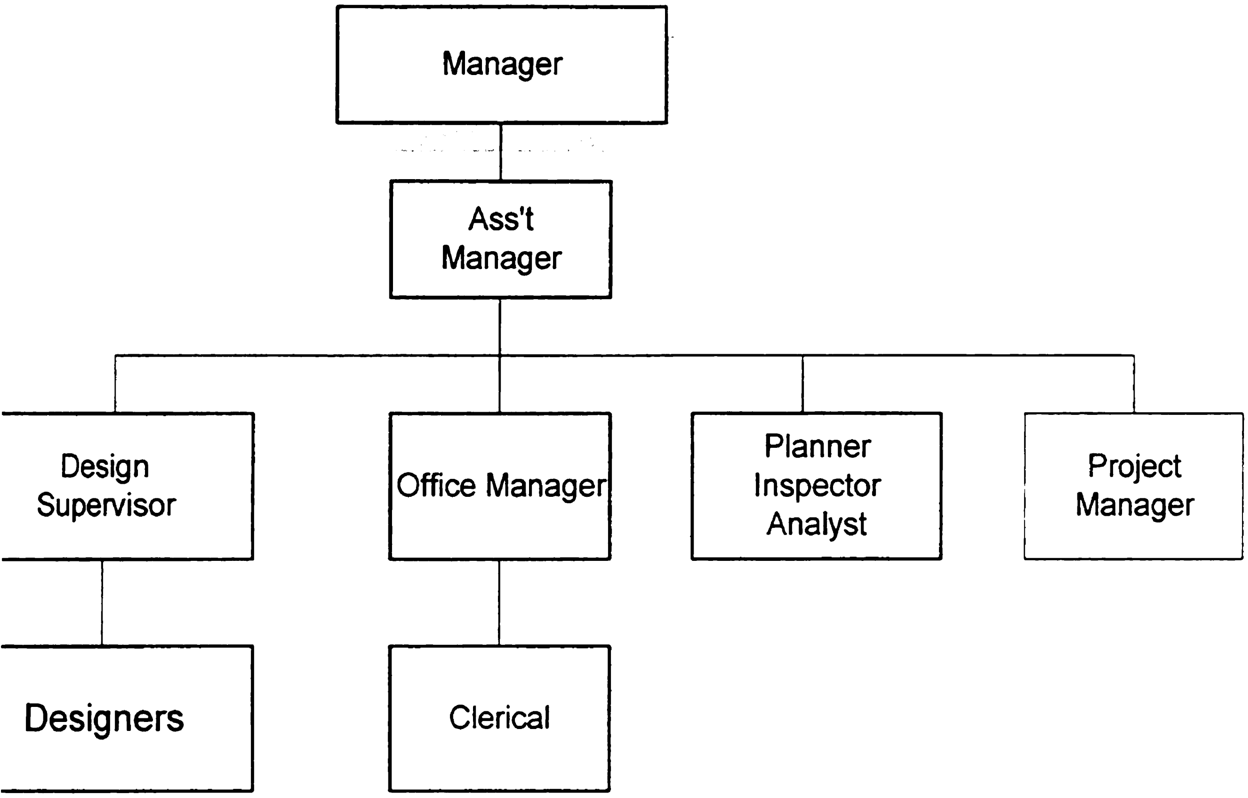



Figure 6.2 CMID organizational chart

To summarize, CMID performs all construction functions in a manual fashion. record storage is based on a file system, either thru use of word processing and spread :t software or paper files and file cabinets.

Four projects were evaluated in order to apply the information system model. :e projects were selected from CMID and one from Physical Plant. The method for :ting these projects is explained in chapter three.

**:ase Study-Dining Hall Renovation**

This project involved the development of the design and estimate for the ›deling of a campus dining facility. The project was designed and estimated by the within CMID. The information gathered by the planner, analyst, inspector (PIA) stored only in personal files. This designation (PIA) represents one individual who ›rms many of the functions typical of the architect. Information gathered by the .or designer was stored only in the interior designers files.

During the project the interior designer had spoken to the client about a removable for the space. This was desired by the client to increase the functionality of the . The PIA had no knowledge of this request, the client had not brought it up in the opment meeting with the PIA. The PIA developed the design and the project budget on the information available. This information included nothing about the ›able wall. The resulting estimate was approximately twenty five thousand dollars than necessary to fund the project, including the removable wall.

Considering the information system model, information regarding the client ı input would be stored in the design database. Ideally all parties to the project have the necessary access to the information. This is documented in the data flow

ıgram as an information input into the design process. It then becomes part of the ;ign which is stored in the data store "contract docs". At this point the information is t of the design and would be automatically included in any information output or uests regarding the project. This example clearly shows the ability of the model to ːctively store and process information so that it is available to all necessary parties. s in turn increases the accuracy of the estimating process. In this example, the ırmation system model has identified the budget shortage, and the project could have n redefined.

**Case study- Multi Unit Apartment Renovation**

This CMID project concerned the renovating of a twelve unit apartment building. ı separate departments in the division of Housing and Food Services were involved in ring materials for the remodeling project. As a consequence, the schedule for llation of the materials was greatly affected by two departments. The second rtment involved in the ordering of materials, University Apartments, was involved ıse they had historically taken on this role in remodeling projects. This was done in ast to insure standardization of materials throughout the complex.

All information for the project was stored locally by the department generating the ular piece of information. Storage was performed both electronically and via a ːonal paper and file system. These information storage practices led to many ɔmmunications and mis-representations over the course of the project. For example partment ordering the doors for the project failed to communicate that the doors not be received as indicated in the project schedule. CMID was responsible for ıling the painting and finishing contractor for the doors. CMID did not have access

o information on the delivery of the doors. Therefore the schedule for this trade was not ıdjusted. The painting and finishing contractor had mobilized their workforce and stocked materials to begin staining and finishing the doors on the original date for the ırrival of the doors. Because the doors were delayed, the contractor had to demobilize ınd find temporary storage for the materials. Informal conversations with this contractor revealed that this event would be reflected in future quotations for projects of this nature. The cost increase would be approximately five percent to "cover" for the possibility of events such as this occurring in the future. The staining and finishing portion of this project was eight thousand five hundred dollars.

The events and information flow in this case are reflected in the data flow diagram of the model system in the sub process "project reporting." Project reporting is a sub process of the "project management" process. It is assumed by the author that the purchase order for the doors would be updated with the "new" delivery date as part of the information identified as "records." This information originates from the "contractor" entity, enters the system in the project management process and is transmitted to the records database, providing a uniform data record of the delivery date for all parties to review.

**6.5 Case study- Office Renovation**

This case involved a flooring project, managed by CMID. The project involved asbestos abatement and demolition, new finished flooring, and other architectural trades. Typically on a project of this nature the CMID assigns a project scheduler for the flooring trades and a project manager for the overall project. If all pertinent information is not shared between the staff, problems can occur and be exacerbated.

In this case, the abatement and demolition of the flooring fell behind schedule. ie project manager did not communicate this information to the person doing the ieduling. Therefore the scheduler did not contact the finished flooring contractor to re edule. The finished flooring contractor was unaware of the schedule change, ilting in an increase in the cost of their work to the owner. For this project, the cost ease was five hundred dollars, incurred for additional storage and re mobilization.

This office renovation project is concerned with the project management process its information flow. The output of the project management process, labeled project s, includes both the information received from the contractor "records" and mation generated by the owner's staff. It is believed by the author that the nation discussed above relating to the progress of the project would be stored in the ds database as part of the records information flow. This normalized storage of the vould enable the scheduler and the project to access the information, in order to the appropriate contractors of changes in the schedule.

The implementation of the information system model in this case would decrease costs by five hundred dollars, provided the information was properly updated and l. There are also hidden costs in this mis-communication such as the time of the s staff taken to correct the problem and time taken up by other trades during the on of the project.

**e study-Office Renovation**

This project involved the renovation of a large office area. The problems studied oject occurred in communication and information management during the design ect administration phases.

During the design phase; electrical, telephone and data outlets were designed to be nstalled at the standard eighteen inches above the finished floor. The office systems urniture for the area was ordered as if the outlets were to be at desktop height of thirty nches. This office area consisted of fifteen work stations with three outlets each for a otal of forty five outlets. The problem was not realized until the furniture arrived on the ight. At this time, all finished materials had been installed and the construction was ubstantially complete. The least expensive alternative at the time of furnishing was to nove the forty five outlets to the height required by the office furniture. The work iecessary to relocate the outlets is detailed in table 6.1.

The electrical contractor quoted five hundred dollars per outlet for this work. The ost to the project for this work was twenty two thousand five hundred dollars to relocate ifteen data outlets, fifteen telephone outlets and fifteen electrical outlets.

Application of the information system model in this case occurs in the design and roject administration processes. The lack of coordination of information between the taff ordering the furniture and the architect/designer was the principle cause of this roblem. The information output generated of the design process "con docs" should ontain the data specifying the outlet heights. This information would then be stored in he contract docs data base, for retrieval by the staff member ordering the furniture. This rdering function is part of the "project administration" process. Within the information low "con docs" is the information regarding the outlet heights. This information could e reconciled against the furniture requisition prior to transmittal to administration, where

**Table 6.1 Work scope for electrical re work**

1) Remove trim
2) Pull wire back to termination point
3) Pull raceway back to point of access
4) Cut raceway to new length
5) Rough cut access for new outlet height
6) Re feed raceway to new location
7) Re feed wire to new location
8) Patch, paint and repair original outlet opening
9) Make final connections and trim new outlet
10) Test outlet

the purchase order is generated. At this point the error in the coordination of the design and the furniture order could be corrected, eliminating the cost expenditure described above.

