Cost Engineering System of Construction Company
Millennium Construction Co., Ltd.

By

Mr. Kampon Chandraruangnabha

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Final Report of Three Credit Course

CS 6998 System Development Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
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November 1999

Project Title   :   Cost Engineering System of Construction Company

                                Millennium Construction Co., Ltd.

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The Graduate School of Assumption University has approved this final report of the three-credit course, CS6998 System Development Project, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer Information System.

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ABSTRACT

Millennium Construction initiates a plan to improve the computerized based Cost Engineering System operation to be more fully automated and well integrated with all interdependent parts in access and under control. Cost Engineering tasks include monitoring and measuring cost status, converting raw data to accurate information for cost analysis and reporting, application and limitations of variances for exception reporting, forecasting and trending procedures in construction project. Information on project schedule and procurement plan, actual work progress is also required. These information resources, much in extent, need to be stored in database files to reduce redundancy and provide easier access. In existing stand alone computer environment, information are scattered in several computer units with different data definitions and making it difficult to integrate when needed. Database management system (DBMS) will be used to keep the information in common standard so that these files can be shared among several users. The electronic routing by linking PCs under distributed client/sever network will allow efficient communication among cost-related data components and reduce tenuous jobs of paper shooting.

The proposed system is expected to minimize inaccuracy, invalidity and missing in data input process. The system development costs will be recovered by the cost-saving and cost-avoidance benefits within 4 years after implementation. The benefits also include the improved service level and improved information which are not interpreted into monetary value but can be perceived by the users and the management.

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I. INTRODUCTION

1.1 Background of the Project

Cost Engineering System provides analytical methods and procedures for monitoring, analyzing, forecasting and controlling the costs on construction project to meet timely and profitable completion. Its concepts can be applied from conceptual planning, through engineering and design, to construction and start-up. As the word "engineering" implies, understanding of plans and specifications and technical aspects of construction works are required as information sources for monitoring, reporting cost and forecasting trend properly.

The system makes use of information which are results of the interface between management, line supervisor, scheduling, procurement, accounting and field engineers. The Cost Engineering activities include consideration of non-linearity in monitoring and measuring cost status, converting raw data to accurate information for analysis and reporting, the application and limitations of variances for exception reporting, forecasting and trending procedures and the appropriate application or abstaining from corrective action.

Cost Engineering System, though connected to the company's accounting systems through a database, is deliberately oriented towards the needs of company and project management. The distinctions are, the system applies principles of engineering economy to include the time value of money in project decision making, and integrate, with schedule through database, for cash-flow forecasting. The important thing is to handle these extensive data in such a way that they are always available in timely manners and can be shared among several computers and departments. Computer network with interactive applications of database management software is necessary for the

improvement of the system. Information communication among several departments in paper document will be converted into electronic form.

1.2 Objectives

This project is to set up distributed database management system for Cost Engineering System and develop centralized computerized information system with a network linking computer system of several departments. It is aimed to provide accurate, timely and current information in the following areas:

- set up a standard format for cost-related data keeping by using conventional "cost code"

- reduce time required in preparing cost-related reports

- reduce errors and discrepancy of the same data kept in and handled by several departments

- reduce cost of system output by eliminating duplicate or unnecessary reports

- integrate the cost-related data from several sources

- speed up input, since shared database allows direct update by the authorized data source departments

1.3 Scope

This Cost Engineering System project deals with the study of existing working system, analyzes system problems and initiates improvements of existing computer systems. The scope of this project includes:

- Studying the work flow of the system, its input and output requirements and database system for the information management.

- Set up standard working procedures from existing operation and documentation to suit computerized working environment.

- Set up of computerized database system by using distributed client-server network. This database system can be shared among several users and departments involved in cost-related information e.g. Planning, Construction, Procurement and Accounting & Finance.

- Develop input and output screen in form of graphical user interface to provide easy and friendly environment.

- Develop query function of database management system that can promptly generate cost-related reports with related "fields" to be furnished according to specific purpose.

II. EXISTING SYSTEM

2.1 Background of the Organization

Millennium Construction is an engineering and construction company set up in 1979 by 2 civil engineers during their successful entrepreneurship in a housing project and with anticipation of long-term prospects of construction industry in Thailand.

During the 20 years of expansion, Millennium Corporation has developed itself to handle several disciplines of design and construction works, especially roads, residential buildings, commercial buildings, industrial plants, bridges and transportation systems. Millennium always emphasizes in quality of workmanship and materials and the adoption of latest technologies in construction together with the commitment to deliver the project on time.

Millennium' achievements in meeting the needs of customers and community through technical excellence have been proven by the increasing number of customers over the recent years. Millennium continually provides services to Thai government organization, private sector organization and property developers. With awareness of the importance of the development in civil engineering and construction industry in Thailand, Millennium is always open to adopt and implement the use of new technologies to assist and support the work in construction sites and in office operations. In terms of computer technology, Millennium has set up a Computer System Department to support and take care of all computer hardware and software and to manage the information system used within the company. Computer applications extensively used are CADs, project management and database management.

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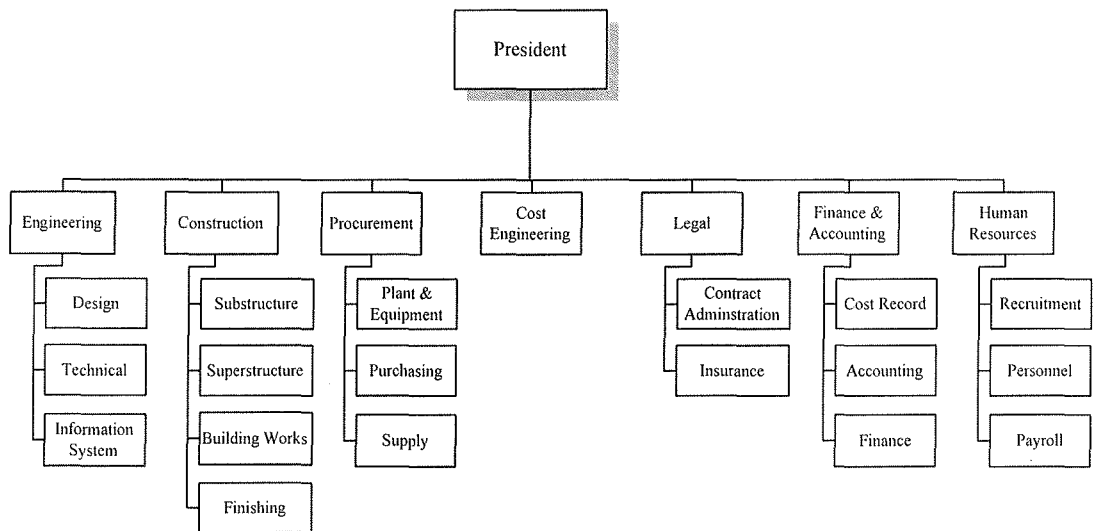
Figure 2.1.   Organization Chart of Millennium Construction.

2.2   Existing Business Function

Cost Engineering System

Cost Engineering Department is responsible for collection, measurement, quantification and analysis of construction project cost, work quantity, schedule and resources taking into account technical and engineering point of view in parallel with commercial and economical factors. The system provides cost-related information on working method, equipment, material and manpower of construction activities used by project management and operation within optimum cost while still maintaining the good quality of work and meeting project schedule. Apart from internal project information from Design and Construction Departments e.g. drawings, design specifications, Cost Engineering also requires external information such as inflation rates, construction cost indexes, bid price indexes for construction activities, labour and materials in conducting analysis and developing reports.

For construction and technical purposes, Cost Engineering System provides information about the cost-effective construction methods or techniques. For procurement management, the system helps indicate the plan to procure materials, equipment and manpower. For financial management, it develops forecast cash flow report from construction plan and progress.

The Cost Engineering information system requires a large amount of data processing and periodical data updating. Since the system needs to integrate information from various sources, on-line network computing system with distributed databases will be set up to provide effective data handling and manipulation. The data will be stored at several locations throughout the network with the master file managed and controlled by Cost Engineering. These databases allow convenient update from several data providers. They are also useful in preparing various kinds of management reports responding to different purposes and used as reference to develop pricing document for new project bidding or tendering.

Overall cost controls

Overall cost controls should be integrated with schedule controls. They include the following:

- Preliminary estimates

- Detailed cost estimates

- Definitive estimates

- Cost report summary

- Value-engineering studies

- Field cost controls

- Other significant data (management reports)

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Preliminary Estimates

Preliminary estimates are the first check against the budget and can be used to indicate cost overruns early enough for project team to review the design for possible alternates. Since these are made prior to completion of detailed drawings, the margin of error and contingency applied is greater than for fair cost estimates, varying with the extent of design and cost information of the projects.

Fair-Cost Estimates

Fair-cost estimates are best prepared from the actual bid documents provided to bidders. They should be completed before receiving bids so that any discrepancies in plans and specifications, duplication in scope and possible value-engineering alternates can be figured out before bids are received. Information required are local conditions such as material price, wage rates, labour productivity.

Definitive Estimates

Definitive estimates fix the anticipated cost of project with little margin for error. Contingency, when the contract has been awarded, is generally limited to providing for plan changes due to interference or error, omissions or conflicts, or for other unanticipated risks in the project. Several numerical and statistical methods are applied for forecasting total cost underruns or overruns at various contract award percentages.

Summary Cost Report

Summary cost report describes the actual and forecast status of the project. It commences with preliminary estimate and end when the project is complete. Cost reports showing estimated cost-at-completion can be prepared from the committed cost plus estimated cost-to-complete. Continual cash-flow projections can be also prepared to accompany the cost reports.

Value Engineering Report

Value engineering studies help in determining the most economical approach prior to detailed design. One approach is application of construction cost knowledge during design and consideration of alternates proposed. The report shows value-engineering savings keeping the results in focus and can be of long term benefit on future projects.

Field Cost Controls

Overall cost control can be developed either at the job site or in office. Itemized breakdown by labour, materials and work quantity for all changes is required in order that adjustment of contract price can be indicated. Preparation of detailed estimate based upon quantity takeoff by field construction manager can pinpoint the differences.

Cost Engineering System provides the following deliverables:

- Work Breakdown Structure

- Cost Code

- Project Budget Report

- Resource Schedule

- Summary Cost Report

- Cash Flow Report

Work breakdown structure

Work breakdown structure is common numbering system used to describe work element of a project in logical hierarchy for management control activities. It is applied at various levels to structure both and schedule planning and reporting. It can also indicate individual or departmental responsibility and accountability, organize drawings

and specifications and other applications. The structure identifies both cost and schedule parameters at various levels of details.

Work breakdown structure describes the work elements of a project in a logical hierarchy which can be used for a number of related management control activities. Integrated management control systems are designed to reflect the interdependence upon cost, schedule and other parameters.

With the use of computer, full detail can be made at lower levels and fully consistent summary information can be distributed up the management levels.

Work Breakdown Structure for a Major Project

Classification of Accounts Basic Numbering Format
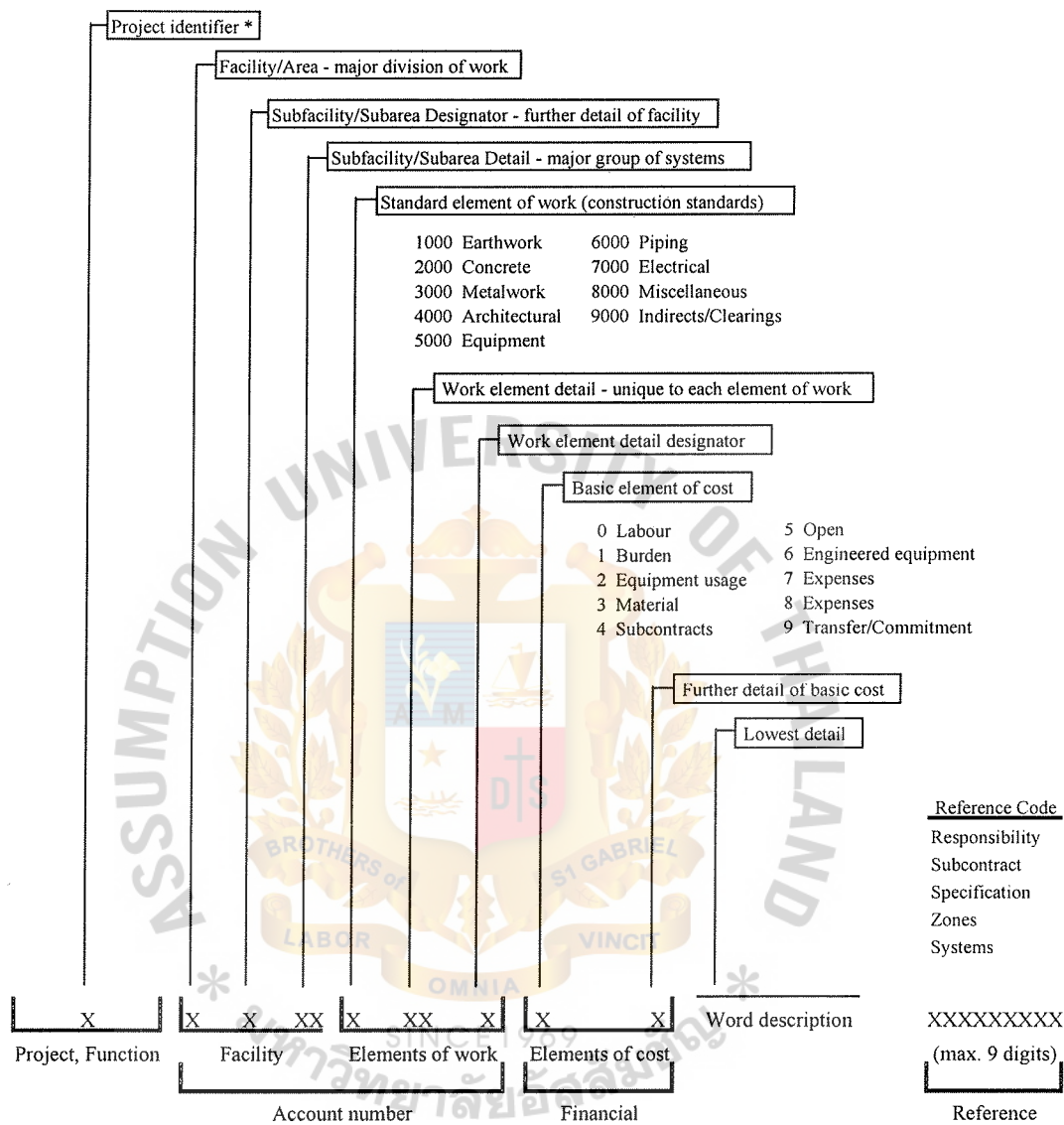
Figure 2.2.   Work Breakdown Structure for Construction Project.

