BARRIERS TO INTEGRATION OF TIME AND COST INFORMATION ACROSS ESTIMATING AND SCHEDULING DEPARTMENTS WITHIN CONSTRUCTION FIRMS

By

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ABSTRACT

BARRIERS TO INTEGRATION OF TIME AND COST INFORMATION ACROSS ESTIMATING AND SCHEDULING DEPARTMENTS WITHIN CONSTRUCTION FIRMS

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As the construction industry moves to use information technology as a part of its effort to improve efficiency, researchers, software vendors, and industry participants have examined approaches for integration of information. While, researchers have proposed integration models, few construction firms have used extensive integration systems. This project is focused on identifying barriers, which may discourage integration of information during the planning phase between estimating and scheduling departments in midsize commercial construction firms. As a part of the research, ten existing integration models were examined. The Appau model, which addressed some industry barriers, was selected and a data flow diagram was developed to illustrate the flow of information suggested by Appau. Twenty interviews of construction professionals were conducted, and along with the literature were used to identify industry perceptions of barriers. Finally, recommendations for overcoming barriers are made. Findings of the research indicated that varying contractual arrangements, a lack of analysis of business processes before adopting new technology, a lack of change management, and a lack of awareness of importance of integration were the most significant barriers to integration.

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LIST OF ABBREVIATIONS

AEC	Architect – Engineer – Contractor
CBS	Cost Breakdown Structure
CAD	Computer Aided Design
CIC	Computer Integrated Construction
CM	Construction Management
CSI	Construction Specification Institute
DFD	Data Flow Diagramming
E-R	Entity-Relationship
ERP	Enterprise Resource Planning
GC	General Contractor
IAI	International Alliance of Interoperability
IT	Information Technology
KB	Knowledge Base
LAN	Local Area Network
OOPS	Object Oriented Programming System
P3	Primavera Project Planner
REA	Resource Event Agent
SQL	Structured Query Language
TGIF	Timberline Gold Interface
WBS	Work Breakdown Structure
XML	Extensible Markup Language

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Many participants in the construction industry are convinced of the advantages of using information technology, but have not been fully successful in its implementation, due to a variety of reasons (Jagtap, 1998). The construction industry needs to consider managerial as well as technical issues when proposing and implementing information technology. Exciting new technologies are continuing to be developed but these advances may not be addressing some business practice issues. Change is always easier said than done; just being technologically enabled does not necessarily lead to changes in actual practice. In an article on the technology revolution published by Engineering News Record (ENR), it states, "We have very good CAD tools, very good cost estimating tools and very good scheduling tools. Now its time to go beyond each of those silos and use the data across disciplines." (ENR, 2001) The literature shows that there is growing interest in the construction industry for integration yet gaps in actual implementation. This research work is undertaken to explore possible barriers during the planning stage of the project, which in turn may limit computerized integration of time and cost information across scheduling and cost estimating departments during the project control phase, within small to mid size general contracting type construction firms.

1.1.1 COMPLEXITY IN CONSTRUCTION PROJECTS

Construction projects are intricate, time-consuming undertakings. Total development of a project normally consists of several phases requiring a diverse range of specialized services. (Clough & Sears, 1998) A journey from the planning phase to the close out phase requires input from various resources such as architects and designers, different

trade personnel, financial organizations, government agencies, lawyers, insurance agents, material manufacturers and suppliers. Furthermore, in the construction industry, no two projects are ever alike, which makes it even more complex to derive any particular pattern. Depending upon the contractual arrangement, each project has different components and participants. Project participants generate various project processes such as designing, estimating, scheduling, procurement, execution, close out, maintenance and so on during different phases of the project life cycle. Thus, to track such highly variable and unpredictable factors, and make use of them in future projects, it is important to track accurate time and cost data at any particular stage of the project. Effective tracking of data flowing through different construction processes can most efficiently be done through organized efforts such as project management and project controls. Project management systems should include estimating, scheduling and tracking (performance budget). (Spencer, 1987) Much of the information required by each of these processes is common to all of them, which offers the possibility of an organized system to integrate information flow between construction project and office functions.

1.1.2 CONSTRUCTION PROJECTS AND INTEGRATION

The construction industry is fragmented by nature. The design process is separated from the construction process and the essential involvement of designers, estimators and other construction professional exacerbates fragmentation. Integration can be defined as the creation of a common database accessed by multiple users with the ability to manipulate data for many applications. (Gould, 1995) In the past, researchers have used information technology (IT) for providing numerous decision support systems for professionals

involved in the industry. These systems have created "islands of automation" and are far from achieving an acceptable level of integration across the disciplines. (Faraj & Alshawi, 1999)

Software products are present in almost all aspects of the construction business – accounting, managing, estimating, scheduling, documentation, etc. What is missing is the ability to forego recreation of data as the project progresses. This missing link is the next phase of the information revolution within construction industry. (Abcede, V2N1) In general, construction projects rest on a tripod. Owners hold one corner, engineers and architects another, and contractors the third. All three track similar elements of the project in a different manner. (Faraj & Alshawi 1999) The next move in construction industry, i.e. integration of different application software at a higher level, will aid in minimizing this redundancy. The various benefits of integration include timesavings, cost savings and improved efficiencies. But integration also improves the quality of information. (Rakow, V3N9) An integrated project promotes teamwork and partnering and provides opportunities for estimating, scheduling and design throughout the life of a project. This research work has been undertaken to find out why such an important feature is still in its infancy in the construction industry.

1.1.3 INFORMATION TECHNOLOGY IN CONSTRUCTION

The construction industry has been slow in adopting and utilizing new technologies with negative consequences on productivity and innovation (Mitropoulos & Tatum, 1999). Though it may lag behind other industries in its rate of Information Technology (IT)

adoption, it is heavily information based, and IT offers great potential for improving management practices, communication, and overall productivity in the industry. IT is not a single technology but a wide range of technical approaches to a variety of problems (Froese, 1999). As mentioned earlier, the construction industry seems to be convinced of the advantages of using IT, but still lacks its successful implementation. (Jagtap, 1998). Industry needs to consider technical as well as managerial issues while implementing IT. Today there are several different software packages used in management of construction; it is also important that the software supports independent PCs as well as a network environment, which is important in being able to use that software in integrating different construction processes. Computer integration is occurring in a number of different forms throughout the industry. Present integration efforts between different application software are shown in Figure 1.1.

Many large corporations have been using computer-integrated construction on a mainframe computer system since the 1970's, such as Bechtel, Stone & Webster, etc. (Gould, 1995) A new era of PC's forced different departments to accept discrete pieces of application software, which further generated a need for integration. It is the author's belief that the need for integration is going to increase as time passes. In 1995, at the Associated Schools of Construction annual conference, one of the speakers said, "Every professional that was interviewed agreed that the potential of integration is enormous and that integration will occur in the future," (Gould, 1995). This was based on the series of interviews, that author carried out with industry professionals.

1.1.4 COST AND TIME INFORMATION FLOW IN CONSTRUCTION PROJECTS

Typically, in the construction industry, tracking costs and scheduling manpower have consisted of two separate processes. "Effective communication of the cost and schedule information between construction site management and its field supervision is a weakness common to most of the project control systems...there are countless instances of gross inefficiencies and impacts stemming from poor information flow to and from the field." (Kratt, 1989) This problem occurs at two levels, at the time of construction and in corporate historical data, which keeps a cycle of delays and over-expenditures continuing. The information flow originates during the planning phase and continues to the project controls phase. During controls, it gets updated and modified and changed as per the actual progress of the project. Figure 1.2 illustrates how information flows from the planning to the controls phase. Since the author assumes that company historical data is used during the planning phase of a construction project, the updated database, as explained in Figure 1.2, plays an important role in providing accurate information to planners.

"The approach of selecting contractors by the competitive bidding process in particular has created a large amount of interest in the ability to both quickly and accurately determine construction costs." (Spencer, 1987). This approach has made general contractors aware of the prime importance of accurate cost estimating in the bidding process. Further, an important factor in accurate implementation of the cost estimate is time, and general contractors are also implementing scheduling to maintain competitiveness in the market. What is missing here is tracking accurate and timely

information, moving back and forth between estimated cost and actual time. To achieve this connection between cost estimating and scheduling processes, it is necessary to integrate these processes first and then integrate the actual flow of information.

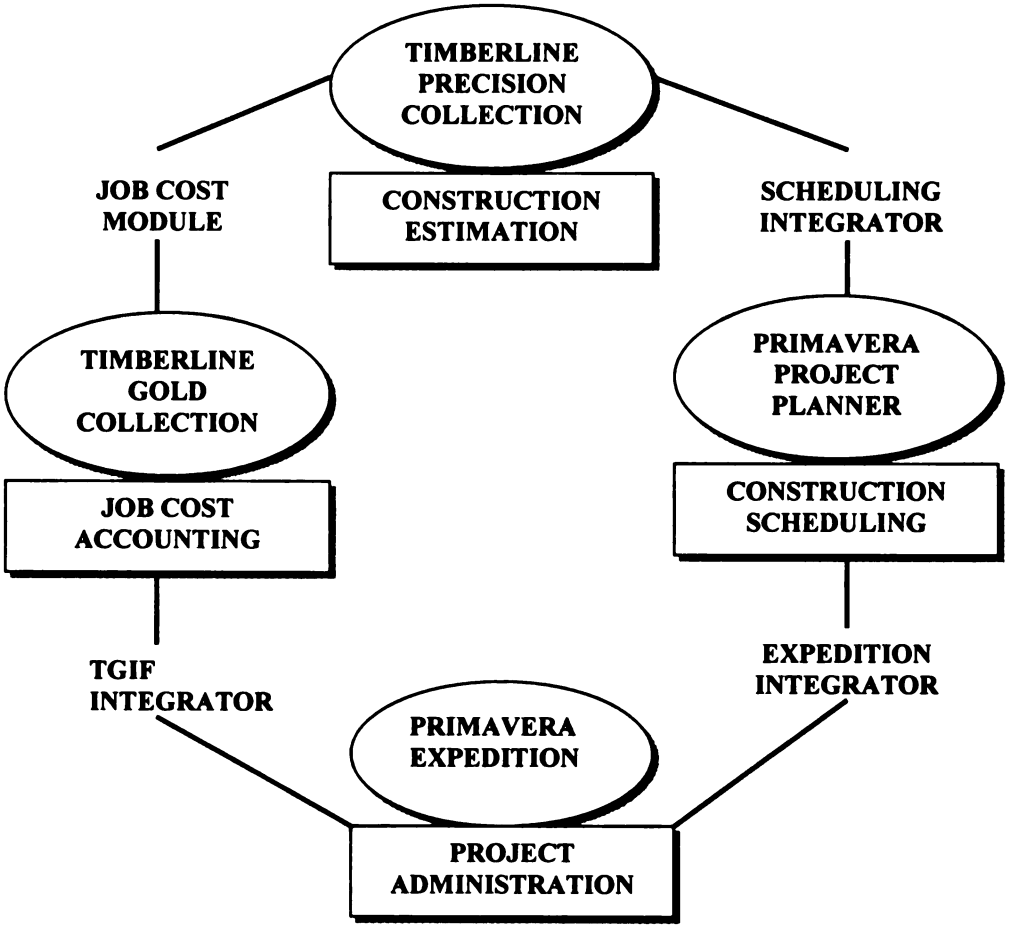

FIG. 1.1

CIRCLE OF INTEGRATION

(Source: Joshi, 2000, Fischer & Kunz, 1995)

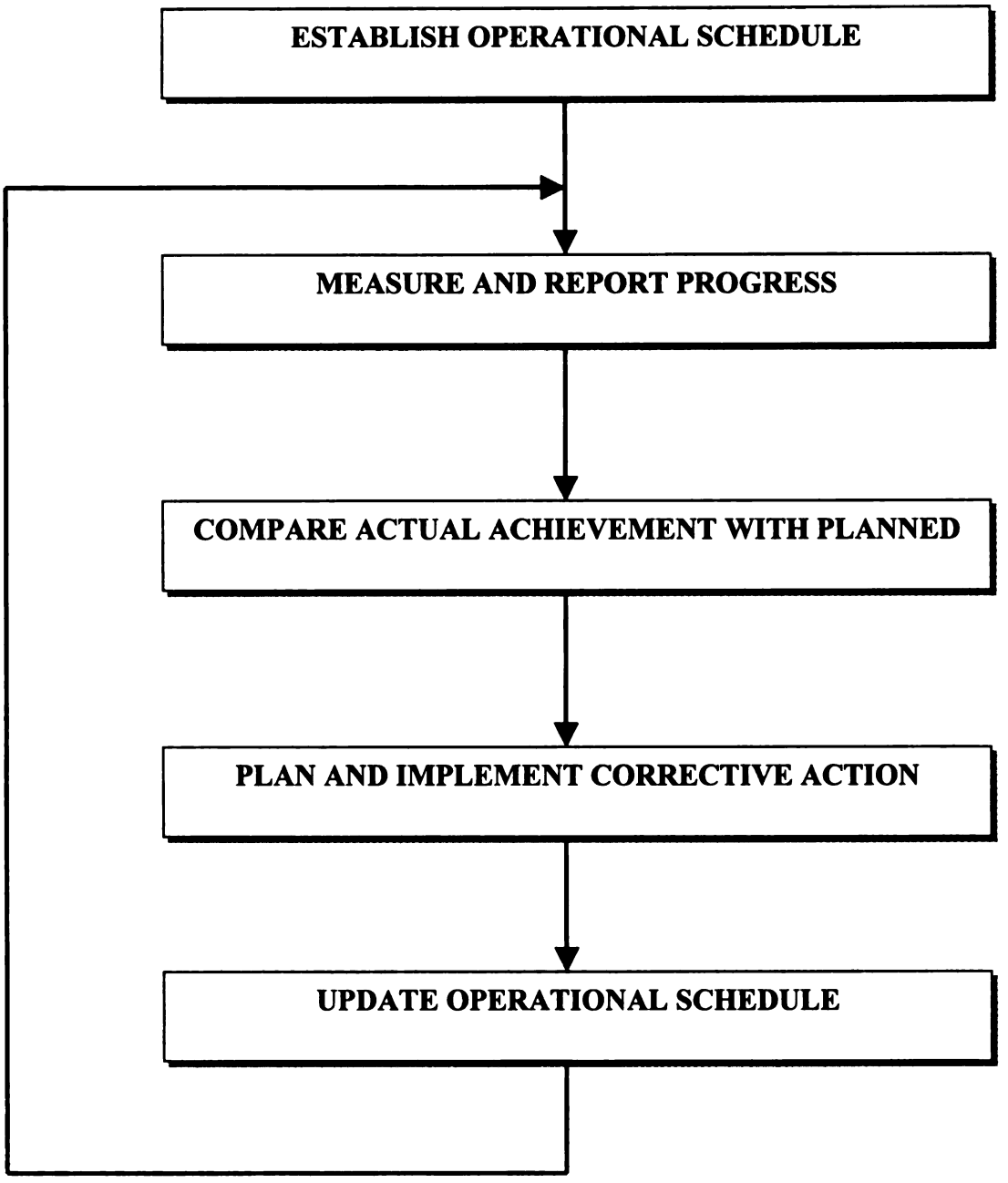

FIG. 1.2

PROJECT CONTROL CYCLE

(Source: Clough & Sears 1991)

The U.S. Department of Energy has recognized the importance of time and cost integration and has included in its General Conditions of the contract the following language: "A project's cost estimate must integrate with the scope, schedule and cost baseline." It further states, "Throughout the phases of a project, reassessment of the cost estimate will be made as specified by the project manager. The capability must exist to calculate TPC (Total Project Cost), and cost estimates must have the ability to distinguish between TPC, TES (Total Estimated Cost), and OPC (Other Project Cost), as defined in DOE Order 413.X. Most projects will be required to provide a revised estimate-to-complete (ETC) on an annual basis. The ETC is an estimate of the cost and time required to complete a project's remaining effort including estimated cost of authorized work not yet completed and authorized work not yet estimated; it is generated in conjunction with the current project schedule." (DOE, 2000) The construction industry has begun to realize the importance of establishing a high level of integration between cost and time factors of a project and has led the research in several aspects of integration. This research work will address the barriers faced at the industry level, during the planning phase of a project in order to carry out integration during project controls phase.

1.2 RESEARCH SCOPE

The proposed research work is based on the study of existing integration models described below and focused on determining barriers to actual integration process at the industry level. The study of existing models helped the author understand different integration concepts developed by researchers. The author believes that in order to integrate time and cost information during the controlling phase, integration of this

information must occur during the planning phase of a construction project. The model proposed by Appau outlines an integration process during the planning stage of the project. Details of the Appau model are given in section 1.6. The author also applied other selection criteria for the selection of the Appau model, which are discussed in section 1.5. Detailed study of the Appau model helped the author understand the flow of information proposed in the model. It also helped in developing interview questionnaires focused on integration concepts proposed by Appau and other researchers. This research work is limited to information tracking during scheduling and cost estimating. The models studied by the author are identified below:

1.3 MODEL REVIEW

Cost estimating and scheduling functions are treated traditionally as separate entities during construction projects. This separation increases the difficulty in coordination during construction. Many construction researchers and practitioners have proposed and suggested integration of cost estimating and scheduling is the true means by which production cost and delivery time are optimized, (Appau, 1994) but the common computerization of the two entities has not yet led to any extensive use of integration of these two aspects in construction practice. The literature review addressed several different integration models, as listed in Table 1.1.

The majority of the authors, who have proposed different integration models, have not focused on possible barriers to integration processes faced at the industry level. This research work focuses on finding out whether problems in actual implementation of

integration concepts proposed by different researchers are related to the concept of integration, company organization and culture, existing software and hardware, or existing business practices. Appau (Appau, 1994) addressed some of the problems faced in carrying out integration of time and cost information at the industry level.

1. Teicholz Model (Teicholz, 1987)	6. Syal Model (Syal, 1992)
2. Hendrickson Model (Hendrickson, 1989)	7. Spencer Model (Spencer, 1987)
3. Ibbs and Kim Model (Ibbs, 1987, Kim, 1989)	8. Abudayyeh & Rasdorf Model (Abudayyeh, 1991)
4. Work Packaging Model (WPM, 1988)	9. Shi Model (Shi, 1998)
5. Stone and Webster Model (Stone & Webster, 1990)	10. Appau Model (Appau, 1994)

TABLE 1.1 - INTEGRATION MODELS

1.4 THE APPAU MODEL

The model review identifies several different integration models, which have been proposed. Typically the models are based on similar concepts of integration of time and cost data; some of them also deal with the design data while proposing an integration concept. The author selected one model, representing the general concepts proposed by most integration models. This research work is based on the generic concepts of integration proposed by different researchers. While selecting the Appau model as representative of integration concepts, the author has applied certain criteria such as 1. planning vs. controlling, 2. author's knowledge about the database, 3. use of simple flow

charts, 4. management structures in the construction industry, etc., which are discussed in detail in chapter four of this report.

The Appau model typically deals with the planning phase of the construction process. The basic structure of this model proposes a common procedure, which combines scheduling and cost estimating processes during the project-planning phase. It does not suggest any software or how the actual data will be integrated, but suggests the integration of basic processes, which create time and cost data. The model also addresses several management related issues and different organization cultures, which may affect integration of time and cost information. The model is further discussed in detail under chapter four of this report.

1.5 PROBLEM STATEMENT

The complex nature of a construction project makes it difficult to stay on schedule and it becomes important to track all cost variances from the original estimated costs for effective cash flow. A cost estimator does not consider activity durations, produced by the scheduler, while assuming construction methods. This has a strong impact on direct and indirect costs. On the other hand, the scheduler does not usually know what crew and equipment assumptions the cost estimator used. (Yau, 1992) While this description applies to information flow between the schedule and cost estimate, the same concept applies to the relationship of cost estimating and job cost accounting, design and the actual construction phase, etc. The amount of information generated during the entire life cycle of a construction project is so massive that it becomes difficult to keep track of

accurate data at every stage of the project, without the help of some kind of integration or an interface implementation. The construction industry has realized the importance of integration. Literature shows that many large size construction firms have been using integration since the 1970s when mainframes were in existence, but research shows that there is still little effective or active implementation of the integration concepts in small and mid size construction firms. The literature review carried out by the author and discussed in different chapters of this report, shows that the need for integration is growing in the industry, but the integration concepts proposed by different researchers are still not being fully implemented. That's where the author feels that work needs to be done, to find out the barriers faced at the industry level to the integration process of time and cost information. The author has restricted her research to the planning phase of the construction projects.

1.6 NEED FOR FINDING OUT BARRIERS TO INTEGRATION

Typically in the construction industry, during the project control phase, project managers are responsible for overall success of the project, which includes meeting goals related to cost, schedule, quality and safety. Some of the tools, which are used to achieve these goals are S-curves and/or Earned Value Analysis. The base on which these tools work is that if the actual values are close to the planned values, the project will achieve a successful outcome. (Russell, et. al., 1997)

If the schedule has been used at the construction site to manage daily work, then schedule status transfer to the cost system will facilitate accurate earned value analysis. In order to

generate a clear picture of the project, data regarding four main factors is required: budget, earned value, actual costs and estimates. An analysis of only budget vs. actual costs can often give an incorrect value. If the contract is 10 % under budget, it might appear that the contract is doing very well but when the earned value is added to the analysis, it might show that only half of the originally planned work has been performed. Thus, the contract is behind schedule and the work that has been done cost more than originally planned. (Schulte, 2000). Further, it is also important to track the earned value for a specific period, as well as for cumulative data, which requires continuous communication between cost and time processes. If there is no continuous flow of information between these two factors and earned value is calculated at the end of the project, there will be no way to figure out when the schedule delay occurred and thus wrong data will be stored in the historic records, which will be used for future projects.

Integration of time and cost information during the project control phase plays an important role in effectively tracking project details and application of these details to future projects. The information flow in the project control phase is generated during a number of different construction processes. In order to effectively integrate these different construction processes during controlling, it is necessary to integrate these processes during the planning phase of the project. Software vendors are creating different active interfaces and integrated databases such as Enterprise Resources Planning (ERP), database by SAP, or aecXML, which help to integrate time and cost information during execution of the project, but to effectively implement such integrated solutions, barriers related to the organization structure, culture, involvement of project participants

and management need to be addressed. Some of the barriers related to these issues, addressed by Appau and other literature are indicated below:

1.7 BARRIERS TO INTEGRATION PROCESS

Appau identified a number of possible barriers to integration of time and cost information, which play an important role, especially during planning phase of the construction project. Barriers addressed by Appau are summarized as follows:

1. Complex nature of the construction industry:

a. Competitive bid process

b. Fear of time or cost records being used during litigation

2. Manpower:

a. Extreme specialization of functions.

b. Poor communication among the departments.

3. Appropriate skills:

a. Lack of appropriate skills.

b. Resistance to change.

c. Lack of essential software technology knowledge.

4. Software Technology:

a. Separate pieces of software for different construction processes.

b. Protective instincts of software development firms, which further restricts the interface between two software programs.

5. Long learning curve.

6. High Cost:

a. High cost for new software purchase.

b. Cost of training the staff for new technology.

c. Maintenance and updating cost for the new software programs.

Although barriers have been previously addressed, the construction industry still does not have a seamless solution for integration, which can take care of barriers in the planning stage of the project and can effectively integrate time and cost information between scheduling and estimating processes during project controls. This research work has been undertaken to find out possible barriers to integration during the planning stage of the construction project, which will help the researchers and vendors in understanding barriers faced at the industry level.

1.8 RESEARCH OBJECTIVES

The objectives of this research work can be summarized as follows:

1. Review several different integration models in general and the Appau model in detail.
2. Introduce Data Flow Diagramming (DFD) modeling technique and develop a DFD characterizing the Appau model with extensions to the original Appau model.
3. To validate and further modify the entities defined in the DFD with the help of industry feedback, develop an interview questionnaire and conduct interviews with the industry personnel and software vendors. This will help to identify

barriers to implementation of the sequence of steps defined by the Appau model and thereby barriers to integration of time and cost information concept.

4. Based on feedback from the interviews, summarize barriers to integration, propose recommendations and incorporate possible recommendations in the DFD developed in the second step.

1.9 METHODOLOGY

The research work was accomplished through four primary activities introduced below and further explained in chapter three "Methodology" of this report.

1. **Literature review**

Literature related to integration models, integrated software, research methodology and interview questionnaires was reviewed.

2. **DFD characterizing the Appau model**

The Appau model was studied in detail and using DFD modeling technique, a DFD was developed characterizing the Appau model.

3. **Feedback from the industry personnel**

Sample Selection

Six Michigan based, small to mid size general contracting firms along with two leading software firms were selected for interviews to obtain feedback related to barriers to integration of time and cost information.

Pre-evaluation

Pre-evaluation of the questionnaires was carried out.

Data collection

On completion of pre-evaluation, the interview questionnaires were finalized and interviews were conducted.

Data analysis:

Data collected through interviews was recorded and managed in a spreadsheet format.

4. Restructuring DFD

In this final phase of the methodology, the DFD characterizing the Appau model was restructured, based on the feedback obtained during the interviews and literature findings.

1.10 EXPECTED OUTPUT

The research is an effort to explore barriers to integration of cost estimating and scheduling processes, during the planning phase of a construction project. The research work addressed possible barriers, which are faced during the planning stage of the project and may be responsible for the non-integration of time and cost information during the project controls phase. The research work produced the following deliverables:

1. A preliminary DFD characterizing the Appau model with extensions by the author.
2. A list of barriers addressing several different issues such as organizational structure, computing and networking facilities, management structure, etc. and

sets of recommendations for contractors, owners, software vendors and researchers.

3. A revised DFD for integration of cost estimating and scheduling processes, based on the changes suggested through recommendations.

1.11 CHAPTER SUMMARY AND ORGANIZATION OF THESIS

Research efforts have indicated the benefits of computer-integration of various construction management processes. The outcome of this research is to help provide direction as the industry steps ahead to implement conceptual integration models. Barriers to implementation of integration concepts in industry are studied, which will lead to possible changes in existing models and aid in more effective implementation.

The research work is organized in six different chapters with appendices. The first chapter describes the introduction, need for the research work, research objectives and the expected outcome. The second chapter is based upon the literature review of existing research work in computer integrated construction processes models and other similar areas.

The third chapter discusses the methodology adopted to complete the research work. It also proposes selection criteria for construction firms contacted for interviews and development of the interview questionnaires. Additionally, data management and analysis is presented.

Chapter four presents the Appau model in detail. It also introduces the DFD modeling technique. Additionally, a DFD characterizing the Appau model is developed.

Chapter five presents data collection, data management and reports data obtained through twenty interviews. Also, barriers found through interview feedback are discussed at the end of the chapter.

Chapter six consists of an overview of barriers found through the literature review and interview feedback and also discusses recommendations for contractors, owners, software vendors and researchers.

Chapter seven consists of the summary, conclusions and limitations of the research. It also focuses on future areas of research.

Appendix I represents a sample data dictionary and structured English example related to DFD modeling. Appendix II consists of features of the database developed to manage data obtained through interviews, and Appendix III describes questions and responses obtained through twenty interviews.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Technology is revolutionizing the AEC industry, but there remains a clear disconnect between traditional manual practices and new automation developments, whether LAN-based (local-area network) or Internet-based. The Internet platform further perpetuates the industry's tradition of fragmented processes because new applications only offer stand-alone solutions. New capabilities such as Internet plan rooms, online materials procurement, equipment rental, and employee recruitment have introduced new challenges by further contributing to the industry's fragmentation. (Inglesby, V3N1) Researchers have proposed several seamless solutions for integration of time and cost information of construction projects, and vendors are providing stronger and more sophisticated specialized software packages, but research shows that small to mid-size construction firms are still not experiencing integration of construction process data to the fullest extent. The author has studied and presented several integration models representing integration of time and cost data in construction projects, proposed by different researchers and vendors. Literature related to research methods for conducting qualitative analysis and developing structured questionnaire was also reviewed and is discussed in chapter three of this report. Additionally, existing research work on barriers to integration of time and cost data was reviewed, and presented in this chapter.

2.2 INTEGRATION MODELS

2.2.1. Teicholz Model (Teicholz, 1987)

One of the basic problems faced by the construction industry as it attempts integration of time and cost information derives from differences in terminology used by estimators and

schedulers. Teicholz at Stanford University identified this problem and proposed mapping the relationship between cost breakdown structure (CBS) and work breakdown structure (WBS), which are used by estimators and schedulers. Figure 2.1 illustrates Teicholz's perception of the difference in terminology used in CBS and WBS. In the Figure, an account for recording cost data of one "strip 8 inch walls" task on the CBS corresponds to many tasks on WBS, including "strip 8 inch wall – area A" and other such tasks for area B and C on 4^{th} floor. Teicholz proposed mapping the relationship between CBS and WBS. This mapping helps to relate one cost account to all related activities as well one activity to all related cost accounts. Mapping of these relationships is based on a percent allocation concept. Each activity contributes a certain percentage toward one or more cost accounts and vice versa.

Though this model suggests an effective method of keeping time and cost data related to a particular activity or line item at one place, it does not necessarily address the integration of actual stages or steps involved in cost estimating and scheduling processes. Further, the model does not address certain issues such as: some incomplete activities may not contribute any percentage to the cost account.

2.2.2. Hendrickson Model (Hendrickson, 1989)

Hendrickson at Carnegie Mellon University, proposed an integration model based on the work elements concept. A work element is a control account defined by a matrix of work packages from the WBS and cost accounts from the CBS, as shown in Figure 2.2. In this model, a work element provides a link between the WBS and the CBS, where a cost

account may relate to one or more activities and at the same time an activity may relate to one or more cost accounts. This relationship uses the work element as a common denominator that achieves cost and time integration. Accurate data collection and data management are required for effective use of this model. The Hendrickson model carries out integration of WBS and CBS in a similar way as proposed by the Teicholz Model. The work element matrix, described in the Hendrickson model, is shown in Figure 2.2 below:

Work Element Matrix

		1st Floor	2nd Floor	3rd Floor	4th Floor
Cost Accounts	12" Wall	X	X	X	X
	10" Wall	X			X
	8" Wall				X

X: Work Element

Figure 2.2 Hendrickson Model

(Source: Hendrickson, 1989)

2.2.3. Ibbs and Kim Model [(Ibbs, et. al. 1987) & (Kim, 1989)]

Ibbs and Kim, at the University of California at Berkley, proposed a computer data model for improving construction project planning and control using an object oriented

programming approach. The data model not only integrates construction cost and schedule information but also integrates the design data of the project. It is based on an element called Basic construction Operation required by a Design object (BOD). BOD is defined as the lowest level construction task needed to build a specific design object and its corresponding construction operation control functions (WBS and CBS). A BOD has three objects: a work package on the WBS, a cost account on the CBS, and a design object on a drawing. The model is further explained with the help of Figure 2.3.

The model addresses the data representation aspects of integrating cost and schedule control by developing storage and manipulation mechanisms using an object oriented programming approach, but it does not address data acquisition issues.

2.2.4. Work Packaging Model (WPM, 1988)

This model was developed by NASA and the DOD for design-build projects in the aerospace and defense industries. The model is based on WBS, where the lowest level of WBS represents the actual tasks that will be used in the project's activity network. The model is also based on the concept of activity based costing. The concept suggests that each activity in the activity network can be used as a control account, within which both cost and time data are required and accumulated. In this model the concept of activity based costing is slightly modified. The modified concept uses WBS as the basis for control, where a package may exist at a higher level than the actual activity level. The work packaging model creates a unified view of project data by adding cost data to the WBS and eliminating the CBS. The model identifies the need for a common denominator

illustrated by the activity based or work package based cost control concepts. This common denominator is considered a major contribution toward the integration of time and cost information. The model is further described with the help of Figure 2.4.

2.2.5. Stone and Webster Model (Stone & Webster, 1990)

Stone and Webster have developed integrated management systems called Stone and Webster Integrated Management Systems. (Badger 87, CII 90). This is a centralized database, which integrates data related to all possible construction processes starting from engineering, procurement, construction and start-up. The concept of the work packaging model was used while developing this database. A common WBS is developed which is used for estimating and scheduling purposes, which is then developed into control account structure. Finally, Stone and Webster added the design view to the integrated database management system by linking a three dimensional geometric modeling software with the centralized database. The model achieves higher level of integration among cost, time and design data throughout the project life cycle.

The design of the relational database developed in this model is briefly described in reference CII 90. The Entity Relationship (ER) modeling technique was used to design the relational database in this model.

2.2.6. Syal Model (Syal, 1992)

Syal at Penn State University proposed this model in his Ph. D. dissertation. The research primarily deals with modeling of the construction project planning process itself, which

further helps in integrating different construction processes and generates integrated time and cost plans. The model further focuses on construction methods selection process practiced particularly in small to mid size building projects. The author also has developed a knowledge based computerized model for construction method selection process.

The model deals with the planning phase of a construction project. Though there are no methods suggested for actual time and cost information during the project controls phase, the basic cost estimating and scheduling processes are integrated in this model, which plays an important role in overall integration of time and cost information.

2.2.7. Spencer Model (Spencer, 1987)

The model proposes integration of cost estimating and critical path scheduling using Turbo Pascal structured programming language. The model is called the ESTCPM model. The author first developed a Visual Table of Contents (VTOC), which basically introduces all the tasks involved in the three main functions in the construction process - estimating, scheduling and the interface required between two, and then with the help of VTOC, developed a data dictionary. With the development of a data dictionary, a flow control diagram is developed, which shows how the data is grouped together and how it flows through the program during processing. With the help of data the flow diagram and data dictionary, the author developed an integrated database for cost and time data.

2.2.8. Abudayyeh / Rasdorf Model (Abudayyeh, 1991)

This is an automated data acquisition model developed on the basis of a work packaging model. It primarily deals with data acquisition, which is not addressed by any of the above integration models. ORACLE database management system is used for the automated storage module, while C and Pro C utilities are used as the interface between the ORACLE and PLANTRAC scheduling packages.

The ORACLE DBMS provides data storage and manipulation mechanisms based on its Data Definition Language (DDL) and Data Manipulation Language (DML). The model uses DML to process time data, such as labor hours to produce, to calculate earned value and percent complete for each control account. The automated data acquisition features of the model strengthen the integration of time and cost information.

2.2.9. Shi Model (Shi, 1998)

This model is based on Entity Relationship modeling technology. This is a relational database model developed to store and manage time and cost data to facilitate effective cost and time control during the project control phase of a construction project. The time related data is proposed to be entered and managed in the cost system in order to integrate time control functions in the same system. This is accomplished by using work items as the basic storage units for cost and time data. The work items are generated by using WBS according to the CSI master format. The research proposes a conceptual database model for the project cost and time data.

2.2.10. Appau Model (Appau, 1994)

Appau has explained the concept of Concurrent Engineering as well as different management styles and aspects important in adopting integration of time and cost data in the construction industry. Further, with the help of horizontal and vertical integration concepts, he explained typical steps in the process of estimating and scheduling and identified common or parallel steps in the two processes.

In the end, while developing an integration model, Appau tried to consolidate time and cost information parameters, from both estimating and scheduling processes during the planning phase of a construction project. The basic structure of this model proposes a common process, which involves all the important participants in the construction industry during project planning. The model does not propose a software solution or object oriented program or database structure for integration of time and cost data, but instead addresses management aspects, and proposes changes in the organizational structure, which will help in integrating cost estimating and scheduling procedures. The model is described in detail in chapter 4 of this report.

2.3 MODEL ANALYAIS

The author studied all the above mentioned integration models to obtain an understanding of research work done regarding integration of time and cost data in a construction project. Different integration models have used different modeling techniques and information technology tools, but the basic concept proposed by all the above models is similar. Two out of ten models address integration of construction processes during the

project planning phase while the rest of the models address integration of actual time and cost information during the project execution phase. Other than the Appau model, no other model, studied by the author addressed management related issues, which may play an important role in carrying out integration of time and cost information of a construction project.

The author also believes that it is necessary that the integration process occur during the planning phase of a project in order to make it feasible during project controlling. Once the industry personnel adopt the integration of cost estimating and scheduling processes during the initial phase of the project, the time and cost data will, for the majority of the time, remain intact and integrated during later phases of the project. The integration techniques, suggested by the rest of the models can be used as a complementary attachment to the one, which addresses integration during the project planning phase.

2.4 INTEGRATED SOFTWARE

2.4.1. Timberline Precision Primavera Integrator

The Precision Primavera integrator provides an interface between Timberline Precision Estimating software and Primavera P3 Project Planner. The interface works one way from Timberline software to Primavera software, but not the other way around. The line items created in the Timberline estimate form activities for scheduling and the software sends them across to the P3 Project Planner. This is similar to creating one common breakdown structure for estimating and scheduling processes. This helps to resolve problems of different terminology used by the estimator and the scheduler.

The integrator can be used in two ways: The user can first create the activities and build the network in Primavera and then use the integrator to extract information from the estimate, in order to provide duration and resource information for the activities. Another way to use the integrator is to create the activities directly in the integrator using the estimating information and then transfer the completed activities to Primavera Project Planner. (Syal, 1992)

2.4.2 Other integrated solutions

Similar to the Timberline Software Company, Meridian Project Systems, J. D. Edwards, Deltek Systems and MC Square have provided interfaces between estimating and scheduling software. The International Alliance of Interoperability (IAI) has been working on standardization of terminology used in the AEC industry, so that they can create an integrated software solution for the AEC industry using aecXML. An aecXML can be defined as extensible markup language used to represent information in the AEC industry. This information may be the form of resources, such as projects, documents, materials, parts, organizations, professionals; or activities, such as proposals, design, estimating, scheduling, and construction. (Albright, V4N9) There are small and large software vendors in the industry who have been working in the filed of integration to address their clients' need, and have been creating a number of customized integrated software versions for the sole purpose of solving their customers' problem of data management. For example there is a new integrated software named, AMX Prolog Adapter, which is a functional interface system that integrates Meridian Project System's Prolog Manager Software with J. D. Edwards' OneWorld system, a leading ERP solution

in the AEC industry. (www.constructech.com). Kodak, Rochester, NY, has written connecting software to tie together a number of off the shelf software packages. They use a combination of CAD, scheduling, and estimating packages which are tied into their accounting and financial systems. The facility development system put out by a SARA group is another example of design-construction integration. This software targets institutional facilities and includes approximately three hundred building models. The software is designed to allow the user to program, design, estimate and manage the lifecycle cost of a project, with information moving electronically between the modules. There are a number of integrated packages available for small to mid size home builders, where construction processes are quite standardized.

2.5 BARRIERS TO INTEGRATION

Several articles and white papers addressing integration and barriers to integration were reviewed. The majority of the articles were obtained from online magazines such as "Constructech", "Itcon" and an online version of "Engineering News Record". The articles are briefly discusses below:

1. Integration Barriers and Benefits, (Rakow, V4N6)

Bob Rakow conducted an interview with the senior vice president of Prima Vera systems regarding integration, barriers to integration and benefits of integration. The article identified several barriers to integration such as "The construction community is very broad with many players of various sizes," "Not only does the size of the company

matter, but also the company's philosophy (plays an important role during integration)," and "corporate culture", etc.

Integrating different departments comprised of people with different corporate cultures was identified as a main hurdle to integration. Further, the article discussed use of XML and aecXML for standardization of data exchange between different systems from various companies. At the end, the vice president of Prima Vera stated, "We are in the world of decision support. You want managers to have access to the right information. Integration enables real time access to data."