### 6.7 Summary

This chapter presented a case study which included four construction projects from two departments in one of the universities surveyed. These projects were selected because they exhibited flawed information flow that could be attributed to problems with the information system in place. Specific attention is drawn to the information flow for these cases and the effect of poor information flow on the problem areas. The problems and effects of the problems were documented in each case. The application of the appropriate portions of the information system model was discussed, as related to the identified problems. This application of the information system model, in each case, was shown to potentially reduce costs incurred and or shorten project schedules.

# CHAPTER SEVEN

# SUMMARY and CONCLUSIONS

## 7.1 Conclusions

The objectives of this project as defined in chapter one are as follows; 1) document the information inputs, processes, and outputs of a typical facilities department; 2) develop an information system model for facility departments that incorporates the information that must be captured, processed and accessed for construction project reporting and decision making in the organization; 3) validate the information system model in a case study.

From the data collected it is apparent that facilities management departments in most universities perform very similar functions. The essential business needs that drive these functions are very similar. These business needs can be satisfied thru an information system model such as the one developed in this paper. Most universities have a common need for a standard method of managing information. The implementation of a database approach, together with a standard method of classifying information can lead to more effective project management.

The research shows that there are a readily identifiable set of inputs, processes and outputs for most facilities departments. These components are documented in this thesis and are included in the appendix. This data provides the background for the development of the information system model. The inputs, processes and outputs are incorporated into the data flow diagram portion of the model. These information flows are typical to the surveyed universities.

The information system model is developed in the form of an event list and data flow diagram depicting the information flow as well as the processes necessary to satisfy the information needs. These needs are driven by construction project reporting and

decision making. The information system model, together with the data dictionary in Appendix D, provides a detailed specification of the data necessary to support the information system needs. The information system model is structured around a normalized database of project information. This database meets a common need of all the surveyed universities. This is the need for a single, central storage point for all of the data.

The information system model is validated in chapter six thru a case study which included four construction projects from one surveyed university. Each of the projects studied reflected either a potential cost reduction, a shorter schedule or a combination of the two. The case study shows the information system model can reduce costs and shorten schedules, given the limitations discussed in this chapter.

A normalized database provides a central point of storage for all information. This enables data to be entered, stored and accessed from one point. The elimination of redundant data entry and duplicate data storage will reduce the likelihood of incorrect data. This concept is critical to the success of the information system. The alternative to a normalized database system is a file system. In a file system records are duplicated and stored in paper or electronic files for reporting needs. The database system, around which the information system model is developed, electronically links all of the data records for a given construction project.

Very little research was found in the area of information systems for facilities owners. Because of this a parallel was drawn between construction management information systems, where much research was found, and facility owner construction management information systems. This research, together with the data from the surveys

allowed the author to develop and validate the information system model in this paper.

The information system model developed in this thesis identifies the information that must be captured, processed and stored for the reporting and decision making needs of a university facility department to be met. This information system model provides a method of organizing and classifying the information necessary for the reporting and decision making needs of a typical construction management department within a university to be met. This will enable construction projects to be completed in a more cost efficient and timely fashion.

**7.2 Limitations**

The validation of the information system model is limited in that the case studies were selected based on existing, identifiable problems. This limited the validation to pre- selected problems. Because of control and time frame issues the author was unable to implement the model information system in an actual construction project, prior to the project beginning. It should be understood that the method of case study selection was undertaken so that the author could gain the necessary measure of control over variables in the project management process.

The application and validation of the information system model was also limited throughout this paper by the assumption that personnel have the proper training to fully use the system. It was assumed by the author, in the case study, that the staff performing the discussed processes were correctly using all of the information available to them via the model information system. Training and use of the system and its output are without a doubt critical to the success of an information system such as the one discussed in this paper. Without support of this nature the information system model will lose value.

Another limitation of this information system model is the failure to include administrative departments such as Purchasing, Accounts Payable and Accounts Receivable in the scope of the system. Some of the universities surveyed include these departments within the scope of their facilities system, by necessity including a great deal more information management needs. The information system model developed in this paper represents these departments as entities outside of the scope of the system. These processes were not modeled. This was done because the basic needs of the system did not require the detailed information produced in these kinds of processes.

**7.3 Areas for future research**

Advancements in information systems are racing far ahead of the ability of organizations to properly apply these advancements to their fundamental business processes. There is a need for research into the use and application of information systems in the facilities management field.

A number of specific topics that have a direct relationship to the subject matter of this paper have been identified. The remainder of this section provides a baseline for others to follow up in conducting further research in order to advance the knowledge in this area

The integration between enterprise wide information systems and construction project specific information systems is a natural progression of organization wide information integration. There are a number of enterprise wide information systems currently on the market. These systems provide a completely integrated information system for the entire organization. All business functions are generally integrated including payroll, human resources, accounting, manufacturing, inventory, sales,

marketing, communications and other functions. The benefits of these systems are along the same lines as the benefits of the system described in this paper. Duplicate and redundant information is eliminated, accuracy and currency of information is increased greatly.

Another area of future research involves the extension of the project management information system to entities outside of the scope of this paper. Specifically contractors, suppliers, administrators and others involved in the construction project. The proliferation of the Internet and the World Wide Web will likely provide the technology and support for a system of this nature. This author firmly believes systems of this nature are likely to be prevalent in the future. Research into the cost structures and information needs is necessary to support this technology.

Cost based research into the impact of information system implementations on administrative and other organizational costs is necessary to provide return on investment and other financial analysis. Financial analysis of the cost savings of a project of this nature is needed to provide the fiscal support to secure funding for these systems. Technology can be a costly proposition and the support for expenditure of these costs is necessary for the commitment of funds to undertake projects of this nature. Research and financial analysis is necessary from the facility owner perspective as well as the contractor and supplier perspective.

There are a number of sub topics and areas for research as well. Included among these are the costs of hardware, software and training. All of these issues must be evaluated from the standpoint of the facility owner as well as the contractor and others.

The area of information systems literacy is ripe for future research. Information

systems literacy is the knowledge of how information and data are used by the organization to better accomplish the fundamental business processes. Research into the application of innovative technology to the core business is necessary to show that the technology has application and can improve the business in a measurable fashion.

Research into the application and systems implementation of the information system model presented in this paper is necessary to develop the needs analysis and resulting request for proposal. The reconciliation of the information system model with the functional abilities of current software is necessary to develop the appropriate implementation plan. Typically there is a compromise between the developed information system model and the available commercial software solutions. Research into the gap between the model and the available solutions is necessary to define the need for further software development. This research will also help further refine the information system model as proposed in the paper. This area of research will also provide documentation of the existing solutions available for an information system of this nature.

**7.4 Summary**

This thesis consists of a review of the existing literature and research into information systems in the field of facilities project management. This research was undertaken in order to develop an information system model that may be applied to university facilities departments.

The information system model was developed using the data flow diagraming method as discussed throughout this paper. This provides a standard method of documenting the events and information flow necessary to accomplish these events. This

information flow model was developed based on the literature review, the surveys, interviews and conversations with facilities administrators. The application of this information system model, together with the suggested list of events provides a framework for information management within the construction management area for a facilities department.

The concept of a central, normalized, database of all construction project information is presented in this paper. This concept is shown to potentially reduce project costs and schedules. The concept is presented as a data flow diagram depicting the information inputs, processes and outputs necessary to satisfy the information needs of a typical college or University facilities department.

# APPENDICES

## Appendix A

## Michigan State University-Physical Plant Division

## Request for Proposal-Facilities Management System

## Chapter Eight-Functional Needs

8 FUNCTIONAL REQUIREMENTS

8.1 WORK ORDER MANAGEMENT

Work Order Management includes several types of projects including planned customer and maintenance projects; recurring preventive maintenance projects, minor work and trouble call items and verbal request customer jobs. The system will involve a variety of supporting functions including Contracts and Contractor monitoring, Billing and Account distribution, Materials Management, Estimating, Scheduling and Web and E-Mail Customer interfaces.

8.1.1 The system must provide automatic project identification numbers within a variety of categories .

8.1.2 Entry screens must provide for entry of projects of diverse complexity and magnitude including large multi-craft alteration projects, minor maintenance and trouble calls, recurring preventive maintenance tasks and standing order or verbal request miscellaneous small volume customer work.

8.1.3 Distributed on-line entry of data at each stage (customer request, review and assignment, estimate development, scheduling and change orders) by a variety of locations and personnel.

8.1.4 Date and Time stamps should be automatically applied by the system.

8.1.6 The system must have the ability to both reference for access and provide in pull down lists authorization files including access authority, account master,

and request authorizations.

8.1.7 The ability must exist to access a project by a variety of keys such as project number, customer account number, department name and orderer.

8.1.8 The system must be able to access detail transaction files from a header screen as well as accessing other related data bases from the work order screen.

8.1.9 The system must include the ability to add projects by cloning other work orders (including archived records).

8.1.10 The system must include the ability to process change orders against a project while maintaining the original request data for historical and audit purposes.

8.1.11 The ability should exist to automatically alter the status of a project based on the calendar as well as activity transactions.

8.1.12 The ability should exist to distribute work orders electronically as well as allowing users/customers the ability to print work orders at their own location.

8.1.13 The ability must exist to have work orders automatically issued and/or printed at a designated lead time prior to the actual date due.

8.1.14 Status and management reports should be automatically generated in predetermined situations such as "no action in xx days" based on control parameters.

8.1.15 The ability must exist to maintain both charge and no-charge activity against a project and change no-charge activity to charge basis depending on job status.

8.1.16 The ability should exist to automatically batch work orders or trouble reports for assignment.

8.1.17 The system should have the ability to interface with the paging system for purposes of issuing assignments.

8.1.18 The customer will be automatically notified via E-Mail when the service

request is received, a job number is assigned and when the project is complete or other significant changes in the status or composition of the project occur.

8.1.19 The customer will be able to access the system via the web for submitting project requests as well as following the status of their existing project(s).