Cost Code

Cost code is standard numbering and classifying system used   as structural discipline for uniformity, transfer and comparison of information for project cost control. Millennium's Cost Engineering System uses CSI's Masterformat, which is

published by the Construction Specification Institute of USA and primarily designed for building construction, in developing cost code. Details are shown in Appendix I.

Types of Cost Codes

- Standard cost code

Standard cost code is classification and categorization of all items of works pertaining to particular type of work. There may be different standard codes for different types of work.

Examples of different types of work that might each have its own standard cost code are the following:

- General building construction (offices, schools, warehouses, etc.)

- Heavy engineering projects (dams, hydroelectric plant, etc.)

- Process plants (oil refineries, petrochemical plants, etc.)

In developing standard cost code, first create exhaustive check list of all the items that might be found in its generic type of construction.

- Project cost code

Project cost code is classification and categorization of all items of work or cost pertaining to a particular project. It should be derived from the standard cost code so that different projects can be compared and the information can be maintained for estimating purposes. Project code may be prepared as soon as the project is authorized so that costs can be accurately distributed from the beginning.

Developing Project Cost Code (See Figure 2.3 and 2.4)

The item code taken from standard cost code becomes one part of code for typical project code item: "work type code".

In addition, add "project number", "area-facility code" and "distribution code" to form complete code for particular item in the project code.

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- Project Number

The project number identifies the costs collected for this code specifically with particular project. It consists of the year the project starts (two final digits), type of the project, type of contract, the sequence with other projects start that year.

- Area Facility Code

The area facility code identifies geographic and physical features that logically separate one part of the project from another. Major breakdown is referred to as "area". Logical subdivisions within each area are referred to as "facility".

The area facility code helps keep track of costs in different areas, and it can isolate the costs attributable to different divisions of works in project.

- Work-Type Code

The work-type code is the part that is based on the "standard cost code".

- Distribution Code

The distribution code break out the resource components of various types of work, separating out the labour, materials, equipment and subcontract costs.

"1" is labour, "2" is material, "3" is equipment and "4" is subcontracts, etc.
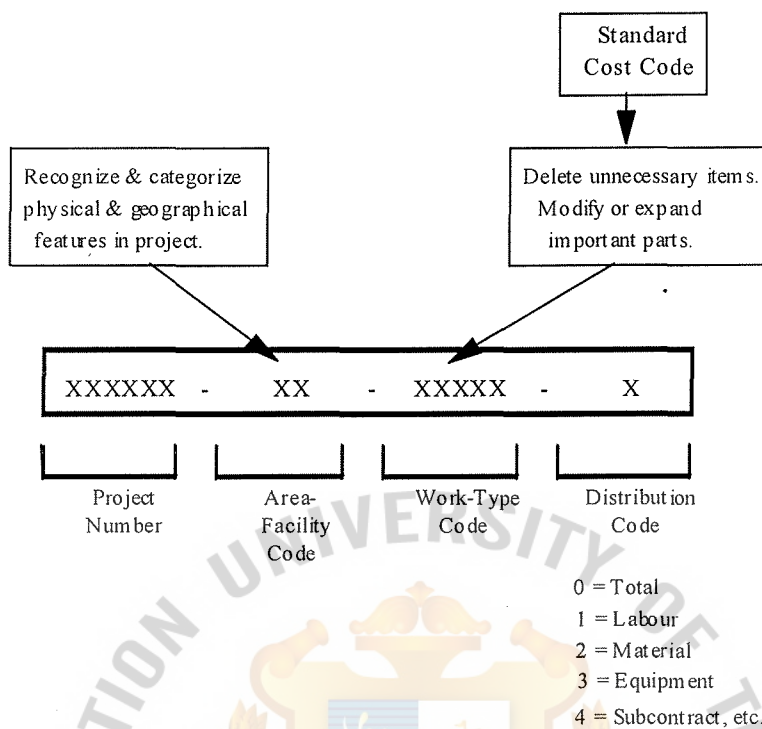
Figure 2.3.   Develop Project Code from Standard Code.
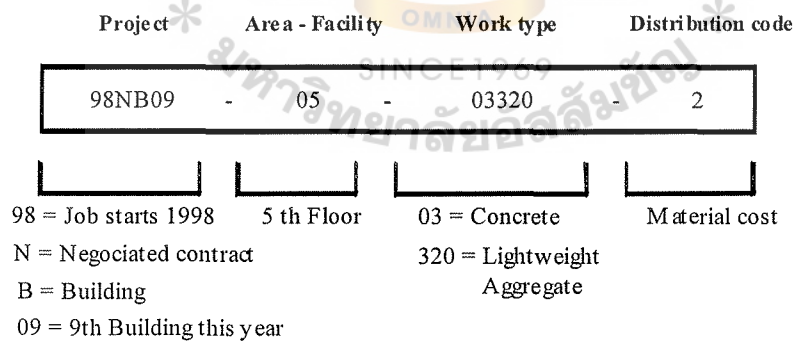
Figure 2.4.   Example of Project Code.

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Account Hierarchy

Account hierarchy is used to reflect level of detail in cost code. Terminology used includes:

Prime Account

The highest level of enumeration in cost code. For example, in the Masterformat, the first two digits of each code: "concrete" is represented by prime account "03".

Subaccount

Subdivision of greater detail within prime account.

Application of Account Hierarchy

Level of detail of code can be set at the level appropriate to scope of work represented. For major part of the project work, it is necessary to collect the costs of work into smallest details by breaking the cost down into several levels. While in minor part of the structure, only the costs at prime account level is enough.

The account hierarchy is also useful for tuning the level of detail of reporting to appropriate levels of management, according to the extent of each cost item in particular project.

Account hierarchy can help in preparing summary reports, exception reports and other techniques for getting the right information at the appropriate level of detail to the right person for decision in time for corrective action.

Project Budget Report

Project budget report is used as basic standard for monitoring and controlling cost status on a project. The structure of project budget is project cost code. Its standards for reference are derived from the cost estimate and include the quantities associated with

each item of work in the code. It makes provision for recording and reporting the following:

- Actual performance

- Projections or forecasts to completion

- Variances in absolute and/or relative terms

- Reasons or conditions associated with excessive variances

Resource Schedule

Resource schedule provides information on the extent of resources required for project during all construction phases according to construction schedule. These resources are manpower, materials and equipment. The schedule is used by Procurement Department to set forth plan in purchasing the supply of project resources. The schedule helps in identifying the need of each resource at any construction phase, quantifying the elements needed and preparation of procurement specifications. It is used to determine the right time to procure resources in different periods of project in the most economical manner.

Summary Cost Report

Summary cost report provides actual and forecast cost status of the project. The report comes in several forms and generally commences with preliminary estimate and end when the project is complete and all claims, if any, have been settled. Cost reports have been developed and updated, usually in monthly basis.

Cash Flow Report

Cash flow report is used for project financial planning and control by Accounting & Finance Department and management. The report gives gross cash requirements for expensed throughout the project and also determine working capital requirements for

the company and in setting lines of credit to borrow funds at appropriate time and favorable rate. Cash flow reports are regularly prepared to accompany summary cost reports

Sources of Data for Cost Control

Cost control system requires good data for materials, equipment and labour. Main sources of these data are:

- Labour and equipment time sheets.

- Field surveys of quantity of work in place.

- Other information for forecasting cost trends.

- Data from other control systems e.g. scheduling, procurement, quality assurance.

Measuring and Reporting Work Quantity

Estimate and measure quantity of elementary work items accomplished during that period. Quantity report should be mixture of actual measurement and judgment estimate. Use projections based on past production rates.

Once the quantity data are combined with the expenditure of labour, equipment and material resources, one can compute unit cost, study learning curve improvement, make projections of cost completion.

2.3   Current Problems and Areas for Improvements

Like any task in handling routine, transaction-based data of massive extent, Cost Engineering System suffers the problems of data updating and storing. Since the system makes use of data which are from several sources i.e. Planning Department, Construction and Accounting & Finance Departments, it is difficult to catch up with all frequently changed cost-related data. Therefore problems of consistency, validity and redundancy of data are usually encountered.

The computers used in these departments are all individual and separate. The format of data keeping and reporting are varied. These departments, while all requiring cost-related data, keep the same piece of information individually. The data update need to be printed out and distributed among departments. Each department then need to update or key-in such data in its own computers. This situation has caused the risk of losing information and potential error in re-entering data. Also the unnecessary redo of data entering the redundancy of data storing in several files. The timeliness of data is also deteriorated under such practice.

The problems of current Cost Engineering System are:

- The error of information due to untimely data update.

- The report cannot be generated promptly at the time required.

- The discrepancy of the same information when cross-checking with report from Accounting & Finance Department.

- Data redundancy caused by keeping data in several computers.

- Reports for new projects need to be re-furnished, but it is not possible to be adopted from past project data.

Areas for improvements in Cost Engineering computerized system can be of 2 aspects:

1. System Hardware

Computer network needs to be installed in order to link the computers of several work divisions. The information from each computers then can be shared with one another.

Current PCs used are still able to handle the processing requirements. Some additional hardware for network setting up needs to be purchased.

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2. System Software

The system requires effective database management software to deal with massive data: to store, ease retrieving and help in furnishing reports of required fields and suit to purpose.

More details are stated in 3.3 Hardware and Software Requirements.

III. PROPOSED SYSTEM

3.1 User Requirements

The current Cost Engineering System deals with cost-related data as dynamic information and should be promptly retrieved at any time required. Analysis has been conducted to figure out how to store, process and retrieve data in practical way. Data flow from one department to another. Database design is required to handle the large quantity of frequently changed cost-related data of Cost Engineering System. The application should assist in preparing full detail of Work Breakdown Structure at lower levels and developing fully consistent summary information to be distributed up the management level. When developing cost-related reports, the required information can be promptly retrieved and report format can be easily furnished. Control of data access and update should be added to provide adequate security and consistency of information. Following are the particulars from system users:

Cost engineer requirements:

- The application should assist in determining major group of activities in construction project and classifying cost items and consolidate these items to be the overall summary.

- The application should be able to generate the form of spreadsheet or table promptly to be used in newly identified cost items.

- The system should support the possible addition and deletion of cost items from conceptual planning stage through actual construction and up until the completion of project.

- The database management system used should discriminate the integrated single account of Work Breakdown Structure that identifies both the process

code and the size or material code. Therefore the costs can be identified by size or material specification (for field installation control) and by process for comparison to initial budget (for schedule control).

- The system should support the conversion and redistribution of cost breakdown in bid estimate into appropriate project code categories. This is to use for project cost control, payment and progress purposes.

- The cost engineer requires for the computer network that gathers, organizes and disseminates cost information from Planning, Accounting & Finance, Procurement and Construction Departments.

Cost technician requirements:

- The cost technician requires for the input screen that is easy to key-in cost information i.e. cost code, work quantity, labour cost, material cost and amount.

- There should be control system for data input to verify key-entered data. For example, if character is found in number fields, error condition should be reported. Or the number keyed to processing falls below or above predefined range, warning message should be reported.

- There should be password in accessing information in Master Files to prevent unauthorized users.

3.2 Systems Design

The Cost Engineering System extensively uses spreadsheet application to produce cost-related reports. The proposed system will add database management application to the existing application with full support of data transfer and maintaining some necessary calculation features. The computer screens are all GUI (graphical user interface) with user friendly interface using windows and mouse. Since the new DBMS

is compatible with existing spreadsheet application, all cost-related reports will then be produced either from database application or from spreadsheet application, where some complicated calculation or special features to represent in multi-dimensional way is required.