2. AEC Dilemma: Exploring the Barriers to Change (Beck, 2002)

This article discussed adoption of IT in the construction industry and resistance to change. It was identified that people carrying out construction processes play an important role in adoption of any new technology and in carrying out integration of information within organizations. Several issues related to current business practices in the construction industry and software solutions for the same are discussed in detail in the article. The article stated, "Construction projects rely upon a variety of disciplines containing poorly integrated silos of knowledge. The process, as currently practiced, creates enormous inefficiencies, which result in massive waste in delivery times and costs." Several causes of these inefficiencies are discussed.

Poor inter-organizational communication between owner, designer and contractor, insufficient margins for all those entities, and lack of information, were some of the barriers indicated by the article.

3. What is the biggest challenge facing the Construction Industry? (O'Neil, V2N3)

This was an online survey conducted by the chief editor of a Constructech magazine online issue. The article focused on challenges faced in the construction industry from different IT managers working for construction firms and software companies.

People skills and behavior were indicated as the largest barriers faced in the construction industry for adoption of new information technology and integration. The lack of standardization of terminology was identified by the respondents as the second biggest hurdle.

The article stated that construction firms no longer have to be worried about cost of "bricks and mortar" but have to be worried about "time", "quality" and "constant change".

4. Other articles related to barriers to integration

Several other articles and white papers were reviewed and are presented in chapter five, six and seven. A review of these articles helped the author to identify barriers to integration other than those found through the interview responses. The literature findings

also helped the author in developing recommendations for contractors, owners, software vendors and researchers.

The articles generally indicated that the awareness of importance of integration in construction firms has increased in the last couple of years, and firms have started asking for better and better software solutions. It was also indicated by these articles that not only hardware and software systems will get upgraded by adopting integration, but also that business processes practiced in the firm need to be upgraded as well. Thus, construction firms need to spend the time and resources required to redefine their business processes and then pursue upgrading of hardware and software systems used in the firm.

Barriers identified by the literature are principally related to organizational culture and philosophies, people skills and behavior, lack of standardization of terminology and also the processes and unique nature of construction projects. The articles are referenced in the reference section and also in the chapters, where applicable.

2.6 SUMMARY

A study of different integration models proposed by researchers and integrated solutions proposed by software vendors shows that integration is occurring, but in a fragmented way. Large owner organizations such as Kodak can design their own software links, or can designate the software requirements for the project. Large Design Build Construction companies like Bechtel or Stone and Webster have the resources to write their own

software, in fact they have been using computer integrated construction on a mainframe computer system since the 1970's. (www.constructech.com). Small to mid size construction companies, who can not invest resources in writing their own software or buying comprehensive packages like ERP or SAP are not being addressed. They are buying software solutions provided by different software companies to carry out construction processes within a firm and trying to integrate flow of information. Several different surveys and research studies showed that there is a missing link between integrated solutions and business processes practiced by these firms. Several articles related to barriers to integration or the challenges faced by construction firms in adopting integrated software solutions. The author believes that involving the right participants during the planning phase, and channeling information flow, will help to keep time and cost information integrated throughout the life cycle of a construction project.

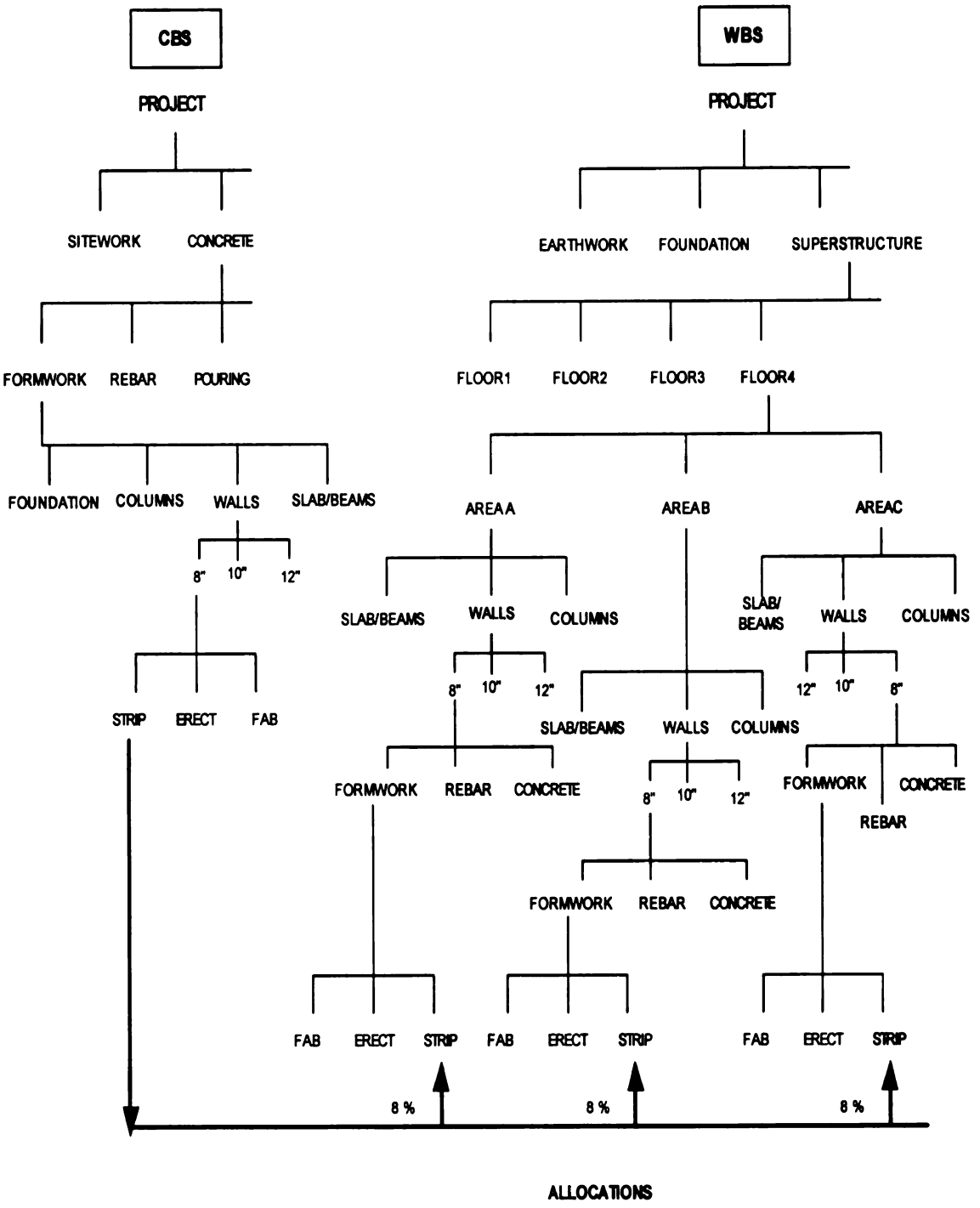

FIGURE 2.1 TEICHOLZ MODEL

(Source: Teicholz, 1987)

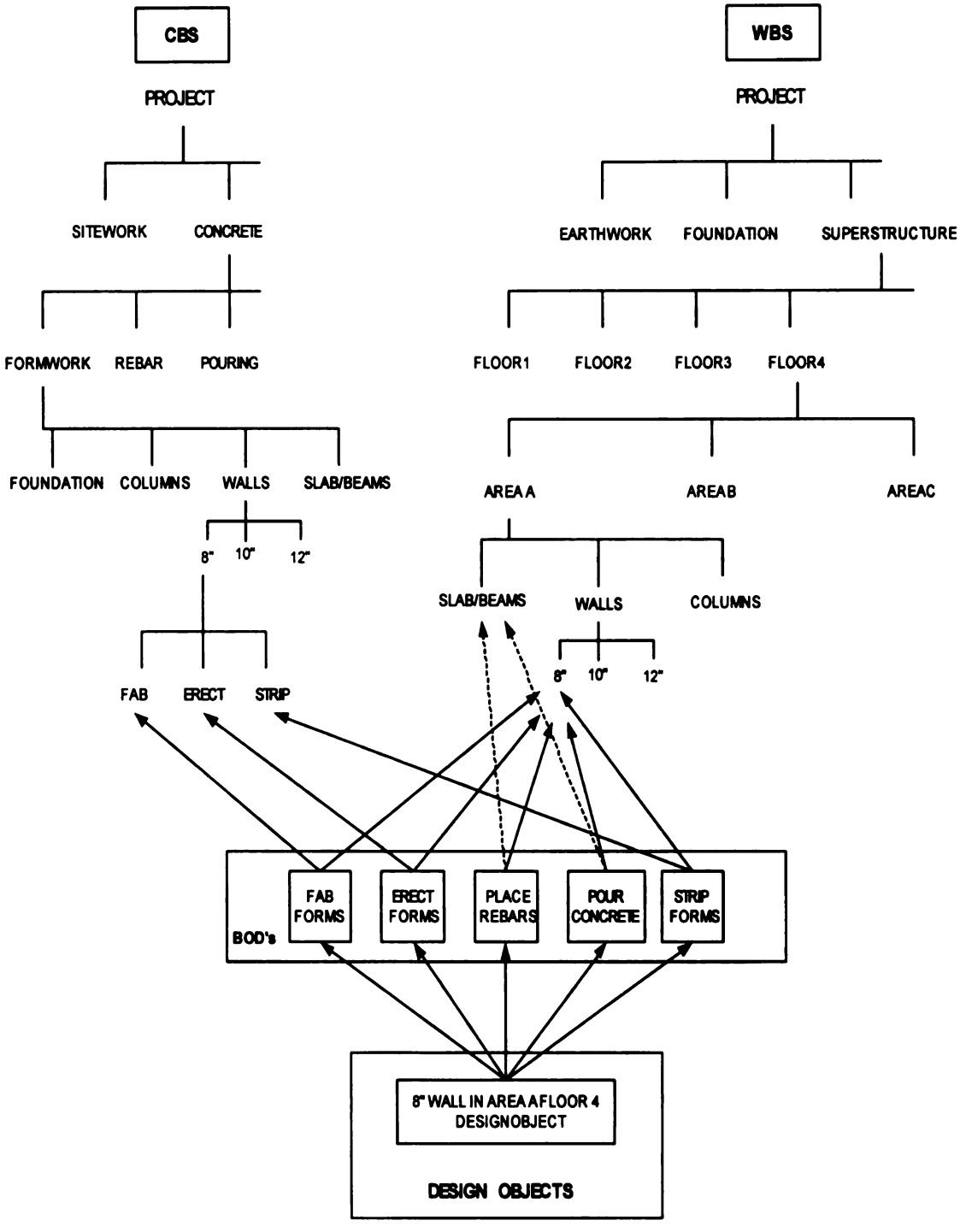

FIGURE 2.3 IBBS / KIM MODEL

(Source: [(Ibbs, et. al. 1987) & (Kim, 1989)]

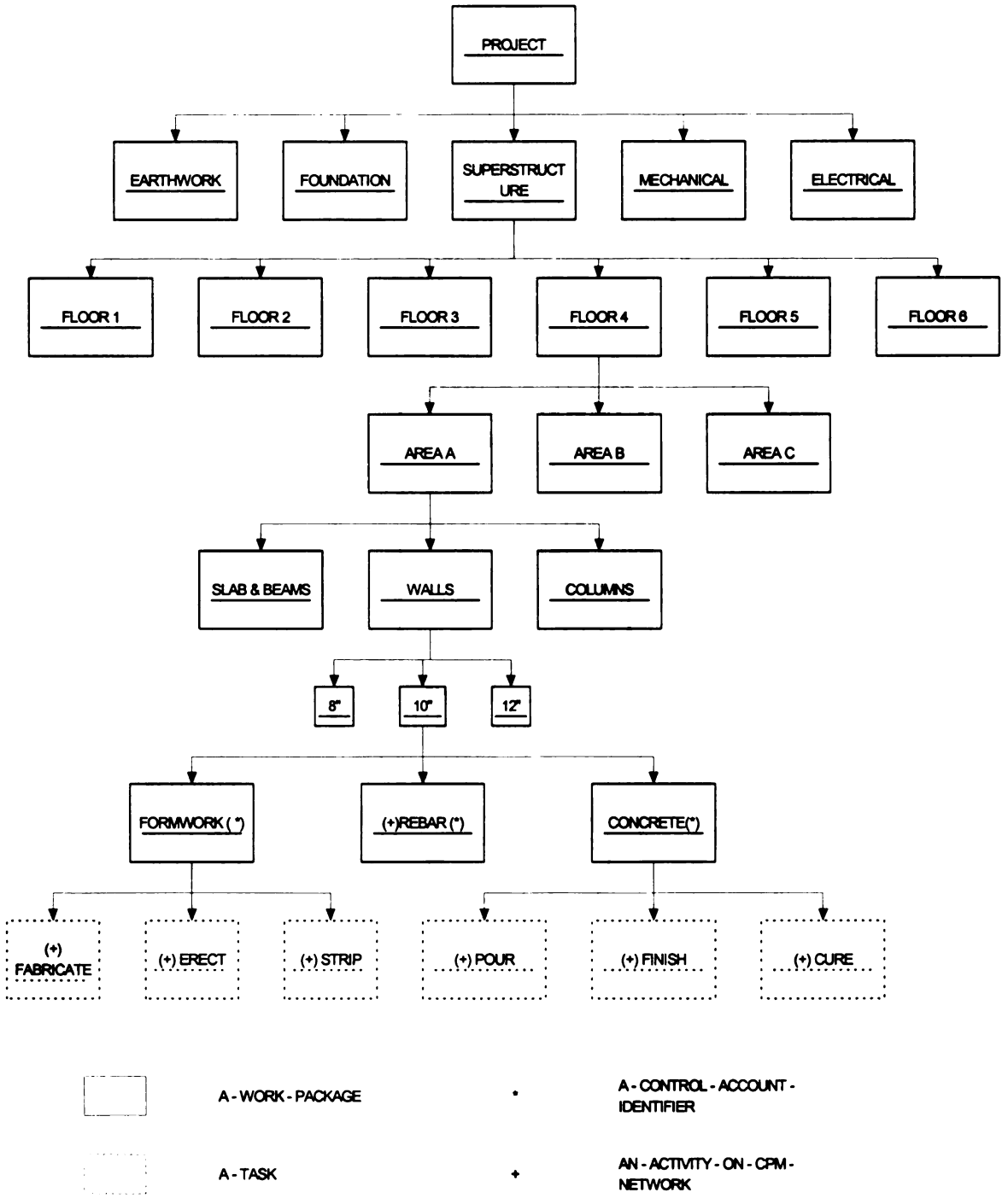

FIGURE 2.4 WORK PACKAGING MODEL

(Source: WPM, 1988)

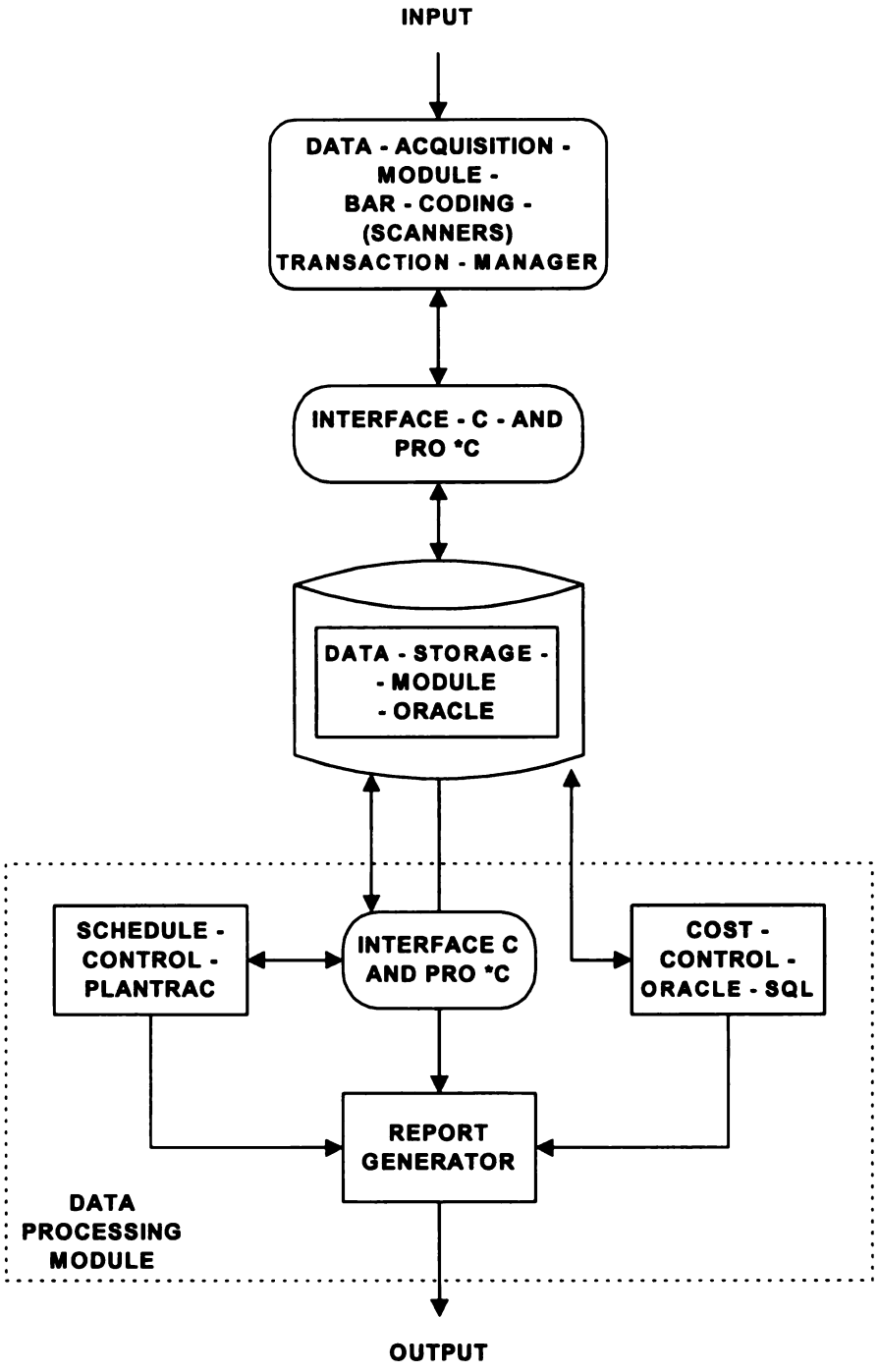

FIGURE 2.5 ABUDAYYEH / RASDORF MODEL

(Source: Abudayyeh, 1991)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter describes the methodology adopted to complete the research work. Literature reviewed by the author related to the methodology is also presented. The chapter focuses on how data was obtained, managed and used to draw conclusions related to the research topic. Upon studying several integration models as discussed in the previous chapter, the author decided to find out the views of industry professionals and software vendors toward the same. Integration of time and cost information during the planning phase was discussed with six vice presidents, six estimators, six schedulers and two software vendors. Interview responses were further used to draw inferences related to barriers to integration, propose changes to the DFD and to propose recommendations to constructors, owners, software vendors and researchers.

3.2 LITERATURE REVIEW

Literature was reviewed in order to study how questionnaires should be structured to obtain the best results. Several websites related to development of questionnaires and qualitative analysis of the data, were examined. A book on Research Methods by Jack Nation was studied to learn more about developing questionnaires and drawing inferences from the feedback.

3.2.1 Developing Questionnaires

A questionnaire is a tool for collecting data in a particular survey, (www.quickmba.com) consisting of a series of written questions to which the respondent provides answers, in a structured fashion. It is an important tool to obtain required information in a

predetermined fashion from the unknown respondents. The following steps were followed by the author while developing a questionnaire, as summarized below from several different references (www.quickmba.com, www.ericae.net, etc.).

1. Determine why the study is being undertaken and what the study aims to learn or determine.
2. Choose a question type based on interview method (such as verbal interview, written form, email form, etc.)
3. Determine the general question content needed to obtain information.
4. Determine the form of response.
5. Choose the exact question wording.
6. Arrange the questions into an effective sequence.
7. Categorize the questions based on the type of information expected to be sought.
8. Give short introduction before the questionnaire starts.
9. Test the questionnaire and revise it if needed.

Since the questionnaires contained more non-structural questions than structural questions each question was tested for its content and the possible response. The author made sure that each question had a specific purpose and was oriented toward the sole purpose of obtaining required information.

3.2.2 Interview Method

The face to face interview method was selected for this research work, however the option of telephone interview was provided for respondents. Face to face interviews have several different advantages including:

1. Enables the interviewer to establish rapport with the respondent.
2. Allows the interviewer to observe as well as listen.
3. Permits more complex questions to be asked than in other types of data collection.
4. Follow up questions can be posed and more information can be obtained.

3.2.3 Open ended questions

The majority of the questions were designed as open ended, which makes it harder to evaluate the responses. Though the open ended questions provided no structure for the answer, they were tightly focused to elicit the kind of information the author intended to obtain. Since the number of respondents was small and the whole object behind the survey was to refine the research, the author believed that the open ended question format was a suitable option for this research.

Several other papers available online were reviewed to obtain information on qualitative analysis of the data and were used while analyzing the data obtained through the interviews. Papers and books referred to are cited in the reference section. Actual steps in the methodology adopted are discussed in the following paragraph.

3.3 METHODOLOGY

The research work was accomplished in four steps as described below, which are also explained with the help of Fig. 3.1

3.3.1 Literature review:

In this phase, existing integration models of time and cost data and other research work on integration were studied. Literature on adoption of information technology in the construction industry was studied. Different modeling techniques used in integration models were reviewed, two modeling techniques related to this research work are further discussed in detail in chapter four. This provided an understanding of the existing on integration of information, which helped in identifying some of the barriers to the integration process, during actual implementation of these models. Literature on "How to develop a structured questionnaire" and also on research methods for qualitative analysis was studied and is discussed earlier in this chapter.

3.3.2 DFD characterizing the Appau model:

Per the selection criteria discussed in chapter one, the Appau model was selected and studied in detail. Different management strategies, which play an important role in adoption of any new changes or technology in the organization addressed in the Appau model were studied in detail. The DFD modeling technique was studied in detail and introduced in chapter four. Using this technique, a DFD characterizing the Appau model was developed. The author believed that developing a DFD for the Appau model would be helpful for representing the flow of information in each of the steps during the planning phase of a construction project, also participants in those processes were identified clearly with the help of DFD.

3.3.3 Feedback from the industry personnel:

Sample Selection:

The author developed selection criteria for the firms to be contacted for interviews. The criteria were as follows: A firm should be in a list of the top four hundred general contracting firms engaged in commercial construction, published by the Engineering News Record in the year 2001. A firm must have an office in the state of Michigan, for ease of travel to the interviews. Further, the author also used her personal contacts to shorten the list. Contacts with professionals working for the same firm were used to identify appropriate contact persons in their offices in the state of Michigan. Eight firms satisfying the above criteria were selected. A total of eighteen interviews from the selected firms (three interviews from each firm) were targeted. Six out of eight firms were contacted with the remaining to be identified as alternates. The vice president, scheduler and estimator were interviewed from each of the firms. The responses to each of the questions from all the interviewees are given in Appendix B with accompanying code. Two more interviews of technical personnel from leading software firms providing software for construction scheduling and cost estimating processes were also conducted.

Pre-evaluation:

Prior to developing the interview questionnaire, the researcher studied different survey and interviewing methods and decided upon the final interview structure, which helped in gathering the required data. Consent from the graduate committee members was obtained before finalizing the questionnaires. The questionnaires

were pre-tested with one of the committee members to verify the tentative time required to complete one interview.

Data collection:

On completion of the pre-evaluation, an interview approach was finalized. Two options were decided: phone interview and personal interview. Fifteen out of total twenty interviews were conducted face to face; the rest were conducted by telephone. Because of the small sample size, interviews were structured open-ended. Each of the interviews took almost 50-60 minutes to go through all the questions. Initially the author had proposed to audio tape the interview responses, but since the equipment was not readily available, the author did not record the responses. Instead hand notes were taken. The data obtained through the interviews was recorded in tabular format in a database developed in Access. A sample database developed in Microsoft Access is attached in appendix I at the end of this report. Four different types of questionnaires were developed: one for vice presidents, one for schedulers, one for estimators, and one for software consultants. The questions were categorized according to the role of the person to be interviewed. There were four different categories of questions: personal demographic, company demographic, project specific, integration concept and barrier related. The actual questionnaires are given in Appendix A. The topics covered in each type of the questionnaires are explained in brief as follows:

1. **Questionnaire for vice presidents:** Personal demographic questions consist of educational qualification, number of years of experience in construction industry and number of years of service with the present firm, computer skills of the interviewee, inclination toward learning new computer skills, etc. Company demographic questions deal with annual sales volume in dollars, type of projects, size of projects, type of contractual arrangements, percentage of investment toward information technology, frequency of up-gradation of information technology, etc. Project details were obtained through questions such as: typical staff on project sites, typical staff involved during the planning stage, computerization and networking facilities on each project site, etc. Finally, questions related to integration concepts and implementation barriers were asked covering the following topics: integration of time and cost data – existing methods and means, any future possible developments toward integration, discussion regarding the integration models developed by different researchers, awareness of such integration models, a brief introduction of the Appau model and a brief walk-through to explain the flow of information in the Appau model, etc.

2. **Questionnaire for estimators:** This was divided into three different categories such as: personal demographics, cost estimating process related and integration of time and cost data related. Personal demographic questions were the same as the ones in the previous questionnaire, while the estimating procedure related questions consisted of the following topics: methods of

obtaining required information while preparing estimates, types of software used for estimating, participants involved other than the estimating department while preparing estimates, total involvement in typical life cycle period of the project, etc. Project related questions consisted of: involvement of schedulers while preparing an estimate, communication with the schedulers during the life cycle of the project, existing means and methods of integration of time and cost data during the life cycle of the project, frequency of updating cost estimates during the life cycle of the project, etc. The information related to integration and implementation barriers was obtained through questions such as: the need for integration, necessity of better means to carry out integration of time and cost data, discussion regarding integration models developed by different researchers, awareness of such integration models, brief introduction of the Appau model and a brief walk through to explain the flow of information in the Appau model.

3. **Questionnaire for schedulers:** This questionnaire was similar to the one for estimators, except all the questions were addressed in context to scheduling rather than estimating.

4. **Questionnaire for software vendors:** This questionnaire was categorized into criteria such as: personal demographics, creation of new software, and integration of time and cost data. Personal demographic questions consisted of details such as: educational qualification of the interviewee, number of years

of experience with the construction related software development, number of years of service with the present firm, typical role played in the firm, etc. the questions related to the development of new software consisted of: clients or type of customers dealt with, participants involved while creating or modifying any construction related software programs, operating systems and programming languages used, etc. Questions related to integration concepts and implementation barriers consisted of: customer interest in integration features of the software, complaints or feedback regarding the existing interface between scheduling and estimating software, reasons for not developing a two way integrator, discussion regarding the integration models developed by different researchers, awareness of such integration models, brief introduction of the Appau model and a brief walk through to explain the flow of information in the Appau model, etc.

After finalization, the interview script was submitted for UCRIHS approval. UCRIHS is the University Committee on Research Involving Human Subjects. UCRIHS reviewed the interview script to make sure that human related matters were handled as per the rules and regulations. Upon approval by UCRIHS, interview dates were scheduled and interviews were conducted. The interview questionnaire was sent to the interviewees a week prior to the interview. This gave them sufficient time to gather statistical details or general demographic details. The interviewees were also sent a reminder email two days prior to the actual interview date. Responses to each type of questionnaire were recorded in the Access database as mentioned earlier.

Data analysis:

As mentioned earlier, data collected through interviews was recorded in Access database. Each question was recorded with the related responses. Each interviewee was assigned a code, as noted with the response obtained from him/her. Because of the small sample size, a statistical study of the data could not be carried out, so a qualitative analysis of the data was used. The responses were evaluated and separated into different categories. The number of categories were decided only after all the responses were obtained. The qualitative nature of the analysis did not allow the author to draw conclusions simply on the basis of higher percentage of agreement. The entire background of the interviewee, his/her technical knowledge, and experience in the related field was studied before deciding the weighted factor of agreement or the significance toward using it while drawing the conclusions. All the open-ended responses were concluded based on the weighted factor they gained.

3.3.4 Restructuring the DFD

In this final phase of the methodology, a DFD characterizing the Appau model was restructured. Restructuring was done based on the feedback obtained from the interviews. It was not possible to incorporate all the comments by the interviewees; but only those that could easily be related to the original Appau's concept and could easily be incorporated into the DFD format were considered. Detail discussion regarding general barriers interpreted from the interview responses was carried out and stated in chapter six of this report. Recommendations for contractors, owners, software vendors and researchers were proposed to be considered while developing a

pragmatic integration model for integrating time and cost data across the scheduling and estimating departments within construction firms; they are also discussed in detail in chapter six.

3.4 SUMMARY

This chapter primarily addresses the steps in the methodology adopted to complete this research. Proper selection of the steps in the methodology determines the success of the research work. The author believes that the steps adopted here helped in obtaining the required information from the industry personnel and software vendors and in finding out barriers to integration of time and cost information.

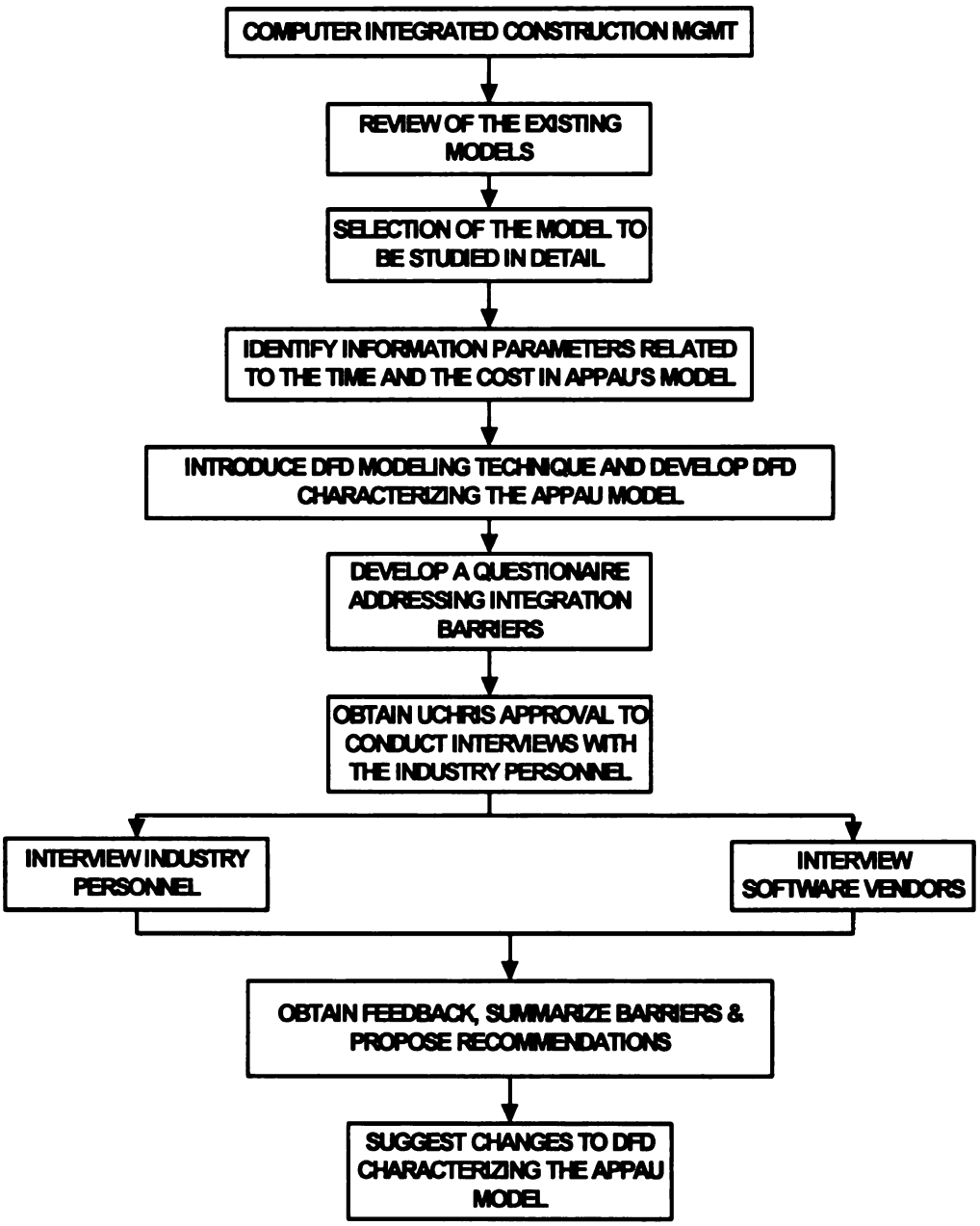

FIG. 3.1

CONCEPTUAL MODEL FOR METHODOLOGY

CHAPTER 4

THE APPAU MODEL AND DFD

4.1 INTRODUCTION

This chapter introduces the Appau model in detail and the selection criteria applied while choosing the Appau model for the research work. Appau used simple flow charts to represent integration of time and cost information during the project planning phase of a construction project. The flow charts are easy to understand, but they are a combination of information collection, actual processes and participants, which makes it difficult to explain the sequence of the processes and to show the exact inflow and outflow of information in each of the processes. To describe the information flow in each of the processes indicated in the Appau model, a Data Flow Diagram (DFD) characterizing the Appau model was developed. Data flow diagramming is used to specify the information flow in different processes or different organizations. Data flow diagrams can further be defined as high level, low level and so on, with which the processes can be aggregated and then classified into different levels. Data flow diagrams are explained in detail later in this chapter. In the end, the benefits of developing a DFD for the Appau model were discussed.

4.2 SELECTION CRITERIA FOR THE APPAU MODEL

A literature review identified different integration models, proposed by researchers representing integration of time and cost information in different ways. The majority of the models proposed integration of time and cost data; while some of them also integrated design data along with time and cost data. To achieve the desired goal, one model representing a generic concept of integration of time and cost information during the project-planning phase was selected. Certain criteria were applied while choosing the

Appau model for this study. Thus, the research work is not based only on the Appau model, but it is based on a generic concept of integration of time and cost information, proposed by different researchers. The selection criteria developed by the author are discussed below:

4.2.1. Planning vs. controlling phase:

The author believed that integration process must begin during the planning phase in order to continue integration during the project control phase of a construction project. Appau has developed an integration model for the planning phase of the project, where most other models deal with the actual integration of time and cost information during project controls.

4.2.2. Information Flow:

Researchers have used different modeling techniques while developing integration models, such as object-oriented structures, structured programming languages, etc, which further made it difficult to identify the exact information flow in each of the processes. The Appau model was found to be reasonably simple to convert into a DFD identifying information flow in different processes.

4.2.3. Conceptual / Mathematical Models:

Most of the models, studied by the author are either conceptual or mathematical in nature. Some of those propose object oriented databases for time and cost information. But none of the models has addressed issues related to the implementation of those concepts in real

practice. Appau on the other hand, conducted several interviews with the industry professionals and revised the model based on the responses.

4.2.4. Management structures in the construction industry:

Management plays an important role in adoption of any new concept or technology into the business structure. Appau described different management styles present in the construction industry and tried to incorporate possible factors related to the same in the model.

4.2.5. Organization culture:

An important factor in adopting any new change in an organization is its organizational culture. Appau, based on feedback from industry personnel, has also incorporated required changes in organization culture into his integration model.

4.2.6. Use of Flow Charts:

It is necessary to understand any model to the fullest extent, before one uses it as an example or base for his/her research work. Appau has demonstrated his model with the help of flow charts, which the author found easy to understand.

4.3 THE APPAU MODEL

Mr. Kwaku, Addae Appau, at Georgia Institute of Technology proposed this integration model as a doctorate dissertation work in 1994 (Appau, 1994). Appau also validated the model while working for an architectural and construction management firm in Atlanta,

Georgia. Appau primarily adopted three phases to develop the integration model as described below. The phases are also explained with the help of Figure 4.1, while the entire Appau model is explained with the help of Figures 4.2, 4.3, 4.4 and 4.5.

In the first phase of establishing the foundation for the modeling process, Appau studied several existing integration models. He proposed a preliminary model based on his concept of integration and conducted interviews with several professional schedulers, estimators and constructors. Based on the feedback, he updated the model.

In the second phase, Appau explained the concept of Concurrent Engineering as well as different management styles and aspects important in adopting integration of time and cost data in the construction industry. Further, with the help of horizontal and vertical integration concepts, he explained typical steps in the process of estimating and scheduling and identified common or parallel steps in the two processes. Appau also explained the advantages and disadvantages of horizontal and vertical integration within the organization and the important role played by the organizational structure in carrying out integration of time and cost information.

In the last phase of development of the integration model, Appau tried to consolidate time and cost information parameters, from both estimating and scheduling processes. This model primarily dealt with the planning phase of the construction process, but could easily be extended to other phases. The basic structure of the model proposed a common process, which involves important participants within a construction organization

required to process cost and time plans for the project. The model did not address any issues related to computerization, but it can easily be computerized, especially with the revised version in DFD format. The model primarily deals with management aspects, which play an important role into defining the processes to carry out time and cost integration across scheduling and estimating departments throughout the life cycle of a construction project. As discussed earlier, Appau used flow charts to represent the integration model, which makes it difficult to explain the exact information flow to and from any particular process in the model. The author believes that the barriers to integration may be related to the flow of information as well the process itself. To further represent the information flows to and from each of the processes in the Appau model, Data Flow Diagram was developed. Developing data flow diagrams for the Appau model helped the author to: 1) understand the Appau model to the fullest extent, 2) understand the planning phase of a construction project in detail, 3) understand the processes in the planning phase, 4) understand the information flows in each of those processes, and 5) understand the information sources and participants involved in those processes.

4.4. DFD MODELING TECHNIQUE

Advances in Information Technology such as client – server architectures, object technology and a variety of Internet technologies such as XML are dramatically changing the way enterprise systems are designed, implemented and operated. The use of object oriented technology has resulted in a decrease of the semantic gap between the analysis, design and implementation phases of information systems. As a result, conceptually designed business models can be fully carried into implementation and the links between

different enterprises are much tighter. The author selected the use of DFD to represent the integration concept proposed by the Appau model in an effort to move one step closer to the implementation phase of this process model. Data flow diagramming is primarily used to specify the information flow in the given processes or in the given organization. A list of events is developed to meet the requirements of the particular sequence of the processes. These events can further be aggregated and then classified into higher and lower level events. Processes in the DFD are the places where data gets transformed into the information or information into the format that can provide value to the organization. (Whitbeck, 2000) The key elements for DFD are defined as follows:

4.4.1. Data flow:

A data flow is a pipeline through which packets of information of known composition flow (DeMarco, 1979). A packet of information can further be broken down and each of the elements of the packet can be defined in the data dictionary. (DeMarco, 1979) A vector, wherein direction of the vector plays an important role to identify inflow and outflow of the database to and from a particular process, represents data flow. Some of the rules applied while naming the data flows are: a) Data flow names are hyphenated, b) No two data flows have the same name, c) Data flow names may also represent the characteristics of particular type of data, etc.

4.4.2. Process:

A process is a transformation of incoming data flow(s) into outgoing data flow(s) (DeMarco, 1979).

Processes show work performed on data. A notational convention used to represent a process is a circle or a bubble on the DFD. In a completed set of DFD, each process is given a separate name. Processes can be classified into higher level and lower level processes, wherein higher level processes typically are broken down further into lower level processes.

4.4.3. File:

A file is a temporary repository of data (DeMarco, 1979).

A file may be a tape, or an area of disk, or a card data set, or an index file in the drawer, or the database (public or private). The direction of arrows leading to or from a file is significant. One way or two way arrows from the file defines the relationship between the data flow and the file. A file is represented by the two parallel lines on the DFD.