8.1.20 The system should have ability to interface with a Property database to provide building location information as well as to flag the property database that alterations have occurred.

8.1.21 The system should have the ability to access a CADD system for purposes of part and building drawing images.

8.1.22 The system should provide the ability to use WordPerfect or Microsoft Word templates or custom templates created by the users.

8.1.23 The system should allow the use of Engineered Performance Standards and Preventative Maintenance Standards in scheduling PM assignments as well as allowing the standards to be modified to reflect MSU standards and experience.

8.1.24 The system should provide the ability to copy a PM task from one piece of equipment to another.

8.1.25 The PM system must allow for assigning frequencies on a variety of bases including yearly, seasonal, monthly, mileage, meter readings, etc.

8.1.26 The PM system should automatically prioritize frequencies to avoid multiple frequency assignments to be issued at the same time.

8.1.27 The PM system should keep track of warranties on equipment as well as a history of PM activity on the particular item.

8.1.28 The system should allow the integration of the PM function with the inventory function to allow material lists to be automatically generated and facilitate

costing of the work,

8.1.29 The system should provide for multiple account distributions, utilizing both percentage and amount splits as well as prioritization of cost assignment.

8.1.30 The system should allow for assigning costs based on the crafts performing on the project and should be able to differentiate between labor, supplies, and service expenditures for purpose of account assignment.

8.1.31 The system should allow for the application of multiple markups at differing rates based on the type of charge, trade performing the work or the customer being charged.

8.1.32 The system should allow for check-sum editing on the project number.

8.1.33 The ability should exist to establish a work order but have it issued at a future date.

## 8.2 ESTIMATING

The system should provide an estimating function integrated with the Work Management function to provide estimating and design personnel with tools to facilitate the project estimating process.

8.2.1 The estimating process must make use of line-item estimating catalogs including facilities cost data from R. S. Means, Engineered Performance Standards (EPS) in addition to standards provided by MSU.

8.2.2 The system must allow a project to be estimated with line items from different cost standards in the same estimate.

8.2.3 Unit prices in the standards must be localized to the MSU area rather than a generic national average.

8.2.4 The system must include contractor/project management functions to allow comparison of estimates vs actual cost and performance dates as well as tracking contractor payments based on job completion stages.

## 8.3 SCHEDULING

8.3.1 The system should provide the ability to interactively schedule work assignments.

8.3.2 The system should include the ability to establish multiple criteria for job scheduling including due date, access schedule for facility, priority, batching of assignments, etc.

8.3.3 The system should provide on-line craft loading reports including commitments and availability.

8.3.4 On-line job schedule reports should be available to managers with the ability to modify to accommodate labor and/or material availability.

8.3.5 Historical craft loading data should be available to aid in staff analysis and project estimating for contract volume.

8.4 MATERIALS MANAGEMENT

The Materials Management function must facilitate effective and timely procurement and management of materials for Physical Plant functions. The primary components of this function are purchase order development and tracking and inventory control and management. These functions must also be an integral part of the Work Order Management function.

Purchase Order Development and Tracking must provide the ability to enter and retrieve requisition and purchase order information, monitor and track expenditures and commitments on-line. The Inventory Control function will monitor and help manage the parts in stock.

8.4.1 Requisitioning: the system must provide the ability to enter requisition information for purchasing on-line and to create an active order record directly from that requisition information.

8.4.1.1 The system must have the ability to generate a unique requisition number with a variety of prefixes for each new requisition added.

8.4.1.2 The system must have the ability to enter a requisition number based on information received from the Michigan State University Purchasing/Stores Department system.

8.4.1.3 The system must have the ability for updating through down-load of purchase order data from the Michigan State University Purchasing/Stores Department system.

8.4.1.4 The ability must exist to enter and track information about items on orders by item.

8.4.1.5 Receipts when posted to the line item must decrement the amount outstanding, update the inventory and/or project data and generate the appropriate billing records.

8.4.1.6 The system must maintain full receipt detail for each line item.

8.4.1.7 The system must be able to track, flag exceptions and create exception reports or E-mail notifications to appropriate persons.

8.4.1.8 The system must generate a commitment record against the relevant project or an outstanding order posting for the inventory.

8.4.1.9 The system must allow access by a variety of keys including requisition number and purchase order number.

8.4.1.10 In addition to direct input descriptions must allow cut and paste from word processors or previous orders or retrieval from the inventory based on part number.

8.4.1.11 The system must provide screens customized to the type of purchase transaction (purchase order, Stores open order, General Stores stock, Purchasing Card, Campus sub-contractors)

8.4.1.12 The system must allow for negative and zero prices.

8.4.1.13 The system should allow for identification of and processing of material returns and/or exchanges.

8.4.1.14 The system must compute a total order price based on accumulation of line item amounts.

8.4.1.15 The system should generate E-mail notification of material receipts to the orderers.

8.4.1.16 The system should automatically generate exception reports on conditions such as overdue shipments or significant price variations.

8.4.1.17 The system must allow scheduled arrival dates to vary by item.

8.4.1.18 The system must be able to record item "complete and waiting for invoice" in the case of a non-material order and not create a billing or modification to project commitments.

8.4.1.19 The system should provide a mechanism for renumbering line items.

8.4.1.20 The system must provide for splitting each line item between multiple project numbers.

8.4.1.21 A cloning function must be provided to facilitate using a previous order as a template for a new order.

8.4.1.22 The system should provide the capability of keeping notes relative to the order and also notes relative to the supplier.

8.4.2 Open Order Purchase Orders: the system must have a reference master file in which authorizations for releases against open order purchase orders can be checked and status information maintained and updated.

8.4.2.1 The reference file must be easily and quickly accessible from the purchase order function via screen lookups or pull-down lists to check status and authorizations.

8.4.2.2 Remaining open order budgets will be updated real-time based on new releases and posting of vendor shipments and updated invoices.

8.4.2.3 The system will create reminder messages when the available budget is getting low or the order is nearing expiration.

8.4.2.4 The system will produce exception reports based on user defined criteria regarding outstanding releases.

8.4.2.5 The system will reference the work order module to identify whether a valid project number is being committed.

8.4.2.6 The system should automatically generate a release number unique to the particular vendor and/or trade.

8.4.3 Contracts and Contractors Orders: the system should provide a module to manage major construction project contracts, contractors and sub-contractors. It should allow for recording of appropriate insurance, waiver, affidavits and other bid documents.

8.4.3.1 This module should interface with the service request and work order management functions for tracking estimate and expenditure data.

8.4.3.2 It should interface with the key module to track contractor issued keys.

8.4.3.3 The module should record bid information and track change orders.

8.4.3.4 The module should provide a means of tracking contractor's performance for the purpose of reviewing and approving contractor invoices.

8.4.3.5 The module should track expenditures by contract phase and identify project status.

8.4.4 Vendor Directory: the system must have a directory master file in which vendor ordering and vendor performance information can be maintained and referenced.

8.4.4.1 The vendor directory must be accessible from both the inventory and purchase order functions.

8.4.4.2 The vendor record must be accessible by multiple keys.

8.4.4.3 Vendor performance and volume information should be updated automatically from the material ordering functions.

8.4.4.4 The vendor records will have a unique alphanumeric mnemonic primary key.

8.4.5 Material Returns: the system must provide a means of managing material returns whether to a campus vendor, off-campus vendor or to our own inventory from a project. The system should allow for full identification of the item through either copying original order information or as an unidentifiable source. It should record reason for the return, replacement value of the items, and provide a means of tracking the item until a refund or replacement is received. The system must allow for updating project or inventory data through an interface with the appropriate module in order to maintain a full audit trail of the item.

8.4.6 Inventory Control: the ability must exist to maintain a perpetual inventory which records disbursements from sales transactions and replenishments of stock through the various material ordering functions. The system must be fully integrated with the Work Management and Purchasing functions.

8.4.6.1 The system must provide for an alphanumeric part number and should provide the ability for checksum editing.

8.4.6.2 Reorder points must be maintainable based on economic order quantity, maximum stock quantity, or reorder quantity.

8.4.6.3 The system must support multiple locations in multiple warehouses and track activity for each location (on-order, committed, on-hand).

8.4.6.4 A monthly item summary must be available for a minimum of 36 months.

8.4.6.5 The system should maintain a parts catalog with a history of transactions for non-inventory items for purpose of analyzing items for stock.

8.4.6.6 The system should be able to flag possible shelf life problems based on item movement.

8.4.6.7 The system should calculate and maintain an average order lead time based on shipments from particular vendors.

8.4.6.8 The system must have the ability to calculate item average price by weighted average of quantity on hand plus new purchases. The system should also have the ability to use other methods should it become necessary.

8.4.6.9 The system should also have the ability to include in average price calculation a factor for item specific costs such as scrap allowance or shelf life. There should also be provisions for markup rates unique to a particular item.

8.4.6.10 The system should maintain the most recent purchase price as well as average billable cost.

8.4.6.11 The system should allow for identification of preferred and multiple alternate suppliers.

8.4.6.12 The system must provide ability for manual adjustments to the inventory.

8.4.6.13 The system should automatically generate reorder reports and exception reports based on problems such as low stock and out-of-stock.

8.4.6.14 The system should allow quantity on hand including commitments to be negative and should create a message identifying the condition.

8.4.6.15 The system must allow item descriptions to be multiple line.

8.4.6.16 The system should be capable of generating a list of stock items added and/or deleted from the stock master within the fiscal year.

8.4.6.17 The system should support cycle counting of stock.

8.5 TOOL AND EQUIPMENT MANAGEMENT

The system should provide a module(s) to manage centrally controlled tools and major equipment.

8.5.1 An equipment inventory record will be provided including tool/equip id, description, location, purchase data and replacement value.