System input and output documentation consists of headings and fields. Mostly numeric fields are used for cost-related data. The "cost code" field is alphanumeric, of which the length is predefined to prevent error in entering. Some alphabetic fields are used for written description of cost elements e.g. materials, equipment and labour and construction project description.

The system input has the same appearance as system output. Most are in form of tables and charts which usually link together.

The following controls are added to system input to ensure the correctness of data in key-entering:

- Numeric Test

    To determine that the data keyed-in consist of numeric characters.

- Range Test

    To determine whether the number keyed-in fall within the predefined range.

The system input screens, output screens and examples of report are shown in Appendix G and H respectively.

As for the database design, relational database model is used because the Cost Engineering data rely much on the relationship of cost items and several summary reports can be simply developed by using relational operation e.g. SELECT, JOIN and PRODUCT. Its tabular representation is familiar and not a different conventional spreadsheet. Its flexibility in concatenating data from several sources also suits the purposes. Entity-relationship diagram of the database is shown in Appendix E.

Processing files consist of 4 master files:

1. Estimate_Cost_Master

2. Work_Structure_Master

3. Control_Budget_Master

4. Actual_Cost_Master

Four transaction files are used for daily cost record for cost control purpose:

1. Material_Transaction

2. Equipment_Transaction

3. Labour_Transaction

4. Indirect_Cost_Transaction

Summary files are also used to store summary record and management reports.

In data processing, the computer program consists of following modules

Module 0:   Cost Engineering System

Module 1.0:   Develop Work Element List

    Module 1.1:   Get Project Information

    Module 1.2:   Get Cost Items

    Module 1.3:   Get Master format

    Module 1.4:   Develop Work Element List

    Module 1.5:   Write Work Element List

Module 2.0:   Develop Work Breakdown Structure

    Module 2.1:   Determine Work Breakdown Structure

    Module 2.2:   Write Work Breakdown Structure

Module 3.0:   Develop Cost Code

    Module 3.1:   Determine Cost Code

Module 3.2:   Write Cost Code

Module 4.0:   Prepare Project Budget Report

Module 4.1:   Get Cost Estimate Summary

Module 4.2:   Enter Cost Code

Module 4.3:   Update Budget Cost

Module 4.4:   Write Project Budget Report

Module 4.5:   Print Project Budget Report

Module 5.0:   Prepare Resource Schedule

Module 5.1:   Determine Resource Schedule

Module 5.2:   Write Resource Schedule

Module 5.2:   Print Resource Schedule

Module 6.0:   Prepare Summary Cost Report

Module 6.1:   Prepare Actual Cost Summary

Module 6.2:   Write Summary Cost Report

Module 7.0:   Prepare Cash Flow Report

Module 7.1:   Prepare Cash Flow Forecast

Module 7.2:   Write Cash Flow Report

Module 7.3:   Print Cash Flow Report

Structure Charts of these Modules are shown in Appendix D.

3.3   Hardware and Software Requirements

The proposed Cost Engineering System requires computer network to link several PCs within department and also connect to computer system of other departments i.e. Planning, Accounting & Finance, Procurement and Construction.

Client/server computing is used to manage the network with all data management and storage put on server side and data processing on client machines.

TCP/IP is used as communications software to support distributed applications. This will allow the functions of the system split between client and server in such a way to optimize network resources. In the case of Cost Engineering System, most application logic is located at client side while the server is essentially maintaining the database. Interaction between the client and server or database accessing by client is done by using structured query language (SQL).

Graphical user interface (GUI) is used to facilitate the user interaction with the system. The presentation services modules on user screens are thus easy to use.

Figure 3.1 illustrates the LAN connection of all cost-related computer systems of the company. The server, as database server, will be located and controlled by Cost-Engineering Department. The network link computer system of 5 departments i.e. Cost-Engineering, Planning, Accounting & Finance, Construction and Procurement.
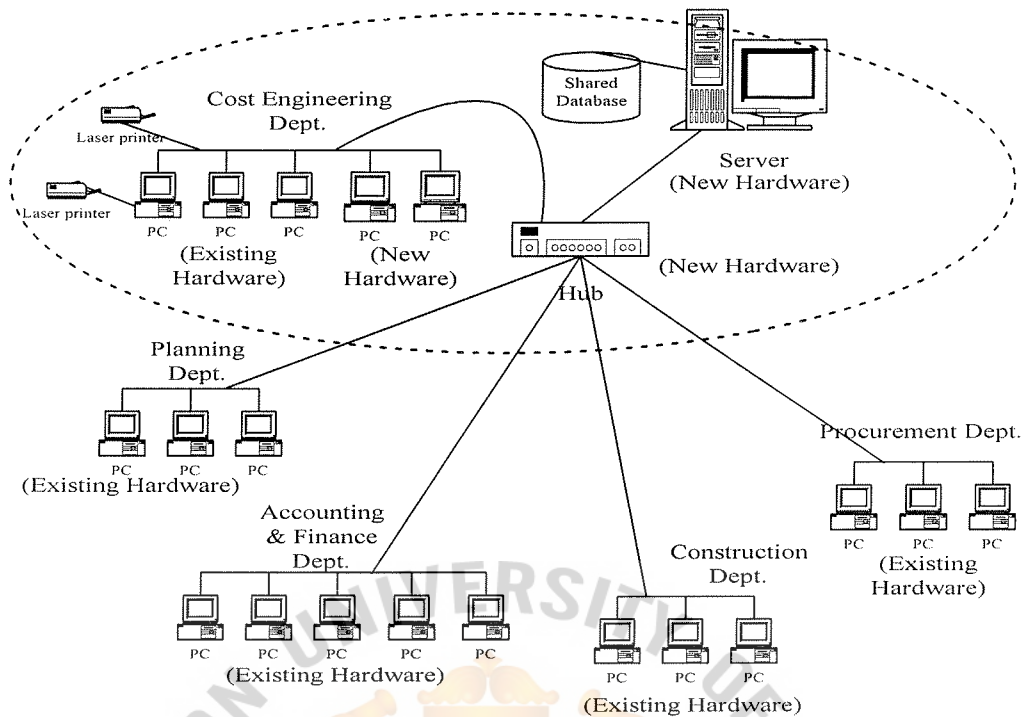
Figure 3.1.   Computer Network System Diagram.

The proposed LAN system with one database server connecting to 5 client PCs of Cost Engineering System and other 14 PCs from several departments. The new hardware requirements are as follows:

1. Net Server   1 no.

    specifications

        - CPU Pentium III 500 MHz

        - 64MB SDRAM memory

        - 10 GB SCSI hard disk

        - 7 mass storage shelves

            ■ 3 front accessible

            ■ 4 internal

- 15" SVGA monitor

2. Client PC   2 no. (for Cost Engineering Department)

- CPU Pentium II 400 MHz

- 512 KB cache

- 32 MB SDRAM

- 4.3 GB hard disk drive

- 8MB Matrox MGA-G200 2D/3D AGP

- 15" monitor

3. Laser printer   2 no.

- 8 pages per minute print speed

- 600 X 600 dpi resolution

- Network interface card

Software requirements

The software required for the system are:

Server unit:

- Windows NT operating system

- Oracle Workgroup version 8

- Oracle Enterprise Manager 1.6

Client units:

- Oracle Developer/2000

- Microsoft Access 97

3.4   Security and Control

The Proposed Cost Engineering System provides protection scheme for information security in the computer network. The database of the system is under

"share via access limitation". This means the operating system checks the permissibility of each access by a specific user to a specific object or data, to ensure authorized access.

Normally user-oriented access control is enforced as control from user side. It requires user log on by entering user identifier and password. As the network of centralized distributed environment, it provides log on service to determine who is allowed to use the network.

In case of more sensitive data protection such as at time of preparing cost proposal for new project bidding, apart form user access control procedure, data-oriented access control is also used as control from server side. The DBMS at server side will enforce control access to specific records of data as another level of security check. Only selected individual, such as Cost Engineering Manager or Project Manager may then have access to the bid cost information.

The password strategy uses "proactive password checker scheme" which allows the user to select his or her own password. The following rules are enforced in selecting password:

- Passwords must be at least eight characters long.
- Passwords must include uppercase, lowercase and numeric digits.

As for antivirus approach, the system uses full-featured protection of scanning and activity trap components. The antivirus software, once purchased, can be updated from time to time via internet from the manufacturer's website.

Backup file scheme is also used for security reasons. The backup is kept in ZIP drive disks which have much storage capacity and need only one cabinet to keep. Transaction files require daily backup and master files weekly.

3.5   System Cost Evaluation and Comparison

3.5.1   Cost Analysis

The cost of new system installation needs to be justified to prove that it renders cost-saving and cost-avoidance benefits in appropriate time after implementation. Quantitative estimates of costs and benefits have been studied.

The cost of the new system consists of:

- Development costs (fixed costs)

- Operational costs (variable costs)

Development Cost

This includes the cost of new hardware, software, LAN connection and implementation.

Hardware

- Database server	150,000
- Client PC (2 no. @ 58,000 Baht)	116,000
- Laser printer (2 no. @ 23,000 Baht)	46,000
- Network accessories and connection	140,000
Total investment cost (Baht)	452,000

Software

- Network operating system	85,000
- DBMS software	180,000
Total software cost (Baht)	265,000

Implementation cost

- System development	200,000
- Employee training	80,000

Total implementation cost (Baht)	<u>280,000</u>
Total Development Cost (Baht)	<u>997,000</u>
Operational Cost (Annual Cost)	
- System maintenance	20,000
- Consumable supplies	38,000
Total Operational Cost (Baht)	<u>58,000</u>

3.5.2   Benefit Analysis

The benefits of the proposed system include tangible and intangible benefits.

Tangible benefits

- Cost reduction due to less waste	379,100
Total Annual Cost Saving	<u>379,100</u>

Payback Period

Payback period is calculated to determine the number of years the investment of proposed system is recovered. The equation for payback period is:

$$P = \frac{I}{(1-T)R}$$

Where   P =   payback period (year)

I =   investment cost (Baht)

T =   tax rate (7%)

R =   annual cost saving

Therefore, from the aforementioned figures in 3.5.1 and 3.5.2:

$$P = \frac{997,000}{(1 - 0.07)\ 379,100}$$

$$P = 2.8 \text{ years}$$

Table 3.1.　Annual Cost of Existing System.

Cost Items	Year 1 (Baht)	Year 2 (Baht)	Year 3 (Baht)	Year 4 (Baht)	Year 5 (Baht)
Employee Cost	945,000	1,257,000	1,456,000	1,612,000	1,841,000
Office Equipment	32,500	45,600	54,200	63,500	74,890
Hardware	165,000	0	0	0	0
Software	85,000	0	0	0	0
System Maintenance	34,500	43,560	55,600	68,750	83,000
Stationery & Paper	55,200	68,500	80,200	95,600	116,000
Total	1,317,200	1,414,660	1,646,000	1,839,850	2,114,890

Table 3.2.   Annual Cost of Proposed System.

Cost Items	Year 1 (Baht)	Year 2 (Baht)	Year 3 (Baht)	Year 4 (Baht)	Year 5 (Baht)
Employee Cost	945,000	1,050,000	1,050,000	1,151,000	1,216,000
Office Equipment	32,500	24,500	21,200	18,600	15,800
Hardware	452,000	0	0	0	0
Software	265,000	0	0	0	0
System Development	280,000	0	0	0	0
System Maintenance	20,000	30,000	35,000	45,600	56,200
Stationery & Paper	38,000	32,000	21,500	8,500	7,800
Total	2,032,500	1,136,500	1,127,700	1,223,700	1,295,800

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Table 3.3.   The Cost of the Proposed System and the Existing System.

Year	The Proposed System Cost		The Existing System Cost	
	Period (Baht)	Cumulative (Baht)	Period (Baht)	Cumulative (Baht)
1	2,032,500	2,032,500	1,317,200	1,317,200
2	1,136,500	3,169,000	1,414,660	2,731,860
3	1,127,700	4,296,700	1,646,000	4,377,860
4	1,223,700	5,520,400	1,839,850	6,217,710
5	1,295,800	6,816,200	2,144,890	8,332,600

Break-Even Analysis

Figure 3.2 illustrates the comparison between the cost of existing system and the cost of proposed system as shown in Table 3.3. The cost of existing system begins at 1,317,200 Baht and climbs to 8,332,600 at year 5. The cost of proposed system begins at 2,032,500 Baht and climbs to 6,816,200 at year 5. The two curves intersect at around year 2.8, which is the break-even point. Therefore the investment of the proposed system will be recovered within the period of less than 3 years.