4.4.4. Source or Sink:

A source or sink is a person or organization, lying outside the context of a system, which is a net originator or receiver of system data (DeMarco, 1979).

The source or sink is primarily used to show where the net input to the system comes from and where the net output of the system goes. As defined above, the source or the sink represents a person or organization outside the context of a system; a person or organization inside the context is characterized by the processes he or it performs. The source or sink is represented on DFD with the help of a rectangular box.

4.4.5 Data Dictionary: A data dictionary can be defined as a set of data parameters used to represent the data flow.

A data flow is typically a combination of different information parameters, which cannot be shown in the DFD because of the complexity. A sample data dictionary is developed, wherein some of the data flows shown in different DFDs in this chapter are defined. Each of the data flows can be defined when it becomes necessary. Table A1-1 shows a sample data dictionary developed for this research work.

4.5 DEVELOPING A DATA FLOW DIAGRAM CHARACTERIZING APPAU'S INTEGRATION CONCEPT

The data flow modeling technique was used as a foundation for analyzing the business processes, which take place during the planning stage of a construction project and are addressed by the Appau model. A general framework for the methodology adopted to develop a DFD is summarized with the help of DeMarco (1979) and David (1998) as follows:

1. Identify information exchanges taking place in different business processes to be analyzed.
2. Identify the processes to be shown on the DFD along with the participants, i.e. the sources and the sinks and the resources for information.
3. Derive the levels of the processes and aggregate the respective lower level processes into the higher-level processes.
4. Develop individual data flow diagrams for each of the lower level processes.

5. Perform integration of the processes, by overlaying the processes and identifying common sources and sinks and information resources. Analyze each process to ensure the proper inflow and outflow of the information.
6. Develop a sample data dictionary explaining data inflow and outflow packets of information.

The processes described in the original Appau model are listed in the following paragraph, which were further used to identify the information resources, sinks and inflow and outflow of data.

4.6 PROCESSES IN THE APPAU MODEL

The processes in the Appau model are identified and stated as follows.

1. Secure design documents
2. Introductory review of the design documents
3. Decide upon staffing and time frame
4. Examine design documents
5. Conduct site and regulatory studies
6. Conduct Designers/ Schedulers/ Estimators meeting
7. Access project features
8. Access own resources
9. Access sub contractors and in-house resources
10. Access historical records
11. Decide upon in-house and sub-contracting work

12. Carry out the apportion of job among estimating and scheduling teams

13. Distribute documents to sub-contractors

14. Conduct co-ordination review meeting

15. Decide completion constraints

16. Detailed study of plans and specifications

17. Develop preliminary milestone schedule

18. Divide plans into preliminary building systems

19. Streamline the rationales

20. Prepare final milestone schedule

21. Finalize building systems

22. Develop detailed work breakdown structure

23. Develop work category and items from building systems

24. Collect scheduling information from the sub contractors

25. Collect estimates from the sub contractors

26. Formulate project activities

27. Determine activity sequence

28. Compute quantities

29. Compute activity durations

30. Perform scheduling calculations

31. Calculate costs of work categories and work items

32. Evaluate resource availability

33. Finalize estimating and scheduling parameters

34. Send the work for the management review

35. Evaluate caliber of the participants

36. Evaluate basis of the estimate

37. Evaluate methods and data used in the estimate

38. Evaluate the quality of documentation

39. Evaluate the performance of the estimate

40. Carry out the revision of the estimate

41. Write up rationales for the estimate and the schedule

42. Finalize upon the construction schedule

43. Finalize upon the construction estimate

44. Finalize upon the format for cost and time controls

45. Publish the estimate

46. Distribute copies of the estimate

4.7 LEVELING THE PROCESSES

The processes described above were further studied to derive different levels, which would help in classifying them into different groups. The three main phases of the Appau model were categorized as the first level processes and numbered as 1, 2 and 3, as shown in Figure 4.7. Each of these phases is further broken down into several different lower level processes. Phase one of the Appau model entitled "Establish the foundation for the modeling process" is divided into second level processes called "Introductory review of contract documents" and "Apportion of the work assignments", as shown in Figure 4.8. Similarly, level one processes for phase two and three of the Appau model are broken down as shown in Figure 4.12 and Figure 4.17, and are called level two processes. Level

two processes can then be broken down into level three processes. For example, in Figure 4.9, level two process "Introductory Review" gets broken down into level three processes as, "Secure contract documents" and "Preliminary review of contract documents". The same applies to all other level two processes. Thus, leveling can be carried out to the extent required. In this DFD, there are total four different levels of processes. Figure 4.10 represents one example of breakdown of level three processes into level four processes.

Leveling of the processes also helps in classifying different processes with the similar data inflow or some other similar characteristics and further helps in sequencing the processes and identifying the required participants to be involved at any given time. The last level processes are typically known as the tasks that can be performed in an understandable way. The entire leveling of the processes is shown in Figure 4.6, wherein different levels of the processes are indicated by numbers and sub numbers format. All the processes in the DFDs characterizing the Appau model are shown in a tree format indicating leveling of the processes in the DFD.

4.8 DEVELOPING THE DATA FLOWS

Leveling of the processes helped in identifying data inflow and outflow for each of the processes. Thus, each of the above mentioned processes was further studied in detail and with the help of literature review, study of the Appau model, and author's expertise in this area, data flows or rather packets of information parameters going into each of the processes and coming out of each of those processes were identified as shown in Figures 4.7 to 4.21. Data inflow and outflows are named as shown in the figures. The names

given to each of the data flows can further be defined in the data dictionary in order to give details of each of the information parameters tracked in each of the packets of information. A sample data dictionary is developed as indicated in Table A2-1. All the data inflows and outflows can be defined in the data dictionary in a similar way.

4.9 INTEGRATION OF THE PROCESSES

As mentioned earlier in step five of the methodology adopted to develop a DFD characterizing the Appau model, the processes were supposed to be overlaid and then integrated per the common sources, sinks and information flows. Since the author conducted interviews with vice presidents, estimators, schedulers and software consultants separately, it was helpful to keep the data flow diagrams for each of the processes separate instead of integrating all into one main data flow diagram. By doing so, it became easier to discuss a related part from the DFD with the respective interviewee and obtain responses for the same. It also helped in identifying which data flow was critical while studying integration of time and cost information. Those participants who were required to be involved in a process but where it is practically not possible to be involved, were easy to identify with the individual data flow diagrams. Therefore, the author did not follow step five of the methodology adopted for developing DFD for the Appau model.

4.10 BENEFITS OF DEVELOPING DATA FLOW DIAGRAMS

A primary intent behind this research work was to find out barriers to integration of time and cost information, for which several different integration models have been proposed

by the researchers and software solutions developed by vendors. It is somewhat like playing the role of an analyst helping industry and researchers / vendors group communicate across the "logical-physical" boundary. Researchers and vendors live in the logical domain, while industry people live in the physical domain of getting the actual work done. To help in analyzing an integration concept proposed by Appau in an unspecified format using flow charts, it was necessary to adopt a certain structured analysis tool. DFD had certain advantages such as: 1. ability to analyze the concept of integration of time and cost information proposed by Appau, 2. helped to understand the project planning phase, 3. helped to understand data inflow, data outflow and participants involved in each of the processes and 4. the ability to convert the Appau model from an unspecified format into a more defined and specified format. This detailed understanding of the project planning process, integration of time and cost information, the participants involved in each process and data transformation taking place in every process, helped the author while finalizing interview questionnaires and also while identifying barriers based on the literature findings and interview responses.

4.11 SUMMARY

The details of the Appau model were further enhanced with the help of data flow diagrams developed for each of the steps indicated in the model. Data flow diagramming proved to be a powerful tool in achieving the goal of this research work. The chapter also gives details of the data flow diagramming technique and the benefits of developing data flow diagrams characterizing the Appau model.

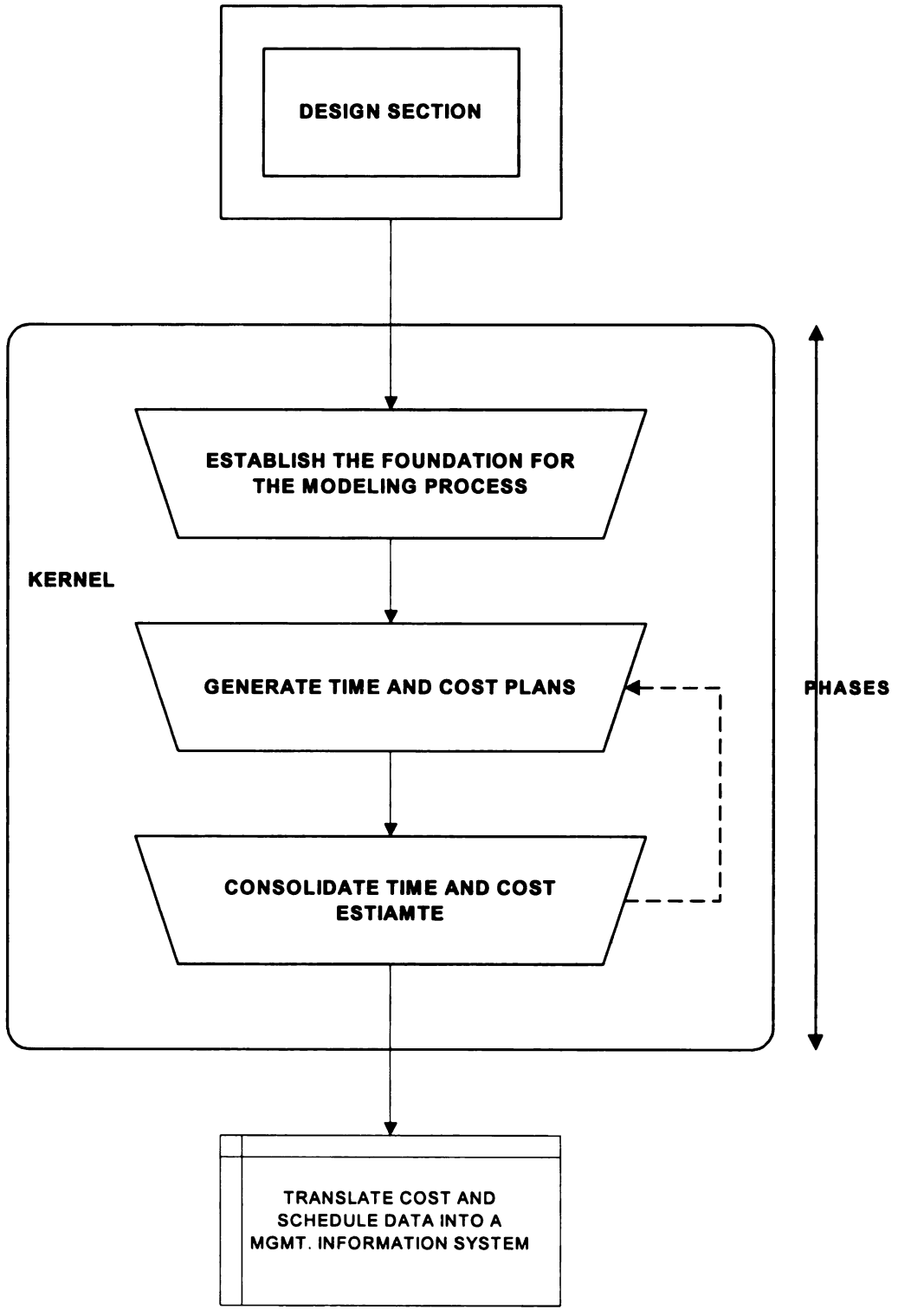

FIG. 4.1 PHASES OF THE MODEL (SOURCE: APPAU, 1994)

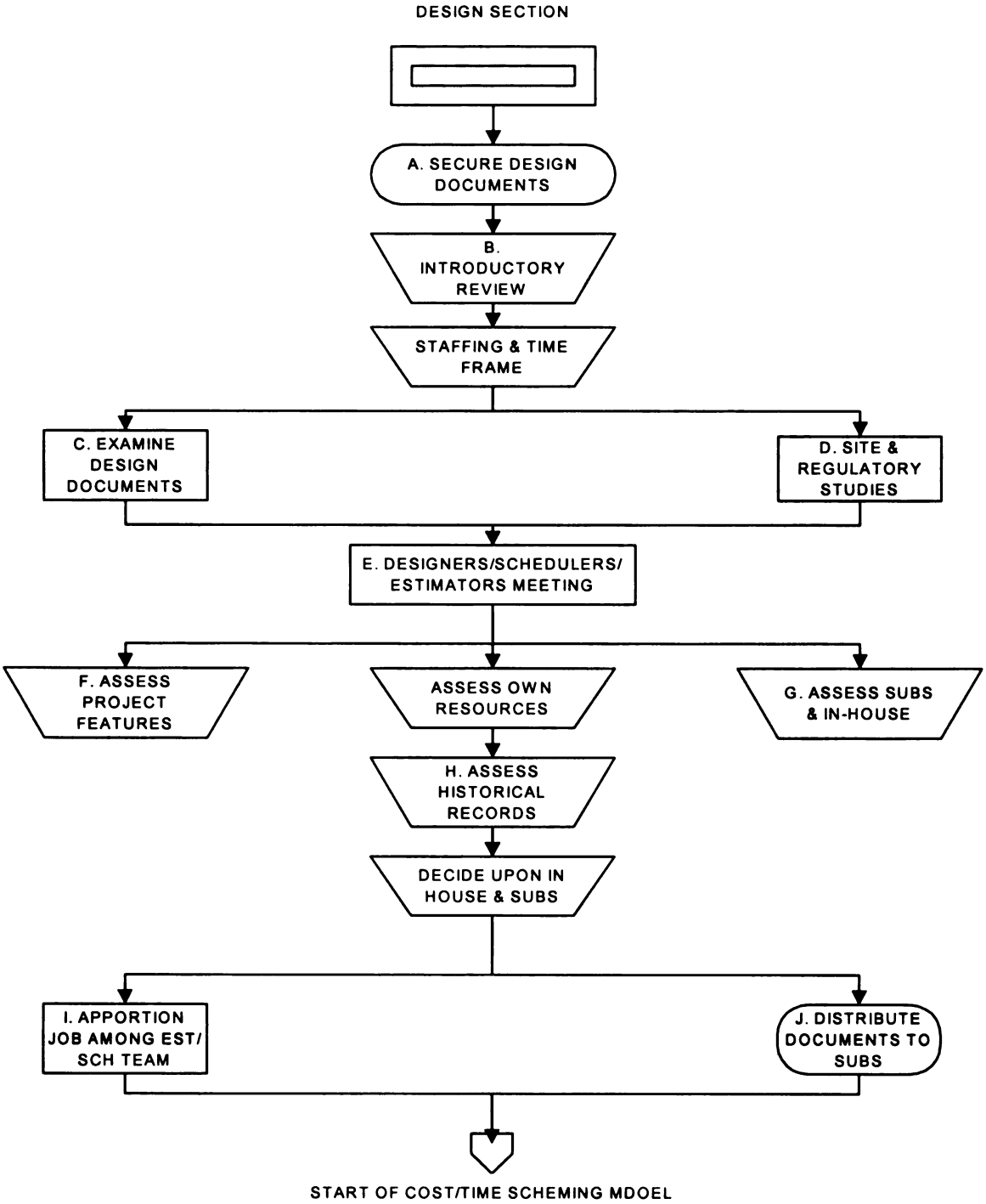

FIG. 4.2 FOUNDATION PHASE OF THE MODELING PROCESS
(Source: Appau, 1994)

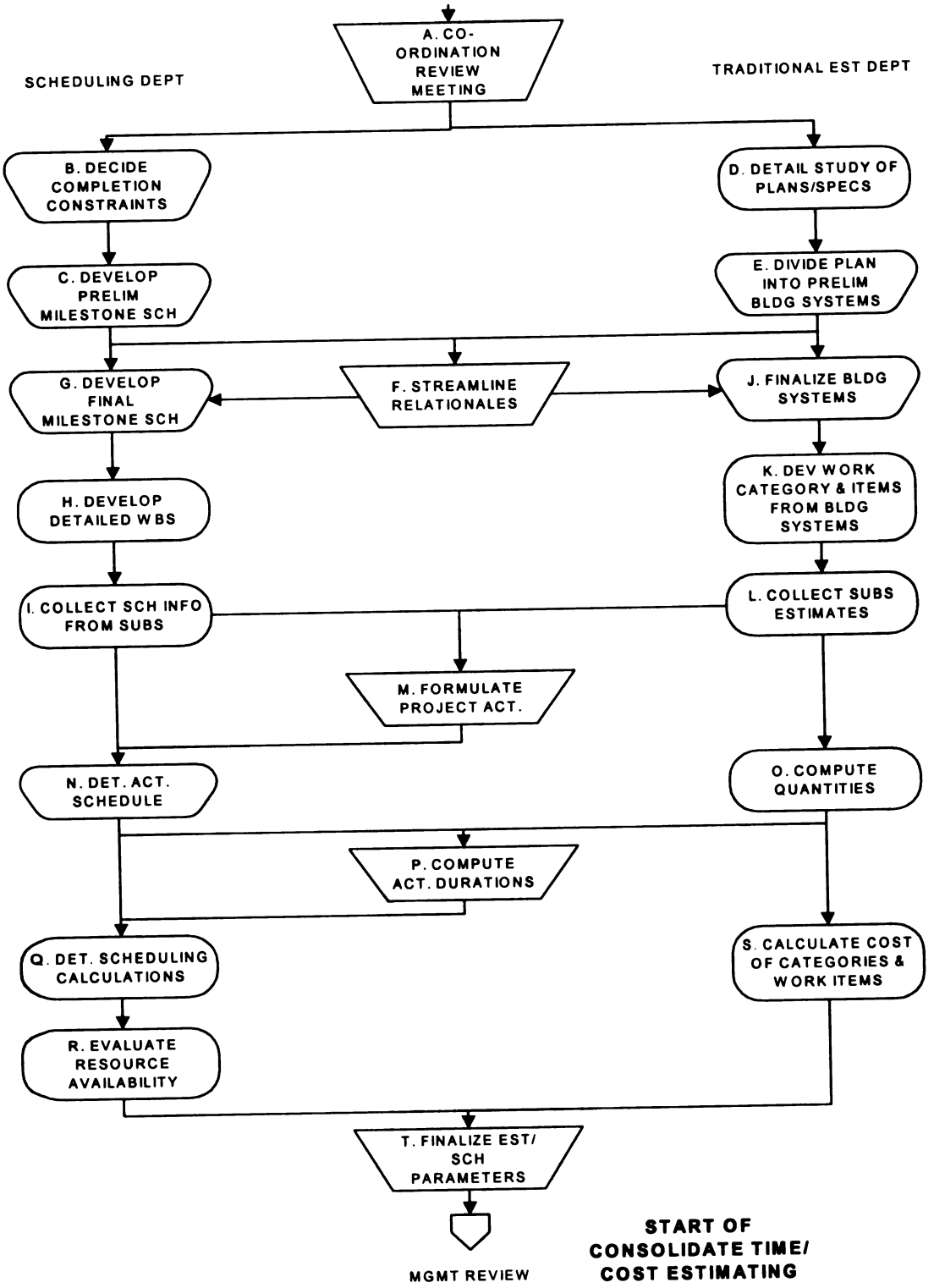

FIG. 4.3 COST/TIME PHASE OF MODEL
(Source: Appau, 1994)

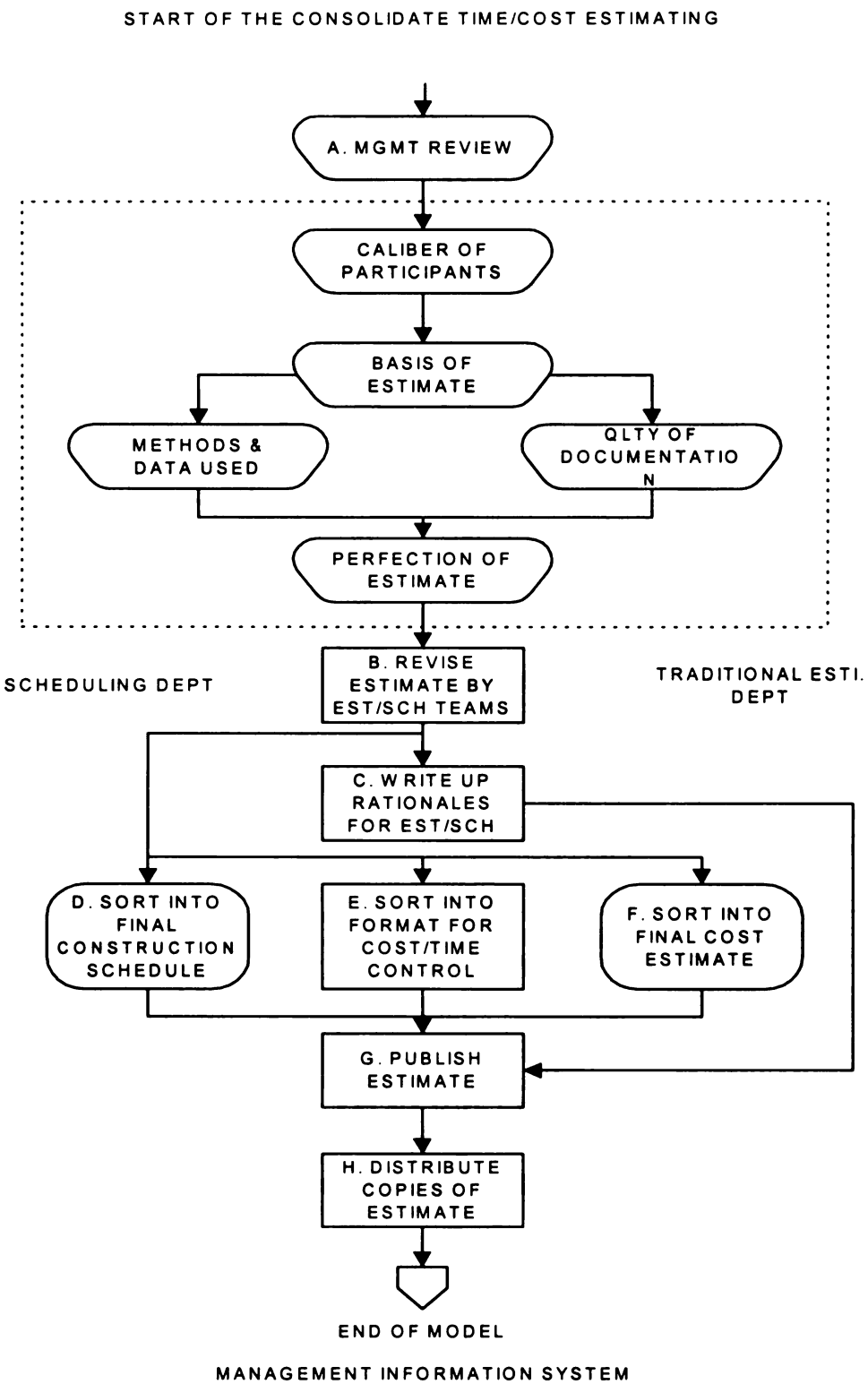

FIG. 4.4 CONSOLIDATE SCHEDULE/COST ESTIMATE INTEGRATION (Source: Appau, 1994)

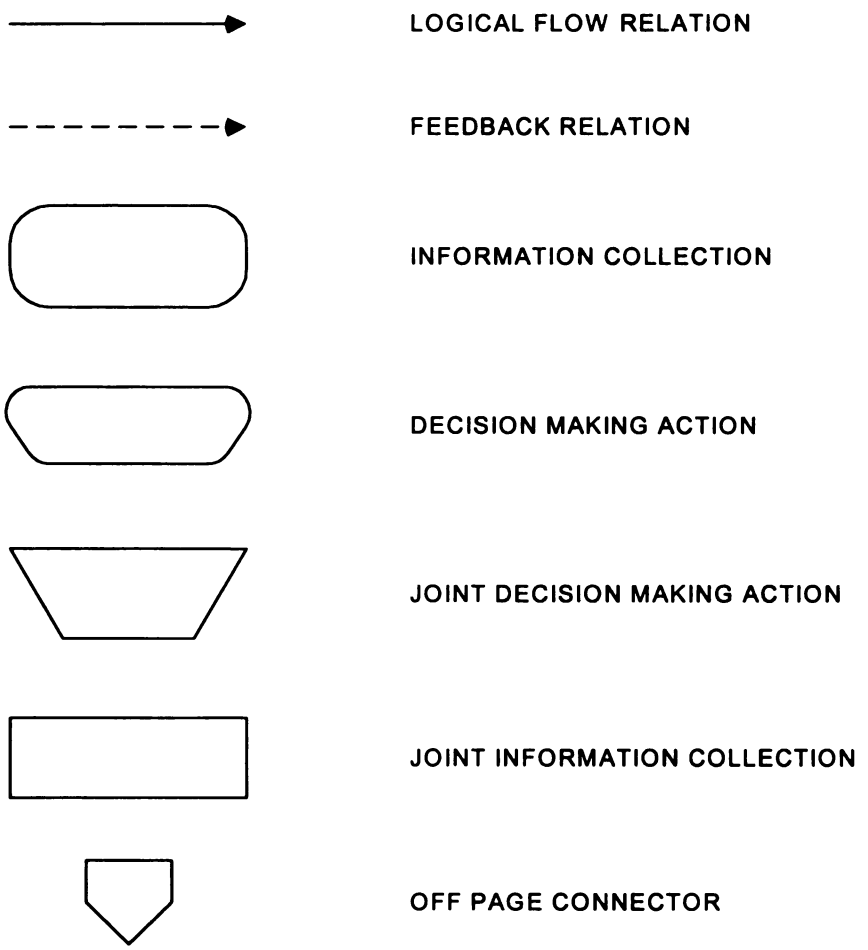

FIG. 4.5 SYMBOLS USED TO REPRESENT THE INTEGRATION MODEL
(Source: Appau, 1994)