8.5.2 A checkout system will be provided including issued to/by/date in/date out as well as condition out and in.

8.5.3 The system will maintain expense records and usage data for each piece of equipment for purposes of determining billing rates and projected replacement budgets.

8.5.4 The system will generate billings based on either usage (days, hours, etc.) or negotiated rates.

8.5.5 The system will provide for damage deposit/charge and replacement billing.

8.5.6 The system will monitor warranties relative to required repair or replacement.

8.6 VEHICLE MANAGEMENT

The system should provide a module to maintain inventory data about vehicle fleets including descriptive data, ownership, registration, preventive maintenance standards, etc.

8.6.1 The system should allow for recording of inspection records and repair and mileage data through interface with the billing system.

8.6.2 The system should provide for generation of maintenance reminders.

8.6.3 The system should automatically update PM data based on maintenance

billings.

8.6.4 The system should provide analytical reports to evaluate profitability of vehicles and replacement projections.

8.6.5 The system will monitor warranties relative to required contractual service through usage and mileage data.

8.6.6 Vehicle PM should interface with inventory to identify availability of required materials and identify suppliers when needed.

8.6.7 The system should identify vehicle assignment and type and length of assignment.

## 8.7 KEY AND LOCK MANAGEMENT

The system should have a module to provide for key, lock and hardware management including key description, cut code, building/room identification, checkout, billing and inventory.

8.7.1 The module should interface with the inventory module to provide a complete key and hardware stock parts inventory.

8.7.2 The module should interface with an authorization file to determine who may request and receive keys.

8.7.3 The module should provide the ability to identify unused series and cut codes on-line.

8.7.4 The module should interface with the work order module as well as billing to record key assignments and generate billings.

8.7.5 The module should provide the ability for markups and standard delivery charge billings.

8.7.6 The module should provide on-line inquiry on name/location/key id.

8.7.7 The module should interface with our CADD system for physical building locations and document updating.

8.8 FINANCIAL

The system should provide a module for billing of labor, materials, service and equipment and maintains current actual and budget balance for each account and project.

8.8.1 The module should provide cost accounting by project, cost center and location.

8.8.2 The module should be able to generate charges by project and distribute project charges to multiple accounts according to criteria assigned to the project header.

8.8.3 The module should be able to identify and track costs by subprojects or project phases within an overall project header.

8.8.4 The module should provide mechanisms that enable transactions to be electronically interfaced to other University systems.

8.8.5 The module should provide for accumulating non-billable charges that may be later changed to billable as well as for evaluating total project expenses.

8.8.6 The module should have the ability to distribute individual overhead expenses based on a variety of markups or based on the distribution of direct expenses, i.e., distribute supervision based on what supervisor's employees charge to, distribute uniform costs based on employee, distribute supply charges based on volume of labor charges, etc.

8.8.7 The module should have the ability to create an invoice to an outside agency at time of completion of project.

8.8.8 The module should be able to interface with related labor and supply transaction processing systems to accumulate project expenses and billing records.

8.9 PROPERTY MANAGEMENT

The system should provide a module to create and maintain a detailed database of campus properties which interfaces with the other facilities management modules as well as CADD.

Information maintained should include name, number, location, area, volume, cost, year built, use, utilities, architect, alteration history, etc.

8.9.1 The module should provide replacement value costing based on selected cost indices.

8.9.2 Reports should be available to identify construction history, utility load, air conditioning volume and capacity.

8.9.3 It should be able to do age analysis by construction phases.

8.9.4 The module should provide the ability to build up a record from a variety of locations over time beginning with original proposal to the point of occupancy.

8.9.5 The module should provide projections of new space and funding requirements.

8.9.6 The module should be able to identify changes to the data base on request for publication and budget reporting purposes.

8.9.7 The module should interface with CADD to provide detailed area and volume during construction as well as for alteration and maintenance project estimating. This interface would also provide for detailed drawings of building areas being studied.

8.9.8 The module should interface with the work management function to provide both an indication of possible data base updates as well as providing for an analysis of work history in the facility.

## Appendix B

## Survey of 94 University and College Physical Plant Officers

Hello, My name is Bill Whitbeck. I am a graduate student at Michigan State University in Building Construction Management, My focus is on information systems in project management. Have you or your organization used any formal information system (IE software) for project management. Specifically for scheduling, estimating and contract administration. Any input would be appreciated. Thanks.

## Appendix C

### Survey of five Universities

# INTRODUCTION TO PROJECT

Many building and land owners and administrators (Universities, State and Federal agencies and other similar organizations) have facilities departments that administer, manage and inspect construction projects. These departments are crucial to the success of any construction project. The flow of information through these departments is a large part of a construction project. Financial approval is generally considered a function of the owner and the architect and or engineer, because of this, information flow affects project funding, financing and payment. There is considerable need for an effective and efficient flow of information within any project. Information is a valuable resource to any business enterprise. Effective management of information has become important for all business enterprises.

This project will consist of research of existing methods of information management, development of an effective method for information management, based on this research and finally application of this method to past projects.

The objective of this project is to provide owner's facilities departments with a proper and effective method of managing information flow in construction projects.

## CONSENT

As a part of this project you are being asked to participate in a survey and interview regarding the information management processes of your organization. Additional conversation may take place, at your discretion, regarding your survey response.. The purpose of this information is to deduce practices which lead to the relative success or failure of the projects in order to develop the most effective method of information management.

It is estimated that this survey will take approximately 30 minutes to complete. It is estimated that project record retrieval would take an additional 30 minutes.

Your decision to participate in the project is entirely at your discretion. You may refuse or discontinue involvement at any time without any penalty real or otherwise.

All findings and results will be held in strict confidence and subjects will remain anonymous in any report of findings.

You indicate your voluntary agreement to participate by completing and returning this questionnaire.

## CONTACT

For questions regarding this survey:

BILL WHITBECK

MICHIGAN STATE UNIVERSITY

(517) 355-7466 PHONE

(517) 432-2077 FAX

WHITBEC2@PILOT.MSU.EDU EMAIL

For questions regarding participants rights:

UCRIHS CHAIR

DAVID E. WRIGHT

(517) 355-2180 PHONE

SURVEY QUESTIONS

1)Please provide the following background information.

Is your University public or private

How many students are enrolled currently +/- 1,000

Provide any other descriptive information.

2) How many projects does your organization build annually?

3) What is the total dollar volume of the projects built by your organization annually?

A)What percentage (dollar volume) of these projects are new construction and what percent is renovation or remodeling?

*These questions relate to the steps undertaken in the project management process in your organization. Example; after receipt of the initial work order what happens to this piece of information, is this step or process documented? Is it the same for each project? Is there a standard form for this step?*

4) Does your organization have a documented method for project management?

5) Does your organization have a standard method of managing projects?

6) Does your organization have standard forms for this process?

7) Are these forms and methods used for every project?

8) Can you briefly outline this process?

9) Does your organization develop estimates or does it record and monitor estimates developed by others?

10) Does your organization develop project schedules or does it track project schedules developed by others?

    A) Is resource leveling used as a scheduling function?

    B) Is cost management used as a part of scheduling software?

11) Does your organization store past project information? Is this information used to plan new projects? Are these functions performed electronically?

12) How does your organization store, retrieve and track submittals? (Electronically or manually)

13) How does your organization store and retrieve information necessary to make decisions on contractor payments? Is there a need for a technology solution in this area?

14) Has your organization considered or implemented internet technology to allow contractors and other parties to the project access to project information?

15) Does your organization perform design services or are designs completed by firms outside of your organization? Or are both systems in use?

16) Would it be useful to have an integrated project management process that

electronically linked all of the functions mentioned in this survey?

## Appendix D

## Data Dictionary

**<u>Processes</u>-** Processes are represented in the data flow diagram by circles. Processes are those functions and tasks which respond to the needs generated by the event list. Processes are explained further in Chapter three of this paper.

**Approve Budget-**This represents the approval of the tentative budget, by the client.

**Approve Design-**This represents the approval of the design, by the client.

**Architectural design-** That portion of the design consisting of demolition plans, architectural plans, electrical plans, mechanical plans and other technical plans.

**Budget-** This process represents the compilation of the estimates from various sources into a complete budget estimate of the project cost.

**Charge back-**This is the process of preparing the charge back to the client account for the total cost of the project. Includes overhead and other additional project costs.

**Client service request-** This process represents the receipt, log and unique, non redundant numbering of the request for service.

**Closeout review-**This is the process of producing the past project records and reviewing the project after completion to provide input for future projects.

**Design-** This process represents the sub processes necessary to produce the construction drawings and specifications.

**Document filing-**This is the process of producing the past project records.

**Facilities construction system-** This process represents the entire construction management process for the organization in question. This process consists of all of the sub processes that respond to the needs as generated by the event list.

**Final Approval**-This is the process of obtaining and producing the final approval for the project.

**Interior design-** That portion of the design process consisting of finish selections and typical interior design elements.

**Notice to proceed**-This is the generation of the notice to proceed.

**Outside design-**This represents the process of transmitting the design requirements to an outside firm, receiving the outside design and reviewing it.

**Payment approval-**This is the process of approving the contractor or supplier request for payment.

**Procurement summary**-This is the process of compiling the contractor's plan and background information for use by the client and the project management team.

**Produce budget-** This is the process of producing and gaining approval for the project budget.

**Produce design**-This is the process of producing and gaining approval for the design.

**Project administration-** This is the process of preparing the final bid documents and managing the administration of the bid process.

**Project management-** This process represents the monitoring , control and record keeping processes thru out the construction of the project.

**Project reporting**-This is the process of generating the project notes, collecting

and distributing the cost records.

**Project review-**This is the process of compiling the contractor review, the final review and other information. This process produces the review docs.

**Start up-** This is the process of notifying the contractor to begin work, distributing the client pack and recording the contractor plan.