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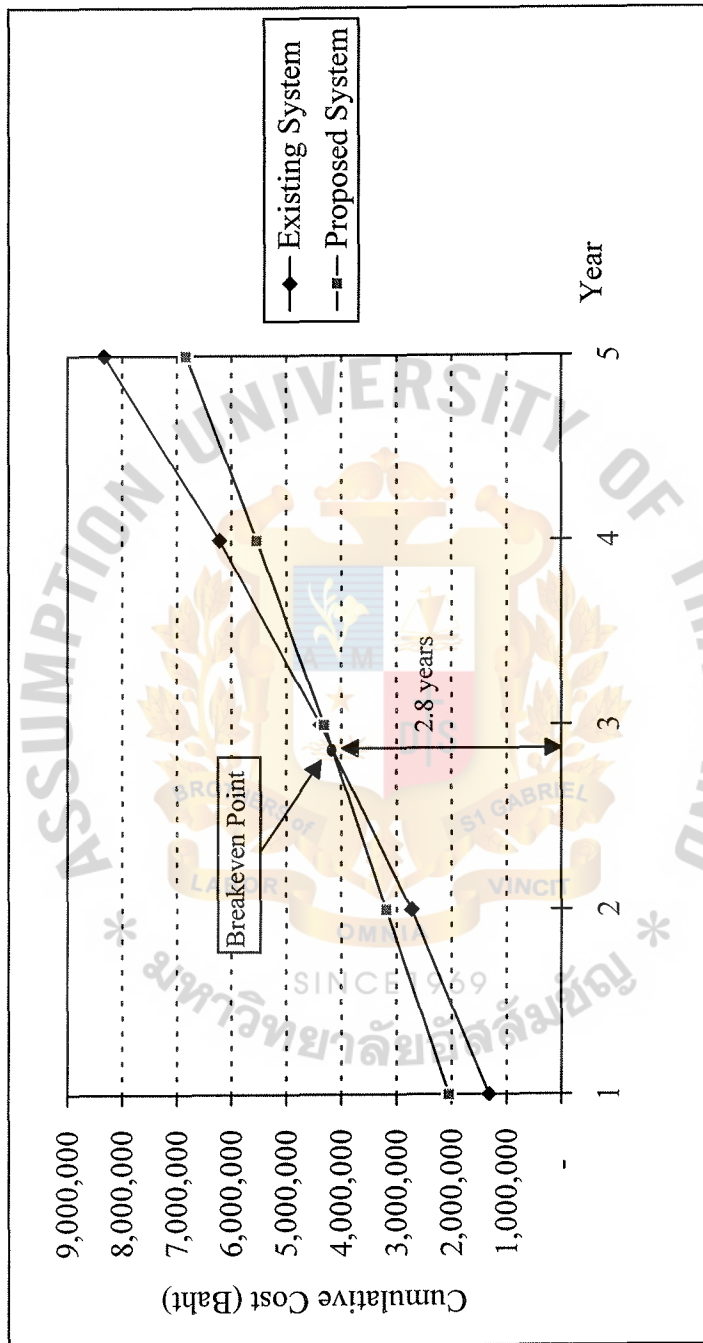
Figure 3.2.   Breakeven Analysis of Existing System and Proposed System.

Intangible Benefits

Improved Service-Level Benefits

With the proposed system, it takes around 5 hours to prepare monthly summary cost report. Currently at least 2 days are needed to collect and key-in data from other departments and verify the validity of data before the final report can be concluded.

Improved-Information Benefits

The proposed system is expected to produce better information for cost status monitoring and decision making. The reports will be more complete and reliable with latest updated information at time of reporting.

The improved-service level and improved information benefits can be perceived by the user and the management. The monetary value is not measured.
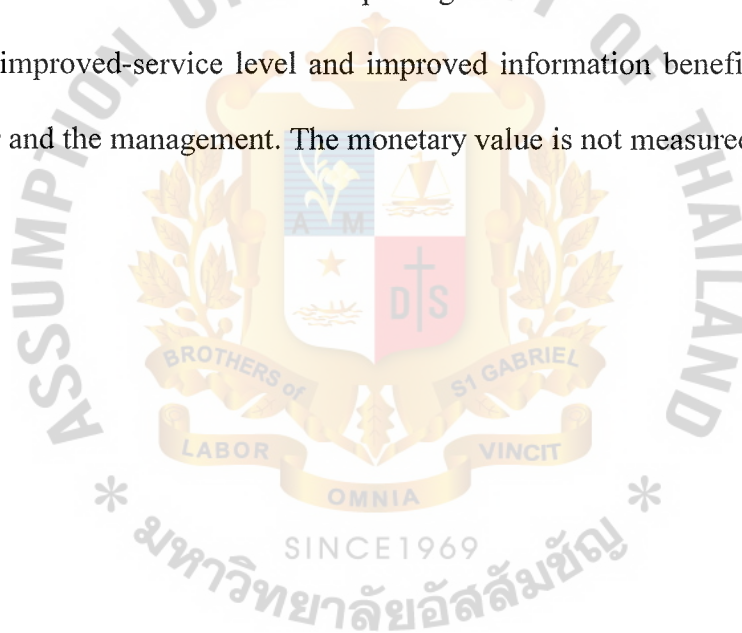
IV. PROJECT IMPLEMENTATION

4.1 System Implementation

System Prototyping

The proposed system uses contract programming for installation of the network management software – Windows NT and database management software Oracle 8 and Microsoft Access. The selected softwares are domain-independent - being built for a variety of processing environments and their specifications are suitable for the Cost Engineering System requirements. The interface of input, output, databases, modules and controls can be easily reviewed.

Working model of cost information system is created to determine if the design meet user needs and expectations.

Prototypes includes the screen data entry and data reporting facilities. The steps are as follows:

1   Design screen and data files. Identify the fields on data entry screen and corresponding fields for each record to be stored on files.

2   Collect some data as sample.

3   Produce report based on information stored on files.

4   Identify problems with the report format and contents.

5   Collect some new data.

6   Report on the files.

7   Return to step 4 if the report continues to show problem.

With all the system design documentation illustrate in context diagrams, data flow diagrams and structure charts, the users can evaluate the requirements of processing and determine if the proposed design meets their requirements. Documenting computer ccde

or to identify and explain the steps of processing is shown in Appendix C – Process Specification.

System Testing

The proposed softwares have been tested to assure that they are easy to use and good for the purposes of the system.

Since the system focuses on the inputs and outputs with no interest on how instructions are executed within each modules, black-box testing is used. The test includes:

- Stress test which is used to test for system capacity and determine throughput and response time characteristics of the system. It is expected that the system will be able to handle around 20,000 cost code with up to unique 50 fields

- Normal path test is used to see if the system can handle valid data so that all valid inputs bring about valid results.

- Error path test is used to see how the system handles invalid data.

System Conversion

The installation of system softwares is just add new features to the existing computer-based operation. The activities in system conversion include:

- Creating new database

- Installing new system

- Completing all work procedure

- Completing all documentation

- Training the users

The conversion uses parallel method on system changeover. The old operation can still be undertaken in concurrent with the new system until the users and company are

ready to fully comply to the new system. The results of the new system can be compared to the old one. If any deviation occurs in the results, corrective actions can be taken. This includes changing or modifying the coded instructions.

User Training

Training session is required to provide the users with hand-on experience with the new system. The comprehensive/progressive training programs are organized one for the cost engineers and another for cost technicians. The program covers all system functions, operation procedures and system maintenance method. The training course start with 3 day classroom training and followed by 3 month on-the-job training. The period is adequate to provide the user time to learn about the new system environment. Since the system is designed to be interactive, users can easily try out the softwares, with only little supervision from the analysis team.

System Maintenance

To keep the software current with the changing processing requirements, to fix the errors of defects of the software and to keep up with changes in computer technology, system maintenance plan have been developed. The plan includes adaptive maintenance, corrective maintenance and perfective maintenance.

Adaptive maintenance will be undertaken when the programs need to be modified to incorporate new system requirements. Routine maintenance tasks using utility programs include:

- File copying and back-up

    To copy data files and database and store them in safe locations to be retrieved or restored when needed.

- File reorganization

Since the system deals with extensive volume of data, reorganization of master files need to be done periodically when records are deleted and written to overflow areas.

- Table update

Data in tables need to be regularly updated when required to keep the system information reliable and valid.

Corrective maintenance is required in response to software failure. To track the problems, Critical incident reports will log the software failures, their probable cause and corrective action taken. These reports help identify classes of errors: program logic error, system errors, operation errors and user errors.

Perfective maintenance is to improve or maintain program efficiency. One example is to modify program data structures by simplifying the organization of data structure.

V.   CONCLUSIONS AND RECOMMENDATIONS

5.1   Conclusions

Cost Engineering is one of the most vital management information and control functions of construction company. The use of work breakdown structure or cost code is basic framework to interrelate costs, schedules, responsibilities and other factors utilizing the common code. Control budget are derived from estimates of costs and quantities, and usually provide a structure for recording actual performance, making forecasts, showing variations and documenting reasons for unexpected problems. The need to recategorize the costs from the estimate record to serve the needs of effective cost control is likely in many projects. Field construction cost control focuses on labour and equipment, with main sources of data from time sheets and estimates or surveys of quantities of work in place. Data from other parts of control system, including scheduling, accounting, procurement and quality assurance are also used for consistency, comparisons and interrelated factors. Theory and principles of engineering economy is also useful in making comparative economic evaluation of alternatives in design or construction and in developing cash flows for project finance. Cost engineering is an interface between management, line supervisors, scheduling, procurement, accounting, field engineers, and others. With the use of computer network system with central database management the integration of information from several work divisions can easily be bound together and provide more synchronized environment in producing useful information for decision making and problem solving. The degree of achievement in using the proposed system can be measured in terms of transaction time. The transaction time for input screen, output report, data update and data retrieval is faster as shown in the Table 5.1:

Table 5.1.   Transaction Time Comparison.

| Transaction Time	Existing System	Proposed System
Input Screen	15 minutes	6 minutes
Output Report	55 minutes	20 minutes
Data Update	45 minutes	10 minutes
Data Retrieval	8 minutes	3 minutes

5.2   Recommendations

To have effective cost control, the trends of cost must be established as soon as possible and be compared against both the planned and actual progress. Project cost code should be simple, concise and easy to interpret. The breakdown structure needs to be consistent and deliberately developed from the beginning, never be changed in the middle of the project.

Together with the system implementation, standard data definitions from application to application up until department to department need to be initiated for data integrity purpose. Such data consistency, under careful administrative control, is essential in developing management information. Tracking and reporting on construction project cost status with full supportive information from other related business functions is possible.

Database system, once designed, may need to be modified from time to time to keep up with different levels of purpose. From initial phase, it is expected to meet short-term application-oriented goals of routine transaction processing. After that, long-term data-oriented goals of managing information as corporate resource should be of upcoming need to anticipate.