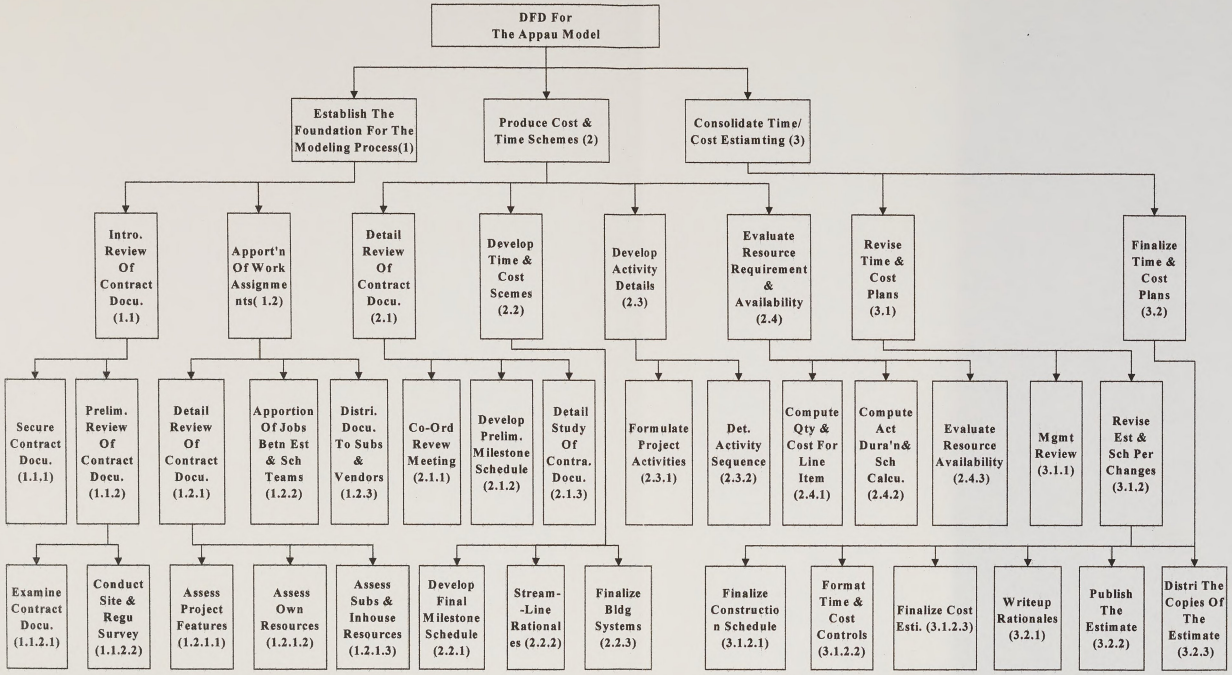

FIGURE 4.6 LEVELLING OF THE PROCESSES IN DFD CHARACTERIZING THE APPAU MODEL

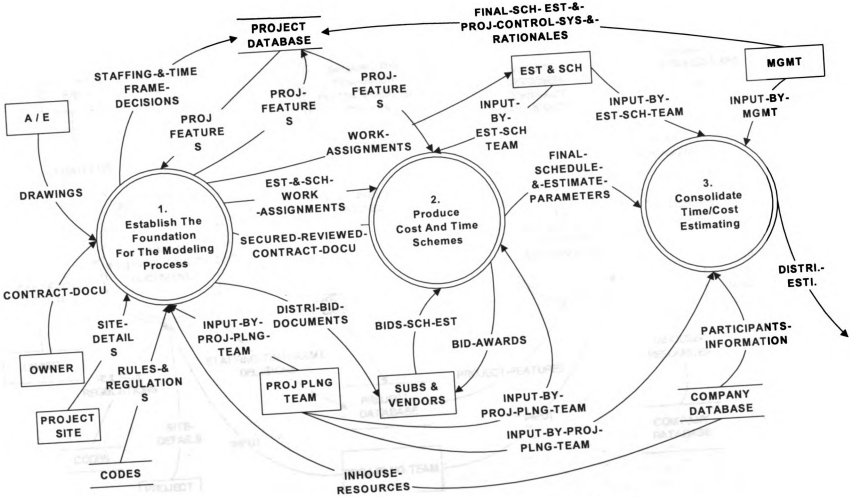

FIG. 4.7 DFD FOR THE APPAU MODEL

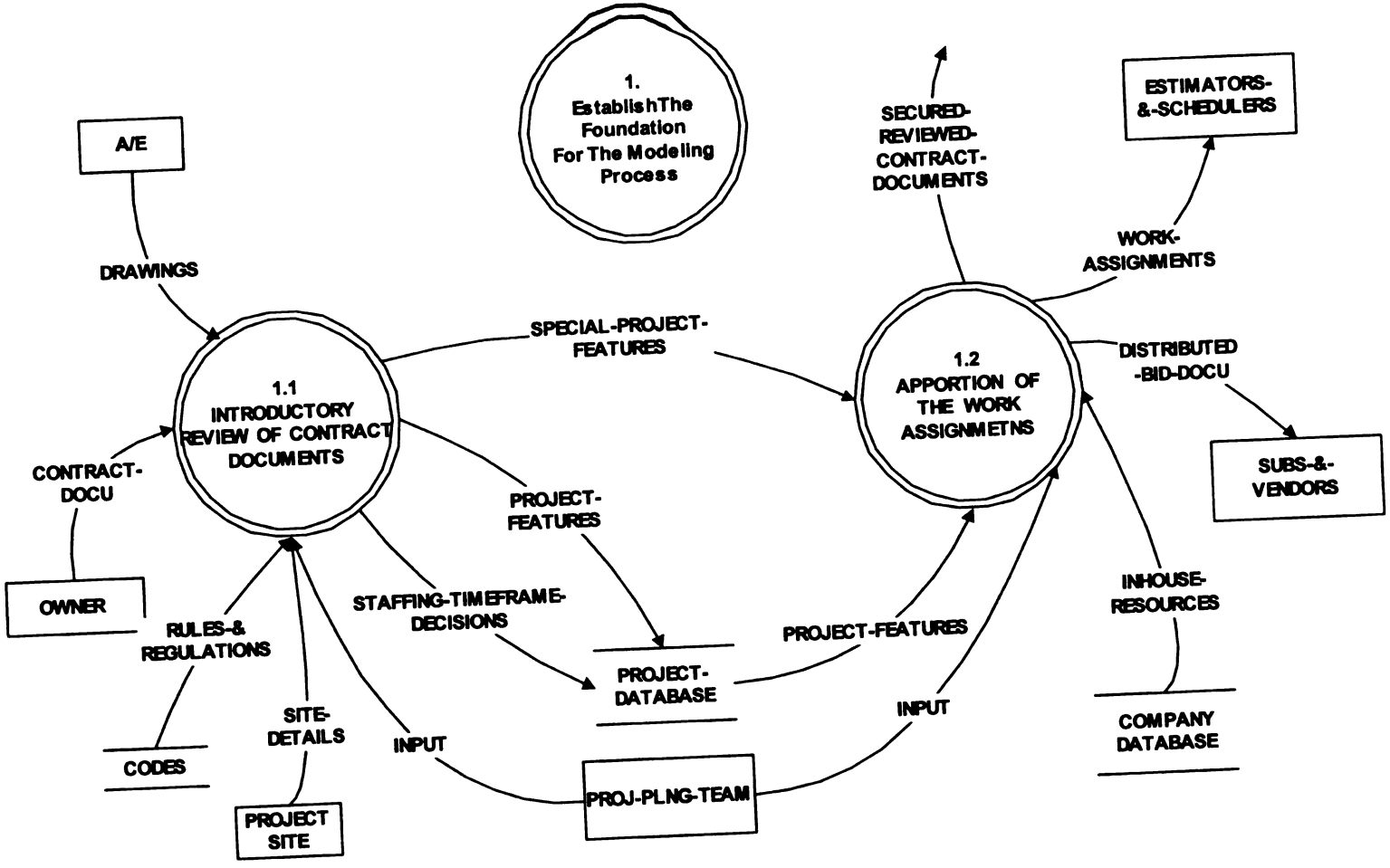

FIG. 4.8 DFD FOR PHASE 1 OF APPAU MODEL

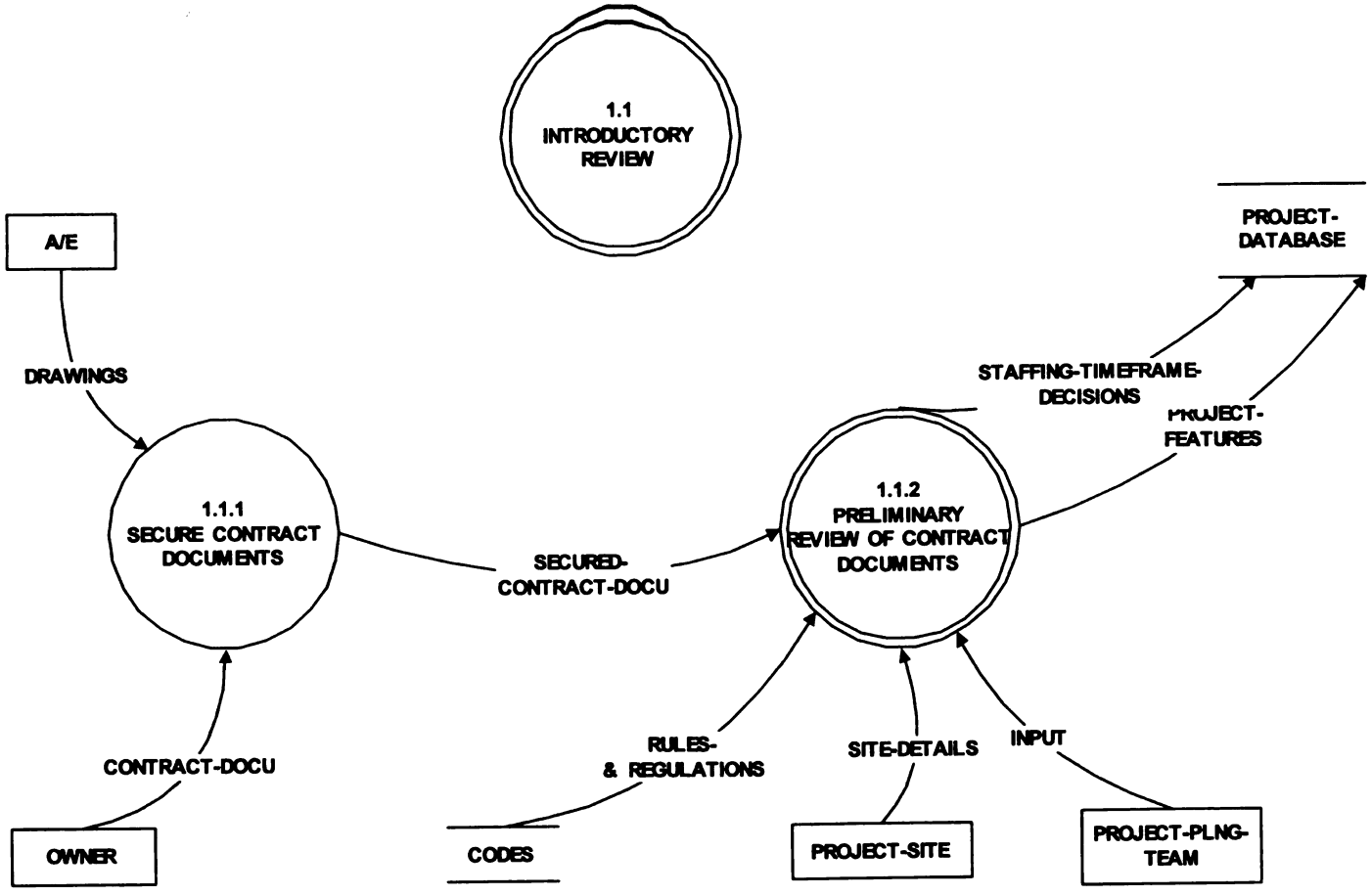

FIG. 4.9 DFD FOR STEP 1.1. OF APPAU MODEL

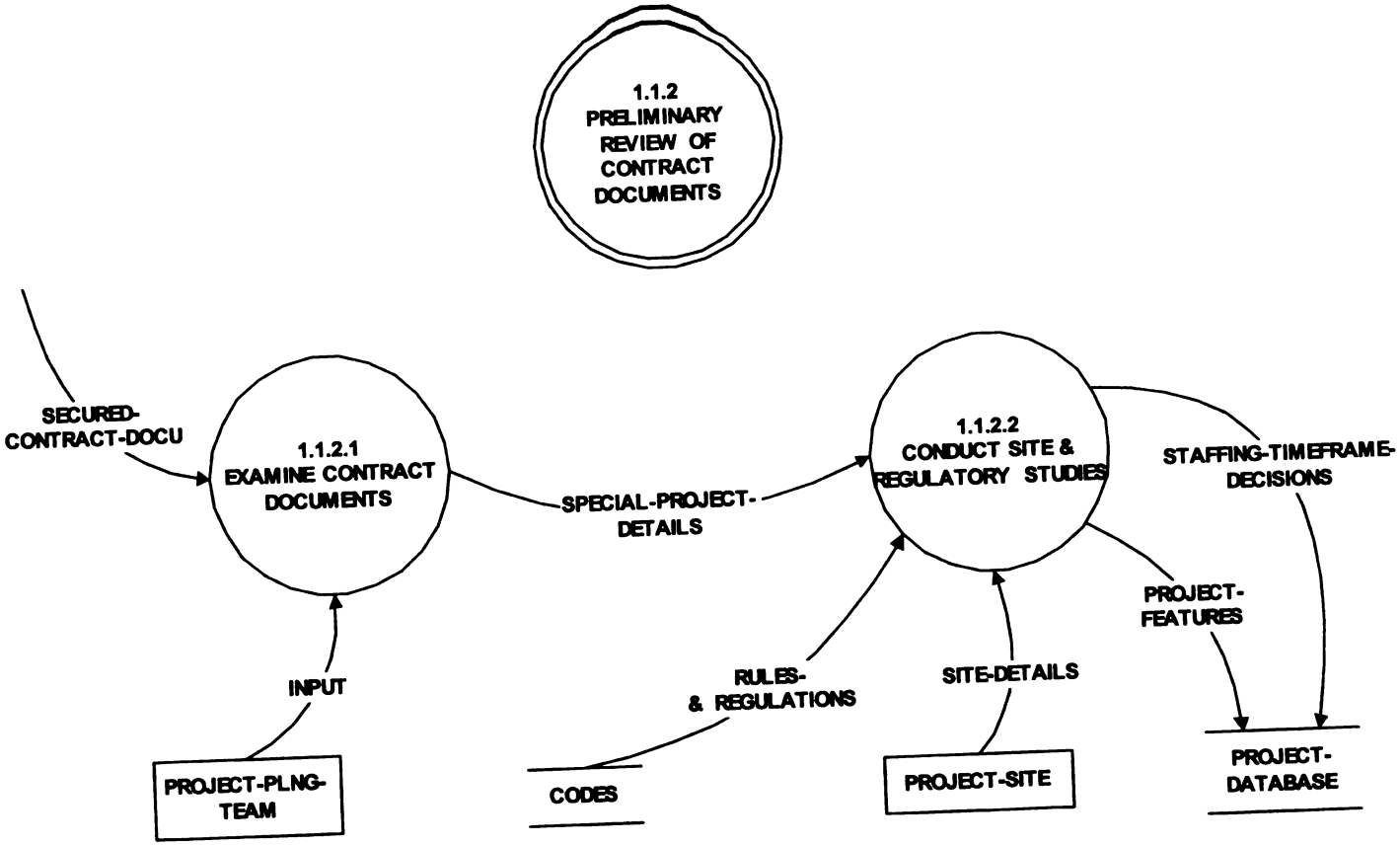

FIG. 4.10 DFD FOR STEP 1.1.2 OF APPAU MODEL

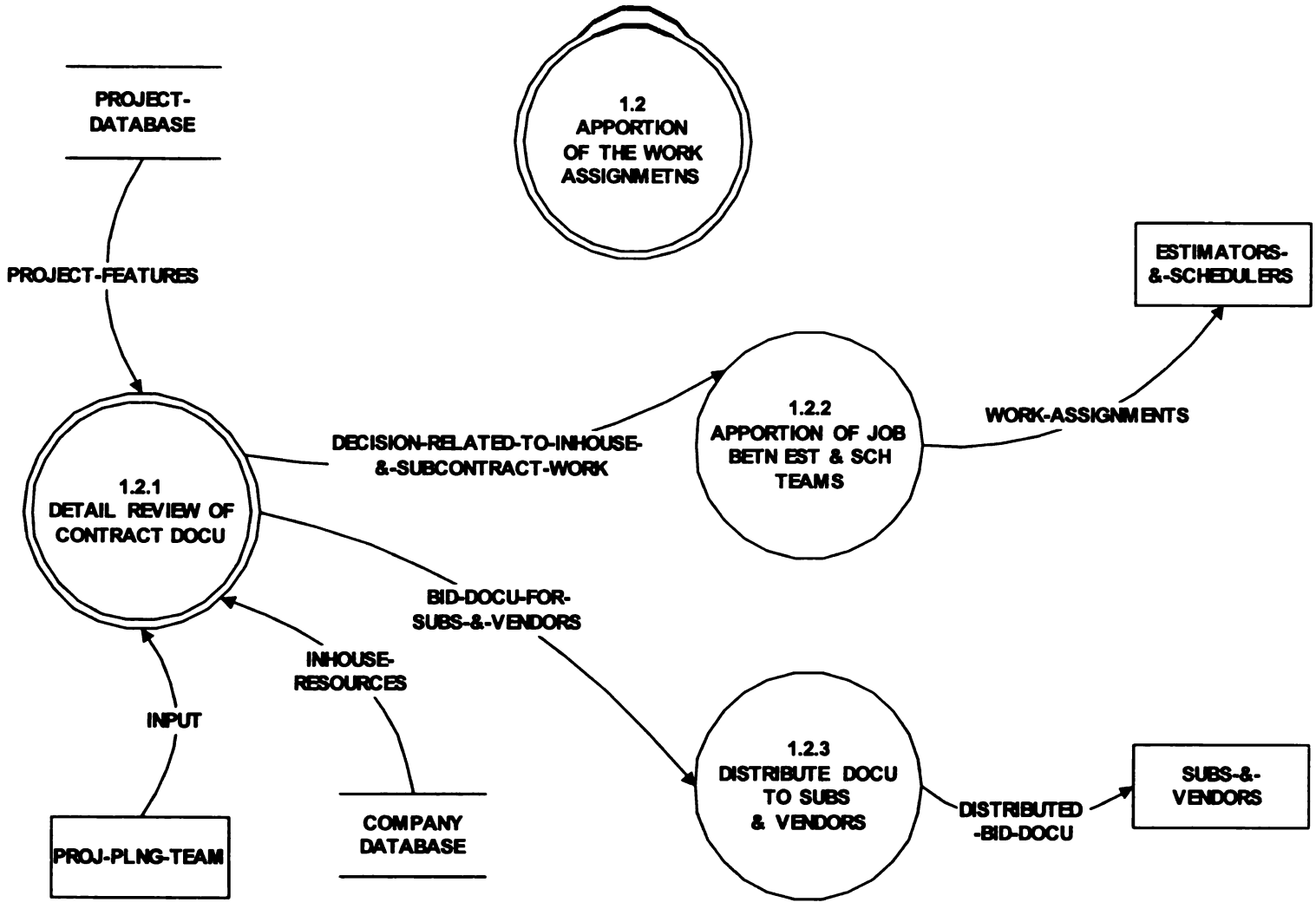

FIG. 4.11 DFD FOR STEP 1.2 OF APPAU MODEL

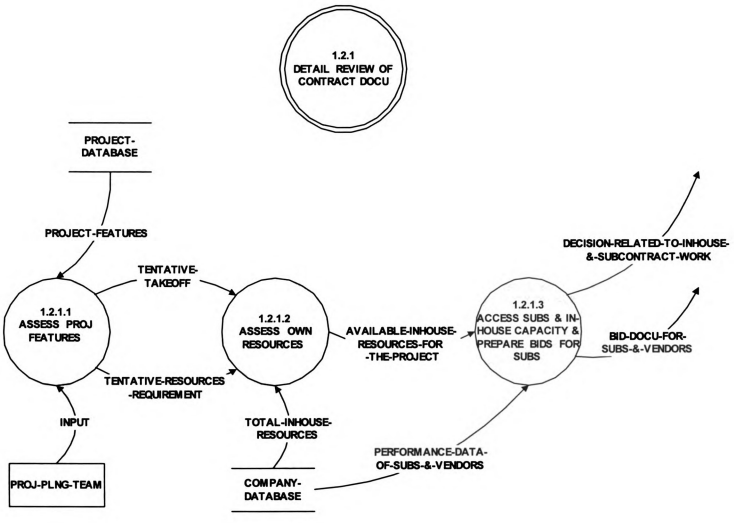

FIG. 4.12 DFD FOR STEP 1.2.1 OF APPAU MODEL

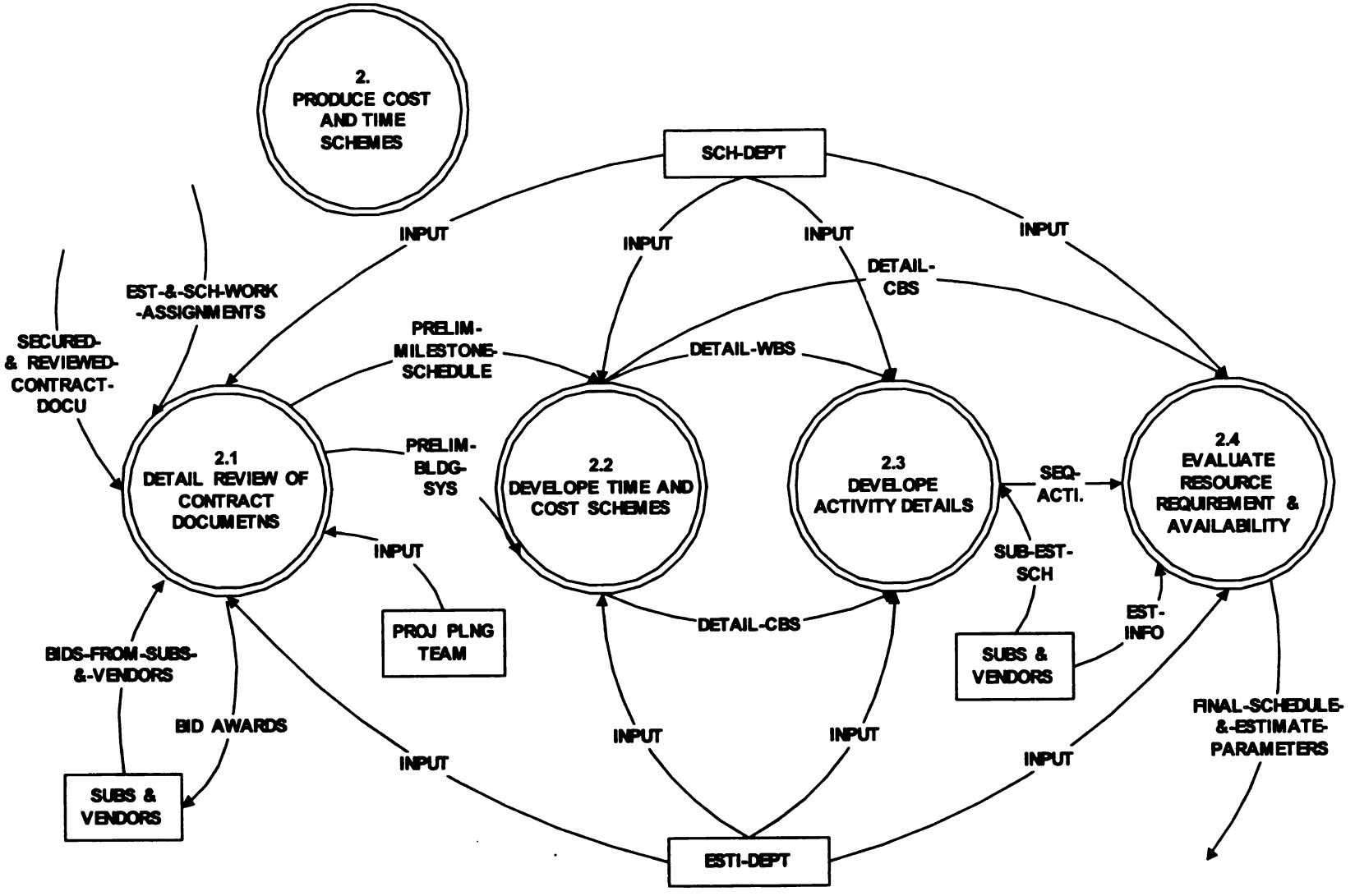

FIG. 4.13 DFD FOR PHASE 2 OF APPAU MODEL

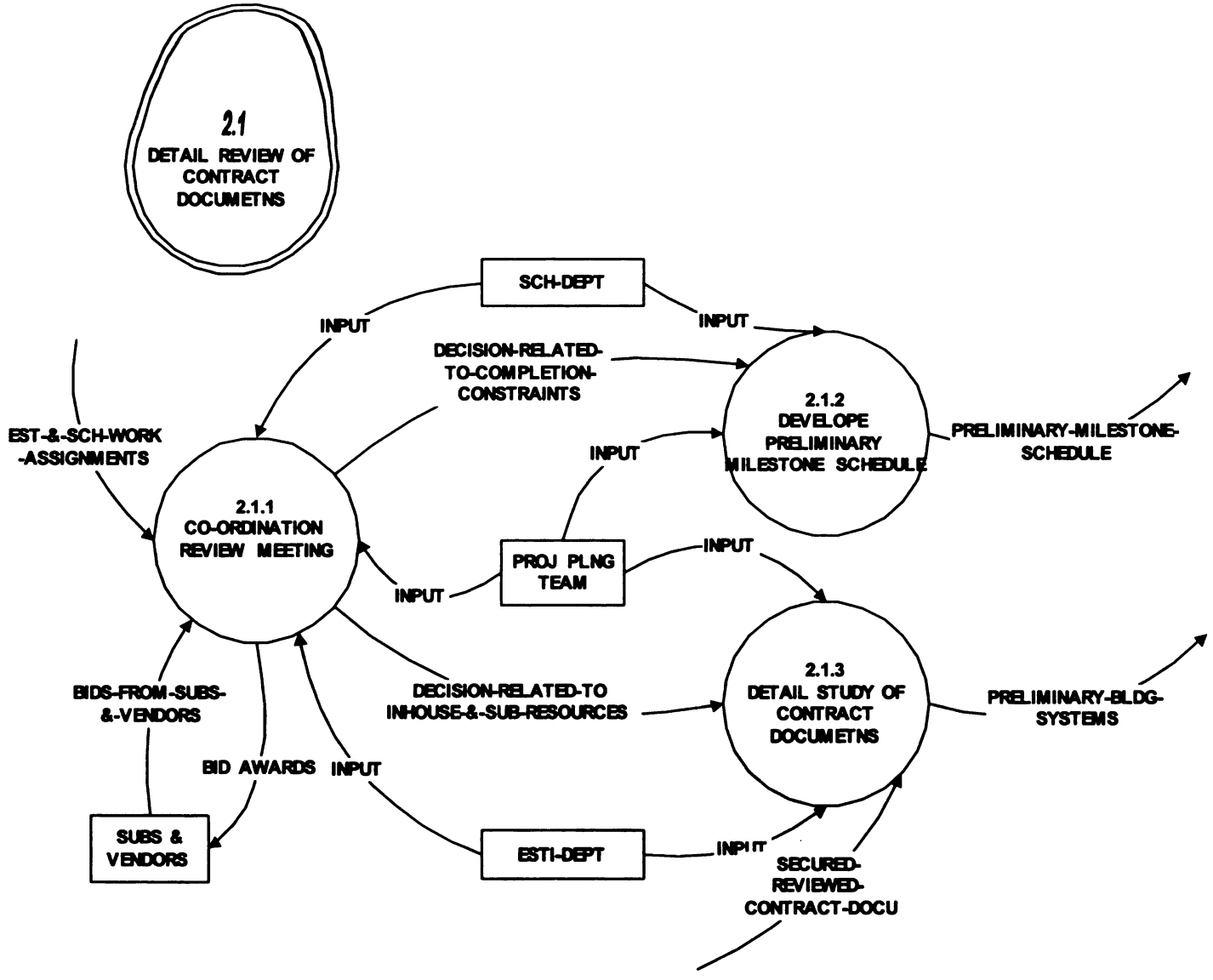

FIG. 4.14 DFD FOR STEP 2.1 OF APPAU MODEL

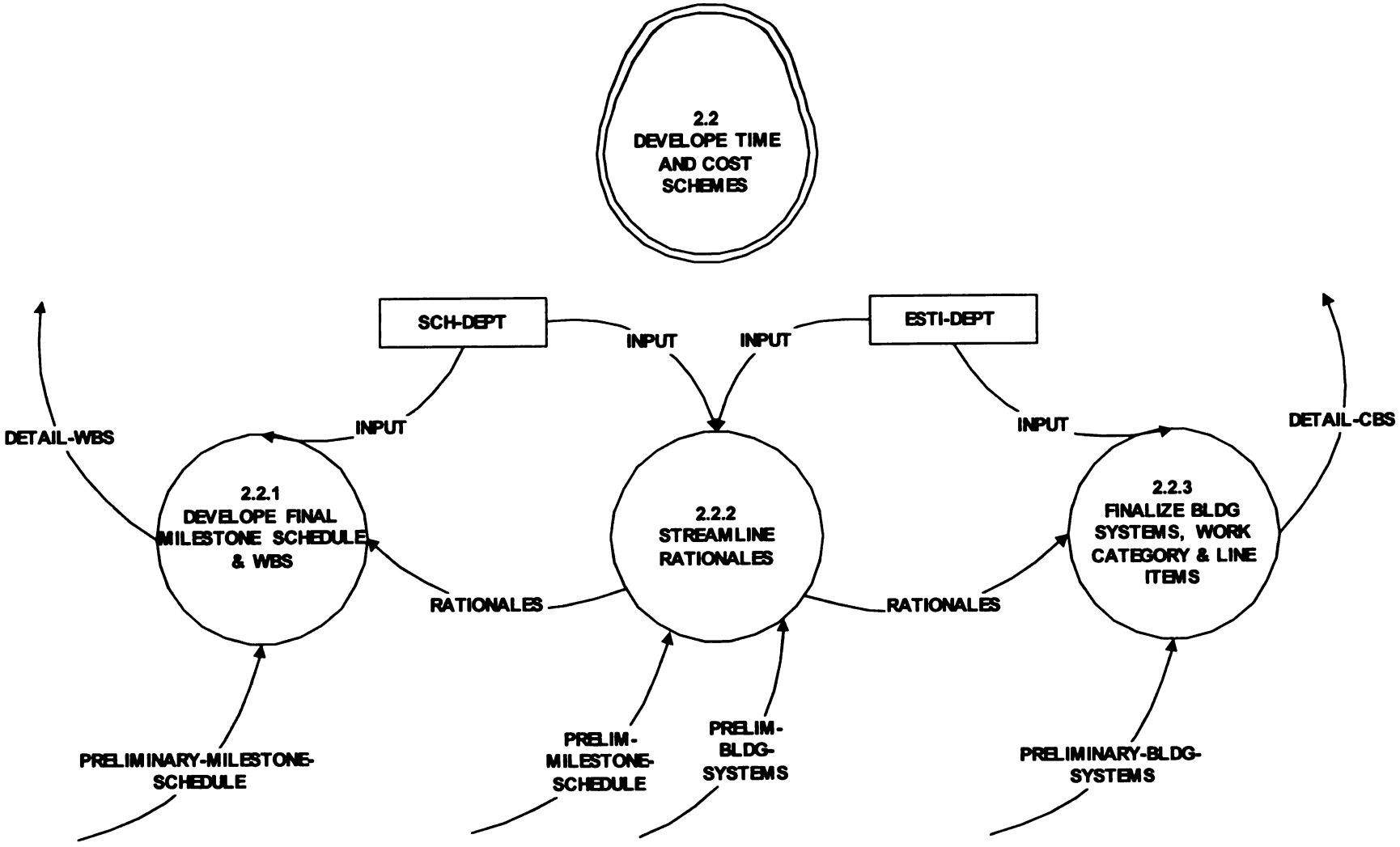

FIG. 4.15 DFD FOR STEP 2.2 OF APPAU MODEL

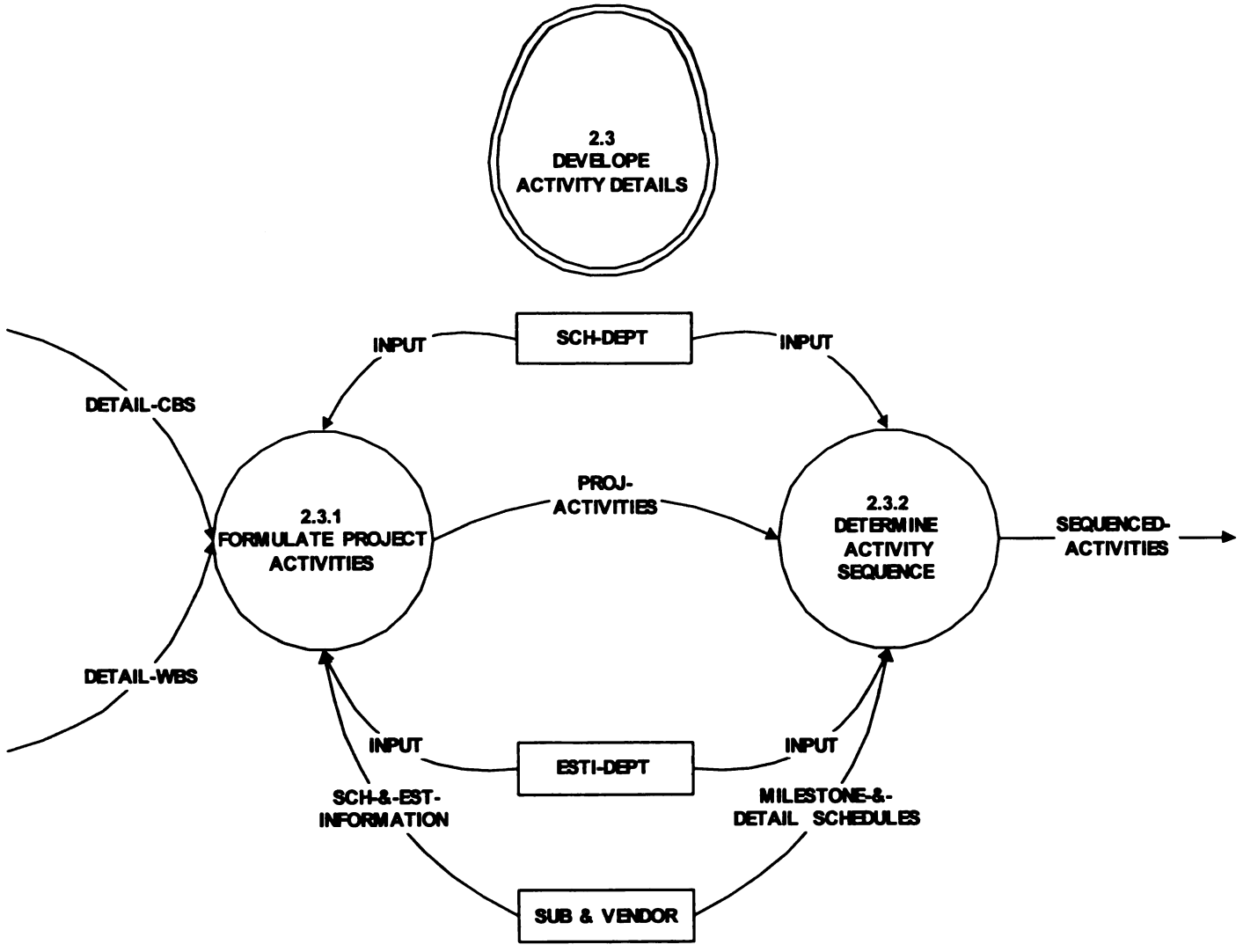

FIG. 4.16 DFD FOR STEP 2.3 OF APPAU MODEL

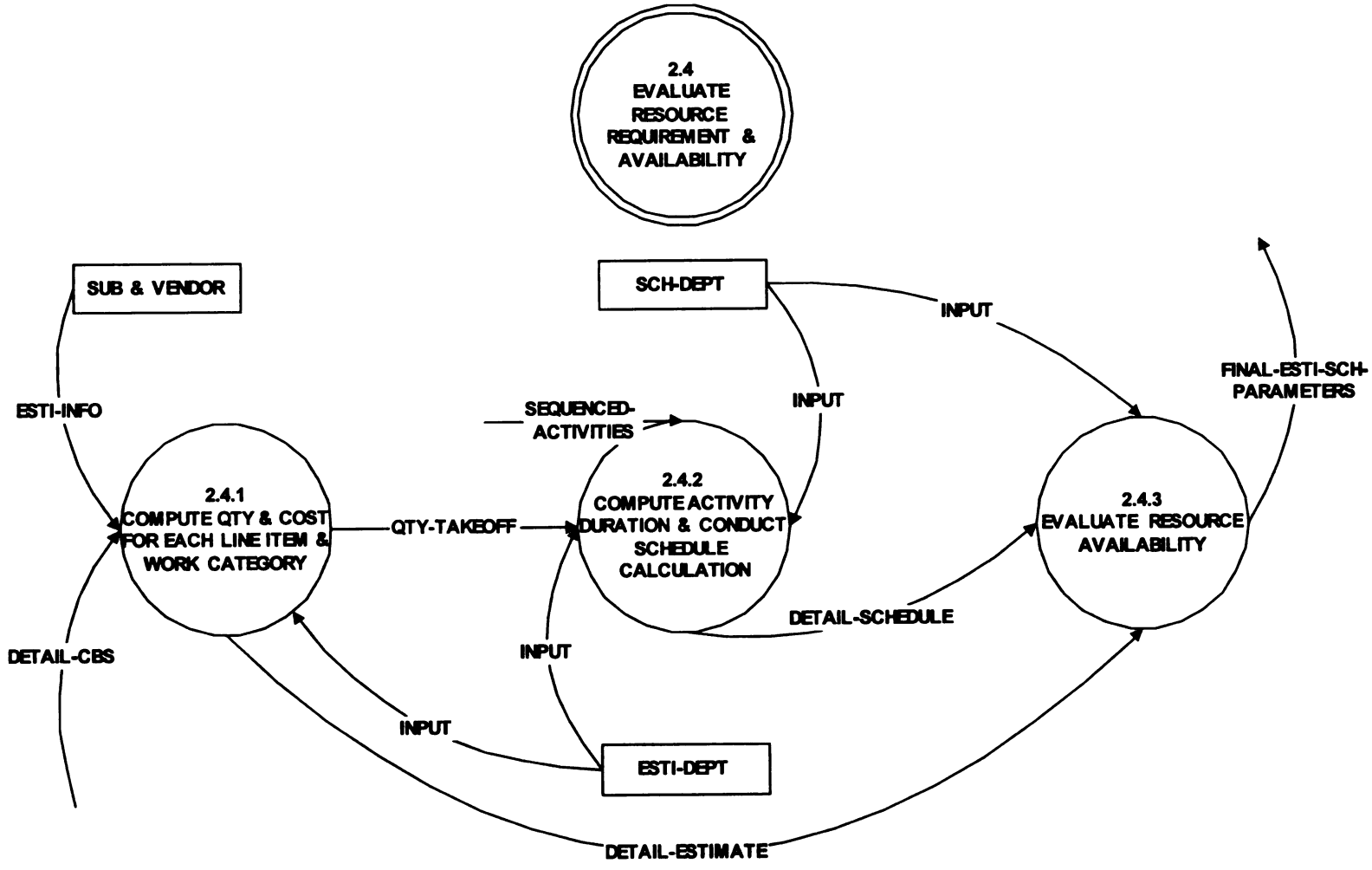

FIG. 4.17 DFD FOR STEP 2.4 OF APPAU MODEL

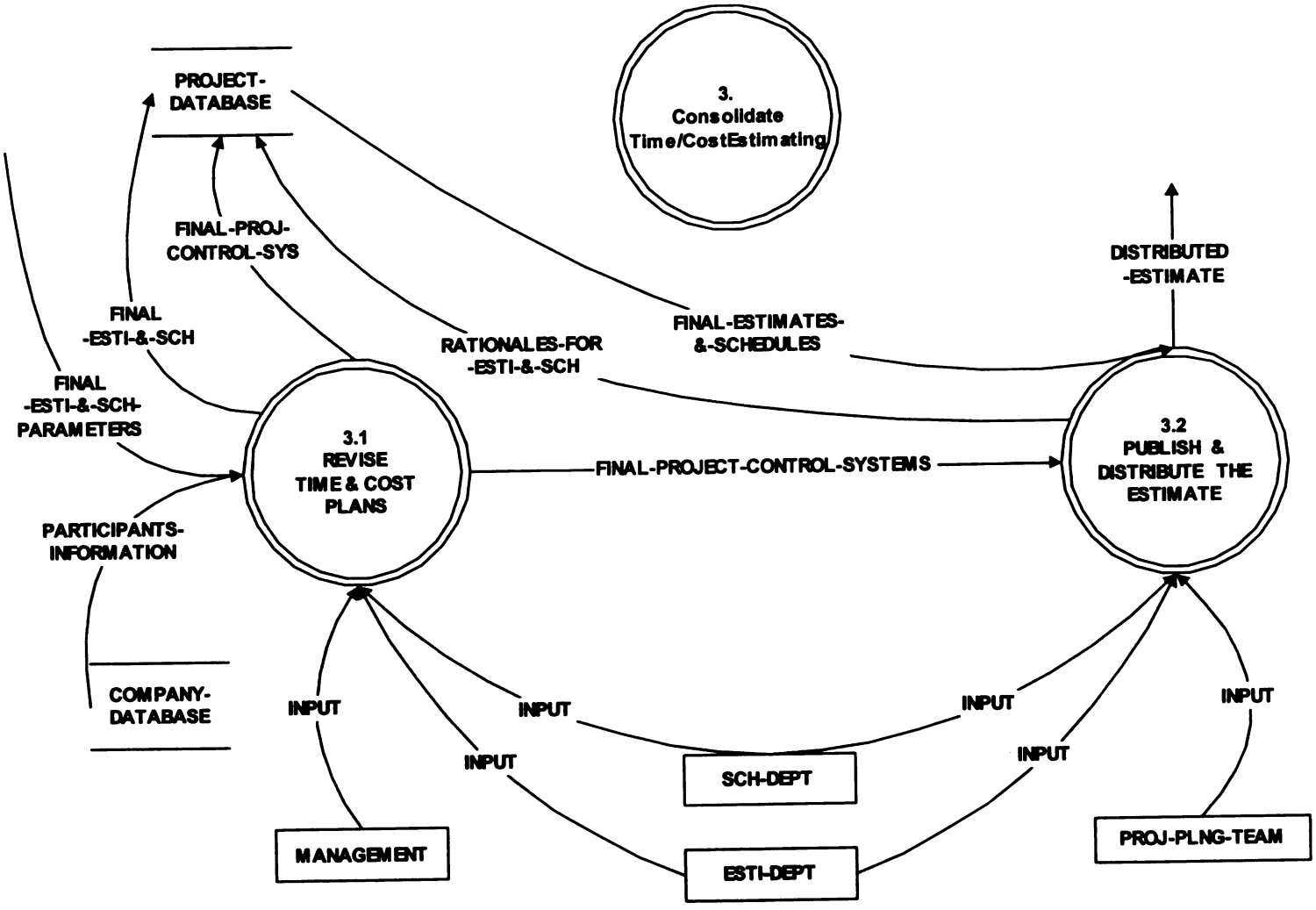

FIG. 4.18 DFD FOR PHASE 3 OF APPAU MODEL

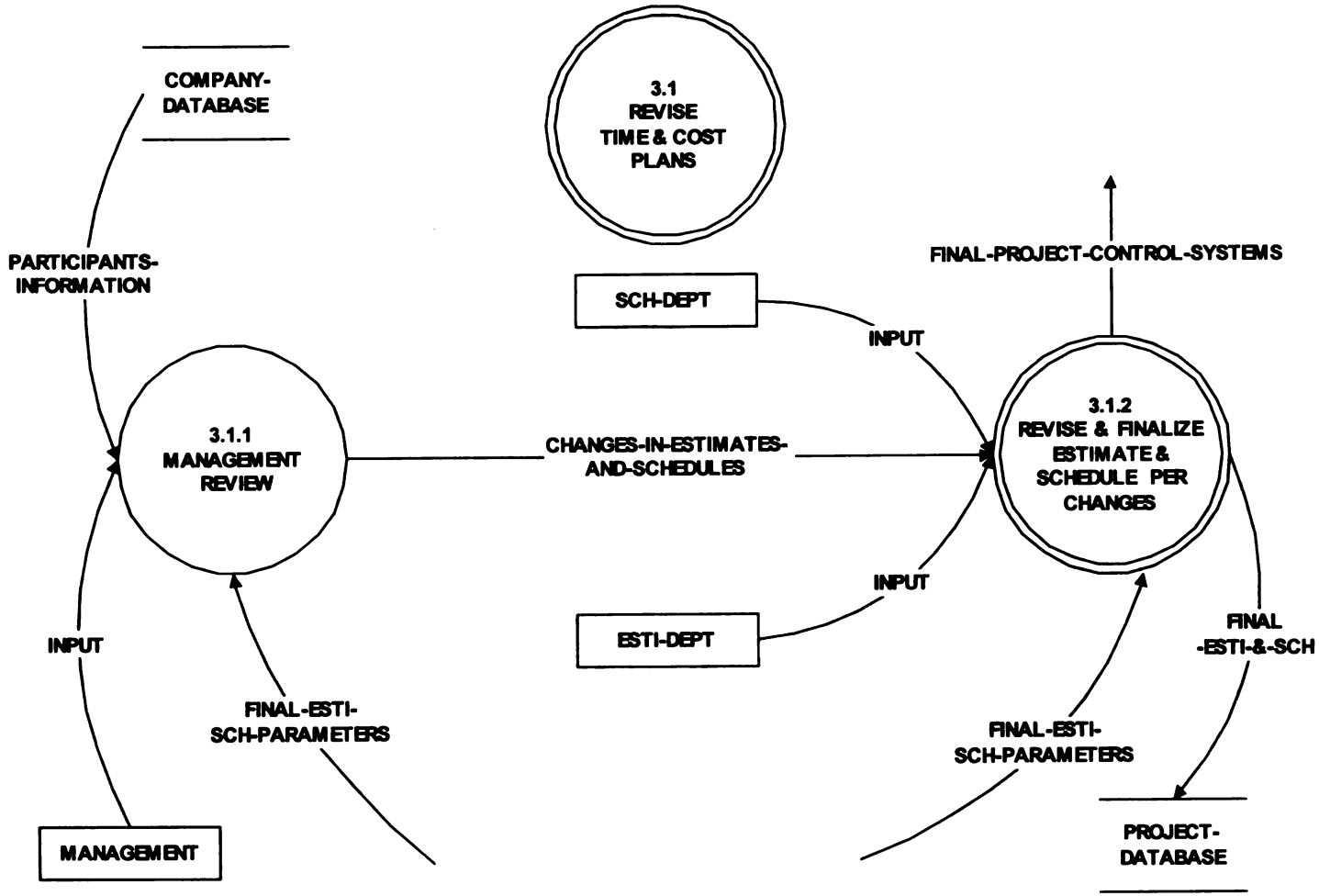

FIG. 4.19 DFD FOR STEP 3.1 OF APPAU MODEL

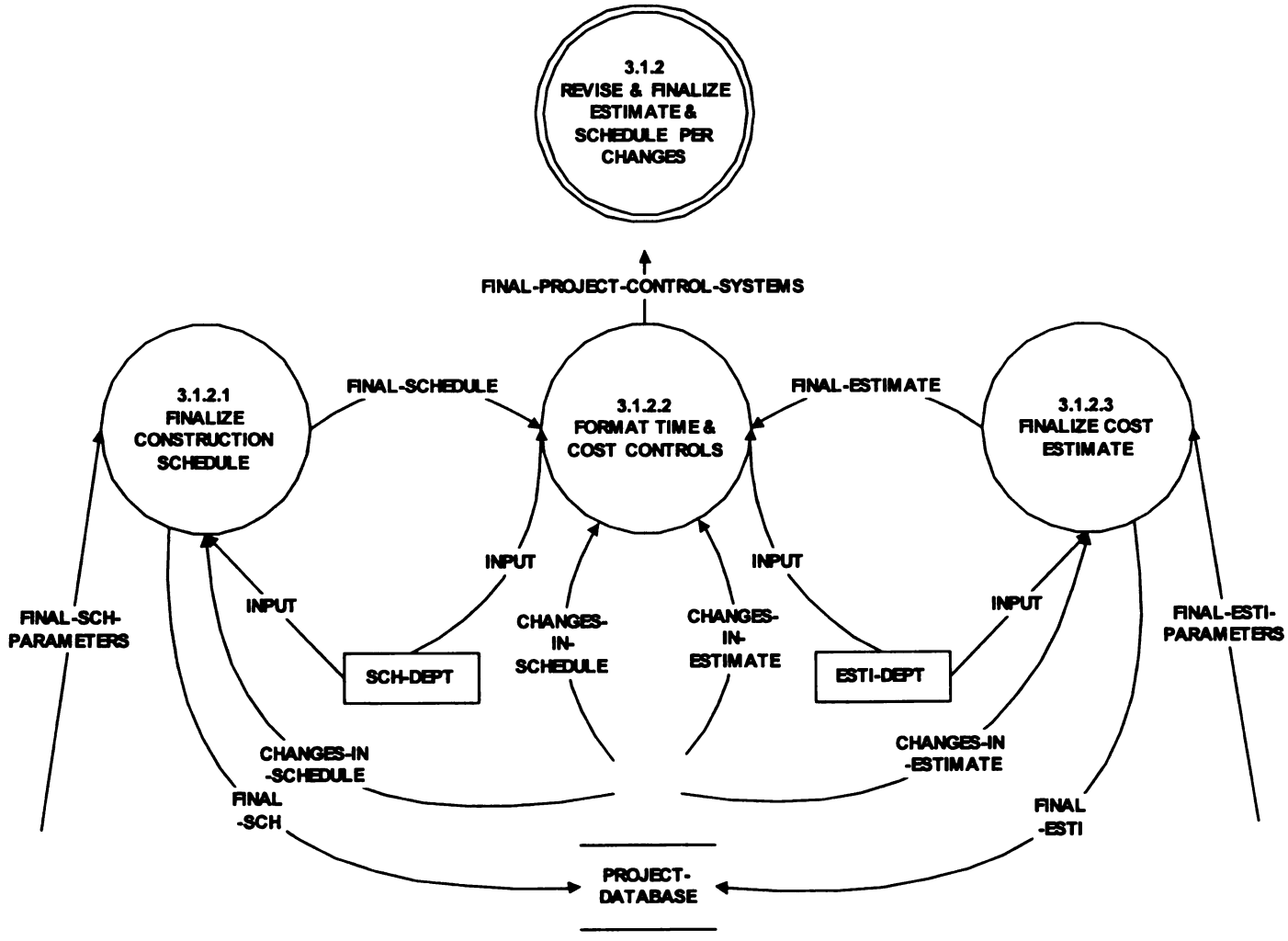

FIG. 4.20 DFD FOR STEP 3.1.2 OF APPAU MODEL

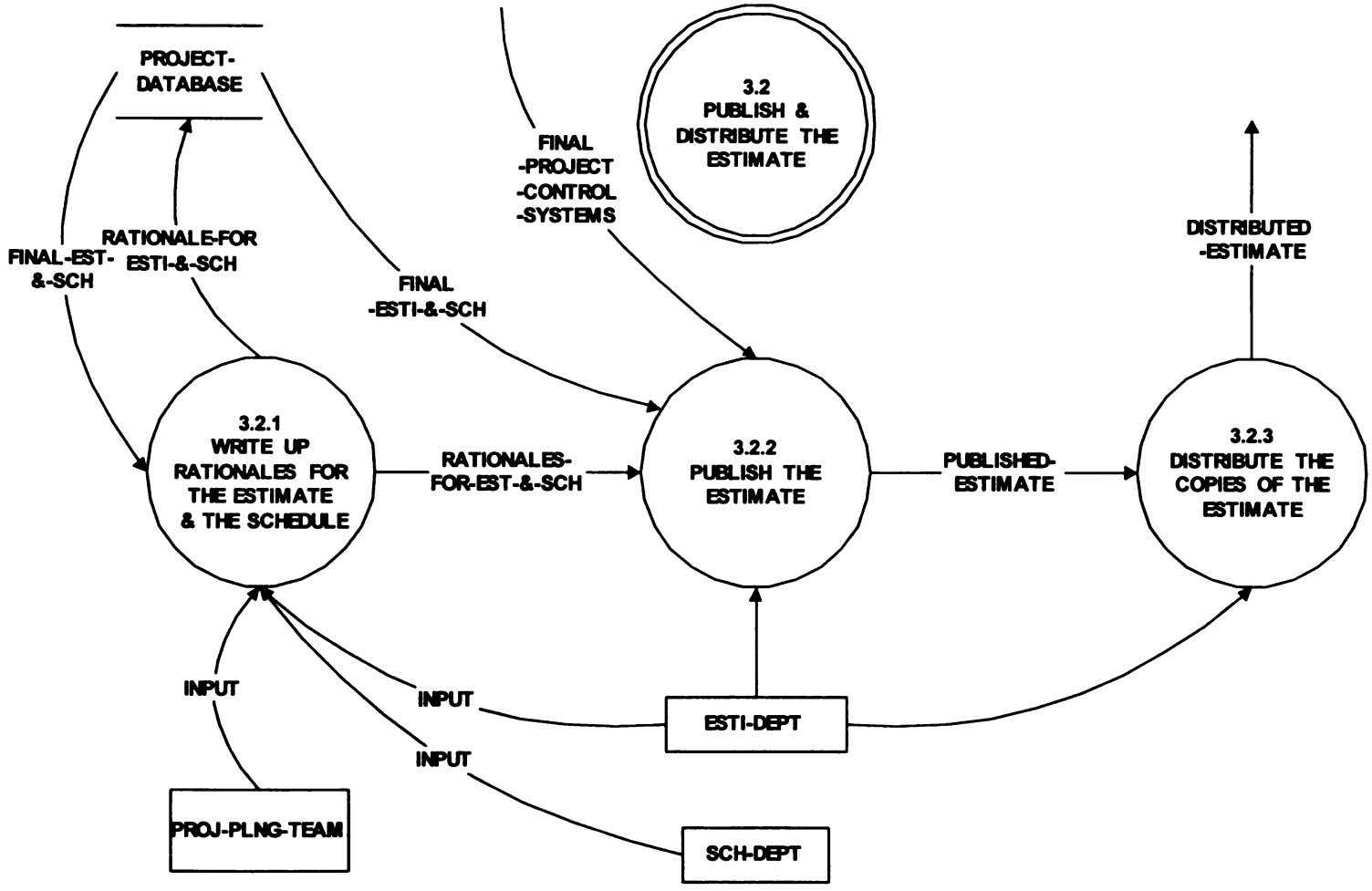

FIG. 4.21 DFD FOR STEP 3.2 OF APPAU MODEL

CHAPTER 5

DATA REPORTING

5.1 INTRODUCTION

This chapter focuses on the process used for data collection, and presents data collected through interviews of industry professionals. Deviations from the original plan for conducting the interviews are also discussed. Data was collected through face to face and telephone interviews. Following the description of the data collection process, data obtained is discussed in detail for each of the interviewee groups including vice presidents, estimators, schedulers and software vendors. In the end, summarized statements are made regarding general agreement or disagreement on certain integration related factors observed from the responses.