**Record plan**- This is the process of recording the contractor plan.

**Information flow**- Represented in the data flow diagram by a vector with the arrow in direction of the flow of the particular information specified.

**Approved invoice-** This data flow is the contractors request for payment, after it has been approved for payment by the appropriate owners staff.

**Approved budget-**This is the final approval of the project budget, prior to procurement.

**Architectural design-**This data flow consists of that portion of the design consisting of demolition plans, architectural plans, electrical plans, mechanical plans and other technical plans.

**Bids-**This is the bid, as submitted by the contractor, to build the project. This information flow is outside of the proposed system. It is modeled in order to show the relationship between administration, the contractor and the proposed system.

**Bid Approval-**Formal acceptance of the successful bidder for the project.

**Bid docs-**The contract documents together with account numbers and authorizations to release for bidding.

**Bid information-**This is the list of all bidders and the associated information such

as pricing and other information requested as a part of the bid package. Includes apparent successful bidder, submitted for approval.

**Bid rejection-**Rejection of the apparent or proposed bidder. Usually requires some form of documentation of reason for rejection.

**Client pack-**The set of information, pulled from the plan that is released to the client.

**Codes and regs-** This data flow represents building codes and regulatory information necessary to complete the design of the project.

**Con Docs-**This information includes the following data items. Design, specifications and other typical contract documents. This is the final complete design. In the change order process, this item would include bulletins and other information. This item includes quotations, change order pricing and other cost estimates.

**Contractor-**This is the name and background information on the contractor(s) building the project.

**Contractor Review-**Post project contractor, sub contractor and supplier input.

**Contract design-**This represents the design of an outside architectural firm.

**Contract estimate-**This represents the estimate developed by an outside firm.

**Contractor Work Plan-**This consists of the following information, the schedule (as developed by the contractor), the schedule of values, a list of sub contractors and any other information required by the bid package.

**Cost Info-**This is the information from out side references, used to produce the estimate.

**Cost records-**This is the record of all costs from any given project, to date.

**Design approval**-This data flow is the clients affirmative approval of the proposed project design.

**Final approval**-The complete and final, authorized approval for the project.

**Final input**- The final client input into the project.

**Final review**- The post project, client input.

**Interior design**- This data flow is that portion of the design consisting of finish selections and typical interior design elements.

**Notice to proceed**-Formal notice to the contractor to commence construction.

**Numbered service request**- This data flow is the request for service with a unique, non redundant identifier.

**Past project records**- These records are all project records, arranged for storage and retrieval for future use.

**Project notes**- This data flow consists of the documentation of the various and on going activities of the project. Consists of superintendent notes and project manager notes and documentation. Includes records.

**Records**- This data flow is the contractor and supplier project notes and other information, submitted to the owner. Subset of project notes.

**Rejected budget**- Information originating from the client, rejecting the tentative budget.

**Rejected design**-Information originating from the client, rejecting the design in progress.

**Request for estimate**-This is the request of the contractor to prepare an estimate,

based on the transmitted design.

**Request for payment**- The contractor's request for payment.

**Review docs**- The summary of the contractor review, final review and project management team input.

**Schematic design**- This data flow is the project design, including drawings and specifications, generated by the designer for client approval.

**Service Request-** This data flow is the clients initial request for service, includes the following data; building name, account number, date, project description, date and authorizing signature.

**Statements-**These are accounting statements providing summary activity of the ledger accounts, received from the administration.

**Tentative budget**- The budget, as proposed to the client, for approval.

**Terminators**- Represented in the data flow diagram by a rectangular box. These entities are outside of the scope of the model system.

**Administration-** This entity represents the department(s) responsible for producing payments, statements summarizing those payments, purchase orders and contracts.