APPENDIX   A

CONTEXT DIAGRAM AND DATA FLOW DIAGRAMS
OF EXISTING SYSTEM
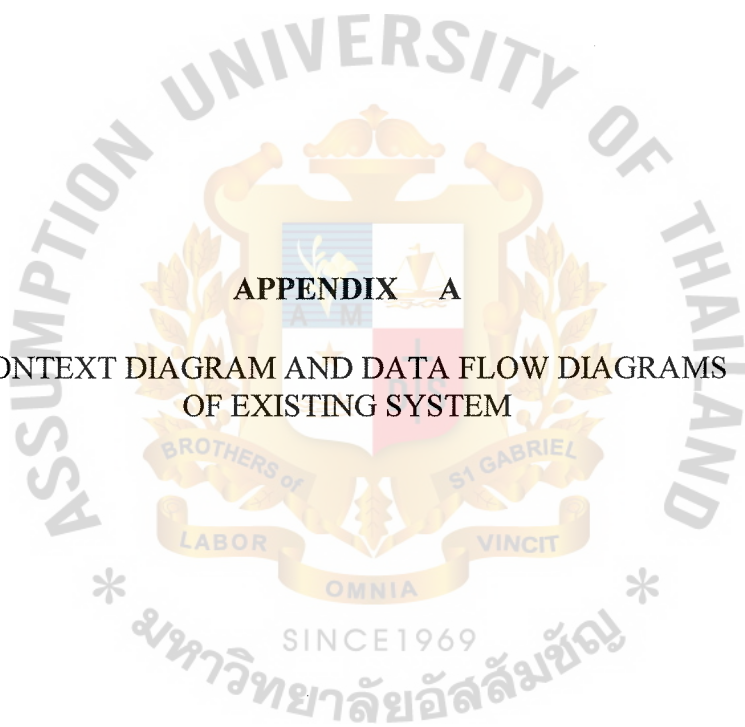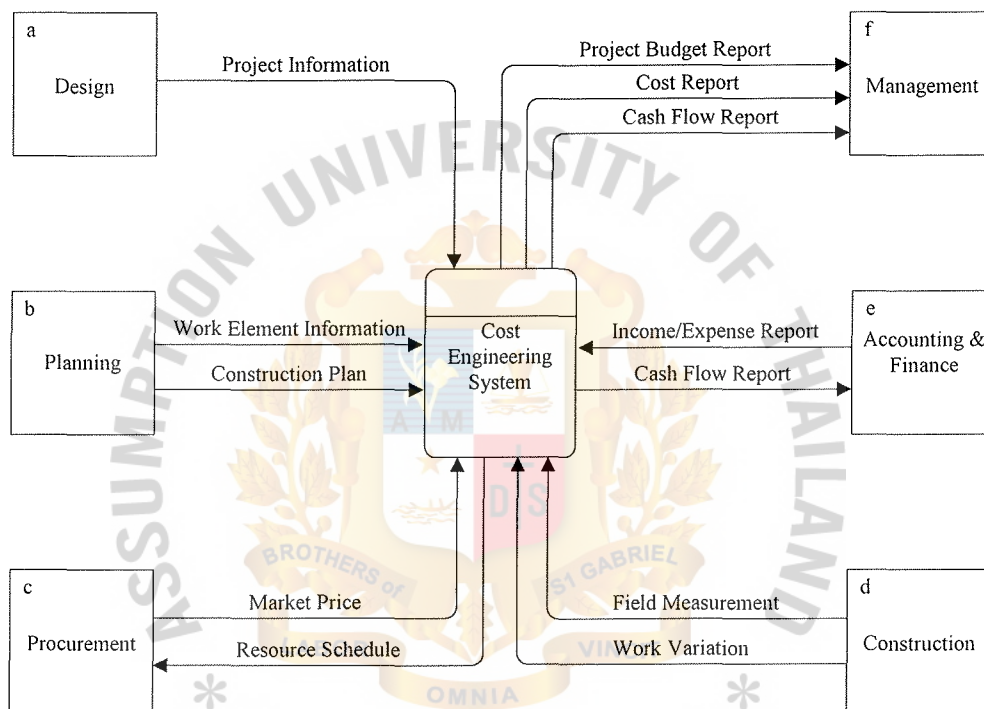
Figure A.1.   Context Diagram - Existing System.
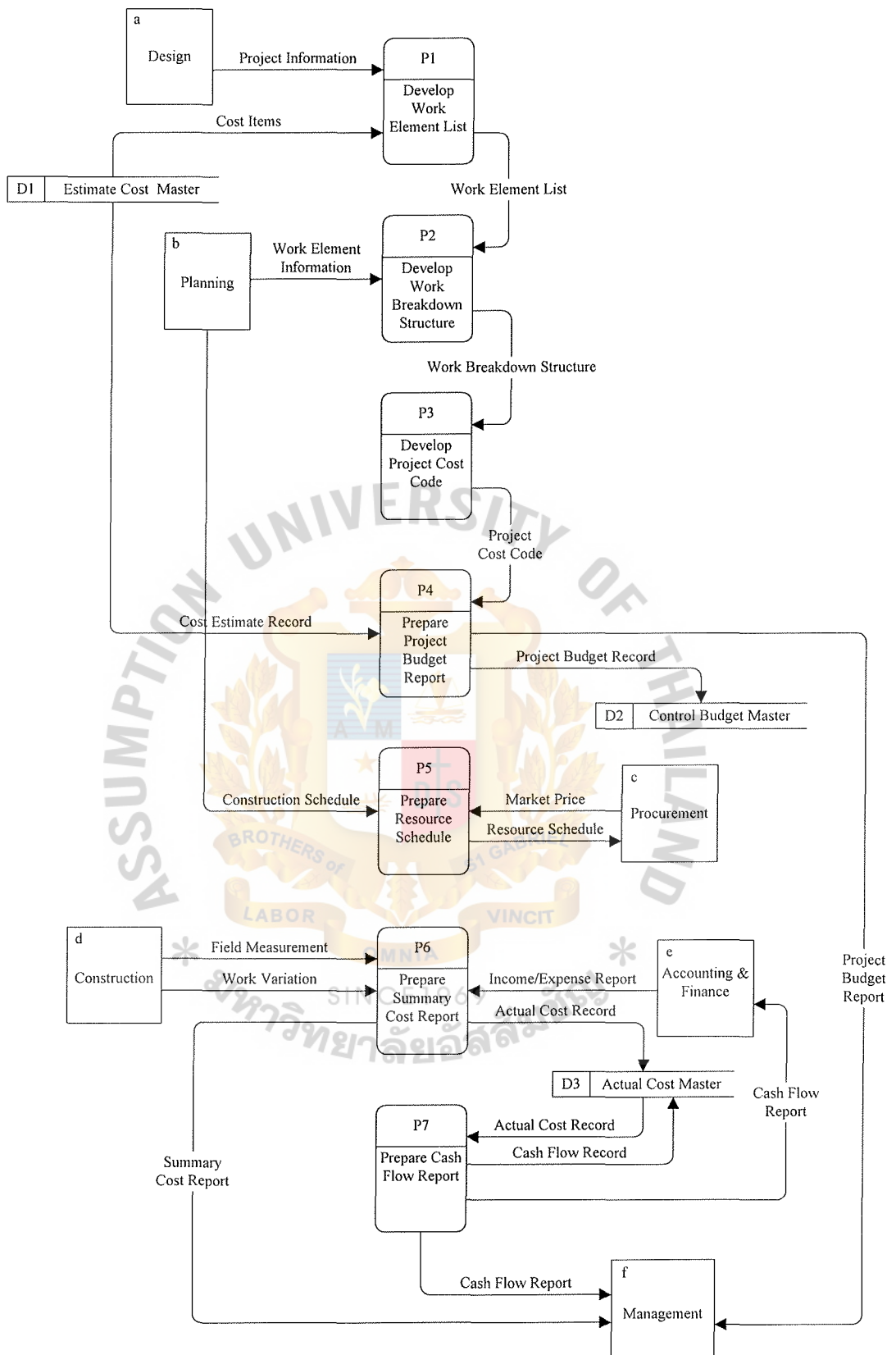
Figure A.2.   Data Flow Diagram Level 0 - Existing Cost Engineering System.
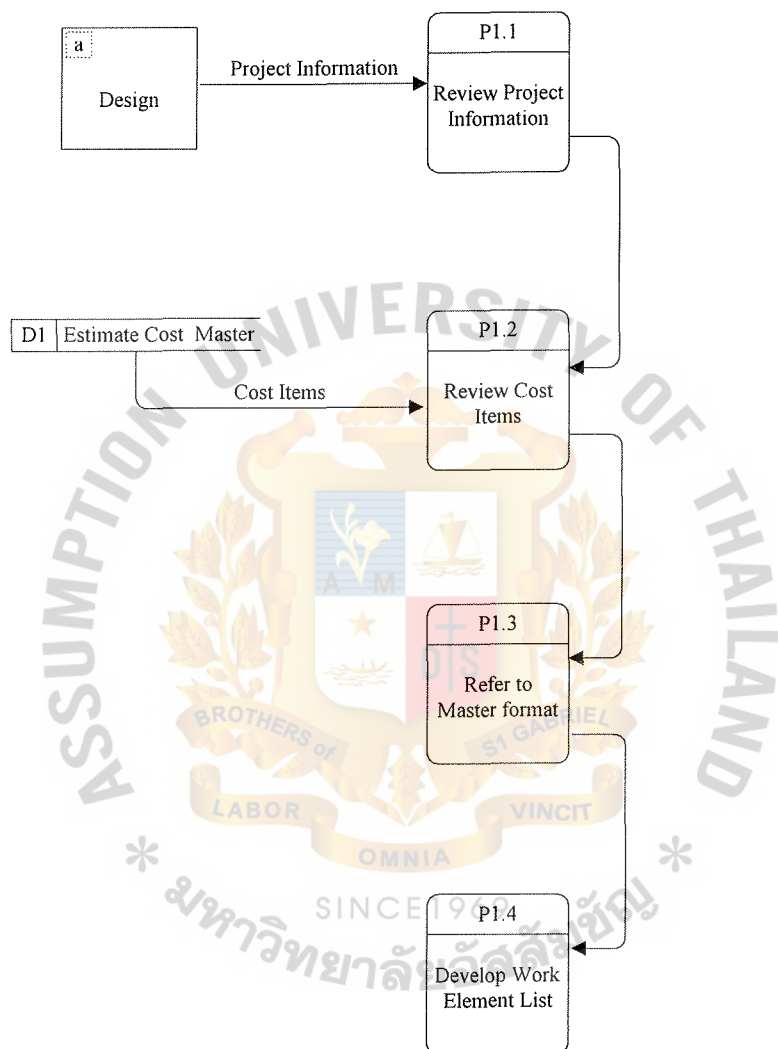
Figure A.3.   Process 1 - Develop Work Element List.
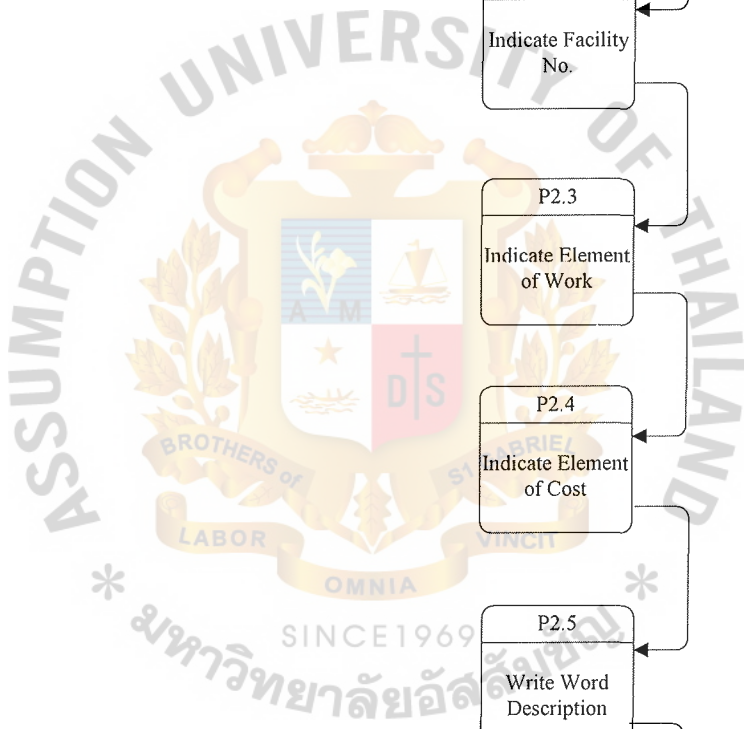
Figure A.4.   Process 2 - Develop Work Breakdown Structure.