5.2 DATA COLLECTION

As discussed in chapter three of this report under methodology, twenty interviewees were selected and approached for participation in this study. An option of personal vs. telephone interview was given to each of them. Upon agreement to participate in the study, interview questionnaires were sent a week in advance of the interview date. A reminder was sent two days prior to the interviews. Fifteen of the interviews were conducted face to face while five interviews were conducted over the phone. Initially the author had planned to audio tape the interviews but equipment was not readily available, therefore none of the interviews were audio taped; hand notes were taken during all the interviews. All interviews lasted 60-70 minutes long. The respondents in general had spent some time on the interview questionnaires before the actual interviews were conducted. At least eight out of twenty respondents had typed their responses beforehand. Only two respondents were totally unaware of the interview topic and the questions

beforehand, due to their personal schedules. The author faced no problem in approaching the respondents or conducting the interviews other than sending extra reminders to some interviewees, who were busy at that time. The data obtained through the interviews was managed with the help of the database, which is further discussed in detail in the following paragraph and attached in Appendix II.

5.3 DATA HANDLING AND REPORTING

As discussed earlier, hand notes were taken during personal and phone interviews. Some of the hand notes were supported by the typed responses. These notes and the typed responses were entered into the database. The features of the database are discussed in Appendix II. The responses from each group of the respondents were separated into different tables in a spreadsheet format. Each question is presented with the correspondent responses obtained as shown in Appendix III. This arrangement of keeping all the responses to a particular question at one place was helpful while drawing conclusions from the responses. Tables showing questions from the questionnaires and the responses are attached in Appendix III of this report.

While drawing conclusions, the author compared the responses obtained through the interviews and the findings from the literature review related to the research work. Each of the factors related to barriers to integration of time and cost information, concluded from the data obtained through the interviews, is reported in this chapter.

5.4 GENERAL DATA REPORTING

A general data reporting section was developed with the intent of providing details about the company demographics and personal demographics related to all the interviewees. Not only the type and size of the firms impacted responses, but also educational background and number of years of experience in particular field had a strong influence. Before conclusions were drawn, it was important to be aware of all possible factors affecting the nature of the responses. Information related to personal and company demographics was obtained through the first two sections of all four questionnaires developed for the different groups of interviewees. Details are attached in Appendix III.

5.4.1 Company Demographics

As discussed in chapter three 'Methodology', eight different construction firms were selected for this study, out of which six firms were contacted for the interviews. The annual sales volume in dollars for these firms differed from $ 175 million to almost $ 800 million. These figures indicate their business in their Michigan based offices. It was observed that due to increased competition in the industry; all six firms adopted various contractual arrangements depending on individual project conditions, but major portions of the work were done through general contracting or hard bid type of contractual arrangements. Three out of six firms were involved in global level business, while the other three worked nationwide. The number of projects undertaken per year by each of these firms differed from 15 to 60. It was observed that the number varied per the size and the type of projects undertaken.

All six firms were observed to be great proponents of information technology and computerization of the construction processes. The responses can be referred to the question number CD5 in the questionnaire developed for the vice presidents. All firms were found to be up to date, with networking techniques providing computer technology to each of the professionals working for the firm. Almost 10 % of total profit per year was invested in information technology by these firms.

The interesting fact observed through the responses to the questions CS08 and SH08 was the use of different application software for the same construction process within a firm. "The increasing competition makes it difficult for firms to win the bids and it is very important for us to produce what the owner wants" was the common response obtained from at least four vice presidents. At least two to three different software products were used within the firm to perform specific functions such as scheduling or estimating to meet owner's requirements. To maintain all software and hardware facilities in the firms, each of the firms maintained a separate IT department in their regional office.

5.4.2 Personal Demographics

A variation in personal demographics caused a great impact on the nature of the responses to the particular question. It was observed that four out of six vice presidents obtained construction related education while two had a masters degree specializing in business administration. None of the vice presidents held a masters degree related to the construction field. On the other hand, five out of six estimators held bachelors degree in construction related fields with varying experience from 6 to 38 years in the construction

industry. All six schedulers had construction related background with the higher percentage of master degree compared to the other three groups of interviewees. Both the production managers (software vendors) interviewed for this research work did not have any construction related degree but one of them did have 16 years of work experience with a construction firm. All the interviewees were great supporters of the use of computers in their work, with the exception of two. Overall the respondents were interested in participating in this study and sharing their views. It was found that at least four out of six vice presidents expressed that they were looking forward to integrated solutions.

5.5 SPECIFIC DATA REPORTING

Data obtained through the interviews with the vice presidents, estimators and schedulers is presented in Appendix III in detail. General discussion about topics covered in the interviews is presented out in this chapter to elucidate the overall nature of the responses and primary areas of barriers to integration of time and cost information.

5.5.1 Vice Presidents

As discussed earlier in personal and company demographic details, six vice presidents were interviewed for this research study from six different construction firms. Five out of six held the title of "Vice President of Operations Department", while one was titled as "Project Director". Data obtained from the personal demographics section indicated that two vice presidents did not have construction related degrees but had strong experience in the construction industry. The number of years of working experience in the construction

industry varied from 19 years to 38 years. There were four different sets of questions asked to the vice presidents such as personal demographics, company demographics, project specific and integration related. Company demographics and personal demographics details are discussed in previous paragraphs and also given in detail in Appendix III of this report. Project specific and integration related responses are discussed in the following paragraphs.

1. Project specific

There were nine different project related questions asked to the vice presidents starting with "Participants involved during project planning phase". Four out of six responses involved project managers and superintendents in the project planning phase along with the vice president of operations and others. Responses obtained to this question played an important role in deriving changes related to the source or sink to be involved during the project planning phase, in data flow diagrams characterizing the Appau model. During follow-up questions, interviewees were asked about the importance of involving or not involving any particular entity during the project planning process. It was observed that almost everyone agreed upon involvement of superintendents and other members of the project management team during the project planning phase but they also agreed that it did not always happen due to timing issues. Also, it was observed that typically during the planning phase of a project, it was not known which project manager or superintendent was going to be assigned to a particular project. The second question addressed decisions made during the planning phase of a project, and the response involved mainly staffing, time frame, subcontractor and vendor selection, long lead

items, tentative budgeting and scheduling decisions, etc. The remaining seven questions were related to the role of the vice president and senior management throughout the project life cycle, typical staffing at project sites, computer and networking facilities at job sites, formalization of information, project historical database and project controlling tools used by the project managers.

It was found that almost every job site for all six construction firms was computerized and connected to the main office via intranet or Internet or other networking means, enabling the project management team to access information from different departments in the main office. Four vice presidents indicated that they maintained a centralized database, wherein all completed project related information was stored, such as estimates, cost vs. budget analysis, resource allocation etc.

It was observed through the responses to question IN01 of estimators and the schedulers that the firms were facing problems in keeping the information updated, because there was no standardized procedure for updating data. Typically, upon completion of a project, the estimating department typed cost vs. budget related data into the system. Sometimes estimates got entered into the system, but it did not happen for all projects. It was revealed through discussion that firms believed they needed a full time software consultant to keep the information integrated and updated. The related responses can be referred to in Appendix III under table A-3.

Staffing at project sites varied from job to job depending upon the type and size of a job. "Each project has its own organization structure", said almost all vice presidents, which made it difficult to derive a pattern or firm staffing structure. Standardization did exist for construction procedures. At least five out of six respondents agreed that they maintained a procedures manual, which helped new project engineers to understand the procedures followed in the firm, but project managers were allowed to make changes in those procedures based on hierarchy, which further hindered complete standardization of procedures.

2. Integration related

This section was comprised of twelve different questions. The section started with a question designed to find out whether the interviewee thought it was necessary to have a common source of data for the estimator and scheduler, while deriving line items and activities. At least five out of six respondents gave a positive reply but at the same time agreed that it would be hard to maintain due to several barriers. A necessity of conducting joint meetings between estimating and scheduling departments got a higher priority among respondents. When the discussion focused on keeping time and cost data integrated through out the project life cycle, respondents came up with a wide variety of responses. It was observed that five out of six respondents indicated that they conducted joint meetings between estimators and schedulers as needed, during the planning phase but everything stopped at the meeting. The entire process of understanding the project, doing the takeoffs, and deriving activities remained fragmented. Only one of the six firms

was found to maintain continuous communication between their estimating and scheduling departments during the project planning phase.

The latter half of the integration related questions consisted of topics related to the awareness of research work addressing integration of time and cost information and their views about the same. It was observed that none of the respondents was aware of any research work done toward integration of time and cost information but they were aware of different software solutions and three out of six firms happened to use some of the integrated software solutions such as job cost and accounting, project management and accounting, scheduling and project controls, etc. In the end, integration concept per the Appau model was discussed. The overall response was that integration needed to be done, but they were not sure how it could be done. Two responses were related to cost vs. benefit issues regarding implementation of the Appau's concept. Overall it was observed that all six firms were not sure whether they needed to utilize integrated solutions for time and cost information because most of the work was subcontracted. Even if they implemented integrated solutions, the respondents indicated they were more inclined toward ready-made solutions rather than modifying their own business processes.

5.5.2 Estimators

Six estimators were interviewed for this research work from six different construction firms. The estimators had varied estimating experience ranging from 6 years to 38 years with almost everyone holding construction related degrees. All six estimators rated their computer skills 5 and above, based on 1 to 10 scales. All of them held a title of chief

estimator and had an estimating team working with them while bidding larger projects. Other than personal demographics, there were two sets of questions covered during the interviews, which related to estimating procedures practiced in the firm and integration of time and cost information, which are further discussed in detail in the following paragraphs.

1. Estimating Procedure

The estimating procedure section consisted of twelve questions starting with "Are there any set procedures for preparing an estimate in different types of contractual arrangements?" Three out of six estimators informed that they had a standardized and defined procedure for estimating, but it was not followed by the majority of the estimating staff. Each staff member preferred a different method of working and breaking down building systems. Also, it was not mandatory to follow company defined procedures. Three estimators indicated that they did not have any set standards for the process of estimating, and every estimator followed his/her own method. The estimators were asked whether they seek any management decisions while preparing an estimate, and all the responses were positive. Typically markup percentages, bid strategies, subcontractor and vendor selection were issues handled by senior management during the estimating phase. Also decisions related to in-house vs. subcontracting work was a main area wherein estimators sought management decisions. It was observed that all six firms involved participants from different departments during the estimating phase such as: operations, accounting, finance, mechanical engineering, electrical engineering, legal, human resources, purchasing, IT, marketing, etc. But the scheduling department was

involved only if needed, depending on project complexity and time constraints. In three of the firms, estimators prepared a base schedule while preparing bids. If the firm was awarded a project, then the same schedule was forwarded to the scheduling department who expanded it further. Two firms did not involve schedulers at all during the estimating process. In this case, the project manager prepared a schedule. Only one firm out of six involved the scheduler thoroughly during the estimating process and the same scheduler further expanded a schedule if the firm was awarded the job. Further discussion with the estimators revealed that only one out of six estimators did not use any kind of estimating software, while five used one or more estimating software packages. Involvement of estimators during the project life cycle and communication between the estimating and the scheduling departments throughout the project life cycle was discussed; details are given in Appendix III. In the end, estimators were asked whether the organization structure affected the estimating process and if yes then whether it was helpful or not. Two out of six estimators responded that the present organization structure needed to be changed, because it was difficult to obtain information from different departments in a timely manner. One response obtained to this question was that estimators needed to be held responsible for their work by making them build what they bid for.

2. Integration related

The discussion started with a necessity of common source data by using a common breakdown structure by estimating and scheduling departments and the benefits of the same. Four out of six respondents acknowledged the need and benefits of having a

common work breakdown structure but also agreed that it was hard to achieve. One respondent denied the need for having common source of data, while one of the respondents stated that it would not help them because the estimate was done by trade, while the schedule was based on work structure. Further the need for joint meetings between estimating and scheduling departments was discussed, to which five out of six estimators strongly supported with one of the estimators stating, "It would be beneficial but not necessary."

The discussion related to information exchange between estimating and scheduling departments revealed that none of the estimators agreed that the integrated software solutions would help them to avoid the need for joint meetings or exchange of information between departments completely, but responses to the next question showed that none of the six estimators had worked with integrated software solutions for managing time and cost information. Also, none was aware of any research efforts toward the same. In the end, computerization of the construction processes and barriers to integration of time and cost information were discussed. Set working methods, inclination toward the use of computers, sharing knowledge with the others, sharing authority, early involvement of schedulers, etc. were the primary barriers explored through the discussion affecting integration.

5.5.3 Schedulers

All six schedulers interviewed for this research had construction related degrees; one of them had a masters degree in construction management. All of them rated their computer

skills higher than vice presidents and estimators. The number of years of work experience in the construction industry varied widely from 4 yrs to 34 years. Three of the six respondents were solely involved in scheduling activities, while the rest also acted as project managers or project engineers, preparing and managing project schedules. Typically, schedulers were involved in all types of projects. Following the personal demographic section, two more sections were covered, which addressed scheduling procedures and integration as discussed in the following paragraphs.

1. Scheduling procedure

When schedulers were asked about standardization of scheduling procedures, three of six schedulers stated that there was a standard procedure defined to carry out scheduling but it was not followed all the time. The remaining three expressed that there was no standardization of scheduling procedures. Following this discussion, management decisions considered during scheduling were discussed. Milestones in the schedule, sub contractors and vendors' selection, resource availability and long lead items were some of the main factors discussed with the senior management during the scheduling process. While discussing staff involved during scheduling, it was observed that for small to mid-size projects, the project manager prepared and managed project schedules, while larger projects involved a full-time scheduler. Two out of six firms did not have a separate scheduling department.

The sources used to obtain the required information while preparing schedules remained standard for all six firms, but participants involved while preparing the schedules varied.

All firms used software solutions to carry out scheduling and at the same time maintained a variety of scheduling software to meet with the varying owner's needs. Following this discussion, schedulers were asked whether they maintained cost loaded schedules; only one out of six responded positive to this question. Further, the organization structure and the effect of organization structure on the scheduling process were discussed. Three out of six respondents expressed that the organization structure was helpful, while the rest responded that the organization structure did not really help a lot in cross-departmental communication. Two respondents indicated that a top down nature of the organization structure made it harder to obtain the required information in a timely manner. Finally, a common work breakdown structure and common source data for scheduling and estimating were discussed. All six schedulers agreed with the need for having common building systems and common source data, though they further stated that it might not be easy.

2. Integration related

Similar to estimators, schedulers were asked a set of integration related questions to find out barriers from a scheduling point of view. All six schedulers indicated that to achieve integration, common source data and joint meetings with estimators would be helpful, and they strongly disagreed that they could achieve the same level of information exchange by using integrated software solutions. As mentioned earlier, all firms used and maintained more than one software package for scheduling, but at least one scheduler expressed "effective software is yet to come". When it came to integrated software solutions, it was found that none of the schedulers had worked with any software package

that integrated estimating and scheduling and none was aware of any research efforts done in this area. Interestingly, all six respondents strongly agreed that it was important for them to consider integration of time and cost information during the planning phase of the project, before they implement integrated software solutions and focus on project controls.

5.5.4 Software Vendors

To obtain feedback from the software vendors and understand their views toward construction processes and complexity of the construction projects, product managers of two leading software firms were interviewed for this research study. Due to location and timing issues, both the interviews were conducted over the phone. As stated earlier in this chapter, none of the two product managers had construction related degrees. Work experience with construction related software varied from 2 ½ years to 16 years. One of the product managers dealt with a variety of clients such as contractors, owners, construction managers and other industries, while the other product manager dealt only with general contractors in the construction industry. A percentage of construction industry related customers handled by these two product managers varied from 10 % to 100 %. Both product managers were responsible for new product development, updating old products and liaison between customers and development.

1. Developing new software

Interviewees were asked which participants were involved while developing new products. The interviewees indicated that a technology leaders, product managers,

software project managers, training specialists, quality assurance, marketing, senior management, etc. were involved. The question was asked with the intent of learning whether there was any involvement of people having construction backgrounds. Through the responses to the later questions in this section, it was observed that the product managers obtained data required for development of new software through surveys, market studies, business trends analysis, etc. An understanding of construction processes was typically obtained with the help of the business process analysts working for the firm, on site research, etc. Both the product managers expressed that joint meetings with the customers were conducted to understand customers' needs. When it came to customization of the product, one of the product managers expressed, "not for one particular client but for a particular group of clients, customization is carried out," while the other one stated, "our software meets the needs of most clients, it is rare that we will customize the software for one client." The discussion further went to integration issues as discussed in the following paragraph.

2. Integration related

Both product managers had worked on integrated software for scheduling and estimating, scheduling and project controls, estimating and accounting and other. One response obtained to the question "Do you think this is the most efficient way of integrating the information between scheduling and estimating processes" was "yes" while the other one was "there is always a scope for improvement". Further, issues related to the efficiency of the existing integrators and improvements in the same were discussed. One out of two product managers responded that they were working on additional features for their

existing software product to meet the varying needs of end users. The other agreed that customers were asking for better means to integrate time and cost information but the product manager did not share the steps taken toward it. In the end, while discussing possible barriers to integration of time and cost information, the responses obtained were, "each general contractor works in a different way", "each participant plays a different role and tracks time and cost information in a different way", "there is nothing common", and these factors made it difficult to standardize the parameters for tracking time and cost information.

5.6 OVERVIEW OF THE RESPONSES

With the study of all the responses discussed in the previous paragraphs and stated in Appendix III, it can be stated that the responses had some consistency. Even though some of the responses were impacted by the educational background and number of years of experience of that particular interviewee, there was still a pattern or a trend in the responses obtained from a group of respondents. In general, all the respondents agreed to one basic fact, that there was no standardization whatsoever in the construction industry. Though the construction processes were defined in the procedure manuals, the manuals were typically used for ISO purposes. On a daily basis, those standard practices were not followed. Vice presidents agreed that they had to maintain all possible software solutions to carry out one type of construction process to meet varying owners' needs. Also they had to be prepared to adapt to any kind of contractual arrangement to obtain competitive advantage, which further made it difficult to derive any fixed or standard organization structure or pattern within the construction firms. Similar responses were obtained from

estimators, schedulers and the software vendors, which lead to the conclusion that the construction industry lacks standardization. Barriers to the process of integration of time and cost information implied by the interviewees are discussed in detail as below.

5.7 BARRIERS

Barriers implied by data obtained from twenty interviews conducted for this research study are discussed here with the supporting quotes from the interviewees where applicable. Barriers are classified into five different categories such as: contractual, organizational, technical, behavioral and general.

1. **Contractual:** Barriers related to contractual arrangements are discussed here.
    a) **Varying staff arrangements:** The responses indicated that all six firms adopted a variety of contractual arrangements depending on the project, which made it difficult for the firms to derive a particular pattern for staff arrangements and resources arrangement beforehand. Each project requires a unique set of business process requirements, staffing and time frame requirements.
    b) **Unavailability of right personnel at right time:** As discussed earlier, different contractual arrangements demand a different group of people to work on a particular project, which makes it difficult to make the right personnel available when required during the project planning process.
    c) **Varying control factors:** Varying contractual arrangements created variations in the control factors for estimating and scheduling and also the responsibilities of the participants for each project.

d) **Base framework for tracking information:** Vice presidents indicated that firms were not convinced of the importance of the integration of time and cost information irrespective of the changes in the contractual arrangements. The response from the respondent number four can be stated here as, "'Continuous communication between the project management team and accounting dept (is required). Estimating scheduling (integration) will not help tremendously like PM and accounting." Different contractual arrangements play an important role behind this opinion, because no matter how long the project takes, or what the reasons of the delay are, the most important parameters for the contractor: "cost" and "budget" always get tracked, unlike "time".

e) **In-house vs. subcontracted work:** The response number six to question IN09 in the questionnaire developed for vice presidents was significant. It stated, since the majority of the general contracting firms subcontracted ninety percent of their work, they did not need any integrated information between time and cost; rather they needed "man hours used" details. It was a response obtained from a vice president who had been in the construction industry for twenty-eight years. A similar response was obtained from the estimator number six to the question IN09. This represents a whole group of people and their beliefs toward the integration of the information. The author believes the biggest barrier is that the professionals need to be convinced of the long term benefits and the value added to the firm by adopting integration of time and cost information.

f) **Lack of knowledge related to importance of integration:** Responses obtained to the question IN04 by the vice presidents also showed that vice presidents representing these organizations were not convinced of the importance of integration, and how possible it was to make it happen. The responses were, "That would be ideal, but construction is a most unpredictable business," "It is possible only in ideal conditions," etc. This is also an effect of changing or varying contractual arrangements.

2. **Organizational:** A question was asked to the estimators and the schedulers "How does the company structure affect the procedure of estimating/scheduling?" (CS11 and SH11 – Appendix III) The responses leading to barriers related to the organization structure were as follows:

   a) **Difficulty in obtaining required information:** Two estimators gave response such as, "Makes it harder to obtain required information from different departments like purchasing, planning, accounting and site office at any given point of time" and "Timing issues, harder to obtain all the required details in a timely manner."

   b) **Lack of cross departmental communication:** The responses obtained to the question IN03 from the estimators also strengthened the belief that the change in the present organization structure was needed, because it did not support the concept of joint meetings between estimating and scheduling departments due to the closed nature of the organizational culture.

c) **Knowledge transfer:** Another barrier related to the organization structure found was that the estimator was the most knowledgeable person about the project characteristics, special features and overall requirements of the project, but the knowledge did not get transferred to other departments or to the project management teams. Two senior estimators expressed a necessity of holding the estimators responsible to construct the projects they bid. This practice is not very common in the construction industry.

d) **Improper channeling of the information flow:** The typical nature of the organization structure further dictated the process of updating the centralized project historical database. The estimator was not involved during the construction phase, thus he typically was not aware of all the pitfalls and the delay reasoning and other problems faced at the site but he was held responsible for updating the database at the end of the project. Cost vs. budget analysis was the only information, which got updated in the database. This process did not help creating valuable information for those planners, who referred to this centralized database while bidding for new projects. (Responses to the question PR07 by the vice presidents)

e) **Involvement of required participants:** Another barrier related to the present organization structure within the construction firms could be described as the involvement of the right people at the right time. The responses to the question SH12, expressed that the schedulers realized the necessity of involving subs, suppliers, project mangers and the superintendents during planning process, but it did not always happen due

to the organization structure present in the construction firms, conventional business processes, etc.

f) **Awareness in subs and vendors:** Another barrier, which could be related to the present organization structure and the business processes practiced in that construction firm, was lack of awareness of integration information within a group of sub contractors or suppliers the company is in business with. At least one scheduler responded to the question IN10 as "Yes (the integration of time and cost information needs to happen during planning phase of the project in order to make it happen during the project controls). Provided the subs do the same - mainly (at the) task level and (at the) resource level." Thus, the construction firms need to establish a long-term relationship with their subs and vendors and create the same awareness.

g) **Lack of standardization of processes:** Current business processes and standardization of procedures was a topic of long discussion with all the industry professionals. Five out of six responses to the question CD9 indicated that project planning was standardized and defined, while all responses to the question CS01 and SH01 indicated that every estimator and the scheduler had their own method of preparing estimates and schedules and the standardized process was almost never followed by anyone. The varying nature of the organization structure had a stronger impact on non-standardization of the business processes.

3. **Technical:** Technical barriers were mostly related to the use of information technology to perform construction processes such as estimating and scheduling.
    a) **Skills:** The first and the most important barrier faced by the construction firms was the unavailability of the right combination of professionals with the real time construction knowledge and information technology expertise. Each of the six firms maintained a separate IT department within the organization to troubleshoot software and hardware related problems. But there was no entity available to make sure that each of the departments knew how to work with a particular software package to perform particular construction process.
    b) **Lack of information / knowledge about the software package:** The older people working for the department did not want to use new software technology tools to perform functions due to lack of information or knowledge about the particular software.
    c) **Training:** A strong competition between the organizations made it mandatory for the construction firms to maintain all possible software to meet owner's varying requirements. The organization could not provide training for all personnel for all software packages available within the organization. This created a large gap in the information exchange. Many times the centralized database did not get updated even though the information laid in one of the computers within the organization but in a different format. The same database was further used during the project planning phase of new projects.

d) **In-house business processes and technology need analysis:** The responses obtained to the question CD6 by the vice presidents indicated that almost ten percent of the total profit was invested in IT annually. But there was little in-house study done before the investment in IT was made. The technology was brought into the organization before people were ready for it.

e) **Effective software:** Overall responses by the estimators and the schedulers regarding the computerization of the construction processes were not positive. Responses to the question IN11 by the estimators and IN12 by the schedulers indicated that professionals wanted software vendors to work more closely with the industry professionals to create less rigid, and more customized and effective software. Industry professionals also expressed that software did not always do what the vendors claimed it would do.

f) **Lack of real time construction knowledge:** It was observed that there was no involvement of construction industry professionals while developing new software. The business process analysts provided required knowledge or understanding of the construction processes, but they were not in touch with the construction projects on a daily or weekly basis to understand the complex nature of the construction projects.

g) **Customization:** Discrepancy was found within the responses obtained from software vendors and from estimators and schedulers regarding the effectiveness of software in general and that estimators and schedulers

were not happy with the software package they used to perform the processes. On the other hand, the response to question CR5 by the software vendor was, "Our software meets the needs of most clients; it is rare that we will customize the software for one client."

h) **Uniqueness of construction projects:** Another barrier related to the standardization of the software used to perform different construction processes could be summarized from the responses obtained to question IN12 from both the software vendors such as, "I would say, it very much depends on the contractual arrangement of the project and from whose perspective you are looking at, each participant plays a different role and tracks time and cost information in a different manner" and "The way the project is broken down time-wise and cost-wise, who is going to use it, each general contracting firm works in a different way, there is nothing common, which makes it harder to standardize."

i) **Variety of software vendors:** It was observed from the responses obtained to the questions CS08 and SH08 that the organizations used different software to perform different construction processes, provided by different software vendors, which further made it difficult for them to keep the information standardized. The response to question IN08 by the vendors indicated that they were not willing to share their plan of actions related to the changes in their present software packages.

4. **Behavioral:** The most important issue related to integration of time and cost integration was found to be "people" and their "behavior". The findings from the data obtained through the interviews are discussed below.

    a) **Set methods of working:** "Each one has its own way of working, they have been practicing the same for years together, its hard to break the habits, as far as they manage to get good results, we don't really bother," was a response obtained to the question IN03 by one of the vice presidents. Similar responses were obtained from the estimators and schedulers.

    b) **Resistance to change:** The response to question IN10 by one of the vice presidents stated, "People resist change." It was found that the higher the amount of work experience, the greater the resistance to the change in their work practice.

    c) **Inclination toward use of Information Technology, etc.:** Regarding factors necessary to be considered while thinking in terms of integration, a scheduler, while answering the question IN11 stated, "Peoples mind set, set working methods, resistance to the change, inclination toward the use of computers, authority, specialty and skill in their area, timing." While one of the vice presidents responded to the question IN11 as, "Cost vs. Benefit analysis, resistance to change, years of business practices, mindset, computer literacy and inclination toward learning new technology, timing issues, natural tendency to control own area of

knowledge," as the factors to be considered while moving toward integration.

d) **Resistance to share authority:** Sharing the authority and each other's domain were some barriers expressed by the vice presidents.

5. **General:** This category was developed to discuss barriers, which indicate construction firms are unaware of the importance of the integration of time and cost information.

   a) **Not sure about the steps to be taken:** The responses to question IN01 by the estimators and the schedulers indicated that either the respondents were not convinced of the importance of the integration or they were not sure about what exactly they need to do to achieve the same. The responses to question IN08 by the vice presidents indicated that the organizations acknowledged the existence of the integration of time and cost information but were not ready to be the first ones to try.

   b) **Importance of integration:** It was obvious from the responses by the vice presidents that they needed to have a demonstration of the "cost vs. benefit" analysis, before they could think of taking any step toward integration of time and cost information.

   c) **Lack of information:** Responses to the question IN05 by the vice presidents, IN07 by the schedulers, IN08 by the estimators and IN11 by the software vendors proved that none of the twenty interviewees were aware of any of the research work done in the area of integration of time

and cost information irrespective of the huge amount of the research work done in the same area.

d) **A gap between logical and physical premises:** Overall the lack of information about the subject matter was observed through a majority of the interviews with the industry professionals. A big gap between theory and the practice was explored.

5.8 SUMMARY

This chapter discussed data handling and data reporting of the responses obtained through the twenty interviews conducted as a part of this research work. A database developed to handle the responses was discussed and also attached in Appendix II. Specific responses were reported for each group of interviewees and are attached in Appendix III. It was observed that all responses obtained through these interviews had a pattern or a trend and represented similar opinions, such as issues related to the standardization of construction processes, organization structure, etc. Barriers to integration summarized from data obtained through the interviews were discussed in detail. Other barriers to integration explored from the literature review are discussed in the following chapter. Recommendations and conclusions drawn based on these barriers and changes in the DFD are also discussed in the following chapter.

CHAPTER 6

BARRIERS AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter discusses integration of time and cost information in general and barriers to integration found through the interview responses and literature review. Recommendations based on these barriers are presented. The recommendations, which were incorporated into the restructured DFD characterizing the Appau model, are discussed in detail along with the justification and support. In the end, a general overview of barriers to integration and the recommendations suggested to owners, contractors, software vendors and researchers are discussed.

6.2 INTEGRATION

Integration has become a buzzword in the construction industry. It is nothing but classifying and aggregating the information parameters in a way, which converts them into useful and valuable information for the firm. Although construction professionals are beginning to understand that integrating various software applications is an important step, they must also realize that integration is not an overnight process. There are various hurdles and they can differ depending on the size of the company, its business philosophy, its corporate culture and many other (Rakow, V4N6).

The construction business boils down to two key business fundamentals: schedule management and cost management. Builders and contractors spend a significant amount of time analyzing those two aspects of a project to ensure its success. While the industry and vendors continue to offer promises to improve project costs and schedule management, the conventional processes of cost estimating and scheduling followed by

the industry prevent it from achieving any significant progress toward integration. The firm belief of the author that the technology is not a solution for this problem led her to focus on the planning process of a construction project. A detailed study of the Appau model explained one way of achieving integration during the planning phase of a project, which revolves around management style and different participants being involved during the project planning phase. To further enhance the concept of integration during the planning phase, the author interviewed eighteen different industry personnel and obtained feedback regarding barriers faced in real practice. This also helped the author to understand why there is a gap between integrated software solutions provided by vendors, integrated process models proposed by researchers, and what the end users actually need. To obtain feedback from vendors, the author interviewed two software vendors providing leading software solutions to the construction industry. Several different articles and papers focusing on the topic of integration and barriers to integration were reviewed. Barriers summarized from data obtained through interviews and literature findings are listed in the following paragraph.

6.3 BARRIERS TO INTEGRATION

As discussed in chapter five, barriers explored through the interview responses are identified and discussed in detail. These barriers are listed here in bulleted format along with those found through the literature review. Barriers are classified into six different categories: Organization structure, Business processes, Contractual arrangements, Information technology, People and General.

6.3.1. Organization structure: The size of a company determines a pattern for the organization structure, which further plays an important role in deriving the business processes for that particular firm. After studying the organization structure for each of the six firms, it was found that the firms were organized based on the project type. Heavy civil is an entirely different division than commercial and so forth. Each division has a vice president, who controls all projects in that division. The operations department is generally shared in all types of projects. This is because five out of six firms subcontract major portions of the work when general contracting; one firm performs fifty percent of the work in house and subcontracts the rest.

The facts stated above play an important role in channeling the flow of information in any particular construction process. Barriers related to the organization structure are summarized as follows:

a) Closed organization culture
b) Fragmented departments
c) Lack of availability of the right people at the right time
d) Lack of assigning appropriate responsibilities to the employees based on the work they perform
e) Lack of effective and useful flow of information during the project life cycle
f) Lack of two way links among various departments
g) Unavailability of the right information at the right time

h) Filtration of management decisions before reaching front line personnel who will carry them out

i) Continuous variation in the responsibilities assigned to the employees

j) Unequal distribution of authority

k) Highly centralized decision making authorities

6.3.2. Business Processes:

Business processes are typically defined by the structure of an organization. The smallest firm interviewed for this research work had a bottom up organization structure, wherein the vice-president of operations department had control over all the ongoing projects. At the end of each month, the vice president received progress reports from all the ongoing projects. The hierarchies and authorities were much different than the largest firm interviewed for this research work. Business processes varied for each of the firms along with the sequence of the processes. A variation in the business processes had a strong impact on the process of estimating and scheduling practiced in each of the six firms. Barriers related to the business processes are listed as below:

a) Undefined construction processes

b) Liberal in making changes in those defined processes

c) Lack of enforcement of the defined construction processes within the organization

d) Lack of possible standardization of the processes

e) No channeling of the information flowing through the different construction processes

f) Undefined responsibilities of the participants involved in a particular construction process

g) Redundancy of the different functions and data tracked within those functions

h) Practicing conventional processes while implementing advanced technological solutions for the same

i) Use of separate software solutions by different vendors to perform already fragmented construction processes

j) Non uniformity between the steps involved in any business process and the information flow need to be tracked

k) Continuous variation in the processes or the steps in the processes per the type or size of the job, and method of working of each employee, etc

l) Lack of awareness of integration of information and required change in current business processes to achieve the same

6.3.3 Contractual arrangements: As discussed in chapter five, all six construction firms approached for this research study adopted a variety of contractual arrangements while bidding new projects. Each contractual arrangement demands a different set of staff, different expertise and thus derives its own organization structure and information flow pattern. Barriers due to varying contractual arrangements to the process of integration of time and cost information are listed as follows:

a) Continuous changes in the responsibilities and the authorities of the certain employees

b) No fixed pattern in the allocation of the in-house resources

c) Continuous changes in assigning the decision making power to the employees

d) Unavailability of the required skilled personnel at the required time

e) Changes in the flow of information

f) Changes in the method of tracking particular information parameters

g) Varying control factors while tracking time and cost information

h) Less ability to set up long term relationships with particular subcontractors or vendors

i) Difficult to set a pattern while maintaining a project historical database

6.3.4 Information Technology: It was observed that almost all six firms invested up to ten percent of the total profit in IT annually. To obtain a survival advantage, each of the firms maintained more than one type of software solution to perform a particular construction process. A lack of in-house study before adopting new information technology was observed while interacting with the vice presidents. Barriers caused by different hardware and software related issues are listed as below:

a) Unavailability of the professional with the right combination of information technology expertise and real time construction knowledge

b) New technology was adopted before employees were ready for the same

c) Lack of change management strategies within the organization

d) Lack of consideration of the generation gap present within employees

e) Lack of consideration of employees' inclination toward use of computers or software solutions

f) Lack of knowledge within departments regarding operation and use of different types of software maintained within the firm to perform a particular construction process

g) Reluctance of project participants to use systems due to one or more of the following reasons: possible loss of control over documents, liability concerns or possible errors in electronic transfer

h) Varying project management systems used by the different project managers

i) Lack of a common platform for different software, while exchanging the information across departments

j) Limited standardization regarding the use of computers or particular software to perform business processes

k) Lack of real time construction knowledge while developing the software product, which further makes it harder to achieve what the industry wants them to

6.3.5 People: Everybody wants to do it or at least say they are integrated; this is become a kind of a thing to do. However, at present integration is in the very early stages. Achieving integration involves much more than simply getting two software systems to interact. Rather, "non-tangible issues" need more attention, including changes to corporate culture and effective teamwork. (Rakow, V4N9) After studying the interview responses, it was seen that the most important issue, "people", was given the least attention by construction firms while adopting new technology solutions. How this affects integration of time and cost is explained through following barriers:

a) Varying educational background determines inclination toward the use of available technological solutions within the firm
b) Varying work experience determines their ability to adapt to changes in the business processes
c) High specialization in their work area makes it difficult to make employees think in broader terms and understand how information flow will be affected down the line, if they fail to follow certain business processes
d) Set methods of working or doing certain things affect inclination toward learning something new
e) Unwillingness to share their authority and domain with the other departments prevent exchange of the information in a timely fashion
f) Employer's attitude toward the employees as "As far as they manage to get good results, we don't really care" does not force the staff to adapt to the changes

6.3.6 General: This category primarily addresses those barriers which can be related to the lack of awareness of the importance of integration of time and cost information irrespective of the different contractual arrangements. Barriers grouped under this category are listed as below:

a) Lack of knowledge about the subject matter within the constructors, owners, subcontractors and vendors
b) Misconception of general contractors that if the majority of the work is subcontracted, then there is no need for tracking time and cost information and integrating them

c) Unwillingness of construction firms to be the first one to try something new

d) Lack of a third entity, who can not only demonstrate the importance of the integration and importance of the business process reengineering, but also would come up with a plan of action to achieve the same

e) Lack of research work done to prove "cost vs. benefit" analysis for integration of time and cost information

f) Presence of a large gap between a large amount of research work done in the area of integration of time and cost information, and actual practice

6.4 RECOMMENDATIONS

Barriers to integration found through the interview responses and literature review were further converted into recommendations for contractors, owners, sub contractors, software vendors and researchers specific to each group. Barriers were studied in detail and a matrix indicating barriers found through the literature review and through the interview responses was developed, as shown in Table 6.1. Further, with the help of the literature review and the author's knowledge, recommendations were suggested which addressed a barrier or a group of barriers where applicable. The recommendations were classified by groups of different direct and indirect contributors of a construction project and included contractors, owners, software vendors and researchers.