**Arch Eng**-This entity is the outside architect and or engineer, producing the contract design.

**Client**- This is the entity requesting service of the representative facilities department.

# Appendix E

## Model Information System Data Flow Diagrams

## for levels below Zero level

Figure A.1

Sub Processes for Design Process

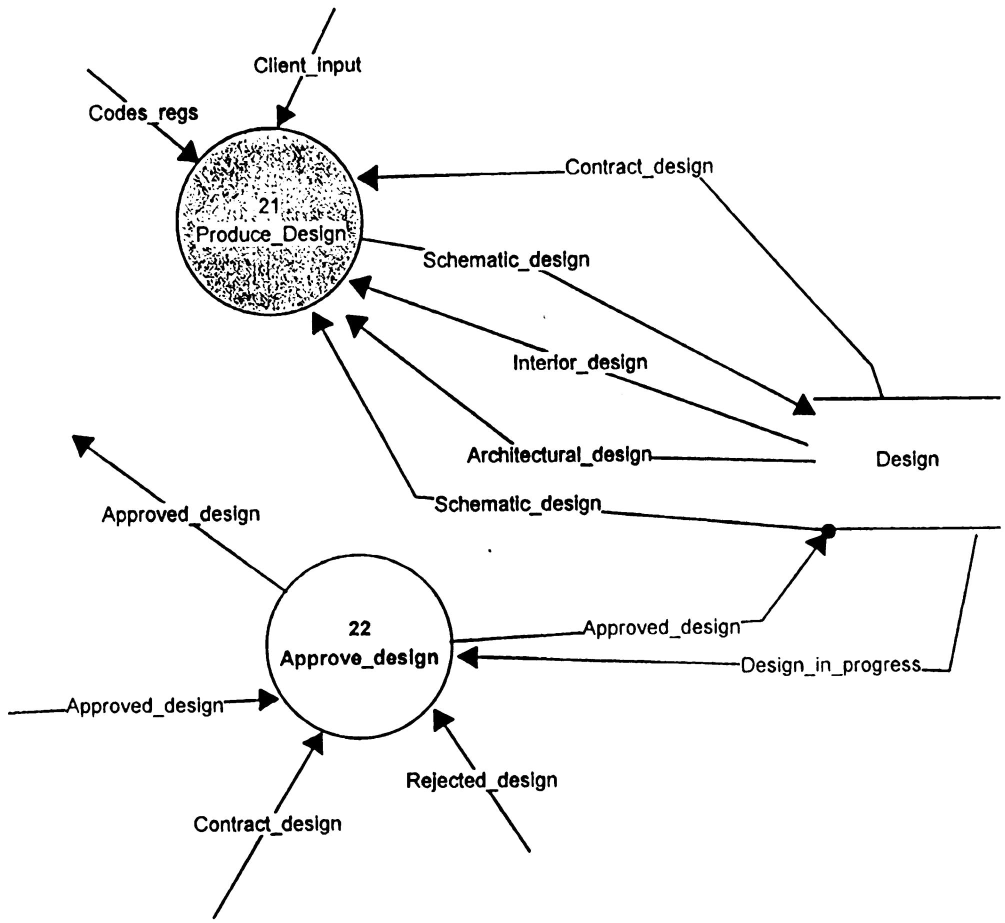


Figure A.2

Sub Processes for Produce Design Process

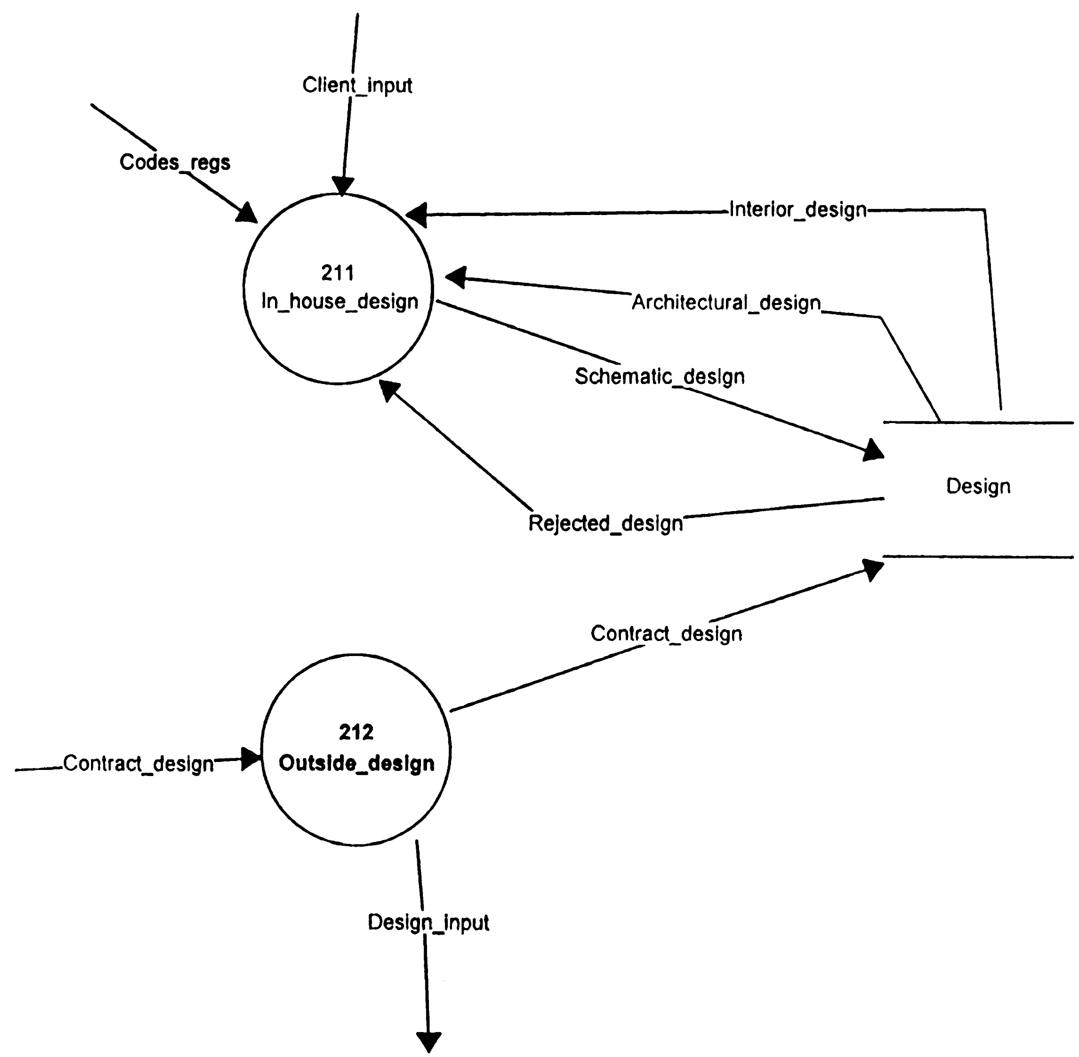


Figure A.3