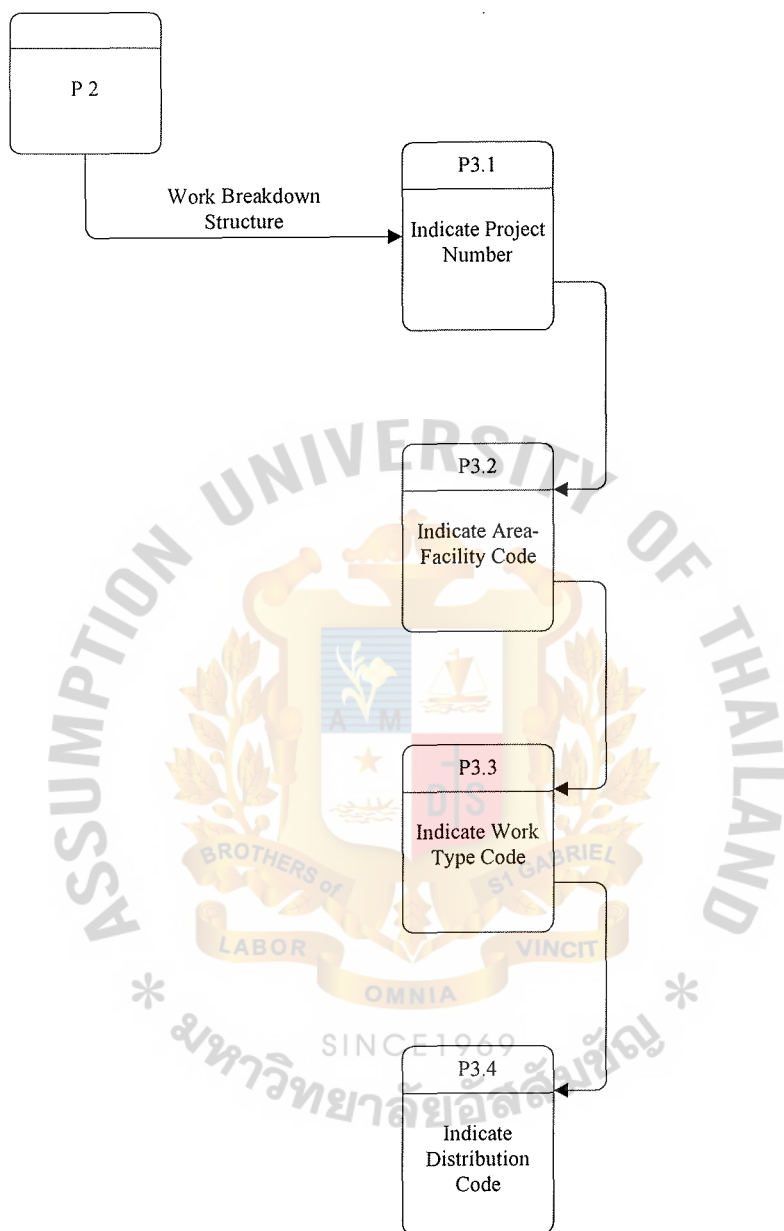
Figure A.5.   Process 3 - Develop Project Cost Code.
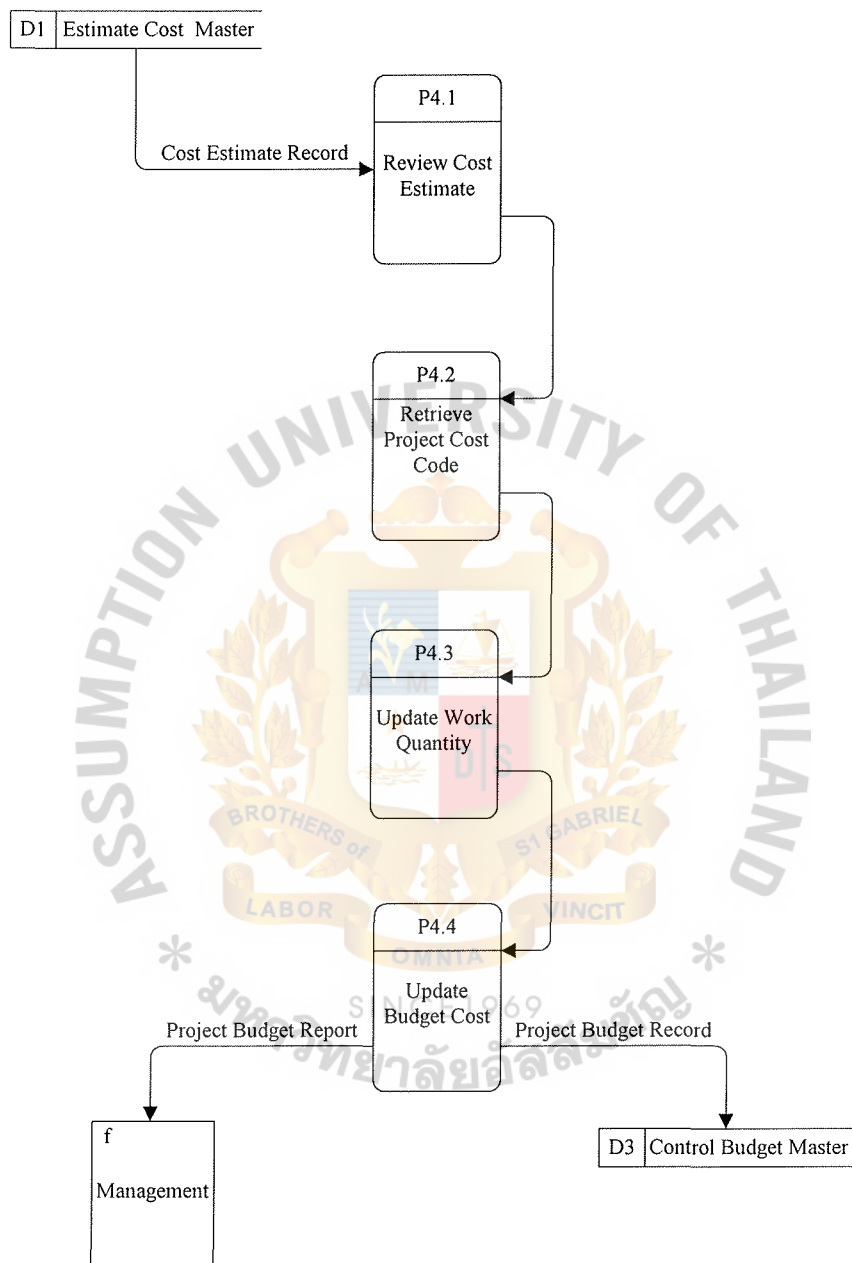
Figure A.6.   Process 4 - Prepare Project Budget Report.
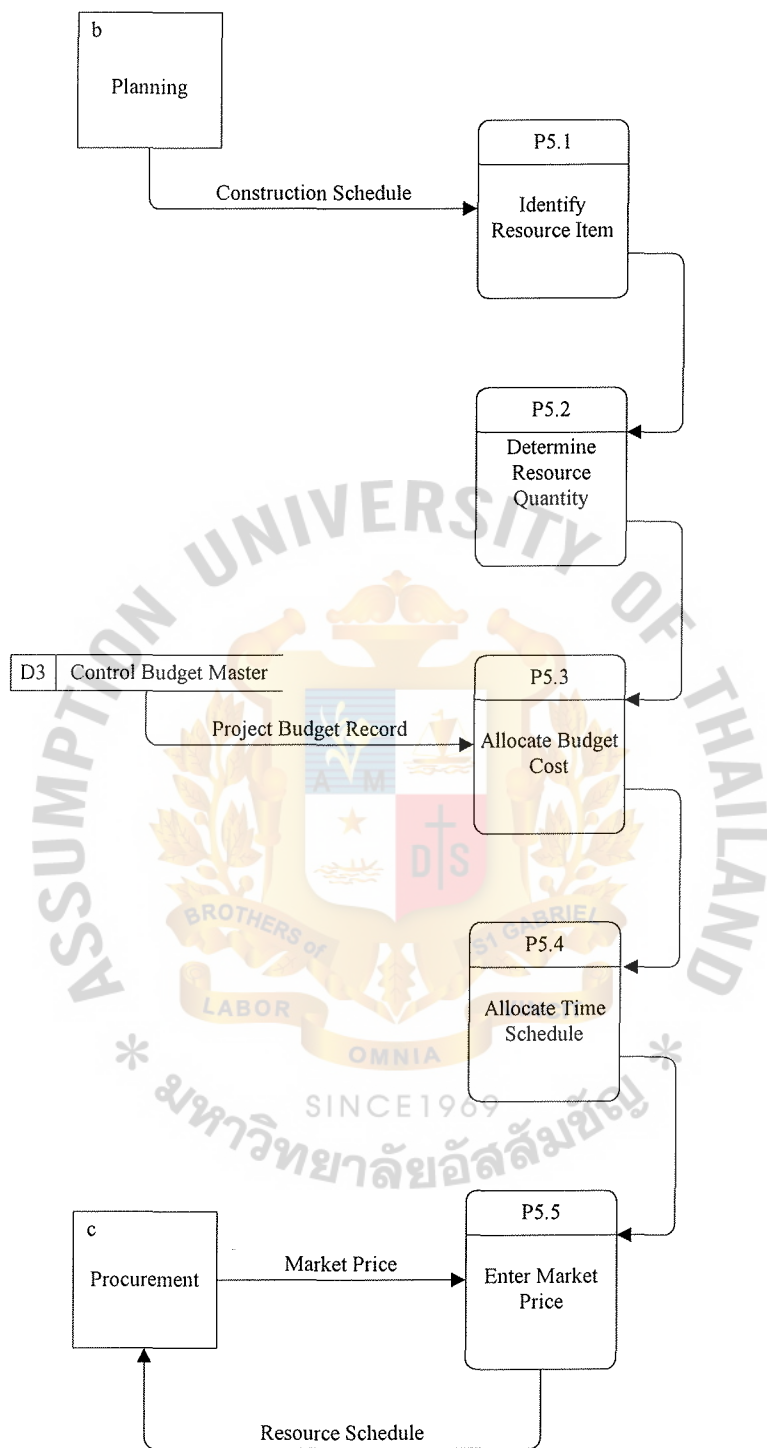
Figure A.7.   Process 5 - Prepare Resource Schedule.
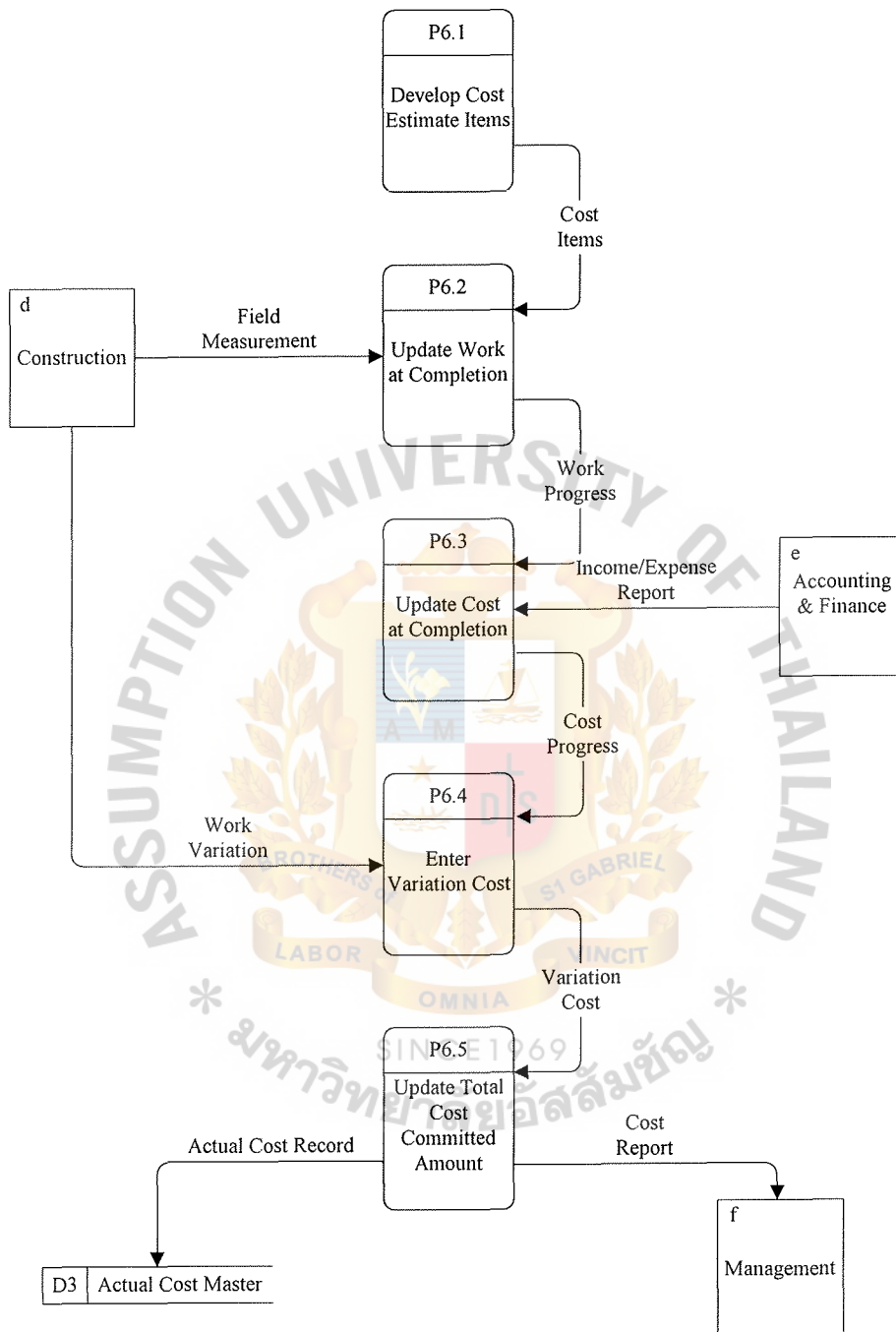
Figure A.8. Process 6 - Prepare Summary Cost Report.
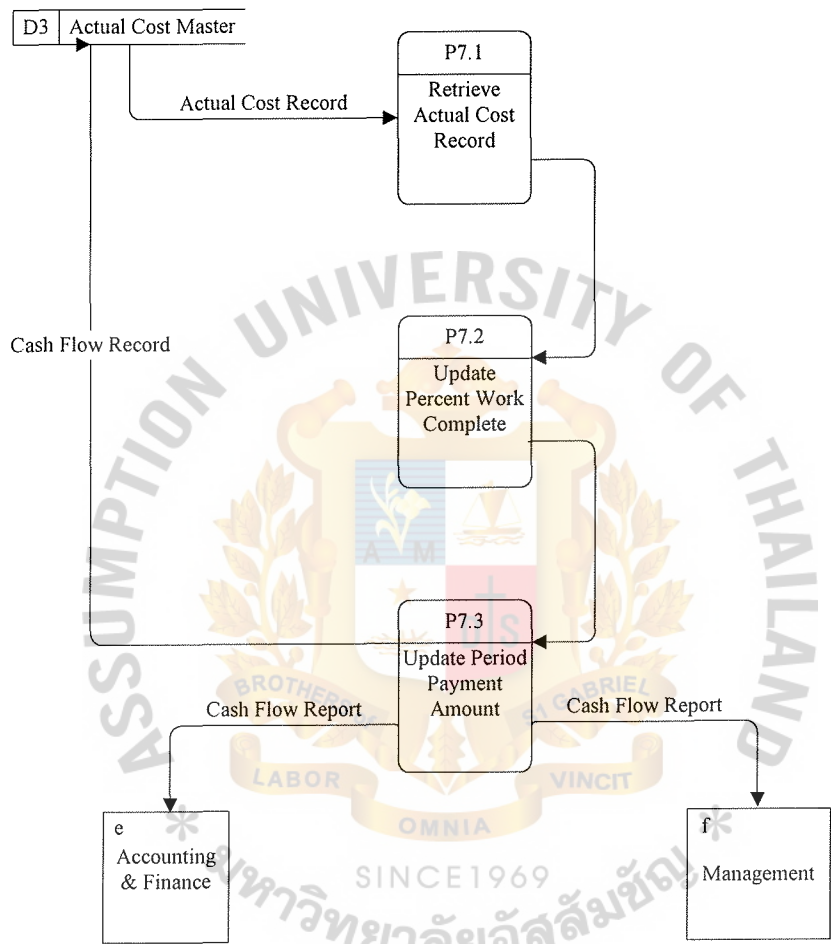
Figure A.9.   Process 7 - Prepare Cash Flow Report.