6.4.1 Recommendations for contractors

"Integration is no longer an unattainable concept or wishful thinking on the part of builders and contractors. Rather, it's a reality that you need to take into account as you

ponder your company's future." (Rakow, V4N9) In another article on barriers to integration, Dubernais states, "You need to learn how to walk before you run. You need a maturity level before starting integration. You need your tools to be implemented and running before you start automation. You need to define your business process first, test them, refine them, and then implement," (Dubernais, V3N1). With the help of these statements and the literature review, several recommendations were proposed for contractors to overcome barriers to integration of time and cost information, as discussed below:

a) The adage, "Don't fix it if it isn't broke" is changing to "If you have been doing it the same way for the past twenty years, chances are you are not doing it right!" (Ahmad, 2000) Construction firms need to refine the current business practices, reengineer the business processes before they adopt new technological solutions. This can not be done individually. This is a team work, wherein the team involves, contractors, owners, designers, sub contractors, suppliers and software vendors. Each of these groups need to come together to talk about things and create an action plan. Business process analysts could be used as catalysts in this process of reengineering. This kind of teamwork would help in promoting internal as well as external integration.
b) Construction firms need to work on creating a new legal infrastructure for contracting and doing business using IT and the Internet, which would help in bridging the gap between conventional business practices and implementation of advanced technological solutions.

c) Construction industry professionals need to realize and understand that the uncertainty of the organizational environment, the uncertainty of the tasks and the complexity of the tasks created a greater need for integration between organizational units, which could only be achieved through organizational and technological upgrades. Organizational means include teamwork and those management systems necessary to make teams effective. Technological means refer to the use of information technology for information exchange and decision making. (Mitropoulos & Tatum, 2000)

d) Organizations are designed to divide the work and coordinate the divided work in order to achieve the desired result. Integration requires exchange of information and knowledge between independent sub systems, furthermore, integration requires joint decision making. (Mitropoulos & Tatum, 2000) Thus, before adopting integrated solutions from software vendors, integration among those sub systems within the organization need to be achieved.

e) Before adopting computer integrated software solutions for the project control phase, industry professionals need to address issues of integration within the organization during the project planning phase. This can be achieved through standardization of information flow regardless of project size or contractual arrangement. If the basic information flow asks the scheduler to send the updated schedule monthly to the estimating department, then he or she would do it. Thus, construction professionals need to work on defining such a pattern for information flow and make it a part of their business strategy.

f) Based on the responses obtained from the vice presidents regarding lack of awareness of importance of integration within subs and vendors, it can be stated that the construction firms need to stress inter-organizational integration. A stronger mechanism for inter-organizational integration is the implementation of TQM to include external "customers" and "suppliers," i.e. subcontractors and vendors. The goal is to improve their work processes and achieve mutual benefits. (Mitropoulos & Tatum, 2000)

g) Lack of joint responsibility, lack of decision making authority to lower organizational levels, and lack of cooperative organizational culture form another area, which needs to be attended by construction organizations. The change is needed in the performance evaluation and incentives system, which determines the responsibilities of each function. Also increased decision making authority by project personnel can accelerate decision making during construction and increase responsiveness to unanticipated events. This would also take care of problems identified by estimators and schedulers regarding filtration of decisions coming from top to bottom and long waiting periods.

h) Based on the discussion related to the cost estimating, scheduling and general business processes, the author suggests that not only project managers but superintendents must be involved during the project planning process. Subcontractors and vendors should also be involved during project planning wherein time and cost plans are generated. Even if the firm is not sure about who is going to be assigned to that particular project, a superintendent should be involved, whoever is available at that time, because he is the person from the

company who typically works directly with the trade contractor. This is practiced by the firm number one, which was interviewed for this research work. Also involvement of subcontractors and vendors will help in preparing a realistic estimate and schedule. It may cause additional overhead expense to the firm, but it will help to minimize delays caused by misinterpretation of data, unavailability of required information and other costs related to schedule delays. This further leads to the advantage of keeping the project related cost and time data at one place. No matter which software is used by the estimator and scheduler, they can create one common file cabinet to enter and extract data, and then use the data as necessary, which is nothing but the integration of the processes of cost estimating and scheduling.

i) Although it may be difficult to deviate from what has been successful in the past, the key to leveraging new technologies is to identify what makes sense for each organization, determine how to best drive the business, and carefully manage the change. (Dubernais, V3N1) Change management should start with people who form the departments, understand their educational background, working methods, inclination toward adopting new changes in their years of business practices. Sometimes changes can be imposed with the help of buffers like incentives such as more decision making power or with the help of appropriate training sessions. Interdepartmental communication also plays an important role in change management. One of the approaches toward increasing interdepartmental communication can be stated as merging disciplines internally

within a firm and sharing risks and rewards across independent disciplines (Beck, 2002).

j) While interviewing different vice presidents as a part of this research work, it was found that, at least three out of six firms were not yet convinced of the value of integration of time and cost information. Since the majority of the work is subcontracted and all the sub contracts are fixed price, they were not inclined to go back and keep the cost estimates updated. The subcontractor is bound to complete the work done for the cost agreed upon. In this case, it may not be necessary to track time and cost data of sub contractors but labor hours spent to complete a particular job is valuable information, which should be tracked and posted to cost estimates in order to help in refining the cost estimating procedure. From time to time informal surveys have reported that project managers devote 50 % of their time checking, fixing, and documenting issues and problems...none of which adds meaningful value to the project (Beck, 2002). Cost and time information becomes more valuable when integrated helping firms to produce full and complete views of a building project as well as providing the opportunity to prevent vital information from falling through the cracks. Many times, cost overruns are related to scheduling problems, which are difficult to identify unless these two information parameters are integrated in some form or another. If a construction project is completed ahead of schedule, a contractor who has access to integrated cost and scheduling data can determine if the work was performed in an especially efficient manner or if corners were cut to expedite the job.

k) All six vice presidents interviewed as a part of this research work indicated that almost ten percent of total profit of the company was invested in information technology every year. They had a separate IT department. They were always open to new ideas, new technologies and integrated solutions. Each firm had a computer per person and networked computers per job site. But the author believes that the key issue is not how quickly one can deliver more information through a bigger channel but rather the quality of information going through it. Size of the company and company philosophy play important roles in adopting new technology in the company, which impacts the hardware setup in the company. Some companies are highly decentralized, managing projects locally and reporting little information to the corporate level. Other companies have a centralized organization and typically it is those companies that are stepping forward in the process of integration.

l) In the end, the author would like to state that the industry needs to do some homework before they adopt any new technology hoping to improve their business processes. The managing director of the Beck Group stated in one of the articles, "While the industry continues to offer lip service to improving project costs and schedules, the conventional processes to which we adhere prevent us from achieving any significant progress. For sure, technology is not the solution to this dilemma; it is merely a tool to getting there. Better technologies will only be adopted if industry participants are motivated to do so." (Beck, 2002)

6.4.2 Recommendations for owners

a) In one of the peer reviewed papers, Mitropoulos and Tatum stated, "At the planning phase, integration within the owner's own organization was identified as the primary issue, especially for large corporate clients. Integration of the numerous departments is essential to agree on facility requirements, develop common expectations, establish clear goals, and resolve conflicts on priorities. Integration with designers, contractor and vendors is also needed to ensure that the owner's expectations are realistic and can be achieved with the available means. Lack of integration during project planning may result in scope uncertainty, ambiguity, unclear priorities, and unidentified needs and constraints, which in turn cause changes, rework and delays." (Mitropoulos & Tatum, 2000)

b) From the literature review and from the feedback obtained from the industry professionals, it was found that contracting firms and owners did not share long-term relationships, which can be called "external integration". When the contractor has good relations and previous experience with the owner, the contractor's perceived risk is lower and his bid more aggressive. Thus, the owner should set up long-term relationships with contractors and obtain mutual benefits.

c) From the responses to questions CS08 and SH08, it was found that the owners were typically not aware of the software solutions used by their contractors. As mentioned above, if owners and contractors work closely, they can understand each other's business strategies.

d) Inter organizational relationships between owners and contractors would encourage technological and strategic solutions, which would benefit both firms.

The same is true with inter organizational relationships between construction and engineering firms.

6.4.3 Recommendations for software vendors

a) Almost every interviewee indicated that software vendors must understand the contractors' business processes. The construction industry is trying to find new technological solutions to perform their conventional processes. However, software vendors are producing solutions, which demand basic, strategic changes in the business processes within construction firms. Inter-organizational relationships between these two entities almost do not exist. A common party is missing here, someone who has expertise in both areas and who can work with contractors as well software vendors to develop workable and effective solutions. Both organizations need to work closely to create that missing breed.

b) Each of the construction processes is computerized by different software companies. These different software packages used in construction firms have entirely different source codes and different base structures, which makes it nearly impossible to integrate different processes through integrating these software packages. It is similar to a conversation between two individuals speaking entirely different languages. Either they need to obtain an interpreter or they need to share the source code with each other to develop an integration solution.

c) Different software companies need to work together as a joint venture or in partnerships to help in solving the problems related to different source codes. Or a centralized organization or institute needs to be set up who will have control and

defined rules and regulations for different software development firms. At least the basic source code or framing used by each one of them could be standardized by using this concept of centralized control.

d) "Provide flexible framing" was another response obtained from the industry professionals as a message to the software vendors, which would help the end users to customize software as needed.

e) Software companies and the construction firms need to incorporate IT education and technical knowledge in their business strategies. IT firms should help contractors to provide IT education as a supplement to the technical knowledge. Construction firms can provide the technical knowledge to the IT professionals.

6.4.4 Recommendations to researchers

a) The literature review described the integration models studied by the author. Each of the models other than the Appau model proposed a means or a method to actually integrate time and cost data during the project planning and project controls phases of a construction project life cycle. None of the models addressed issues related to implementation and barriers related to implementation of the integration concept proposed in the models. To integrate the data flow in the construction processes, one needs to focus on integration of the processes. Integration of the processes cannot happen solely by using integrated software, it has to happen through the integration of those departments carrying out construction processes. Departments are nothing but people working in that department. Thus, finally it comes to understanding the people i.e. staff, their

background, knowledge level, inclination toward the use of information technology, the way they have been performing certain functions for years together and so on. Changes in business processes, which encourage integration of information flows within construction firms need to be addressed.

b) The author suggests that before actual time and cost data values or numbers can be integrated, one must address where those numbers are generated, who generated those numbers, in what phase of the project those numbers are generated and finally how information technology would help do it more efficiently. The author also feels it is necessary for research work to be done to define reengineering of the current business practices followed in construction firms. This would help the construction industry understand what they are looking for before adopting any new technology or automated processes.

c) Research work also needs to be done in the area of demonstrating cost vs. benefits analysis of reengineering the business processes and implementing the conept of integration.

6.5 A WAY TO INTEGRATION

Barriers and recommendations lead to one final conclusion, as 'change is inevitable'. To adopt new technologies and integrate information flows within construction firms, business processes need to be reengineered and refined. Based on the literature review findings, the author developed a sequence of events construction firms need to go through before adopting new integrated software solutions, which would help to overcome a majority of barriers to integration.

1. Assessment of the organization
2. Assessment of the current business practices and construction processes
3. Integration at the level of departments and people in the departments
4. Involvement of owners, architects, sub contractors and vendors
5. Systems integration
6. Levels of security and access needs
7. Quick start for new users
8. Internal training
9. External training

6.6 RESTRUCTURING THE DFD

Based on the feedback obtained through interviews and findings from the literature review, some changes were suggested to the original concept of the Appau model. While developing a DFD characterizing the Appau model, the author defined the data inflows, data outflows, sources and data storages for each of the processes and participants involved in those processes. Based on the discussion of barriers and recommendations earlier in this chapter, some changes were suggested in the processes, data flows, sources and data files to the original data flow diagram. The changes do not address all barriers or all the recommendations. Only those recommendations, which could easily be incorporated into original Appau's concept of integration of time and cost information, are discussed here. The restructured DFD can be considered as a bi-product of the research work. Implementation of the same may help construction firms to move closer to

the main goal of reengineering the business processes and integrating the information flows within the organization and among organizations.

1. Processes

Processes shown by bubbles in the DFD represent the transformation of the data into useful or valuable information. In Figure 6.3, a new process was added named "Kick-Off Meeting" in the DFD. This process would help in getting required departments together such as estimating, scheduling, planning, operations, etc. The data coming into this process is contract documents and site investigation details. The input from estimating and scheduling departments would be experiences of the participants with the similar type of projects, similar site conditions, etc. The operations department would be represented by the project manager and superintendent participating in this process to provide their input on special adjustments or requirements for that particular type of project or particular type of site conditions. The planning department would have similar input. General study of the project and tentative staffing and time frame requirements can be decided through this meeting. The added process is shown hatched. Addition of this process would help eliminate certain barriers such as: unavailability of the right person at the right time, unavailability of required information, knowledge transfer, common source of data, common work breakdown structure, cross departmental communication, involvement of required departments, close organization culture, unclear definition of the responsibilities, etc.

2. Sources and Sinks

As shown in data flow diagrams characterizing the Appau model, described in chapter four (Fig. 4.7 to 4.21), sources and sinks were defined for each of the processes represented in the Appau model. Based on the findings from the literature review and responses from the interviews with the industry personnel, additional sources were suggested to the data flow diagram as follows:

a) **Superintendent:** superintendent is involved in process 1.2.1 shown in data flow diagram (figure 6.6.). The superintendent can provide input on constructability review of the project. He/she can also be able to provide insights on the performance of the particular subcontractor or vendor, they have worked with on previous projects. Actual productivity of the in-house crew and equipment can also be obtained from the superintendent. The data flow and the source added is shown in the restructured data flow diagram in the first phase of the Appau model.

b) **Estimators:** Involvement of the estimators during detail review of the documents during phase one of the Appau model is suggested (Figure 6.4 and 6.6). Estimators, while conducting detail review of the documents, can provide information about similar projects done in the past, pitfalls and plus points of assigning particular work to the in-house team or to subcontractors, cost vs. benefit analysis. Estimators along with the schedulers can work on developing a breakdown structure.

c) **Schedulers:** Schedulers are suggested to be involved during detail review of the contract documents. They can provide insights related to the time constraints and problems anticipated from their experiences with past

projects. Long lead items can be identified and thus, the effect of long lead on the schedule can be analyzed. Further, schedulers along with the estimators can work on developing a breakdown structures. During this process, schedulers will be aware of the assumptions made by the estimators and can also offer their views. (Figure 6.4 and 6.6)

d) **Marketing department:** Information related to current material, bonds and insurance rates could be obtained. This information would further help in creating accurate estimates. This can either be done by involving marketing personnel for a portion of the time or by accessing the latest data from the marketing department. The changes are shown in phase one of the Appau model (Figure 6.6.).

e) **Business development:** Input from the business development department can be obtained regarding construction methods and means used by the competitors. Some value adding options can be created through involvement of this department. It is represented in phase one of the Appau model in the restructured data flow diagram (Figure 6.6).

f) **Owner:** During detailed review of the contract documents, insights from the owner can also be obtained regarding his expectations of the end product. This would also help clarify any doubts regarding general conditions or special conditions of the project. This would also encourage inter-organizational communication between contractor and owner organizations. The source is added during phase one of the Appau model (Figure 6.6).

g) **Safety:** Input from the safety department is essential while preparing estimates. It was observed from the interview responses, only two out of six vice firms said they consult their safety group while preparing estimates. Most of the time safety related information comes from the estimator's knowledge and if needed, the contingency takes care of additional costs. Involvement of the safety manager would help in understanding the latest code requirements. Phase one in the restructured data flow diagram identifies involvement of the safety group while preparing estimates. (Figure 6.6)

h) **Company database:** During detailed review of the contract documents, performance evaluation data of the subs and vendors can be obtained. If the firms do not have any such data, then superintendents can fill the void. This data flow is added during the detail review of the contract documents in phase one of the Appau model (Figure 6.6 and 6.13). The company database will also be able to provide information related to the performance of employees and in-house resources.

6.7 SUMMARY

This chapter discussed barriers to integration found through the responses obtained from interviews and through the literature review. With the detailed discussion of these barriers and comparison from the Table 6.1, five prominent barriers were identified. These five barriers can be considered as direct causes of the forty seven barriers described in this chapter. For example, the varying nature of contractual arrangements

was identified as one of the prominent barriers, which can be assumed to cause other barriers such as varying organizational structures, varying staffing patterns, varying responsibilities, varying control factors, unavailability of right person at the right time, etc. Similarly, the other four prominent barriers could be described as a cause to secondary barriers. These five primary barriers are summarized as: 1) varying contractual arrangements, 2) no fixed organizational structure and staffing pattern, 3) adoption of new technology with little or no study of in-house business processes analysis, 4) lack of change management to handle intangible issues, and 5) lack of awareness of importance of the subject matter.

Based on these barriers and the literature review, several recommendations were proposed addressing contractors, owners, software vendors and researchers. Further, those recommendations, which could easily be incorporated in the original DFD characterizing the Appau model, were discussed and changes were suggested. The DFD is restructured based on the changes suggested. Implementation of the restructured DFD may help construction firms to move closer to the goal of reengineering their business processes and achieve integration of information within and across their organizations. The restructured DFD, barriers matrix and summary of recommendations were mailed to four of the respondents to obtain their views. Due to busy schedule, only two respondents mailed their views back. Both the responses were positive and stated that the report has done extensive and valuable research on barriers to integration of time and cost information and now it was their turn to act upon the same along with owners, sub contractors and software vendors.

TABLE 6.1 BARRIERS MATRIX

BARRIERS-CATEGORY	LITERATURE REVIEW	INTERVIEW RESPONSES
1.Contractual	a) No fixed pattern in the allocation of the in-house resources	a) Varying staff arrangements, b) Unavailability of right personnel at right time
	b) Changes in the method of tracking particular information parameters	c) Varying control factors
	c) Less ability to set up long term relationship with particular subcontractors or vendors	
	d) Difficult to set a pattern while maintaining project historical database	d) Base framework for tracking information
		e) In-house vs. sub contracted work
		f) Lack of knowledge related to the importance of integration
2.Organizational	a) Closed organization culture	a) Lack of cross departmental communication
	b) Fragmented departments	b) Difficulty in obtaining required information, c) Knowledge transfer
	c) Lack of assigning appropriate responsibilities to the employees based on the work they perform.	d) Involvement of required participants, e) Improper channeling of the information flow
	d) Filtration of management decisions before reaching front line personnel who will carry them out.	
	e) Unequal distribution of authority	
	f) Highly centralized decision making authorities	
	g) Redundancy of the different functions and data tracked within those functions	
	h) Non uniformity between the steps involved in any business	f) Lack of standardization of processes

	process and the information flow need to be tracked	
		g) Awareness in subs and vendors
3. Technical	a) New technology was adopted before the employees were ready for the same	a) In-house business processes and technology need analysis
	b) Lack of change management strategies within the organization	b) Lack of information / knowledge about the software package
	c) Lack of consideration of the generation gap present within the employees	
	d) Reluctance of project participants to use systems due to one or more of the following reasons: possible loss of control over documents, liability concerns or possible errors in electronic transfer	
	e) Lack of common platform	c) Variety of software vendors
	f) Limited standardization regarding the use of computers or particular software	
		d) Training
		e) Skills
		f) Lack of real time construction processes knowledge
		g) Lack of real time construction knowledge while developing new software product
		h) Customization
		i) Uniqueness of construction projects
		j) Varying owner's needs
		k) Effective software
4. Behavioral / People	a) Varying educational background	
	b) Varying work experience	
	c) High specialization	
	d) Unavailability of real time construction experience in younger generation	
		a) Set methods of working
		b) Resistance to change

		c) Inclination toward use of Information Technology, etc
		d) Resistance to share authority
5. General	a) Lack of knowledge about the subject matter within the constructors, owners, subcontractors and vendors	a) Importance of integration, b) Lack of information
	b) Unwillingness of construction firms to be the first one to try something new	
	c) Lack of a third entity, who can not only demonstrate the importance of the integration and importance of the business process reengineering but also would come up with a plan of action to achieve the same	
	d) Lack of research work done to prove "cost vs. benefit" analysis	
		c) Not sure about the steps to be taken
		d) A gap between logical and physical premises