Sub Processes for In House Design Process

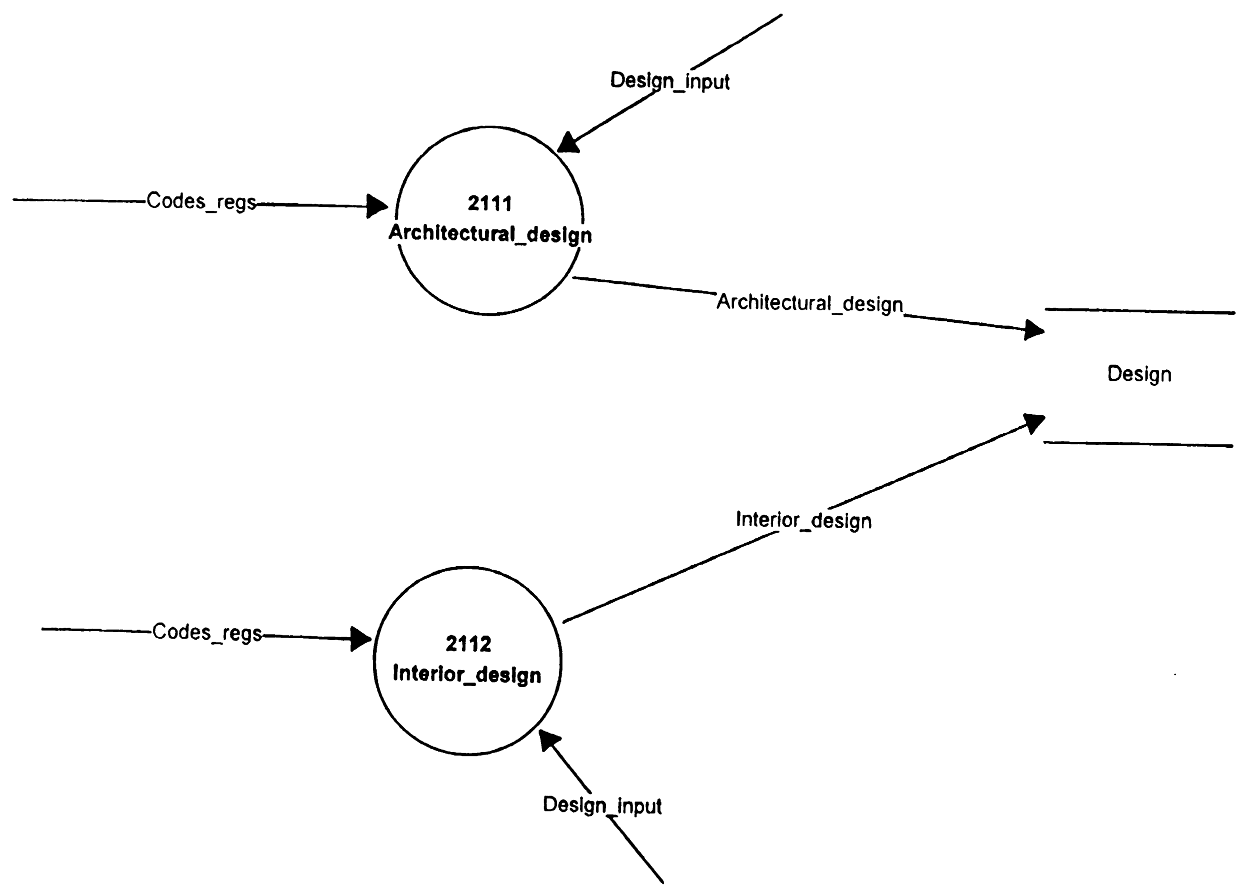


Figure A.4

Sub Processes for Budget Process

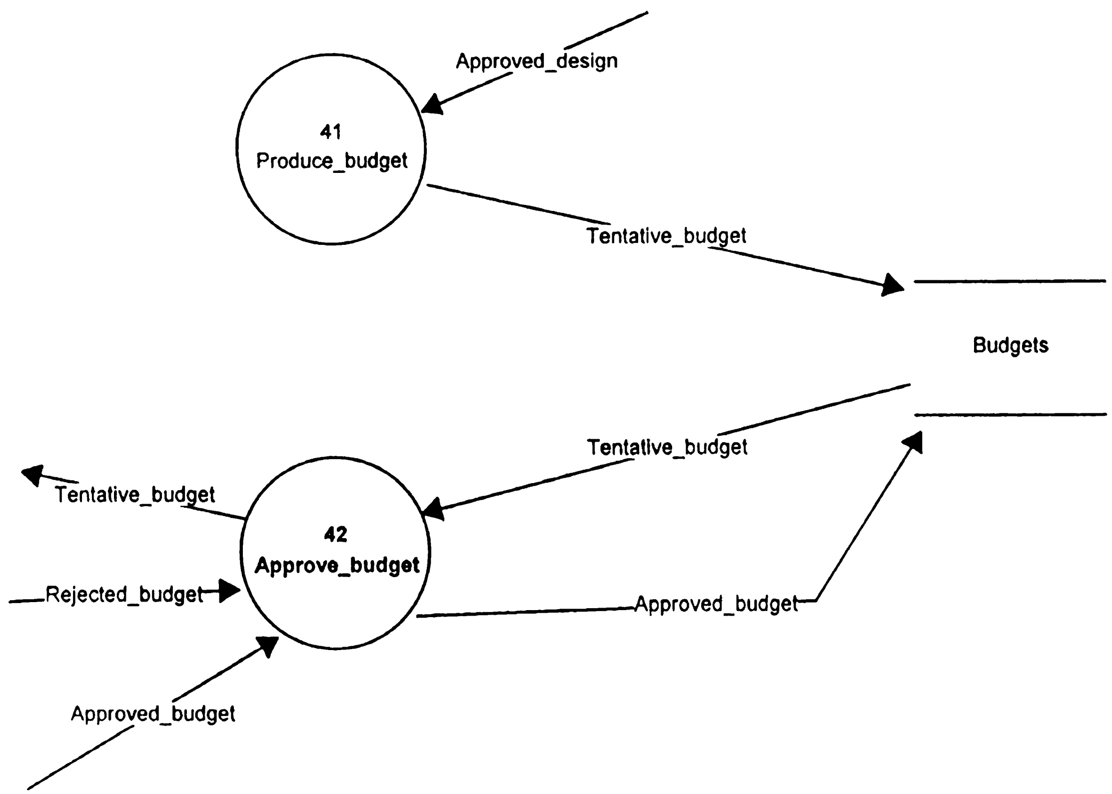


Figure A.5

Sub Processes for Produce Budget Process

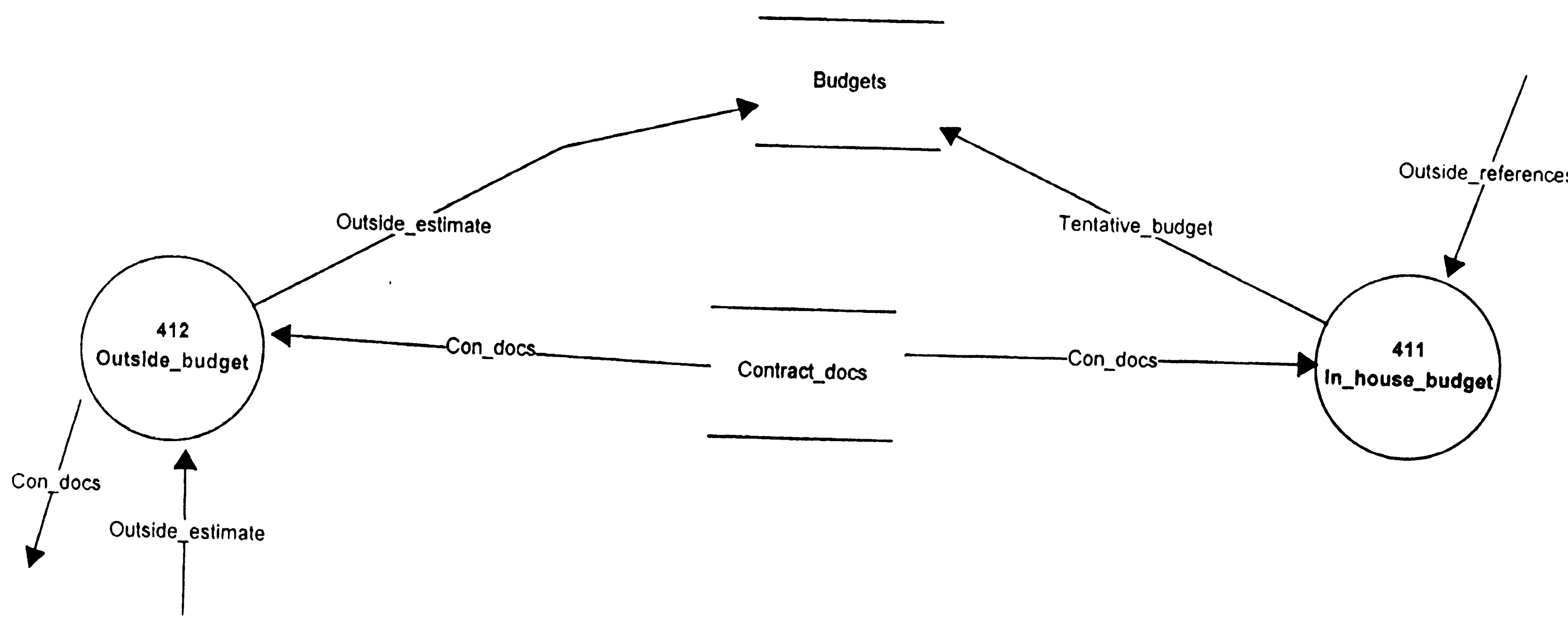


Figure A.6 Sub Processes for Start Up

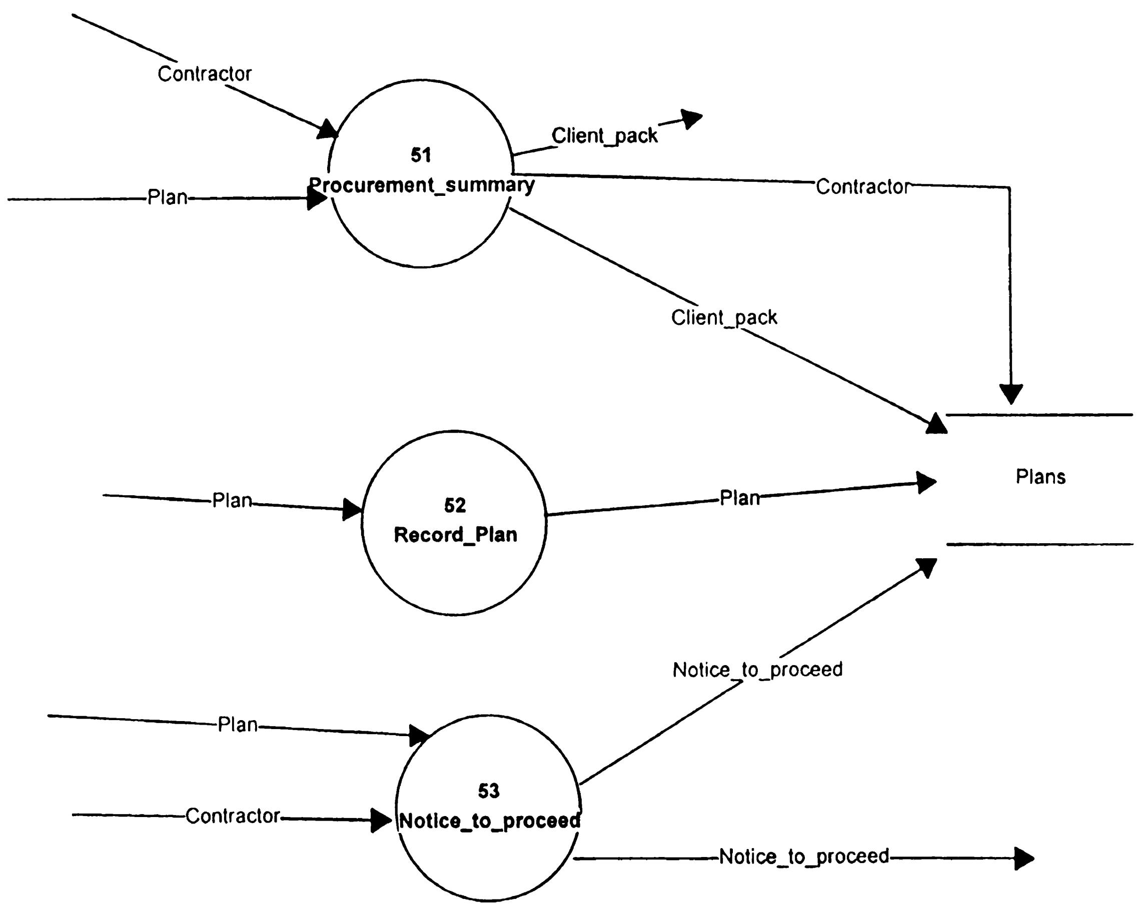


Figure A.7

Sub Processes for Project Management

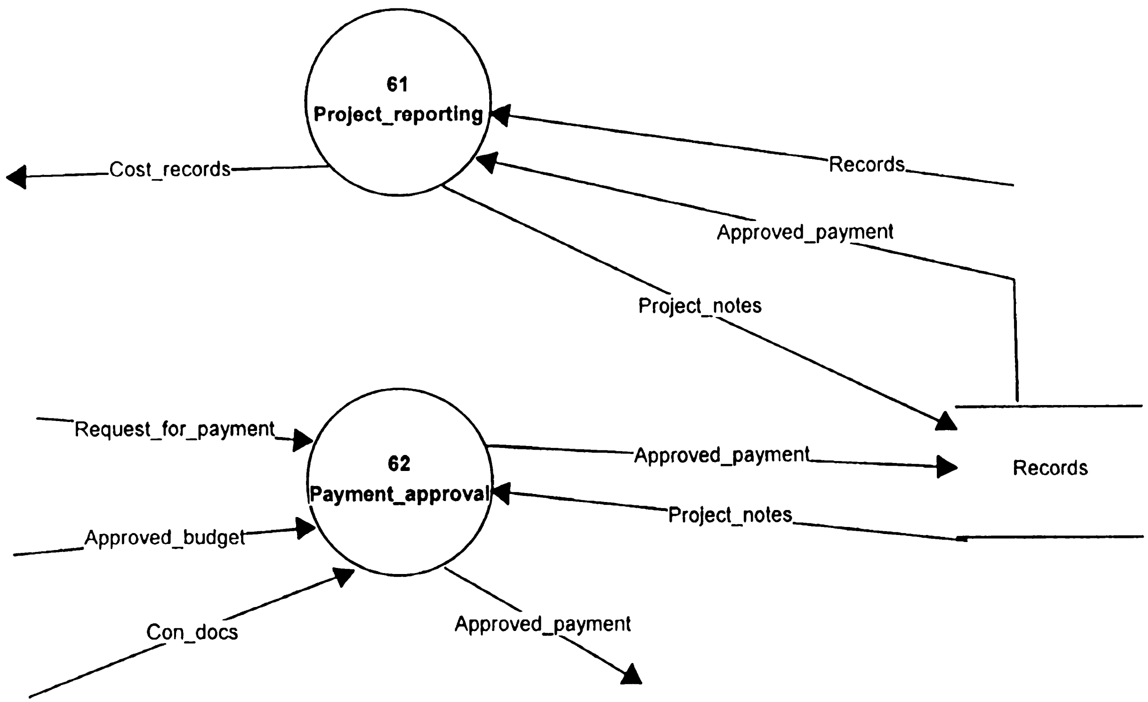
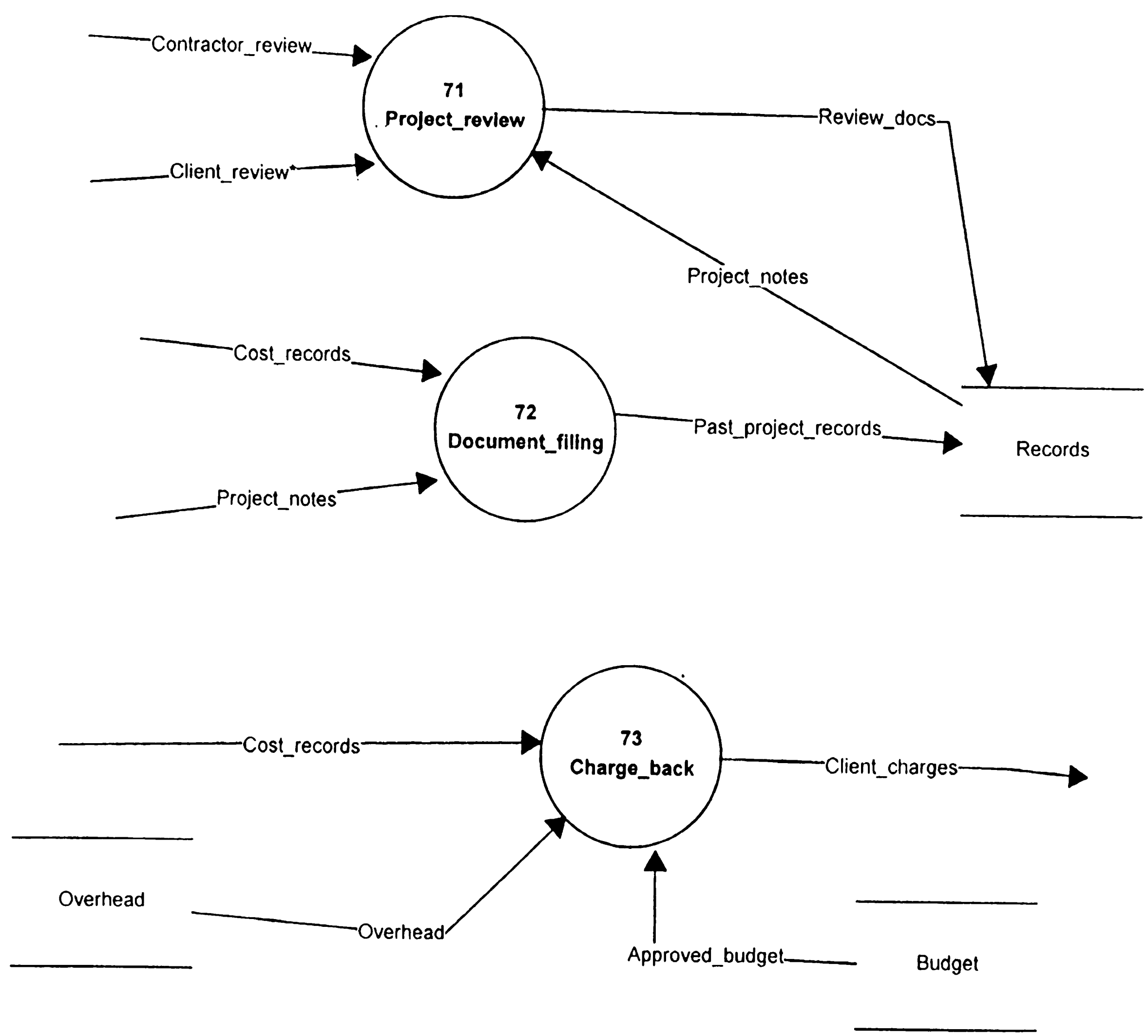