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APPENDIX   B

CONTEXT DIAGRAM AND DATA FLOW DIAGRAMS
OF PROPOSED SYSTEM
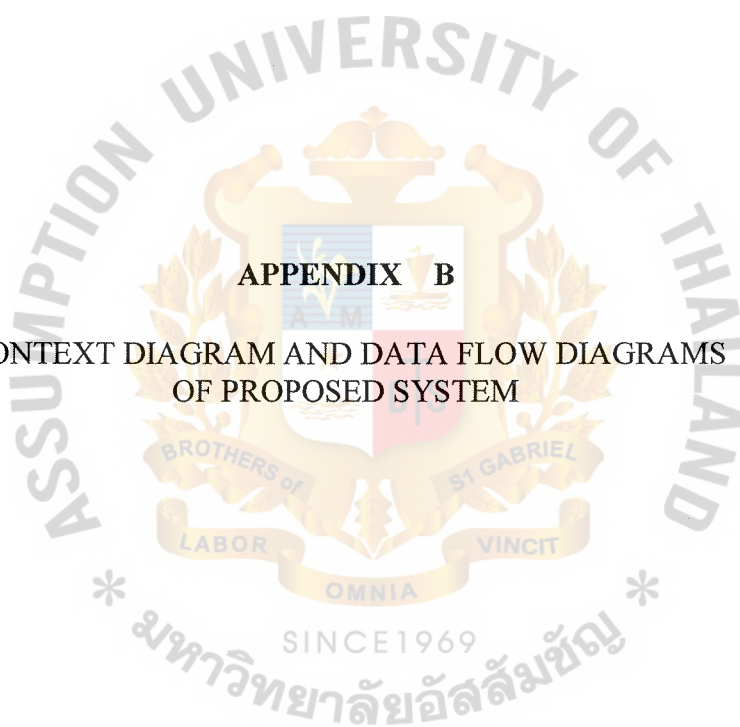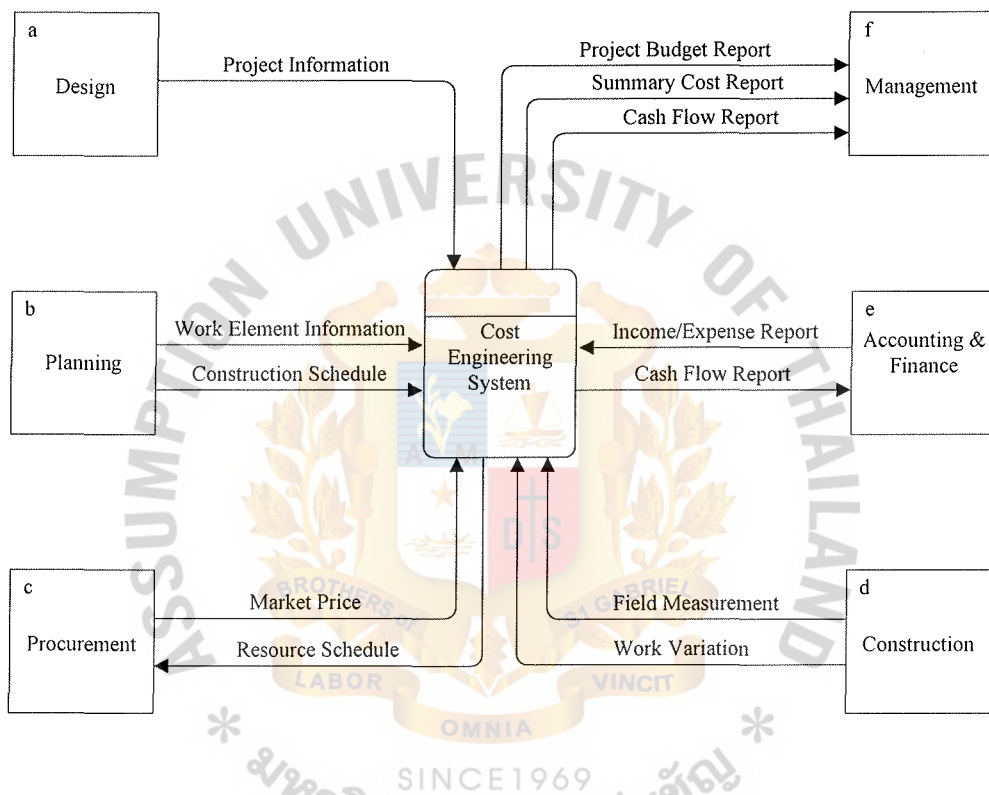
Figure B.1.   Context Diagram - Proposed System.

Figure B.2.   Data Flow Diagram Level 0 - Proposed Cost Engineering System.
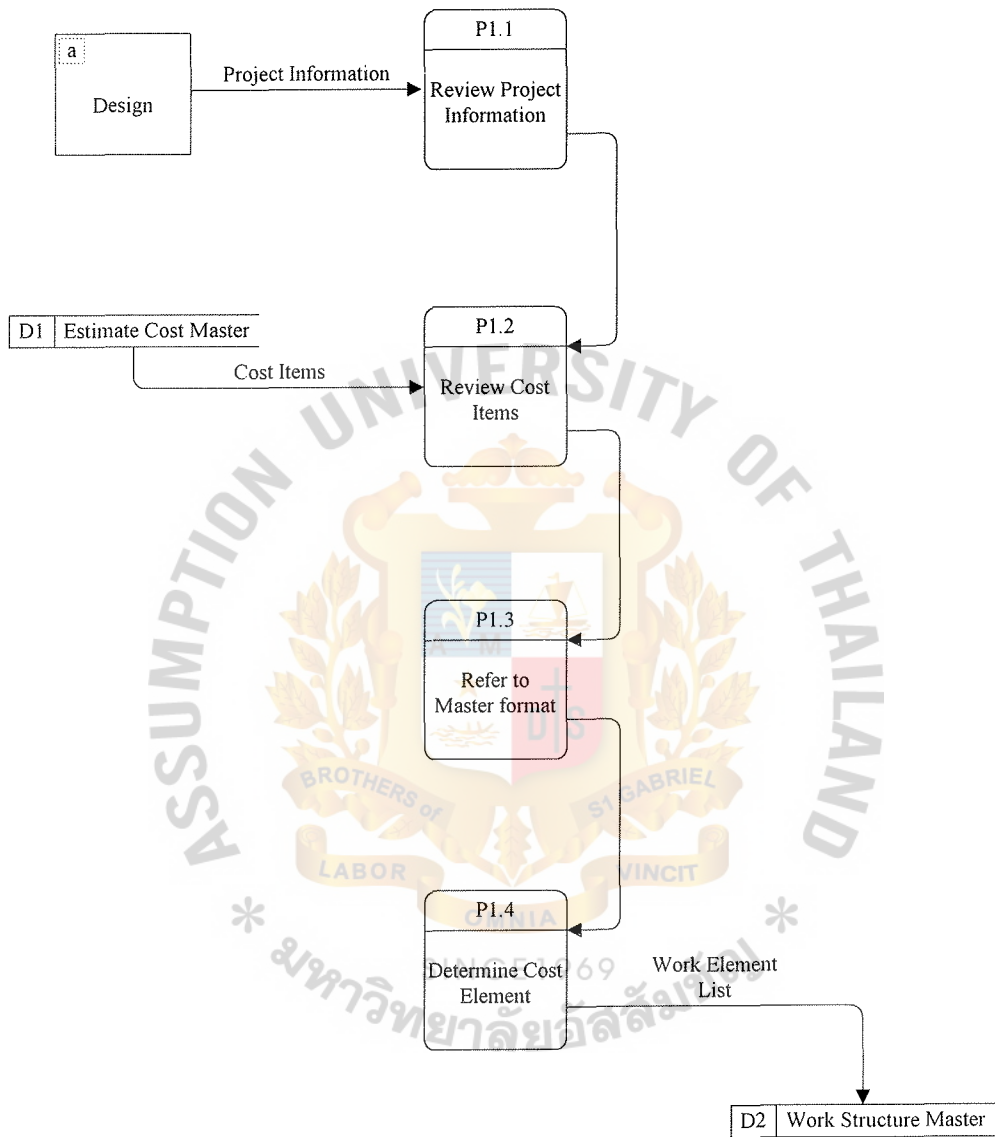
Figure B.3.   Process 1 - Develop Work Element List.