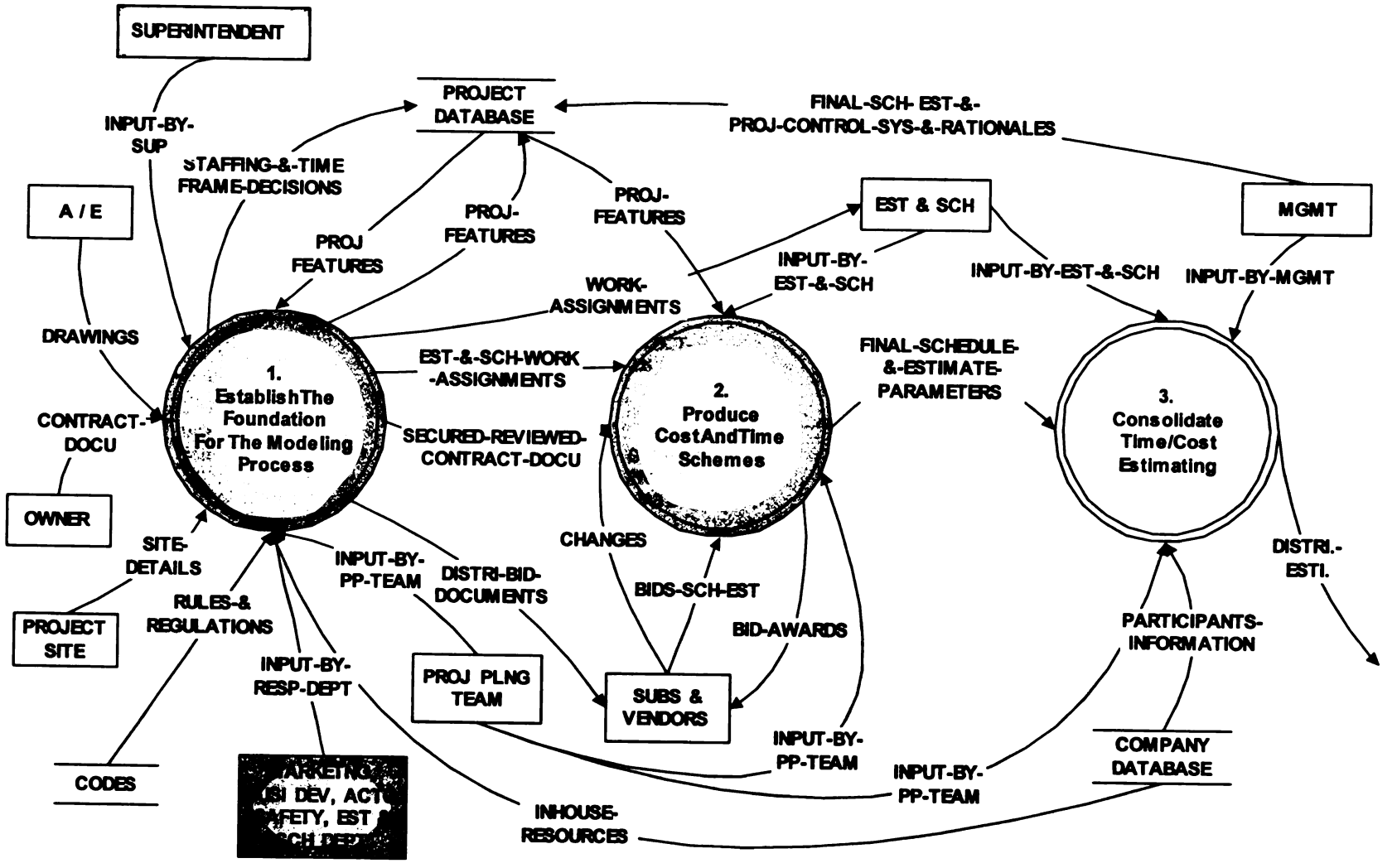

FIG. 6.1 RESTRUCTURED DFD FOR THE APPAU MODEL

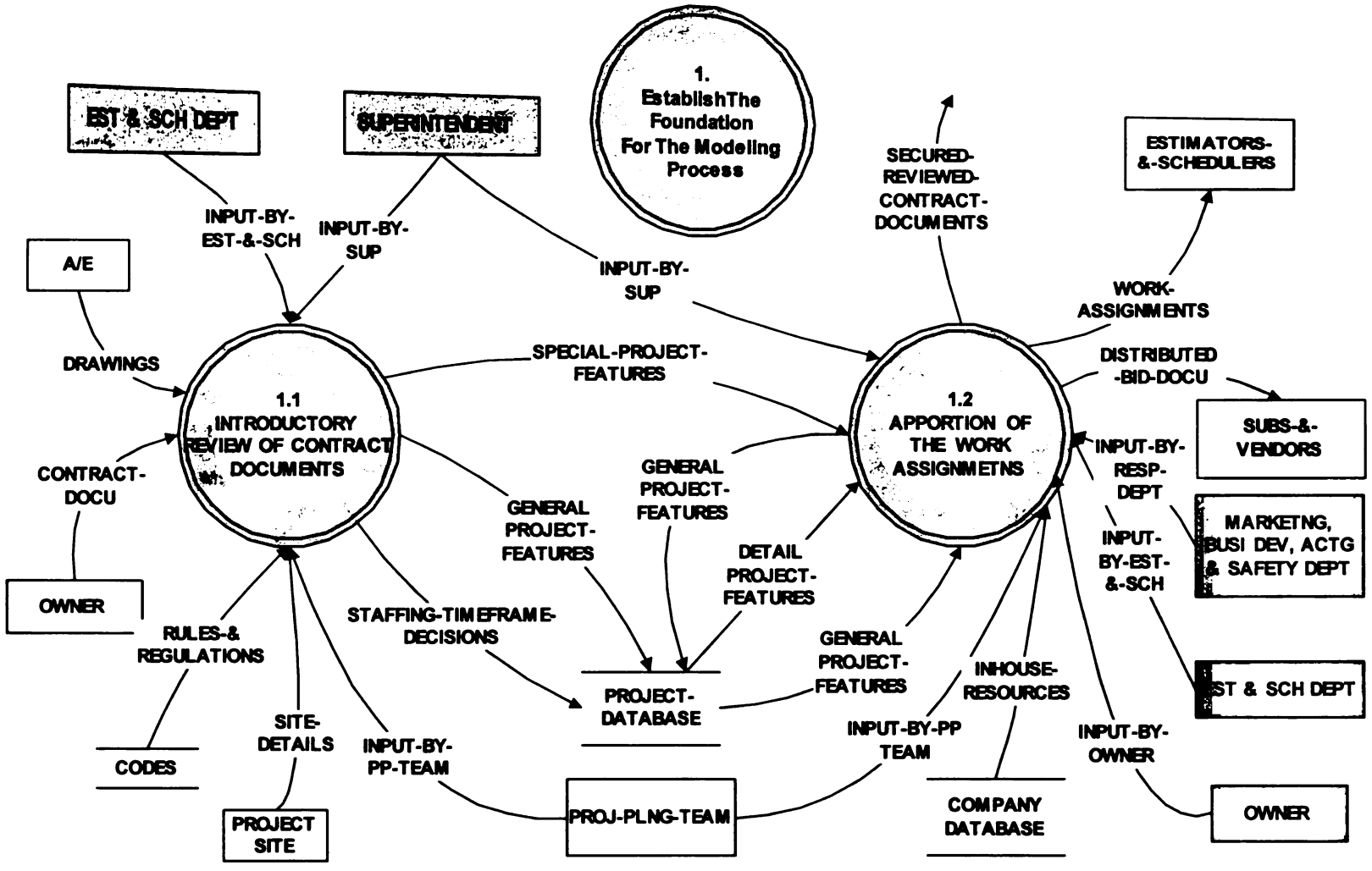

FIG. 6.2 RESTRUCTURED DFD FOR PHASE 1 OF APPAU MODEL

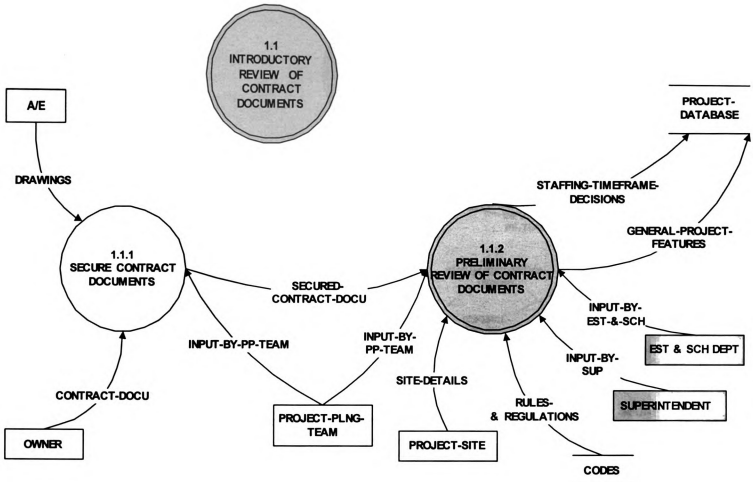

FIG. 6.3 RESTRUCTURED DFD FOR STEP 1.1. OF APPAU MODEL

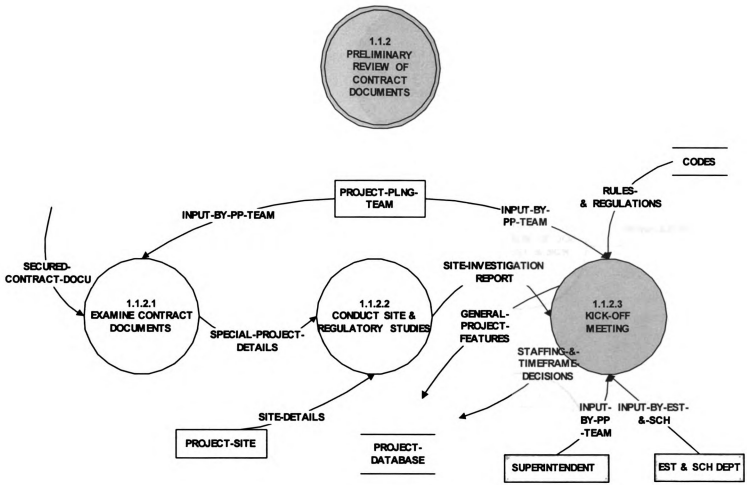

FIG. 6.4 RESTRUCTURED DFD FOR STEP 1.1.2 OF APPAU MODEL

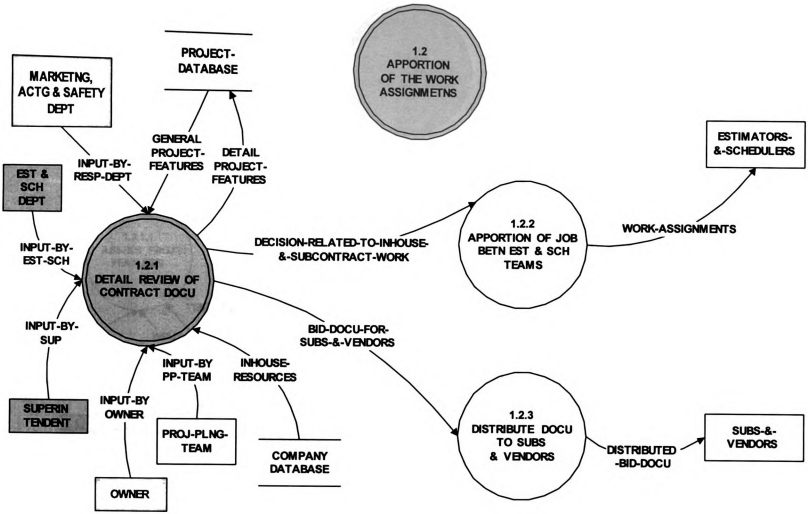

FIG. 6.5 RESTRUCTURED DFD FOR STEP 1.2 OF APPAU MODEL

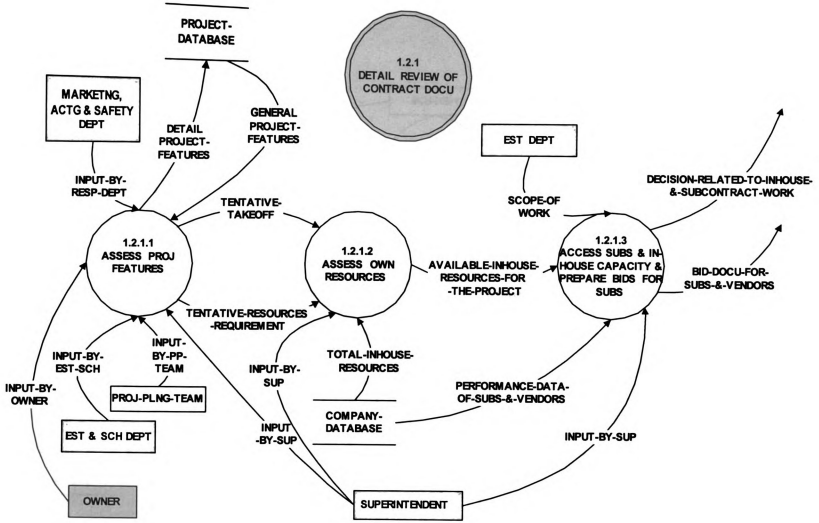

FIG. 6.6 RESTRUCTURED DFD FOR STEP 1.2.1 OF APPAU MODEL

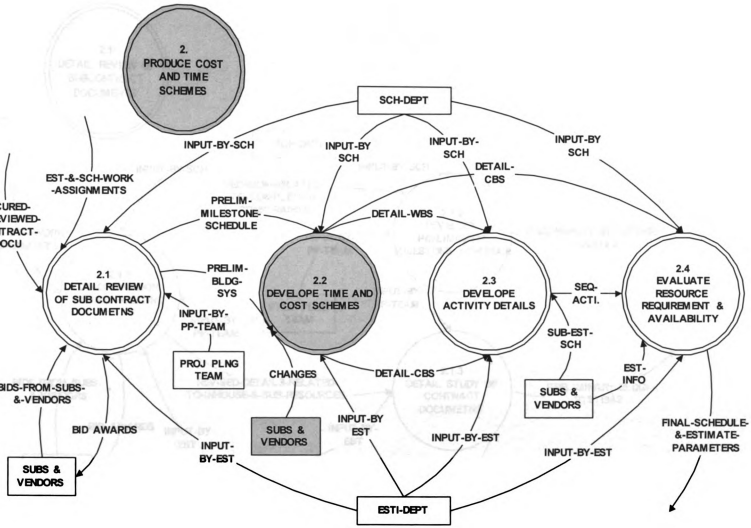

FIG. 6.7 RESTRUCTURED DFD FOR PHASE 2 OF APPAU MODEL

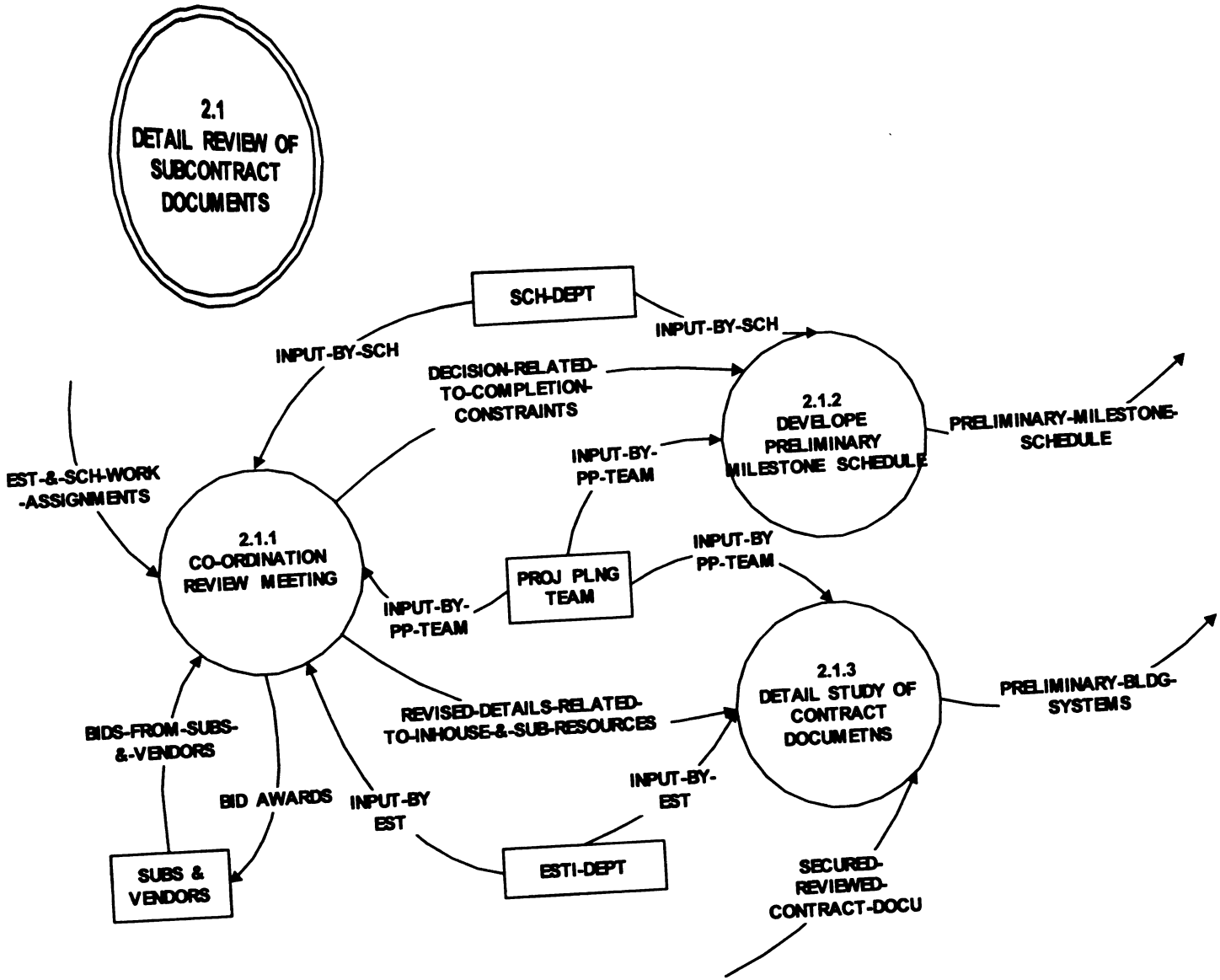

FIG. 6.8 RESTRUCTURED DFD FOR STEP 2.1 OF APPAU MODEL

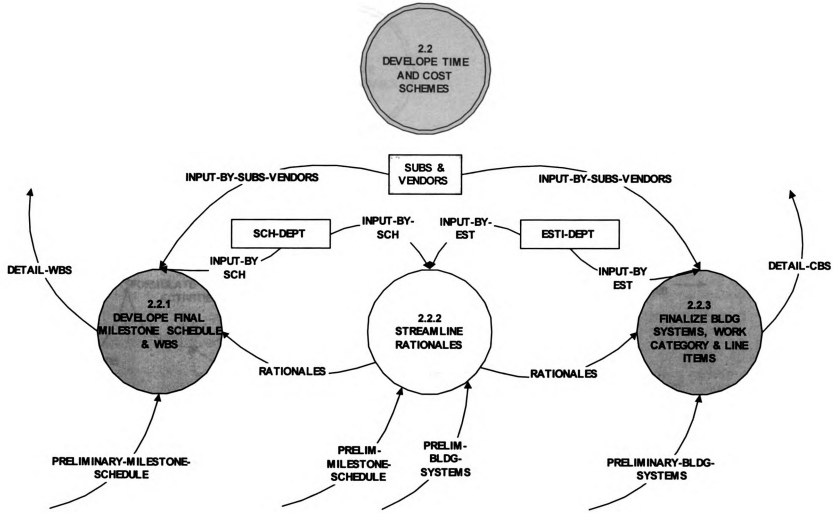

FIG. 6.9 RESTRUCTURED DFD FOR STEP 2.2 OF APPAU MODEL

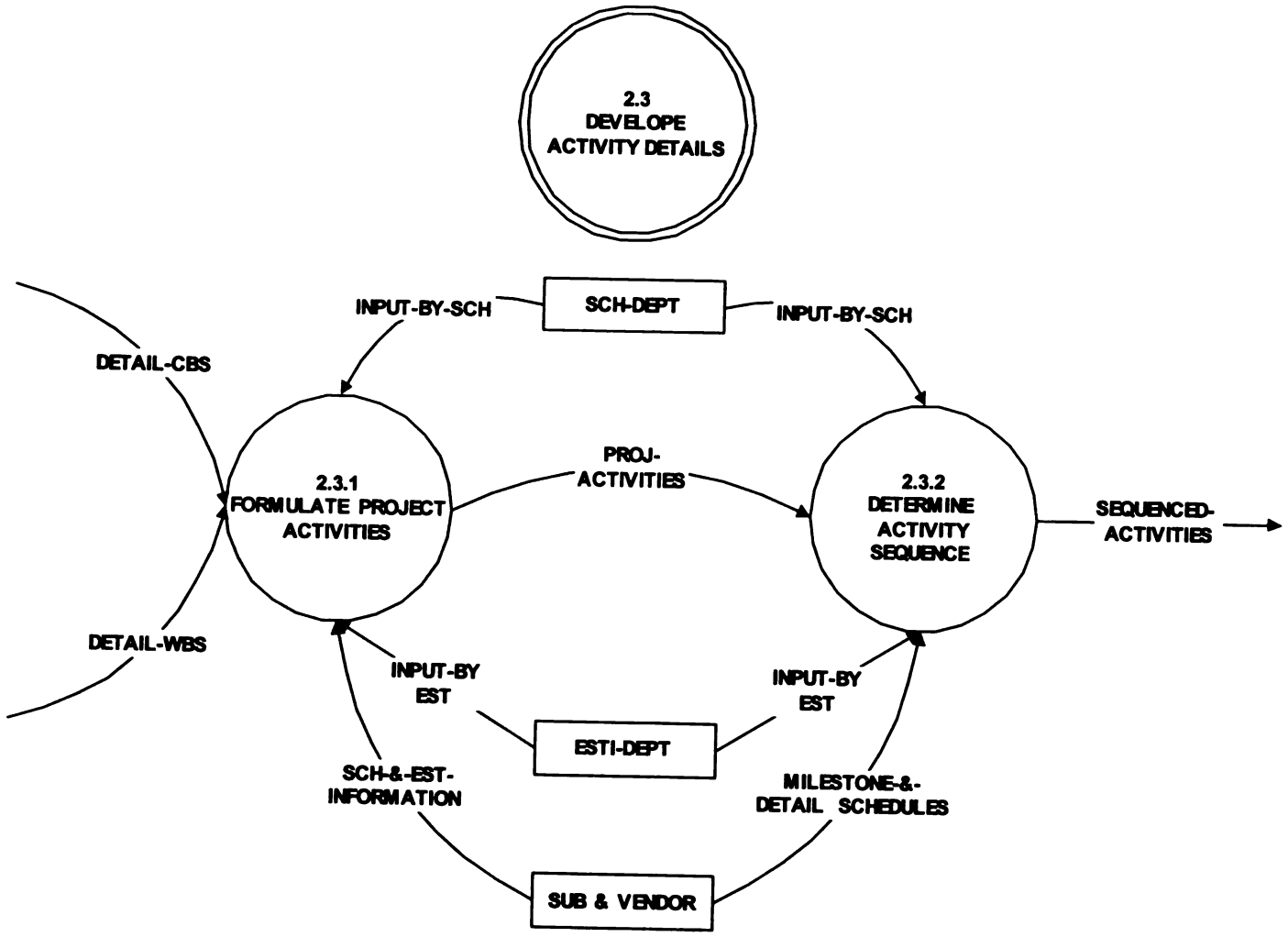

FIG. 6.10 RESTRUCTURED DFD FOR STEP 2.3 OF APPAU MODEL

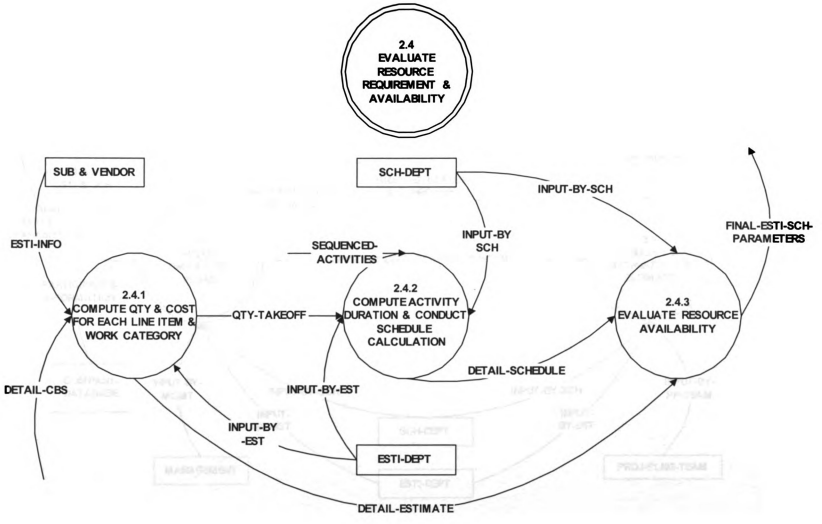

FIG. 6.11 RESTRUCTURED DFD FOR STEP 2.4 OF APPAU MODEL

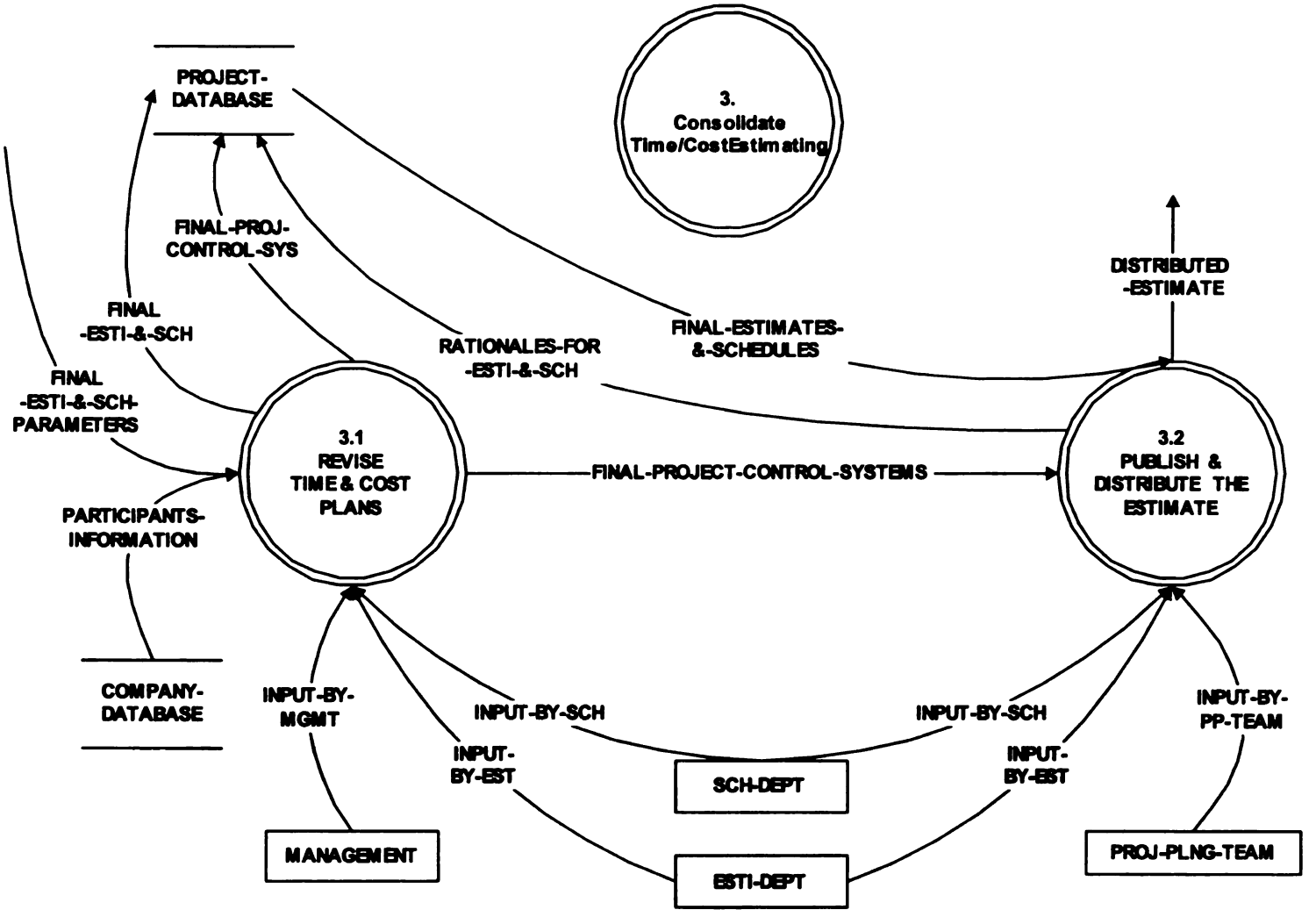

FIG. 6.12 RESTRUCTURED DFD FOR PHASE 3 OF APPAU MODEL

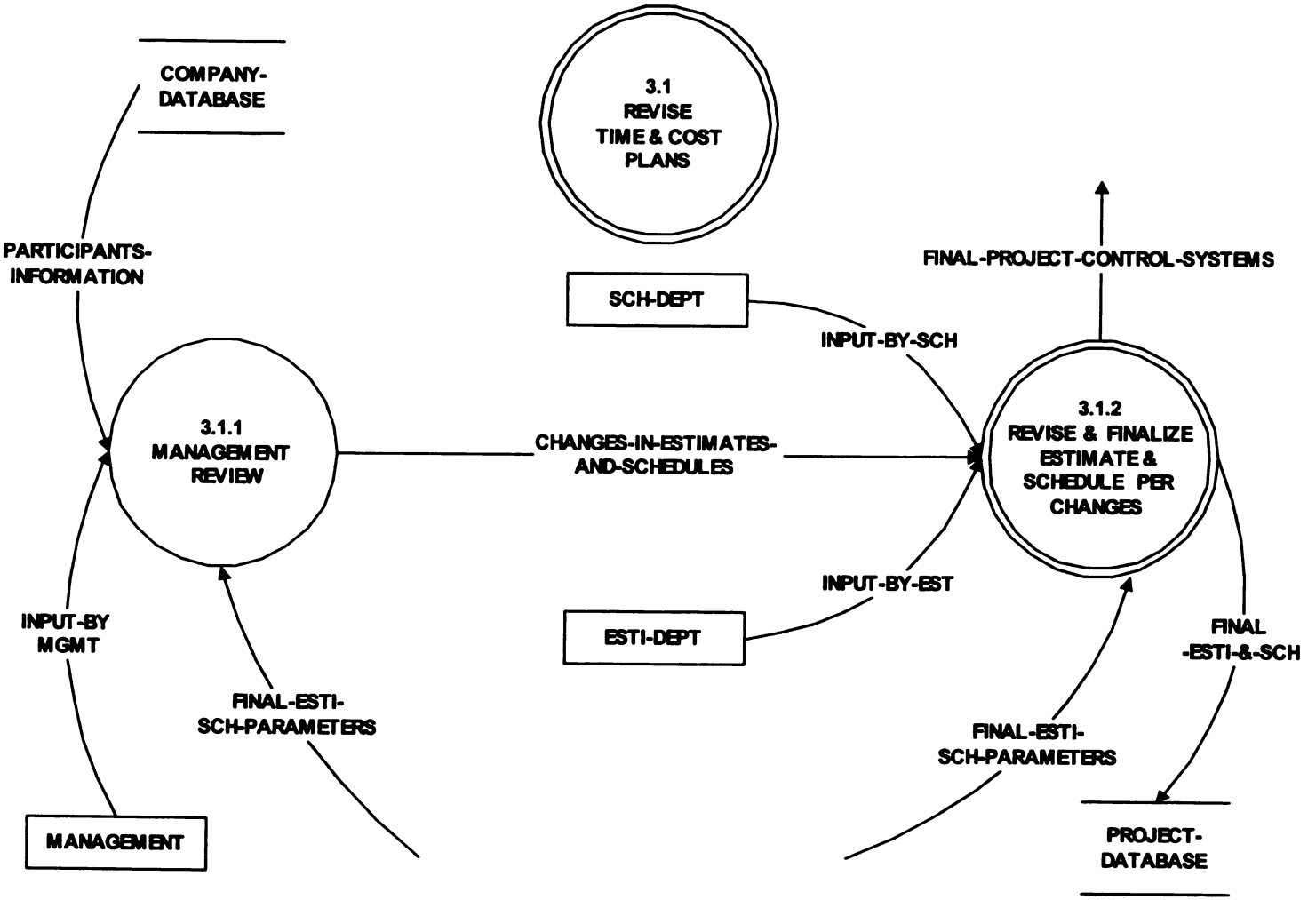

FIG. 6.13 RESTRUCTURED DFD FOR STEP 3.1 OF APPAU MODEL

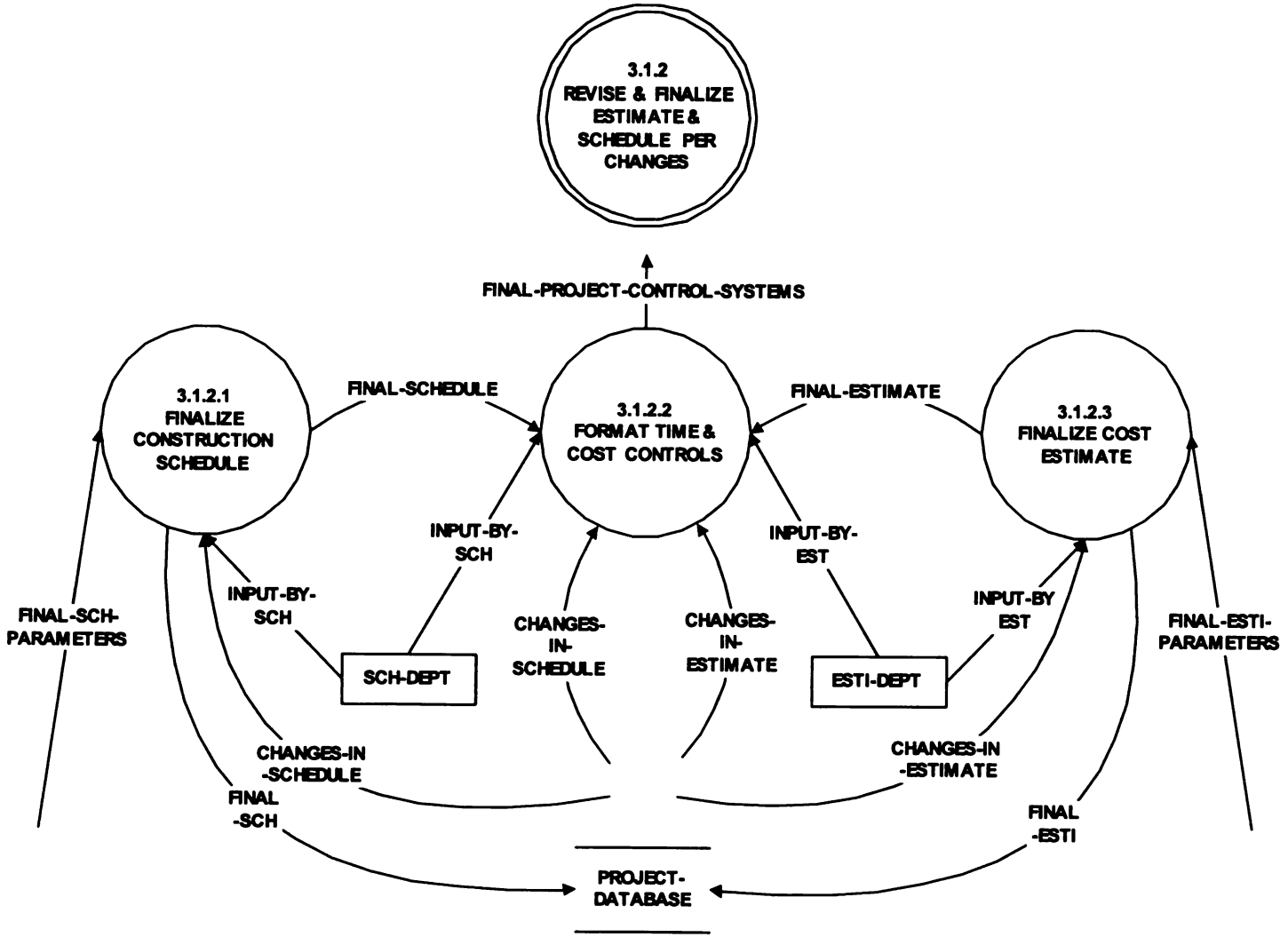

FIG. 6.14 RESTRUCTURED DFD FOR STEP 3.1.2 OF APPAU MODEL

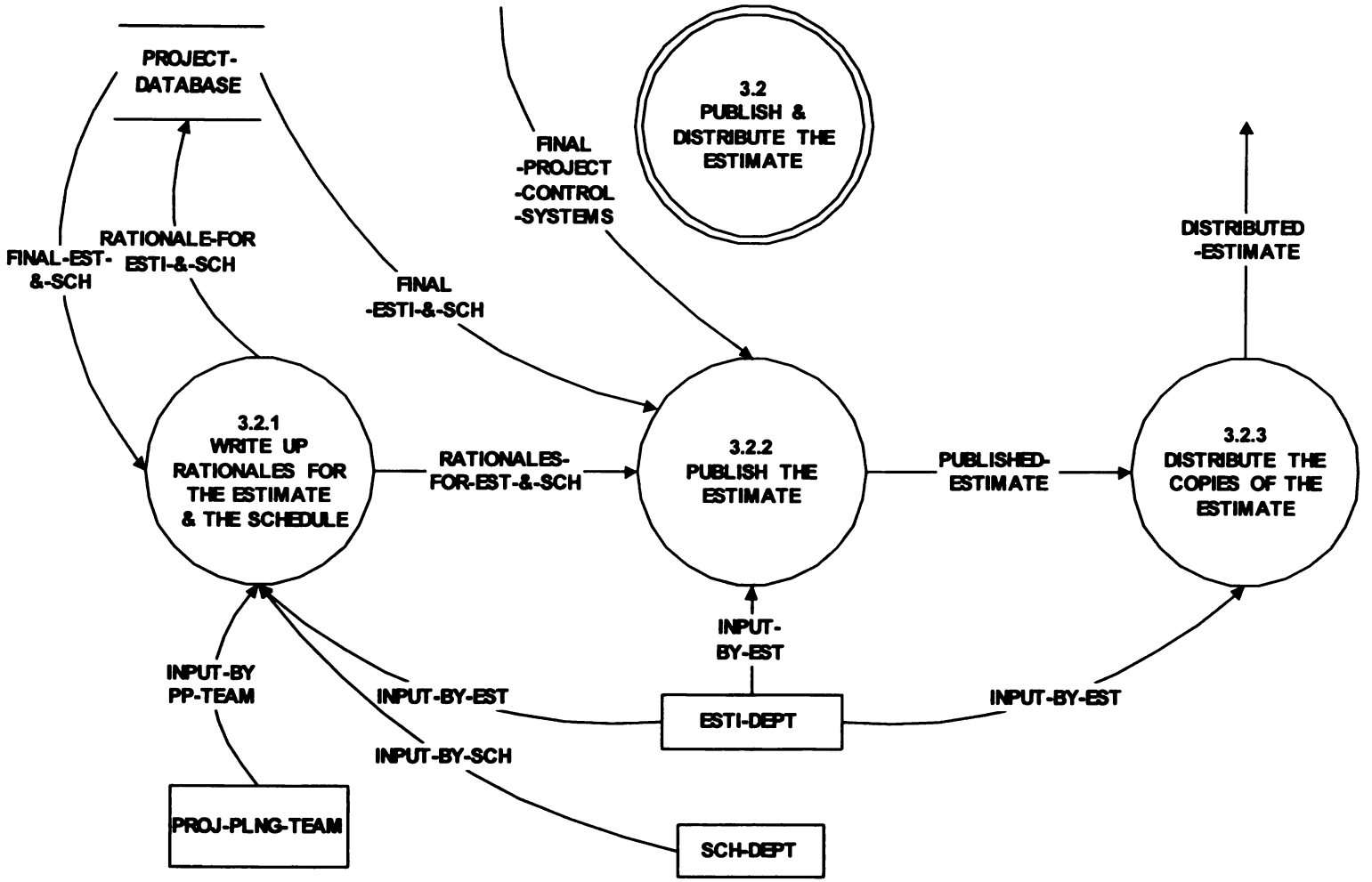

FIG. 6.15 RESTRUCTURED DFD FOR STEP 3.2 OF APPAU MODEL

CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 INTRODUCTION

This research work was aimed at finding barriers to integration of time and cost information across cost estimating and scheduling processes during the planning phase of a construction project. The specific research objectives are discussed below. This chapter further provides a brief overview of the report, limitations of the research, conclusions regarding barriers; conclusions on recommendations and changes to the DFD. Future areas of research and summary of the report are presented at the end of the chapter.

7.2 OVERVIEW OF THE REPORT

The research objectives were as follows:

1. Review several different integration models in general and the Appau model in detail.
2. Introduce DFD modeling technique and develop a DFD characterizing the Appau model with extensions to the original Appau model.
3. Develop an interview questionnaire and conduct interviews with industry personnel and software vendors to identify barriers to integration of time and cost information.
4. Based on feedback from the interviews and findings from the literature review, summarize barriers and suggest recommendations. Incorporate possible changes in the original DFD based on the recommendations.

To accomplish these four objectives the research methodology was adopted, which is discussed in detail in chapter three of the report. A literature review related to integration

models is discussed in chapter two while other literature related to developing structured questionnaires, conducting interviews and qualitative analysis of the data, is discussed in chapter three. Several different papers and articles were reviewed addressing integration and barriers to integration. These are discussed in chapter five and six where applicable.

Data for this research study was obtained through the literature review along with twenty interviews conducted with industry professionals. Six vice presidents, six estimators, six schedulers and two product managers of the leading software companies were interviewed as a part of this study. Construction firms approached for these interviews were sized from $ 175 million to $ 850 million annual sales volume. All six firms had regional offices in the state of Michigan. Four out of six were involved in global level business while two were involved in national level business. They all adopted a variety of contractual arrangements for the building projects; major portions of the work were carried out through general contracting type of delivery system. The responses obtained through interviews are attached in Appendix III. Based on the findings from the literature review and responses from interviews, several different barriers to integration of time and cost information were found as discussed in chapter five and six. Based on these barriers, recommendations were developed addressing contractors, owners, software vendors and researchers as described in chapter six. The recommendations, which were possible to incorporate in the DFD characterizing the Appau model, were discussed and changes to the DFD were carried out. The author believes that the implementation of this DFD in real practice would help construction firms move closer to the goal of reengineering

business processes and integrating information flows within organizations and across organizations.

7.3 BARRIERS TO INTEGRATION

Every system: mechanical, electronic or biological, undergoes changes during its lifecycle. The important thing for a company is to have a method in place to manage change with new business methods and new technology as it moves forward. It is very important for construction firms to understand that with advances in technology and increasing competition, things won't be done the way they used to be. It won't just be a different way of doing same things; it will be much more than the sum of the separate parts. Barriers found through interview feedback and literature review indicated that the construction firms were trying to incorporate new software solutions to perform their old business processes, which created improper information flow. People comprising different departments lacked knowledge or understanding of the other end of business processes or what goes in other departments when he/she fails to pass on the information at right time. It is important for construction firms to train and educate staff about construction processes and systems used to perform those processes. Lack of knowledge of operating existing systems or poor inclination toward use of existing systems was found as another barrier to integration in construction firms. A lack of proper change management was found in construction firms, creating additional barriers to integration of information. Barriers found through the literature review and interviews were further classified into different categories including organization structure, organization culture, business processes, people, technology and general and are discussed in detail in chapter

five and six. Organization structure, organization culture and philosophies were identified as primary barriers. A second major category focused on "people". Intangible issues of understanding people comprising departments, their background, methods of working and inclinations toward the use of information technology were found most neglected in construction firms. To overcome these barriers recommendations were proposed addressing contractors, owners, software vendors and researchers as discussed briefly below:

7.4 RECOMMENDATIONS

Recommendations for contractors mainly consisted of steps to be taken to increase interdepartmental and inter organizational communication as well as changes in business processes. Change management and addressing intangible issues within organizations were also some of the recommendations made. Contractors also need to establish long term relationship with owners, helping them to understand each other's business processes and create mutual benefits. Contractors need to realize that these changes are not going to happen overnight, but it is a gradual process and will take lot of effort to achieve the goal.

Owners have a central role in increasing integration for two reasons: first, owners can gain important benefits because their competitiveness is affected by the performance of the facility development process. Second the owner is the first actor who needs to make an investment in integration. This investment may include 1) selection of a contractor who does not make the lowest bid, but has greater "integration capabilities", 2) a larger

investment in training project personnel in integration skills; and 3) distribution of benefits from project success. (Mitropoulos & Tatum, 2000) The recommendations further suggest that owners need to increase inter organizational communication with contractors and designers to understand their business processes, to carry out required changes in their business strategies and thereby to increase mutual benefits.

IT and the Internet enable us to bypass many business functions. Many "reinventing-the – wheel" type functions will become obsolete within the organization as well as the industry. The demise of certain functions may give rise to uneasiness and resistance in the industry. This phenomenon, however, should be viewed as "creative destruction", since new and better ways of doing business are supplanting old and unnecessary ones. (Ahmad, 2000) Software vendors need to extend their hands further to work with the industry to make this change of "creative destruction" smoother. Software companies and construction firms need to increase inter organizational communication to help each other in understanding business processes, required changes in business strategies and how those changes can be computerized without loosing functionality of the software and business processes.

Researchers play an important role as liaison between a huge amount of research work done in the area of integration of different construction processes, and the actual implementation of those ideas. They need to close the gap between logical and physical premises. Some research also needs to address issues such as: what changes should be

made in the present business processes practiced in construction firms and how those changes can be carried out.

Based on recommendations discussed in chapter six, changes to the DFD were suggested. The changes do not address all the recommendations, but they address only those recommendations, which could easily be incorporated into the original concept of integration of time and cost information proposed by the Appau model. The author believes that involvement of different departments such as accounting, safety, marketing, business development and operations during early stages of a project as suggested in the restructured DFD would create an effective and useful flow of information and make it available to project participants at the right time. A detailed description of the changes is given in chapter six.

7.5 CONCLUSIONS

Based on the literature review and detailed study of the interview responses, five primary barriers to integration of time and cost information during the planning phase of a construction project can be summarized as:

1. Varying contractual arrangements
2. No fixed organizational structure and staffing pattern
3. Adoption of new technology with little or no study of in-house business processes analysis
4. Lack of change management to handle intangible issues
5. Lack of awareness of importance of the subject matter

To further eliminate these barriers a detailed discussion of recommendations was carried out in chapter six, which can be summarized as follows:

Recommendations to Contractors:

1. Increase inter-organizational communication with sub contractors and vendors.
2. Increase inter-organizational communication with owners
3. Promote inter-organizational relationships with the software firms
4. Conduct detailed analysis of the current business processes
5. Carry out detailed analysis of the varying background of the staff
6. Conduct detailed analysis of the technological needs of the different departments
7. Introduce a new entity (business process analyst) to help in creating new legal infrastructure for contracting and doing business using IT and the Internet
8. Encourage teamwork within the organization
9. Promote integration within the sub units in the organization
10. Increase joint decision making within the organization
11. Consider implementation of Total Quality Management to improve work processes
12. Introduce performance evaluation and incentives systems into current business practices
13. Reduce unequal distribution of authority
14. Practice involving all possible key personnel during the project planning phase such as subcontractors, vendors, owners, project management team along with estimators and schedulers

15. Practice change management before adopting any new technological solutions
16. Introduce a basic framework to channel the information flow and thus to improve quality of information

Recommendations to Owners:

1. Increase integration among the sub systems within the organization to help in establishing clear goals and developing common expectations
2. Increase inter-organization communication with contractors, designers and architects
3. Try to involve key participants such as contractors and designers while setting the general conditions
4. Encourage setting up long-term relationship with the contractors
5. Encourage creating technological and strategic solutions while working with the contractors, to increase mutual benefits

Recommendations to Software Vendors:

1. Increase integration among the sub systems within the organization
2. Increase inter-organizational relationships with construction firms
3. Increase inter-organizational communication with other software vendors
4. Encourage involving construction personnel with real time construction knowledge while developing new software products for construction firms

5. Encourage practice of institutions like International Alliance of Interoperability (IAI) to help in standardizing the business processes and terminology for the construction industry
6. Encourage using a common platform along with other software vendors while developing software products for construction firms
7. Encourage developing joint ventures with construction firms to provide technical knowledge to construction personnel and to obtain an understanding of the business processes practiced in construction firms

Recommendations to Researchers:

1. Focus on business processes practiced in the construction industry
2. Understand the source of the time and cost data while proposing different integration techniques
3. Incorporate organizational and managerial issues while proposing conceptual or mathematical models
4. Understand background of people comprising different departments and who strongly affect information flow within the organization
5. Develop an action plan for the construction industry to help in reengineering current business processes
6. Conduct research to demonstrate cost vs. benefit analysis related to implementation of integration of time and cost information

7.6 LIMITATIONS OF THE RESEARCH

Though the research involved industry professionals from varying backgrounds and construction firms from the lower side of mid volume to the upper side of mid volume, there are several limitations to this research study. These limitations may have a strong impact on the results obtained through this research work. The limitations are summarized as below:

1. The construction firms approached for this research study represent only Michigan based business activities; the responses cannot be related to the corporate level offices of those firms
2. The business strategies practiced in the firms approached through the study may differ for each regional office
3. During the interviews, the responses were not tape-recorded; the author took hand notes, which were input into the database developed by the author, possible paraphrasing inaccuracies may exist
4. Five out of twenty interviews were conducted over the phone, which may have certain limitations within the process itself, such as inefficiency in taking down notes, less time gap between to conversations, etc
5. The results may also have certain demographic impact such as, at least eleven out of twenty interviewees had more than twenty years of work experience and six interviewees had more than ten years of work experience. A younger generation may have entirely different views toward the subject matter than this group of interviewees

7.7 FUTURE AREAS OF RESEARCH

This research study was an effort to explore tangible and intangible issues acting as barriers to integration of time and cost information. The research does not address any phase other than project planning phase of the construction project life cycle. Ten different integration models were studied and six different construction firms were interviewed to obtain the data to complete this research work. There may be some other integration concepts proposed by different researchers, which address these or other barriers need to be explored further.

Based on the conclusions drawn in the earlier section of this chapter, it can be stated that, researchers need to conduct a tremendous amount of study to redefine the business processes currently practiced in the construction firms. This study will help industry professionals to reengineer their business processes to accommodate the tangible and intangible issues important to determine organization cultures. New organization cultures will the help in standardizing some of the construction processes and terminology. Standard terminology can be used by software vendors to develop standardized software. Thus, all these events are interlinked as defined in the chapter five and six during which addressed barriers.

Barriers addressed in this research work can further be used in revising the integration concepts proposed by different researchers, which are introduced in chapter two. Barriers identified by the author will help researchers to redefine the flow of information represented by the integration concepts in the respective models. The recommendations

discussed in detail in chapter six addressing contractors, owners, software vendors and researchers can further be explored separately to develop a plan of action for each of those entities.

Through the interview responses, it was revealed that at least three vice presidents expressed that the cost benefits of integration needed to be demonstrated cost vs. benefit analysis prior to implementation of integration concepts. Therefore, it is important that researchers also do work to demonstrate the cost effectiveness of implementation of integration of time and cost information in the construction firms.

Finally, the data flow diagrams as proposed in chapter six can further be extended to the project controls phase and can be computerized with the help of a structured programming language or database applications.

7.7 SUMMARY

Engineering News Record recently projected that delays and project overruns may approach 200 billion dollars of the 700 billion dollars U. S. commercial construction market, (Beck, 2002). This fact illustrates the importance of tracking time and cost information in such a way that one can evaluate both the factors simultaneously. Time delays cost money while unavailability of money causes further delays. These two pieces of information, if not tied together can give a misleading picture of the health of a project. Although integrating project information appears to be a common sense approach for members of the construction industry, there are several barriers holding things back.

Standardization of the terminology by redefining the business processes is an important step to overcome all barriers identified in this report. IAI has taken a few steps toward standardization of terminology by defining aecXML as "an XML based language used to represent information in the architecture, engineering, and construction (AEC industry)." (Albright, V4N9) The next step is expected to be taken by construction firms in redefining or reengineering their business processes.

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APPENDIX I

TABLE A1-1 SAMPLE DATA DICTIONARY

SR. NO.	DATA FLOW	DATA PARAMETERS
1	Drawings	Architectural drawings + Structural / Civil drawings + Electrical drawings + Mechanical drawings + (Other applicable design data)
2	Contract-documents	General conditions of the contract + Supplementary conditions of the contract + Technical specifications + Addendums + (Other applicable documents)
3	Secured-contract-documents	Drawings + Contract Documents
4	Staffing-and-time-frame-decisions	Project related office staff details + Project management team members details + tentative project duration + preliminary milestones
5	Project-features	Type of project + size of project + general conditions requirements + supplementary conditions requirement
6	Site-details	Preliminary investigation details of the site + soil type and other soil investigation details + details of the main highways closer to the site + other site access details + details related to the temporary utilities and facilities at the site + electricity and water mains details
7	Distributed-bid-documents	General conditions of the sub-contract + supplementary conditions if any + technical specifications of the respective division + drawings
8	Rules-and-regulations	Code requirements for different parts and phases of the construction + required permits details, etc.
9	Final-project-control-systems	Project time and cost tracking schemes + estimate and schedule updating schemes + responsibilities and assignment of different project team members + details of the project controlling tool required to be used
10	Project-database	Centralized database for a project storing (estimating details + scheduling details + general and special project features + other project details)
10	Participants-information	Number of years of work experience of the particular employee participating in the project planning process + specialization area + performance record + type and size of projects worked on + any other applicable information

A1.1 AN EXAMPLE OF USE OF STRUCTURED ENGLISH

Structured English is a specification language that makes use of a limited vocabulary and a limited syntax. The vocabulary of Structured English consists only of

- imperative English language verbs
- terms defined in the data dictionary
- certain reserved words for logic formulation

The syntax of a Structured English statement is limited to these possibilities:

- simple declarative statements
- closed-end decision construct
- closed-end repetition construct

Source: (DeMarco, 1979)

A sample of step-by-step details of the data transformation in a particular process is described using Structured English. A process 3.1.1 "Management Review" as shown in Figure 4.18 in chapter four, is described here.

The process, "Management Review" has data inflow shown as "Participants-information", "Final-estimating-and-scheduling-parameters" and "Input-by-the-senior-management" and data outflow shown as "Changes-in-estimates-and-schedules"

Management review is a final revision of the estimate and the schedule with the senior management. This review can lead to changes in the estimate and the schedule due to various reasons. In this review, participants' information is used to check the accuracy of

the estimate and schedule and the quality of documentation. The same process is defined using Structured English as follows:

Structured English

1. Check budget vs. estimated cost analysis.
    i) Check:
        a) the caliber of the participant based on the participant's information obtained form the company database
        b) basis of the estimate.
        c) the methods and the data used to prepare the estimate
        d) the quality of the documentation
        e) If any discrepancies, suggest suitable changes in the estimate and the schedule, else finalize the cost estimate and the schedule.

Similarly, using structured English tool, all the processes in DFD can be described in detail to explain exact transformation of the data inflow into data outflow.

APPENDIX II

A2-1.1 DATABASE

To manage data obtained through twenty interviews conducted as a part of this research work, the author developed a database using Microsoft Access. The form shown in Figure A2-1 has several features embedded in it, which are described as follows:

1. A question code describes category for each question such as PD for Personal Demographics, CD for Company Demographics and so on.
2. Text box for category indicates type of questionnaire, e.g. VP for the questionnaire developed for vice presidents, SH for Schedulers, ES for Estimators and SC for Software Vendors.
3. Description box describes actual question.
4. Type describes a type of question such as "O" for open ended, "OB" for objective type questions and so on.
5. Response Category primarily indicates category developed to differentiate type of responses such as "MG" for management related issues, "SF" for software related issues, "OG" for company organization, etc. A pull down menu lets the user select related category from predefined set of categories. A set can always be edited as needed.
6. Person Code describes code developed for each interviewee.
7. Text box for response lets the user input actual response into the database for each question.
8. First navigating bar at the bottom showing "1 of 1" lets the user type in number of responses for the same question while the navigating bar at the bottom allows the

user to move to the next question. There are total one hundred and thirty six questions in all four questionnaires.