Figure A.8 Sub Processes for Closeout



# Appendix F

## Data Flow Diagrams for five

## Surveyed University Facility departments

Figure A.9

Data Flow Diagram for Michigan State University Department of Construction, Maintenance and Interior Design

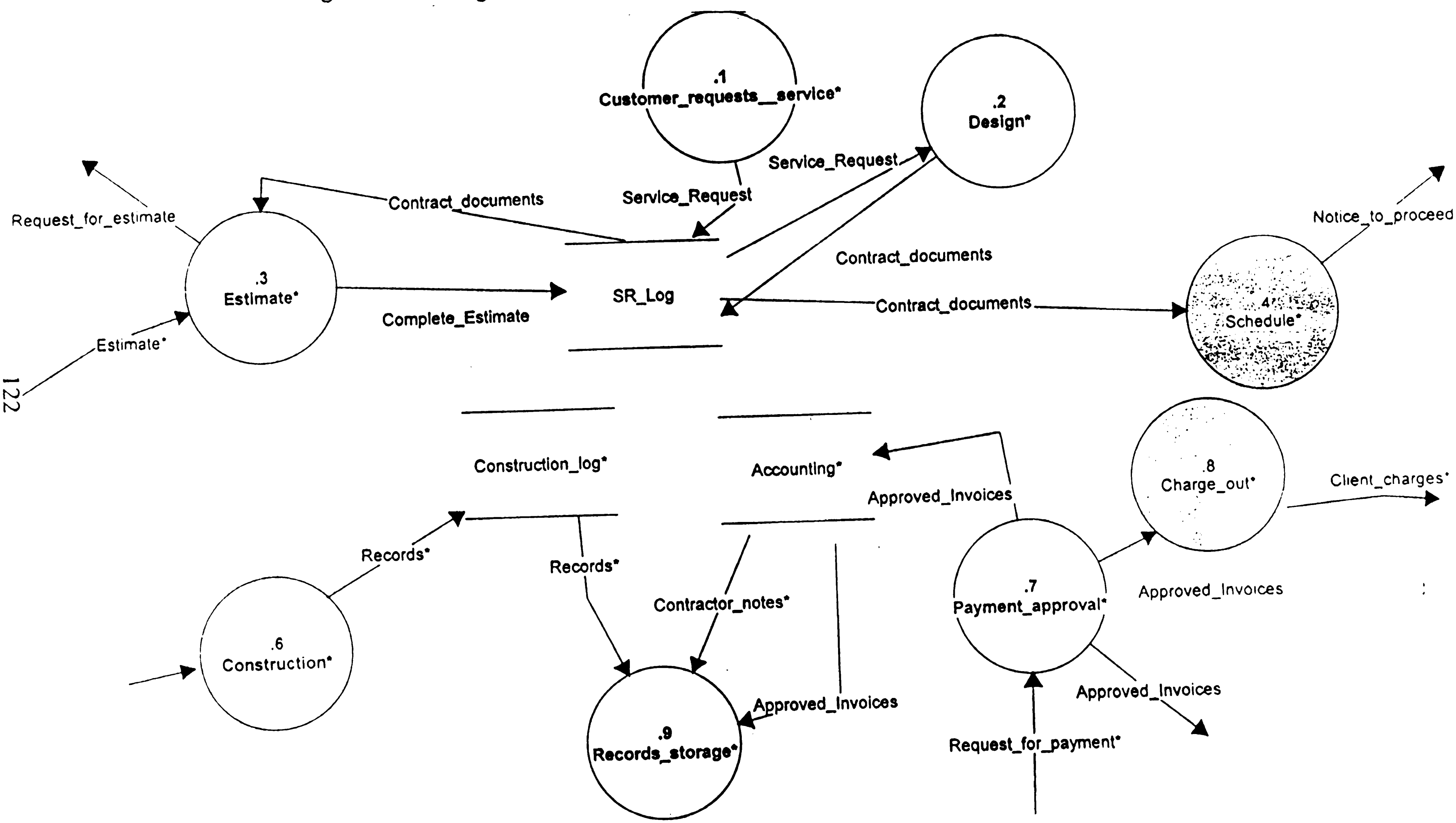


Figure A.10

Data Flow Diagram for Michigan State University Physical Plant Engineering and Architecture Services

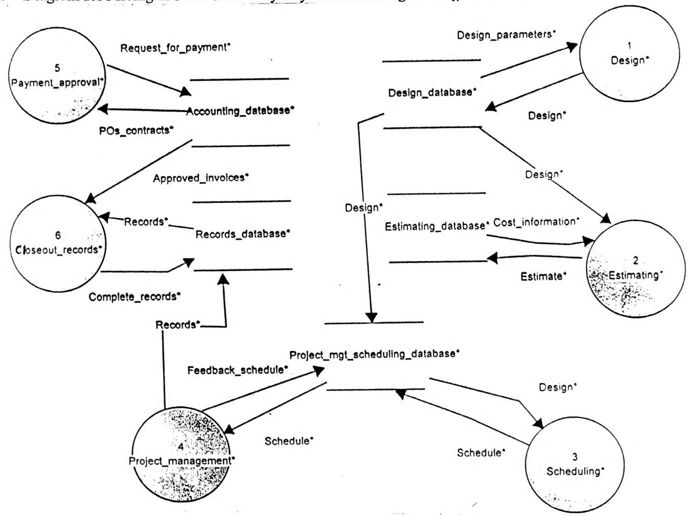


Figure A.11

Data Flow Diagram for Miami University Physical Facilities Department

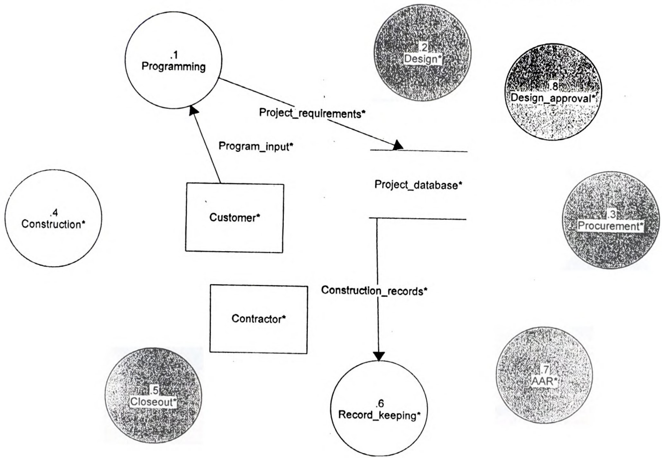


Figure A.12

Data Flow Diagram for University of Michigan Plant Operations Department

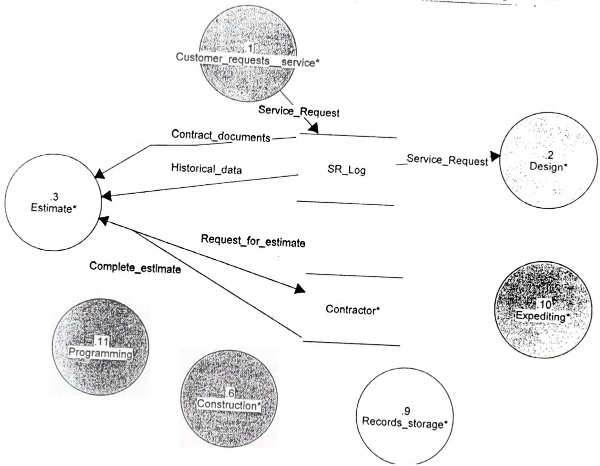
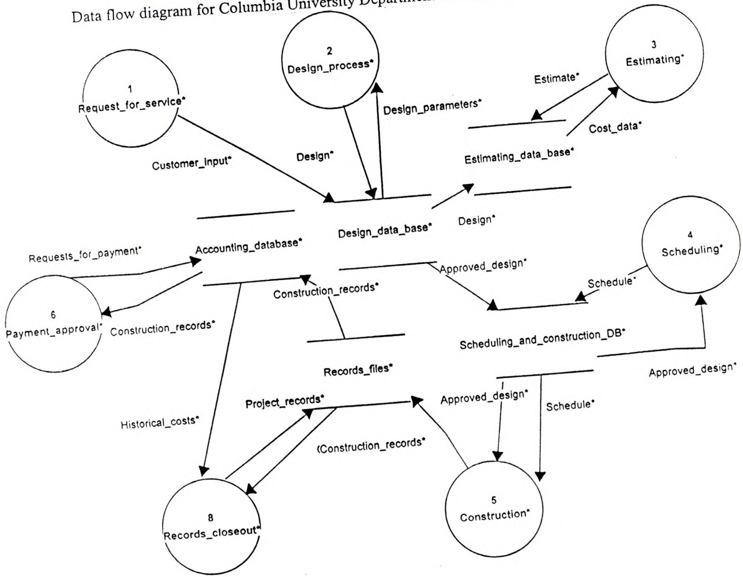


Figure A.13

Data flow diagram for Columbia University Department of Planning, Design and Construction



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