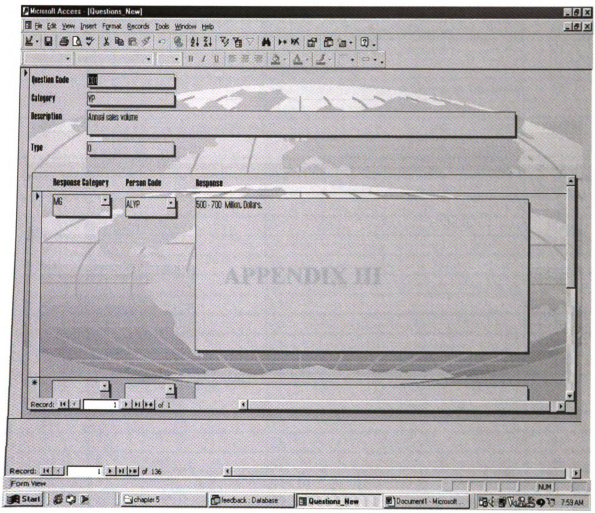

FIGURE A2-1 DATABASE INPUT FORM

APPENDIX III

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
PD1	Educational Background	B. S. Construction Mgmt.	13
		B. S. in Industrial Mgmt.	14
		B.S. in Business Admin.	15
		Degree in Industrial Education	16
		B.S. Civil Engg, M.S. Business Administration.	17
		Associate Civil Engg, Masters in Business Mgmt.	18
PD2	Rating for computer skills on a scale of 1-10	1	13
		9	14
		7	15
		7	16
		9	17
		10	18
PD3	# of yrs in CI	38	13
		22	14
		24	15
		19	16
		28	17
		28	18
PD4	# of years of working with the present firm	10	13
		19	14
		24	15
		17	16
		27	17
		28	18
PD5	# of projects managed at a time	Around 15 in Great lakes region.	13
		10	14
		6-8	15
		Not directly involved in any of the projects.	16
		"As a VP, I am indirectly involved in all the on going projects."	17
		Upto 5	18
CD1	Annual sales volume	$ 700 M	13
		$ 300 M	14

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		$ 175 M	15
		$ 250 M	16
		$ 850 M	17
		$ 700 M	18
CD2	Type of contractual arrangements used most frequently	General Contracting, DB	13
		All are used, whatever is required at that particular time of bidding.	14
		CM-Agency the most then GC, rest all are used at smaller scale.	15
		CM at Risk, LS - GC, DB	16
		All types, more General contracting.	17
		All types equally.	18
CD3	Project locations	Great Lakes for the Division Office, Corporate wide - International.	13
		Nationwide.	14
		Statewide mostly, sometimes neighboring states.	15
		Entire lower peninsula of MI.	16
		Worldwide.	17
		International.	18
CD4	# of 'projects under construction per year	15-20 for Great Lakes Regional Office.	13
		60	14
		35-40, depends on the size of projects.	15
		30 -40	16
		Varies, very hard to put down the number, it is based on the size of the projects.	17
		Varies per the size of the project.	18
CD5	Mmanagement policies toward computerization of the construction processes.	Very much inclined toward computerization, evreyone has computer. About processes, software are used but not integrated.	13
		Pretty strong, all the computers are networked. State of the Art application softeware are used.	14

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		Not the first necessarily, keep upto date, networking, latest software are used.	15
		All the constuction operations are highly computerized. One of the company strategic initiatives. CMIC is being implemented integrating PM and Actg. (Construction Methods International Corporation)	16
		It's a great proponent of the use of computers and state of the art software, always encouraging the employees to use it and come up with the new ideas.	17
		Quite strong and always encourages evryone to come up with new ideas. All the computers are networked, everyone has computer, latest software are used.	18
CD6	Percentage of profit invested in Information Technology per year	About 10 %	13
		10 % of the net income.	14
		Almost 250,000 per year.	15
		400, 000 Dollars.	16
		Almost 8 to 10 %.	17
		Between 10 and 15 %	18
CD7	Is there a separate IT department in this office?	Yes.	13
		Yes.	14
		Yes.	15
		Yes	16
		Yes.	17
		Yes.	18
CD8	Frequency of upgrading the existing software?	Depends on the staff demand.	13
		Constantly.	14
		Constantly	15
		Constantly	16

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		Whenever it becomes necessary, whenever employees demand for it.	17
		Every 2 years.	18
CD9	Is there a defined project planning process?	Yes. Defined and documented for ISO purpose and most of the time followed the same.	13
		Yes in guidelines format.	14
		Yes for ISO purpose.	15
		Yes. The compnay is ISO certified and both pre and post construction processes are outlined in ISO procedures.	16
		Yes.	17
		"Yes, but there is liberal as per hierarchy to make changes in it."	18
PR1	Participants involved during project planning	PM, Estimator, PE, Scheduler, VP-Operations	13
		Director-Operations, Estimator, PM	14
		Project Director, PM, Superintendent, Estimator, Financial Manager.	15
		Sr. PM, PM, PE, Sup.s, Est, depends on the size of the project. At minimum PM, Sup and Est are always involved in planning process.	16
		VP-Operations, Planners, Estimators, Project Managers, Schedulers, Superintendents.	17
		VP-Operations, Proj Director, Estimator, Sup, Scheduler, PM, PE.	18
PR2	Decisions taken during planning process	Cost, Budget, Close Out, Union related isues, Subs, Suppliers, Vendors selection.	13
		Project approach, gross scheduling phases, staffing and time frame, general conditions analysis.	14
		Staffing, time frame, cost analysis, budget.	15

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		Required staffing, Roles and responsibilities assigning to all the participants, development of master schedule for pre and post construction, estmate, VE and life cycle analysis, site logistics, constru phasing layout plans, pre qualification of subs	16
		Inhouse vs subcontracting items, Staffing, time frame, long lead items, contingency distribution, payment terms for subs and vendors, mark up for subs and vendors, etc.	17
		Staffing, time and cost constraints, contingency planning, procurement details	18
PR3	What role do you play during planning, cost estimating and scheduling stages of the project?	Selection of Staff, Meet with Subs, Vendors, Meet with Owner, Keep up with the cost vs. Budget issues.	13
		Responsible for time and cost analysis, contingenecy analysis, staffing, phases in the schedule, selecting subs and vendors, mark-ups, etc.	14
		Time, cost analysis, staffing, selection of subs, suppliers, determine mark ups for the subs, allocate contingencies.	15
		Involved in diff projects on a needed basis.	16
		Make sure, things are right per the conditions stated in contract documents.	17
		Every manager works differently, it also varies for each type of contractual arrangement.	18
PR4	Typical staffing at the project site	PE and Sup always, involvement of PM varies from project to project. Bigger and more complicated project always have residential PM, Smaller don't.	13
		PM, PE, Sup, Clerk	14

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		PM, Sup, Proj Co-ordinator, accountant	15
		Sr PM, PM, PE, Sup, Est	16
		Varies from job to job, based on type of job, size of job, contractual arrangement. E.g.mid to large size, hard bid type of projects will always have PM, PE, Superintendent.	17
		Proj Planner/ Controller, PM, PE, Sup again it changes from project to project.	18
PR5	Computer and networking facilities on project site	Every site has computers connected to the main office.	13
		Each site has computers and networking facility.	14
		All the cmputers on the job site are connected to the main office.	15
		90 % of the projects have computers on site and on larger site computers are connected by LAN.	16
		Each site office has computers, laptops, which are connected to the main office via intranet or internet.	17
		Every site is connected to the main office, there are also many software which are installed on the main server and can be used in the site office as a copy of the original one.	18
PR6	Do you support formalization of the available information including formal and informal types?	"Yes, we have procedure manuals for every construction process, also conduct mentoring and training programs for all the new employees. There are classes offered by senior staff for the junior ones, in which knowledge transfer takes place."	13
		"We document project information at the end of the project, but there is no formal way of doing it."	14

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		"From last 15 years, we have computerized information related to all the jobs, which are completed. The information is available to everyone. We don't have any KB systems though".	15
		Somewhat	16
		"Yes we do, but the company has just started progressing in that direction, database is being created to document all the procedures and all possible data at one place, some kind of KB, which will be accessible to every employee based on reqquirements and hierarchy."	17
		"We have centralized databases, wherein we have estimates and schedules and other project related data, which typically is uploaded into the database at the end of the project. There is also a KB system to help understand company procedures."	18
PR7	How do you maintain project historical database?	Estimator at the end of project, enters the cost vs budget data, which further gets stored in the centralized databse.	13
		Estimator at the end of the project file the analysis of cost vs. budget.	14
		Estimator updates cost and budget analysis into the database at the end of the project. Even those projects which were bid for but did not get awarded are also entered.	15
		Completed projects' information is filed out by PM, which is then entered into common database by business development department, copies of estimates are maintained, bid vs esttimate comparison are carried out and stored in public estimates folder.	16

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		Typically PM at the end hands over the report of cost vs. budget analysis to the estimating dept, who further keeps track of the same in the main database.	17
		Project Director with the help of information obtained from each project site prepares profit loss statement at the end of each quarter, which is then uploaded into the central databse.	18
PR8	What role does management play while estimates and schedules are being prepared for a particular project?	Review.	13
		As explained earlier.	14
		Review and comment, make sure everything is as per specs.	15
		Make sure specifications are followed, mostly the involvement is on needed basis.	16
		Mgmt is involved only on needed basis, if it is std type of project, wherein company has excelled over the years, there will be less involvement, for complex and large projects, mgmt will play major role right from the beginning.	17
		During estimating, manpower, staffing, timeframe, project mgmt team, inhouse vs subcontracting work, many such issues are analyzed. Typically preliminary schedule is prepared at the time of estimating with the consent of the sr. managment, which further gets expanded by PM or scheduler.	18
PR9	Different project controlling tools used	PPC, PERT, Graphs.	13
		Bar charts, cost reports, cash flow, contingency analysis.	14
		PPC, manhour analysis.	15

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		Expedition, MS project, and or Suretrack, Proj Summary reports, Bid Track, PPC.	16
		Bar charts, PPC, Cach flow analysis.	17
		Schedule driven cash flows.	18
IN01	Do you think it is necessary to have a common source of data for estimators and schedulers, while deriving line items and activities?	Would help, but hard to make it happen for all kinds of contractual arrangements.	13
		Yes.	14
		Yes.	15
		No.	16
		"Well, we always involve our scheduler during estimating process, which makes it easier, even though we don't have some kind of common database, so right now I would say no."	17
		Yes.	18
IN02	Do you think it is necessary to conduct joint meetings between estimators and schedulers during project planning phase?	"Oh yes, very much."	13
		"Yes, in fact our estimator prepares preliminary project schedule and hands over to the project management team."	14
		"Yes, but most of the time we are not sure about who is gonna work on particular project until we know we got the project award."	15
		Yes during planning phase.	16
		Yes.	17
		Yes, as and when needed.	18

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
IN03	What do you think are the main barriers to getting all the project participants together during the planning process and making them think in similar terms?	"Each one has its own way of working, they have been practicing the same for years together, its hard to break the habits, as far as they manage to get good results, we don't really bother."	13
		Each one works differently.	14
		Timing.	15
		Timing.	16
		Timing, too many resources are involved.	17
		Overhead, too many resources.	18
IN04	Do you think it is important to integrate time and cost information throughout the project life cycle?	That would be ideal, but construction is most unpredictable business.	13
		It would be helpful. But increases compications.	14
		It is possible only in ideal conditions.	15
		"If someone proves benefit vs. cost, I would go for it".	16
		Yes.	17
		Right now no, but company is moving toward the same guidelines.	18
IN05	Are you aware of any research work done toward the integration of cost and time information of the project during planning as well during the controlling phase?	No.	13
		No.	14
		No.	15
		No	16
		No.	17
		No.	18
IN06	If yes, what is your opinion about it?	NA.	13
		NA.	14

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		NA	15
		NA	16
		NA.	17
		NA	18
IN07	Appau model introduction / discussion / questions	Model was introduced.	13
		Model was introduced.	14
		Model was introduced.	15
		Appau model was introduced, the difficulty in getting est and sch together lies in timing issue plus typically PM prepares the schedule and he is present during pre construction meetings with the estimators.	16
		Appau model was introduced.	17
		Model was introduced.	18
IN08	What are your views about the integration concept proposed by Appau model?	"Sounds great, but as I mentioned earlier, its hard to work out."	13
		"Looks interesting, don't know how would it work in our firm, unless someone demonstrates its implementation in detail with cost-benefit analyais.	14
		It needs to be implemented, most of the problems will vanish.	15
		The compnay will go for a integrated database if it proves to be beneficial. They recognize that there is double or triple entry of data, and redundancy in data. But not happy with the integrated software solutions, they don't do what they claim to do.	16
		It involves too many resources at any particular time.	17
		Its hard to imeplemnt due to timing and over head issues.	18

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
IN09	What are the main barriers you will face if you decide to implement this model?	Timing, specialized knowledge of the staff early involevement of PM is not always possible, updating the database is another issue.	13
		Extra overhead, too much information.	14
		Early involvement of schedulers and Project Managers is not always possible. As well sharing each other's domain is another issue.	15
		As discussed in previous question's response.	16
		Timing, cost vs. benefits issue, Over head.	17
		It will be more useful for self performing firms. We only care for man hours spent on each activity, all contracts are typically lumpsum, so there is not much problem related to cost overruns.	18
IN10	The construction industry is now thinking in terms of integration and automation of different construction processes, what are your views about it?	One should use it just as tool and should not be dependent on it completely, that wont work in construction business. It is peaople oriented.	13
		"It all sounds good, but one needs to be very careful in choosing right technology suitable to business practiceses and organization culture."	14
		"People resist change. Not all subs use computers and latest technology, we cant stop working with the subs because they are not technologically equipped, one has to find golden mean."	15

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		"Our org is extremely commited to overall proj integration and automation, although I am not sure about benefits of integration between est and sch, currently we are trying intgrated software betn PM and Actg."	16
		Its gonna take much longer than what is being discussed out there. It is highly people oriented business.	17
		Everyone has its own method of working, people have certain mind set, and it becomes hard to accept the change. People give way too much importance to computers and in fact its affecting the productivity negatively, they don't use their minds enough.	18
IN11	What are other factors you find necessary to be considered to carry out integration of time and cost information across scheduling ad estimating?	Its really a tricky issue, it depends on project to ptoject, each contractual arrangement has entirely different set of issues to be considered, different roles to be played. Its hard to standardize something in this industry.	13
		As mentioned earlier.	14
		Its very difficult to standardize the parameters tracked in estimating and scheduling. Each sub does it differently, each estimator works differently, each job has unique characteristics and so on.	15
		Cost vs Benefit analysis, resistance to change in yrs of business practices, mind set, comp literacy and inclination toward leanring new technology, timing issues, natural tendency to control own area of knowledge.	16

FEEDBACK FROM VICE PRESIDENTS			
Question code	**Questions**	**Response**	**Person Code**
		Unless someone can prove cost vs benefits its hard to go for any solution. Every one has its own way of working which works for them and works for the company too, so it becomes difficult to standardize any terminology, or create a common database.	17
		As discussed before.	18
IN12	Do you have any message for the researchers or the software vendors?	"Nope."	13
		Work at the customer level.	14
		Be more realistic, work with the client to understand how exactly the business processes work.	15
		"Provide solutions which actually will carry out integration or processes in real practice, many vendors say the software is integrated but in reality it does not really integrate the information what company is looking for."	16
		Understand the business practice to the fullest extent.	17
		No.	18

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
PD1	Educational background	B.S. Construction Engg.	1
		B.S. Civil Engg.	2
		B.S. Civil Engg.	3
		2 years of college education.	4
		B.S. Architecture	5
		B.S. Building Construction Mgmt.	6
PD2	Rating for computer skills on a scale of 1 to 10	8	1
		6	2
		8	3
		5	4
		6	5
		9.5	6
PD3	# of yrs in Construction Industry	24	1
		15	2
		6	3
		38	4
		25	5
		17	6
PD4	# of years of working with the present firm	18	1
		15	2
		6	3
		7	4
		3.5	5
		14	6
PD5	Type and size of projects worked for, with the present firm	Upto $ 3 M individually, larger in a group. All types of contractual arrangement.	1
		$ 100,000 to 75 M, All types of contractual arrangements.	2
		$ 3 to 70M, All types of contractual aarangements, but only building projects.	3
		All the projects, company undertakes.	4
		All the projects company undertakes, all types of contractual arrangements, only building projects.	5

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
		Upto 150 M, primarily Industrial projects, all types of contractual arrangements.	6
CS01	Are there any set procedures for preparing an estimate in different types of contractual arrangements?	Yes, defined process for ISO purpose, but each one has its own method of working.	1
		Std process of estimating. Does vary from person to person especially in breaking down the structure and doing calculations.	2
		No set procedure, depends on person to person.	3
		Yes, for ISO purpose. But it may change from person to person.	4
		Depends on person to person.	5
		Yes, defined in ISO manual.	6
CS02	Are there any management decisions considered while preparing an estimate	Cost Breakdown, Markup percentage, bid strategies, subs selection.	1
		Yes. Estimates are always subjected to mgmt review.	2
		Inhouse vs subcontracting work, OH & P, Insurance policies, unique characteristics of the project, communication or web site requirement by the owner, etc.	3
		Crew size, subs-vendors selection. Euipment fleet.	4
		Inhouse, sub work, consultants' fees, insurance, new equip, buy vs. rent, contingency bonds, sub bonds, etc.	5
		Consultants fees, insurance, bonds, inhouse vs subcontracting work.	6

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
CS03	What is typical technical staff involved in the cost-estimating phase of the project? Does it change project-wise?	Sr. Estimator and estimating team, which varies per the size of the project.	1
		Chief estimator and estimating team, which varies per job size.	2
		Chief estimator and estimating team, which varies project wise.	3
		Chief estimator and estimating team, which varies per job size.	4
		Chief estimator and esti team, which varies from project to project.	5
		Chief estimator and team, which changes project wise.	6
CS04	Who are the participants involved while preparing an estimate other than estimating staff?	Project Mgmt team, Operations Manager, Safety Dept, Sr. Management,	1
		Project Manager, if available.	2
		Mech engg, Ele. Engg, Local subs, vendors. For DB - CM, Superintendent, other proj mgmt team.	3
		PM team, mgmt, proj director, VP-operations	4
		Operations dept, PM, Proj executives, Mktg dept, Contracts dept, Purchasing, Acctg, subs, vendors, Safety manager, etc.	5
		Operations-VP, PM, Sup, Scheduler, Project controls, legal, HR, Real estate manager, Finance, IT, other project mgmt team members.	6
CS05	What are the sources, which are used to obtain required information while preparing an estimate?	Contract documents, Labor Productivity report, Discussion with Project Managers, Old Estimates, Company Database.	1

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
		Reference manuals, code books, contract documents, discussion with subs and vendors, old projects-estimates.	2
		Local subs and historical database.	3
		Company database, bldg exchange plan rm, historical records, contract database	4
		Historical databse.	5
		Buyer's guide, Cost indexes, cost databses, Historical databse, internet.	6
CS06	Do you communicate with the schedulers and / or designers while preparing an estimate?	Only if needed.	1
		Yes. Typically estimator prepares a preliminary schedule and then hands over to the project management team to further expands it.	2
		Designers yes. Not with schedulers.	3
		No.	4
		yes.	5
		Designers-if needed. Estimator prepares preliminary schedule, so scheduler is not involved.	6
CS07	Do you communicate with management while preparing an estimate?	Yes, especially before preparing detail estimate, to decide upon inhouse and subcontracted work.	1
		Yes. Major elemenets such as mark up, inhouse vs subcontracting work, are discussed with the sr. mgmt.	2
		yes.	3
		yes.	4
		Yes.	5
		Yes. Feeing strategy.	6
CS08	Do you use estimating software? Which?	MC2, Excel	1
		MC2, Excel, BidFax.	2
		Timberline	3
		No.	4

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
		Excel	5
		Self developed spreadsheet, Excel, Timberline, MC2.	6
CS09	What is your involvement during the entire project life cycle, other than estimating or planning phase of the project?	Pre-construction meeting - discussion and pass on the information to the project management team. During construction phase only if needed. (Drastic cost changes)	1
		Handing over the job to the project mgmt team. Writing subcontracts. Later as and when needed basis.	2
		Evaluating bulletin and change order pricing.	3
		Write P.O., meet with project mgmt team and explain the project features. Visit job site frequently. Attend the meetings on the job site as and when needed.	4
		P.O. for subs and vendors, pricing bulletins and change orders. If major change by owner, then estimating the same, otherwise no involvement during construction phase.	5
		Issue subcontracts. Pricing of changes.	6
CS10	Is there communication between estimating and scheduling departments while schedule is being prepared or during later stages of the project?	Not necessarily. During pre-construction meeting typically the details are passed on. Later on involvement is need based.	1
		Estimator always prepares a preliminary schedule, and hands over to the project manager. For small projects, PM expands the schedule while for bigger projects scheduler expands the shcedule.	2
		Yes, PMs are generally involved during estiamting phase and they are the ones, who develop detail schedule for the project.	3

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
		Yes.	4
		No. Chief scheduler is involved during estimating phase so he is aware of typical details of the project.	5
		No. Bid schedules and other timing requirements by owner are passed on to the project management team, which further creates their own detailed schedule.	6
CS11	How does the company structure affect the procedure of estimating?	In a positive way, we can involve superintendant intensly during bidding phase.	1
		Doesn't really interfere.	2
		Makes it harder to obtain required information from diff depts like purchasing, planning, accounting and site office at any given point of time.	3
		It is helpful.	4
		Timing issues, littler harder to obtain all the required details in a timely manner.	5
		It works good.	6
CS12	Would you like to make any changes to the present estimating procedure followed in the company?	More estimating staff is needed. Estimators need to be held responsible for their job. Interdepartmental communication needs to be improved.	1
		At present the estimates are centrally controlled. It would be better if the regional offices develop their own estimating procedure and controls.	2
		Not really.	3
		No. But estimators need to be held responsible for the bid, need to run the job they bid.	4
		No.	5
		Centralized databse and automation. General conditions should be more detailed. Better access to historical cost details.	6

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
IN01	Do you think it is necessary to have a common source of data such as common work breakdown structure, etc., while deriving line items and activities?	It would be interesting, but the way scheduling is carried out is much different than estimating, the cntrol factors are different in both the cases.	1
		Yes.	2
		No.	3
		Yes, for preliminary schedule.	4
		Wont help much. Estimate is typically done tradewise, while the schedule is based on work structure.	5
		Yes. During planning phase, during actual construciton phase, its not needed cause typically all the contracts are lumpsum.	6
IN02	If yes, how would it benefit you?	It would save time, data redundancy. Schedules will speak the same language as the estimates and vice versa. Cost variances will be easier to detect.	1
		Help improve efficiency and manage risk. Consistent work category is always wanted.	2
		NA	3
		Proj mgmt team will have a better idea of what they need to do.	4
		No double work. Estimators and schedulers will be on same page.	5
		NA.	6
IN03	Do you think it is necessary to conduct joint meetings between estimators and schedulers during project planning and project controlling phases?	Yes.	1

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
		Yes. Estimators and schedulers will remain on same page which will help managing time and cost in a much better fashion.	2
		Would be beneficial but not necessary.	3
		Yes.	4
		Yes. Very much.	5
		Yes for large and complex projects. But still estimators can help preparing macro level schedules, detail schedules are much different than the estimating breakdown structure.	6
IN04	Do you think you can achieve this by using integrated software during project control phases?	No.	1
		Not really.	2
		May be possible but the best way is person to person discussion.	3
		Oh no.	4
		Yes to the certain extent.	5
		No.	6
IN05	Have you used any kind of integrator between estimating and scheduling software? If yes, which one?	No	1
		No.	2
		No.	3
		No.	4
		No.	5
		No.	6
IN06	How does it help you?	NA	1
		NA	2
		NA.	3
		NA.	4
		NA.	5
		NA.	6

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
IN07	Are you aware of any research work done toward the integration of cost and time information of a construction project during planning as well during controlling phase of a construction project?	No	1
		No	2
		No.	3
		No.	4
		No.	5
		No.	6
IN08	If yes, what is your opinion about it?	NA	1
		NA	2
		NA.	3
		NA.	4
		NA.	5
		NA.	6
IN09	The entire construction industry is now thinking in terms of integration and automation of different construction processes, what are your views about it?	Use it as a tool only.	1
		Should be used as means to achieve the goal and right technology should be chosen. One should not depend on it completely, cause construction industry is primarily based on skill of the people, which can not be computerized or standardized.	2
		Defined mind set or set working methods, staff is specialized in its own area, majority of the times not inclined toward the use of computers vs manual work.	3

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
		Restrict the use of computers and different software to certain limit, they cant replace human minds.	4
		Each job is unique. Each sub has its own way of working. Its very hard or rather impossible to standardise the processes.	5
		It would be more valuable for self performed work. Integrated software would be very helpful for time and cost control, but there is very limited use of it in the case of managing subcontracting work.	6
IN10	What are other factors you find necessary to be considered to carry out integration of time and cost information across scheduling ad estimating throughout the life cycle of a construction project?	People's set mind and set working methods. Inclination toward the use of information technology. Inter departmental interaction. Early involvement of schedulers and project management teams.	1
		Material cost don't have any relation with the time. Labor productivity should be related with the time. Weather, bldg layout, market condition, quality of design, payment process, talent of superintendent, co-operation of architect,change processes are the factors affcting time and total project cost.	2
		Computers cant replace human beings. Especially construction industry is preople oriented, how much data are you gonna store related to project characteristics and labor productivity? Each project is unique.	3
		Continuous communication between proj mgmt team and accounting dept. Est-sch will not help trememndoulsy like PM and accounting.	4

FEEDBACK FROM ESTIMATORS			
Question code	**Question**	**Response**	**Person Code**
		Uniqueness of the construction project. People oriented nature of the construction projects.	5
		Cross training. Both estimator and scheduler need to know other's job to understand the implementation of the inftegrated software, which sounds little unrealistic.	6
IN11	Do you have any message for the researchers or the software vendors?	No.	1
		Spend time on an actual project to become familiar with the dynamics of a construction proj.	2
		Focus on what customres want while developing a software program.	3
		No.	4
		Understand the business processes completely.	5
		Try to keep the framework less rigid.	6

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
PD1	Educational background	B.S. Construction mgmt.	7
		B. S. Arch.	8
		B. S. Civil Engg.	9
		B. S. Business Admin. Associate in Arch science.	10
		B.S. Civil engg. M.S. Construction mgmt	11
		M.S. Construction Mgmt.	12
PD2	Rating for computer skills	8	7
		9	8
		7	9
		7	10
		10	11
		9	12
PD3	# of yrs in Construction Industry	5	7
		34	8
		16	9
		24	10
		4	11
		13	12
PD4	# of years of working with the present firm	3	7
		5	8
		16	9
		24	10
		2	11
		6	12
PD5	Type and size of projects worked for, with the present firm	Industrial-mid size.	7
		Resi and Comm Bldg projects, all types of contractual arrangements, 500, 000 to 80 M Dollars.	8
		All types of projects, all types of contractual arrangemtns, upto 50 M Dollars.	9
		All types, small to mid size, all contractual arrangements.	10

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
		upto 170 M dollars typically bldg projects: all kinds of contractual arrangements.	11
		Auto industry, Building projects, all kinds of contractual arrangements, 40-300 M.	12
SH01	Are there any set procedures by the management for preparing a schedule in different types of contractual arrangements?	No. depends on contractual arrangement and owner's requirements. Sometimes owner provides the schedule, sometimes we have to rpepare.	7
		Not really, its typically done with the consensus of the project management team.	8
		No.	9
		Yes for ISO purpose but most of the time it changes as per the owner's requirements.	10
		Yes, but its upto person to person to make changes in it.	11
		Yes, some sort of guidelines, but it changes for person to person.	12
SH02	Are there any management decisions considered while preparing a schedule?	Yes. Especially for larger jobs. Long lead items.	7
		Yes during planning phase or while preparing milestone schedule but not while prepaing detail or actual working schedule.	8
		Yes, during planning phase, not during detail scheduling.	9
		Yes. Long lead items, resource allocation, sometimes network logic.	10
		Preliminary milestones, subs and vendor selection.	11
		Yes. Milestones, float arrangement.	12

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
SH03	What is typical technical staff involved while preparing a schedule? Does it change project-wise?	Proj director, Proj Manager, Superintendent. For bigger projects scheduler.	7
		One scheduler or PM or only PE, depends on project to project.	8
		PM, that's it.	9
		Scheduler or Project Manager.	10
		Depends on size of the project. Typically chief scheduler.	11
		Scheduler, or Project Manager.	12
SH04	Who are the participants involved while preparing a schedule other than scheduling staff?	As mentioned before. Varies from project to project, especially size of the project.	7
		Trade contractors especially foremen.	8
		PE, Superintendent, Subs, Vendors.	9
		Depends on project size, contractual arrangement. Typically subs, vendors, Superintendents.	10
		Construction manager, estimator, management, project director, project superintendent.	11
		Superintendent, Subs, Vendors, Management, Owner. Sometimes owner defines the schedule, we just expand the same.	12
SH05	What are the sources used to obtain required information while preparing a schedule?	Discussion with estimator, Old projects data.	7
		Discussion with trade-contractors, contract documents, old scheduels.	8
		Old project database, contract documents, discussion with the trade contractors.	9
		Historical database.	10
		Historical databse, contract documents, site investigation reports.	11

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
		Historical database, construction documents.	12
SH06	Do you communicate with the estimators and / or designers while preparing a schedule?	Yes.	7
		Yes, if needed.	8
		"'Only if needed. Being present during estimating phase I am pretty well aware of the estimating details."	9
		Yes.	10
		yes.	11
		Yes, if needed, its not a std procedure to involve them in scheduling procedure.	12
SH07	Do you communicate with management while preparing a schedule for a construction project?	Yes, if needed.	7
		As mentioned earlier.	8
		Yes, whenever needed, as well schedules are subject to mgmt review.	9
		Yes.	10
		Yes, estimates and schedules get updated per changes suggested during mgmt review.	11
		Yes during bidding and planning phase, especially for long lead items arrangement	12
SH08	Which scheduling software are used in the company?	P3, MS Project, Suretrack per owner requirement.	7
		Suretrack, MS Project.	8
		MS Project, P3.	9
		P3-Planner	10
		P3, MS project-if required by owner, Suretrack for smaller size peojects,	11
		P3, Suretrack, MS Project, changes per owner's requirements.	12

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
SH09	What is typical involvement of a scheduler through out the project life cycle?	Larger jobs- full time scheduler. Smaller jobs- typically PM prepares and manages the schedule.	7
		There are two types of schedulers, hands-on, i.e.proactive and observation ie.reactive. Hands-on typically drives the actual schedule, while reactive just observes it and documents the same.	8
		"'As a PM, I am involved during entire life cycle of the project, we update the schedule every month or as per owner's requirements."	9
		For larger projects-full time scheduler-if required by the owner, otherwise PM updates the schedule.	10
		Bidding, pre planning and planning, pre construction, cost loaded schedule, preparing project specific procedures manual, handing over preliminary schedule to project management team and explaining specific project characteristics.	11
		Depends on contractual arrangement, not every project requires full time scheduler, most of the time, PM or PE manages the scheduling part. Only if owner requires or project is time driven or more complicated resident scheduler will be assigned.	12
SH10	Can you define scheduling procedure followed by you?	Std. Schedule gets updated, per the owner's requirements.	7
		Std, Milestone-detail.	8
		Standard.	9
		Standard, but subjected to change per owner's requirement.	10
		Standard. Schedule gets updated once a month, cost and schedule variances are calculated at the same time.	11

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
		Typically estimator prepares preliminary schedule, called bid schedule, which further get handed over to the PM team, wherein PM or scheduler expands it further with all the details from subs, vendors, original estimate, contract documents, etc.	12
SH11	How does the company structure affect the procedure of scheduling?	Is helpful.	7
		Is helpful.	8
		"'I think its helpful."	9
		Cross departmental communication is not very effective.	10
		Communication problems and flow of information across diff depts especially in fast track projects, the problem is more intense.	11
		Since it is top-down structure, executive decisions take long time to filter through and reach to the right person, which delays the entire procedure.	12
SH12	Would you like to make any changes to the present scheduling procedure followed in the company?	Early involvement of subs and suppliers.	7
		No.	8
		For larger and complicated projects, full time scheduler may be a better option.	9
		Early involvement of Superintendents and Project managers will definitely help. Also involvement of subs and vendors.	10

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
		"'Each project has different organization structure, processes need to be more standardized for different scenarios. Make the older project management teams come up with the project plans for the new projects."	11
		Involvement of right people at right time. Contract docu should involve more information regarding scheduling.	12
IN01	Do you think it is necessary to have a common source of data such as common work breakdown structure, etc., while deriving activities and line items?	Yes. But hard to work out. Estimates are laid out in a different way than schedules.	7
		Yes.	8
		Yes.	9
		Yes, would be helpful but gets a lot complicated.	10
		Yes at summary level. At the detail level, the control factors are different for the scheduling and estimating processes.	11
		Yes.	12
IN02	If yes, how would it benefit you?	Consider all the assumptions by the estimator into the schedule. Less mistakes, more realistic schedule.	7
		"'In fact in our firm, estimator prepares preliminary schedule, and hands it over to the project mgmt team or scheduler, who further expand the same."	8
		"'Estimats and schedules can easily be linked, in fact, in our firm PM is always involved during estiamting phase and he is the one who prepares and manages the schedule for the project, we don't have schedulers or scheduling department."	9

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
		Estimators and Schedulers will remain on same page.	10
		Avoid redundancy.	11
		Save time, resources, less complications, right information will be available at any given time of the project.	12
IN03	Do you think it is necessary to conduct joint meetings between estimators and schedulers during project planning and project controlling phases?	Yes.	7
		Yes, only if needed.	8
		Yes.	9
		Yes.	10
		Yes.	11
		Yes.	12
IN04	Do you think you can achieve information exchange across scheduling and estimating departments using integrated software?	Would like to try, not sure though.	7
		No.	8
		No.	9
		No.	10
		No.	11
		Not really.	12
IN05	Can you name any root level changes in the basic scheduling procedure, which may help integrating time and cost information throughout project life cycle?	No.	7
		No.	8
		Not really.	9

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
		'"Effective software is yet to come. Present software do not help to manage look ahead plans or schedules, which further makes it difficult to keep track of cost variances."	10
		Early involvement of project management team.	11
		Timing, root level changes in the organization culture and structure. Assignment of the Project Mgmt team esrlier i.e. during bidding and pre-planning phase.	12
IN06	Have you used any kind of integrator between estimating and scheduling software? If yes, which one?	No	7
		No.	8
		No.	9
		No.	10
		No.	11
		No.	12
IN07	How does it help you?	NA	7
		NA.	8
		NA.	9
		NA.	10
		NA	11
		NA.	12
IN08	Are you aware of any research work done towards the integration of cost and time information of a construction project during planning as well as controlling phase of a construction project?	No.	7
		No.	8
		No.	9
		No.	10
		No.	11

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
		No.	12
IN09	If yes, what is your opinion about it?	NA	7
		NA.	8
		NA.	9
		NA.	10
		NA.	11
		NA.	12
IN10	Do you think it is important that the integration of time and cost information needs to happen during planning phase of the project in order to make it happen during project controls?	Yes.	7
		Yes.	8
		Yes.	9
		Yes.	10
		Yes. Provided the subs do the same - mainly task level and resource level.	11
		Yes.	12
IN11	What are other factors you find necessary to be considered to carry out integration of time and cost information across scheduling ad estimating throughout the life cycle of a construction project?	Staffing is not always known before hand. Timing issues. Different working methods.	7
		Not everyone is aware of different construction processes or how exactly the stuff works. Staff is more specialized in their own field. Further it is important to integrate the data at the end of the project to assess the performance.	8

FEEDBACK FROM SCHEDULERS			
Question code	**Questions**	**Response**	**Person Code**
		Peoples mind set, set working methods, resistance to the change, inclination towards the use of computers, authority, specialty and skill in their area, timing.	9
		Peoples mind set, set working methods, current software, timing issues.	10
		Staff-highly specialized people, not inclined to use high technology or complicated software, separate full time employee needed to keep up with the integrated software programs. Each proj has diff staffing reqquirements and layout.	11
		Use of integration requires highly skilled personnel, timing, inclination towards the change in the business practices, cost vs benefit issues.	12
IN12	Do you have any message for the researchers or the software vendors?	Focus on actual business processes.	7
		Understand the processes.	8
		Understand what the customer's needs are.	9
		Understand the customers' requirements and create flexible software packages, which would be easy to be customized.	10
		Understand the business processes completely.	11
		Provide more flexible framing.	12

FEEDBACK FROM SOFTWARE VENDORS			
Question code	**Questions**	**Response**	**Person Code**
PD1	Educational background	M.S. Electrical Engg.	19
		High School Graduate.	20
PD2	Have you worked in the construction industry other than Information Technology department? If yes, for how many years?	No.	19
		Yes. 16 years.	20
PD3	Number of years of work experience in a software firm related to the construction industry and not related to the construction industry	20 years, it has always been construciton related along with other industries.	19
		2 and 1/2 years construction related.	20
PD4	Number of years of service with the present firm	7 years.	19
		2 and 1/2 years.	20
PD5	What type of clients you typically deal with related to your product development? (Construction Manager/GC/Sub contractor/ Supplier /Owner/ other)	General Contractor, Owner, Other industry professionals.	19
		General Contractor.	20
PD6	What is the percentage of the construction related customers to the total customers using this application software?	10 %	19
		100 %	20
PD7	What role do you exactly play in the company?	Responsible for new product development, updating the old products, supply-demand analysis, etc.	19
		Tech lead, liason between the customers and the development.	20

FEEDBACK FROM SOFTWARE VENDORS			
Question code	**Questions**	**Response**	**Person Code**
CR1	Who are the participants involved when any new construction related software is being developed?	Project Manager and team working for him/her, Product Manager, Business Development dept, senior mgmt, Marketing dept.	19
		Tech lead, Training specialist, Business System Analysts, Quality Assurance, Developers, Marketing, Senior Mgmt.	20
CR2	How do you obtain data required for the development of new software? (Define different sources of information)	Customer needs, market study and trends, changes in the business processes, informatin systems, surveys.	19
		Customer survey, on site research for work flow and needs, business trends.	20
CR3	How do you obtain understanding or knowledge about the construction processes, which you computerize with the help of your code?	Specialist from that field, Business process analysts.	19
		Surveys, on site research.	20
CR4	Do you conduct any meetings with the end users to understand their needs before creating new software	"Oh yes."	19
		Yes.	20
CR5	How often do you have to customize the software as per the client's needs?	"Customization will not be for one client, but it will be for a particular group of clients with the similar interests. Well, soemtimes we do customize our software if the client is making big business with us."	19
		"Our software meets the needs of most clients, it is rare that we will customize the software for one client."	20

FEEDBACK FROM SOFTWARE VENDORS			
Question code	**Questions**	**Response**	**Person Code**
IN01	Have you worked on any interface integrating different construction processes? Which ones?	Yes. Scheduling and Project Controls, Scheduling and estimating and other application software used for bids and contracts.	19
		Yes. Estimating and accounting, Estimating and Scheduling.	20
IN02	Have you worked with the existing interface between estimating and scheduling software	"Not me as individual, but our tech dept has."	19
		Yes.	20
IN03	If yes, do you think this is the most efficient way of integrating the information between scheduling and estimating processes?	There is always a scope for improvement.	19
		Yes.	20
IN04	Do you think this type of interface helps integrating time and cost information through out the life cycle of a project, i.e. from planning to close out?	Its hard to answer, each project can have different type of contractual arrangement, for the repeat business, it will be more useful.	19
		Yes.	20
IN05	Are you working on any better or more efficient way of tracking time/cost information than it is done by the present software?	"Yes, as I mentioned earlier there is always a scope for improvement."	19
		Yes.	20
IN06	If yes, would you like to comment on advanced features of your new software and how it is going to help your clients?	Its in R & D phase.	19
		No.	20

FEEDBACK FROM SOFTWARE VENDORS			
Question code	**Questions**	**Response**	**Person Code**
IN07	Are your customers asking for better means to integrate time and cost information during the life cycle of a construction project?	Not really.	19
		Yes.	20
IN08	What steps have you taken toward the customers' need?	NA.	19
		"I am not in a position to answer this question at thie moment."	20
IN09	Is there any thought about standardization of the information parameters tracked in different construction processes throughout the project life cycle?	It's a big undertaking, it will be in R & D phase for quite a long time.	19
		Its just a thought, nothing is done in that direction yet.	20
IN10	As per your understanding of the scheduling and cost estimating processes, what are the possible difficulties faced while integrating time and cost information across these two processes through out the life cycle of a project?	"I would say, it very much depends on the contractual arrangmenet of the project and from whose perspective you are looking at each participant plays different role and tracks time and cost information in a different manner."	19
		The way project is broken down time wise and cost wise, who is gonna use it, each general contractng firm works in different way, there is nothing common, which makes it harder to standardize.	20

FEEDBACK FROM SOFTWARE VENDORS			
Question code	**Questions**	**Response**	**Person Code**
IN11	Are you aware of any research work done toward integration of cost and time information of a construction project during planning as well as controlling phase of a construction project?	No.	19
		No.	20
IN12	If yes, what is your opinion about it?	NA	19
		NA	20
IN13	The entire construction industry is now thinking in terms of integration and automation of different construction processes, what are your views about it?	"It will take a while to actually make it happen."	19
		"They have to cross lots of hurdles before they reach there."	20