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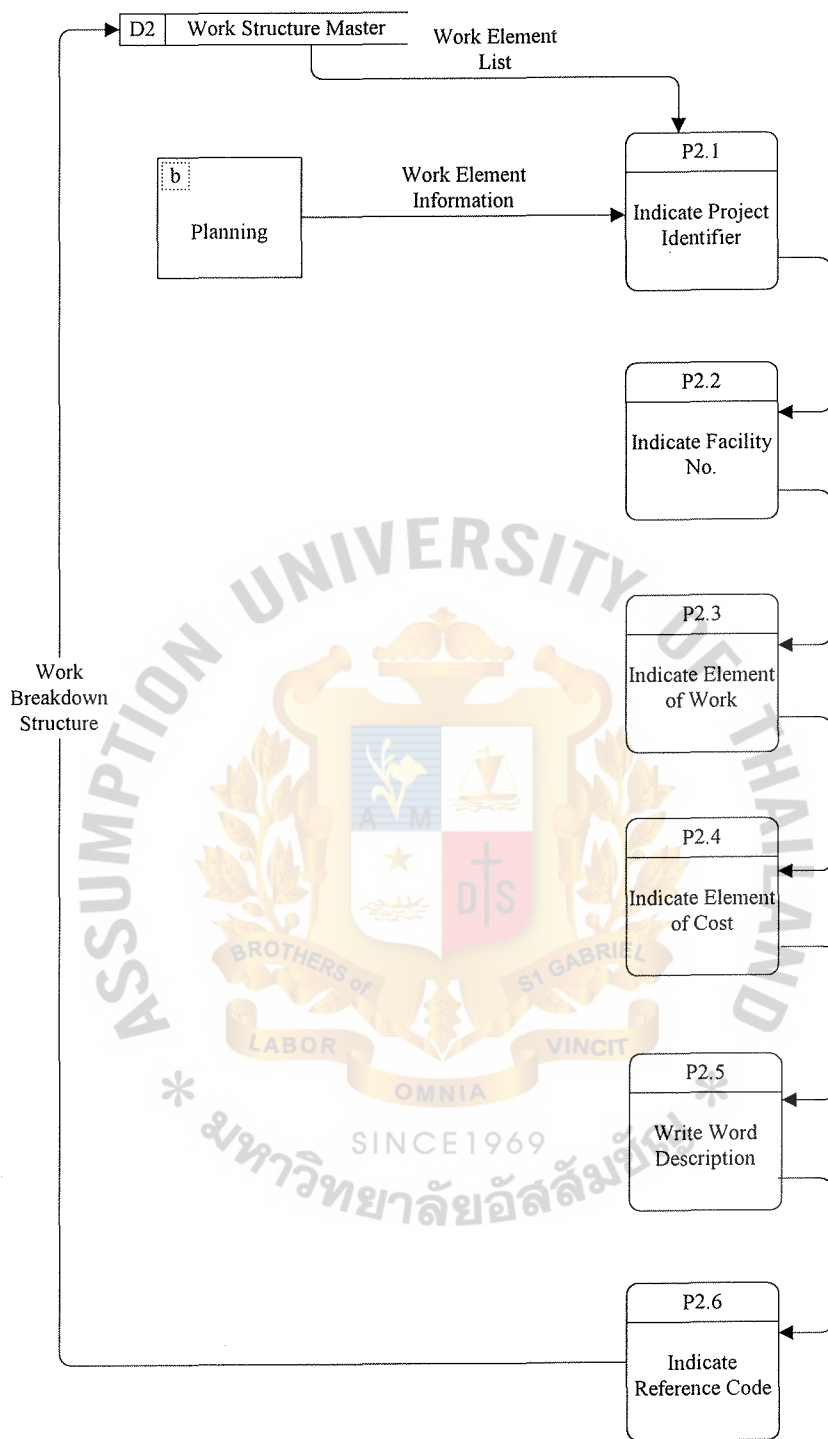
Figure B.4.   Process 2 - Develop Work Breakdown Structure.
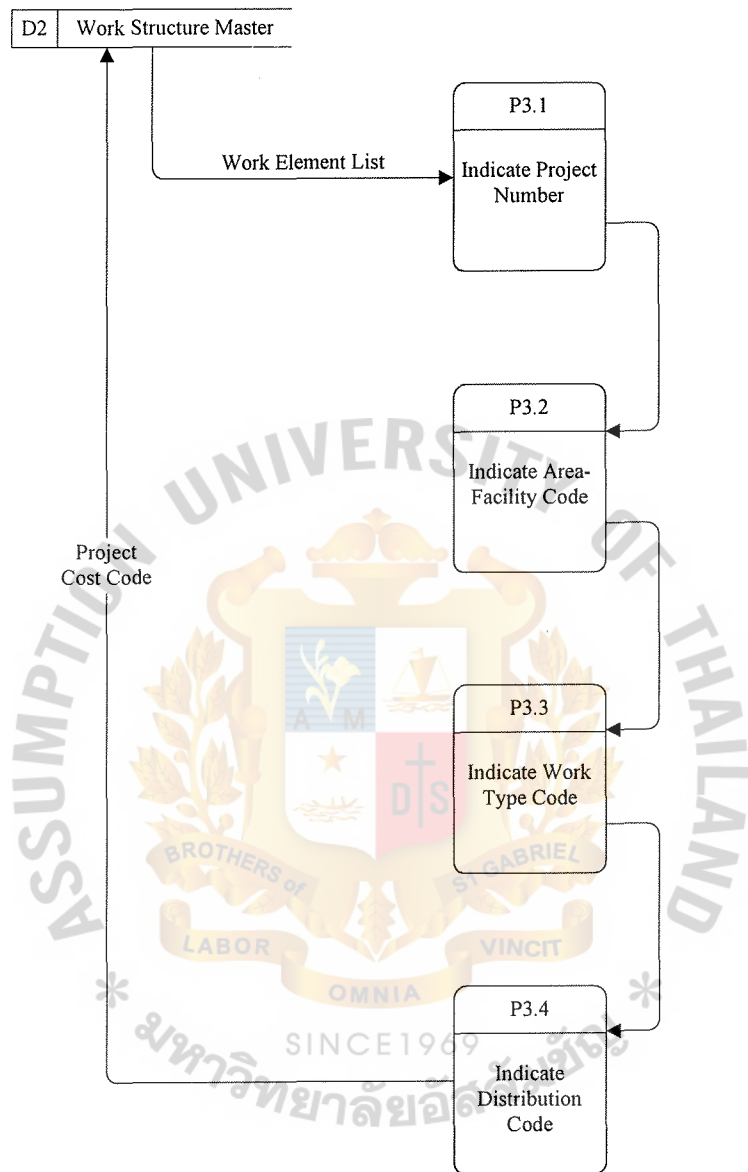
Figure B.5.   Process 3 - Develop Project Cost Code.
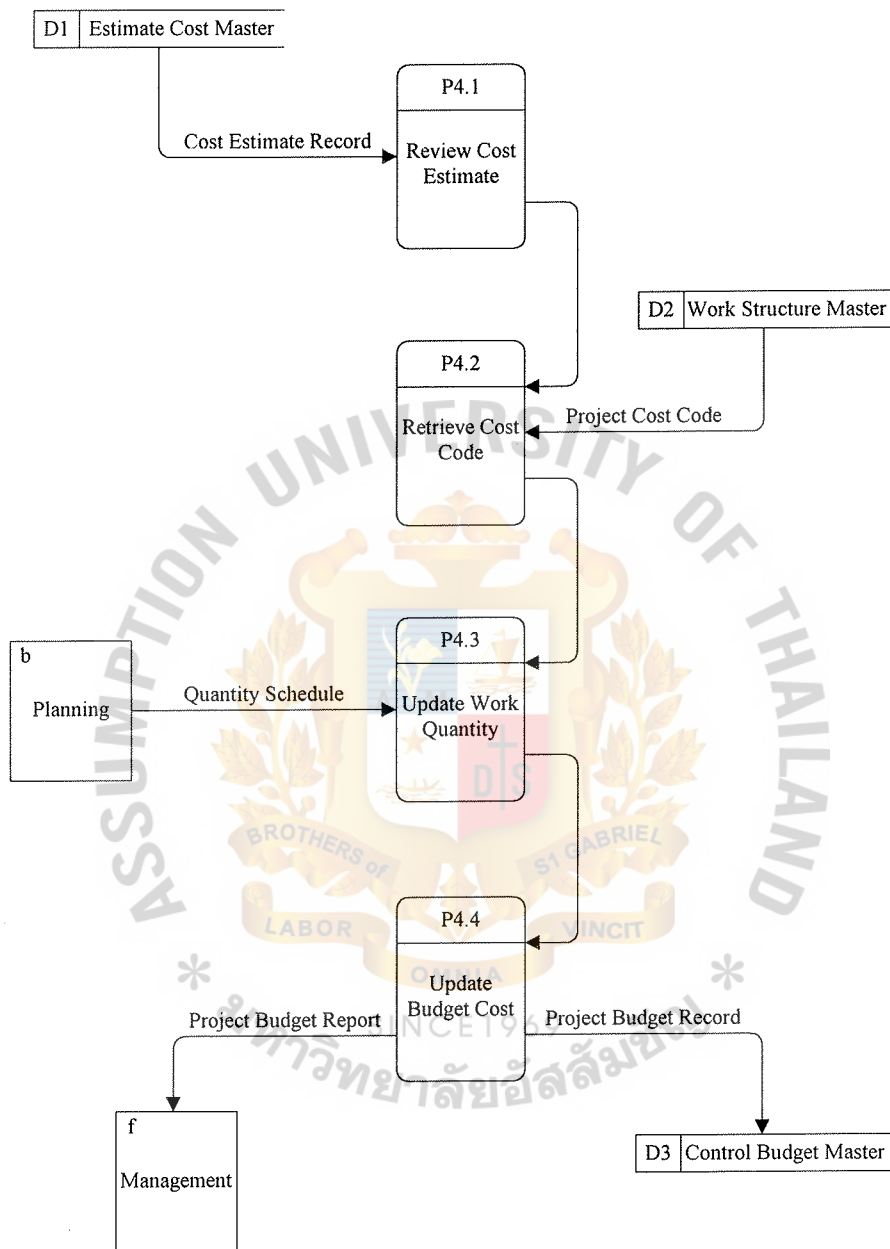
Figure B.6.   Process 4 - Prepare Project Budget Report.
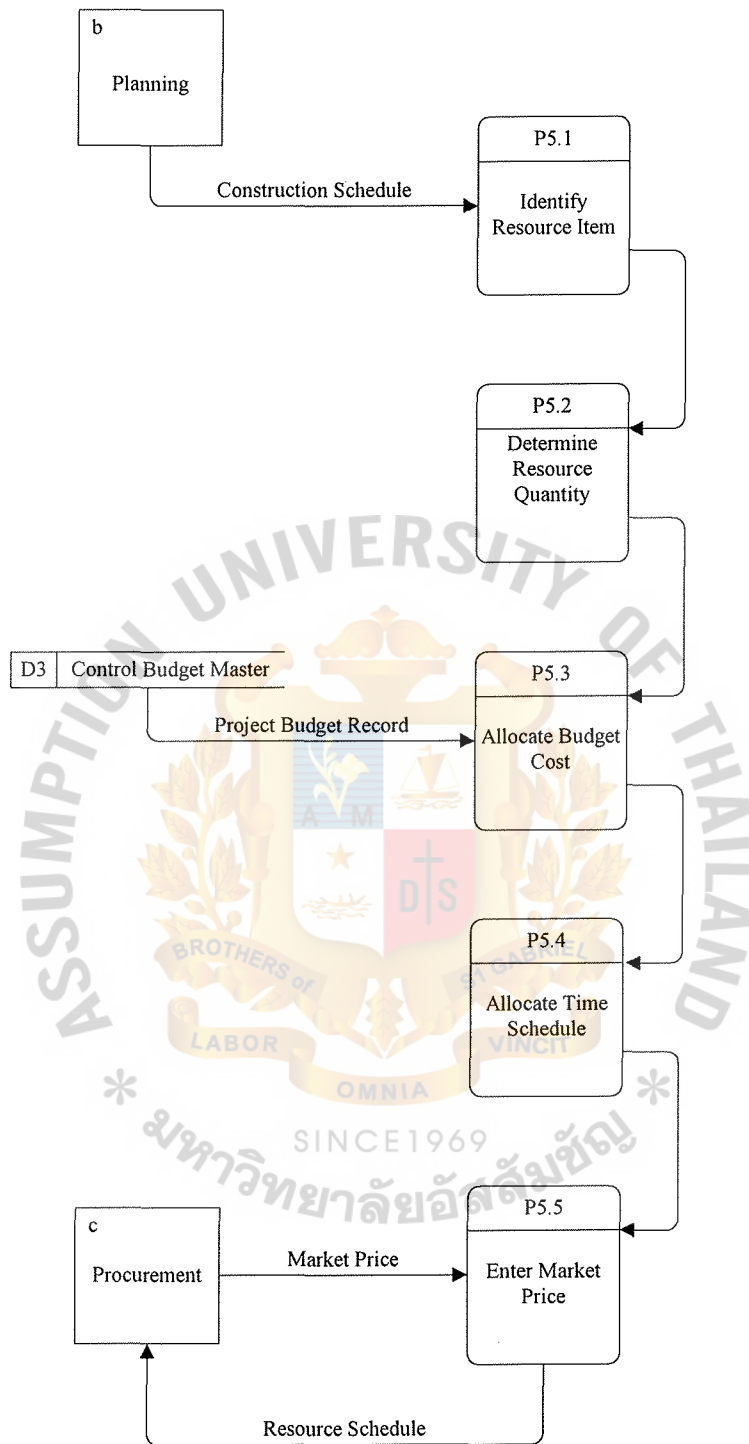
Figure B.7.   Process 5 - Prepare Resource Schedule.
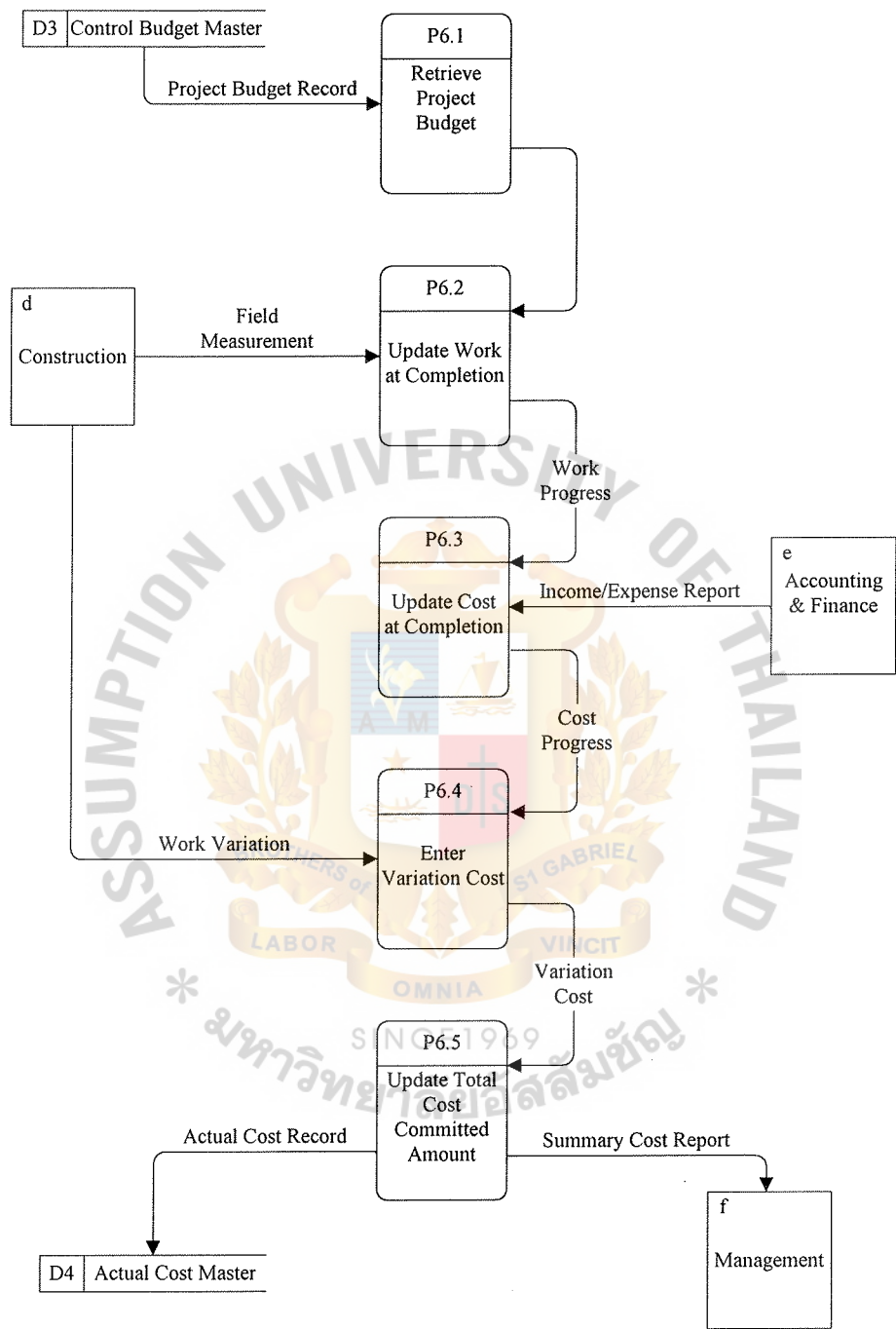
Figure B.8.   Process 6 - Prepare Summary Cost Report .
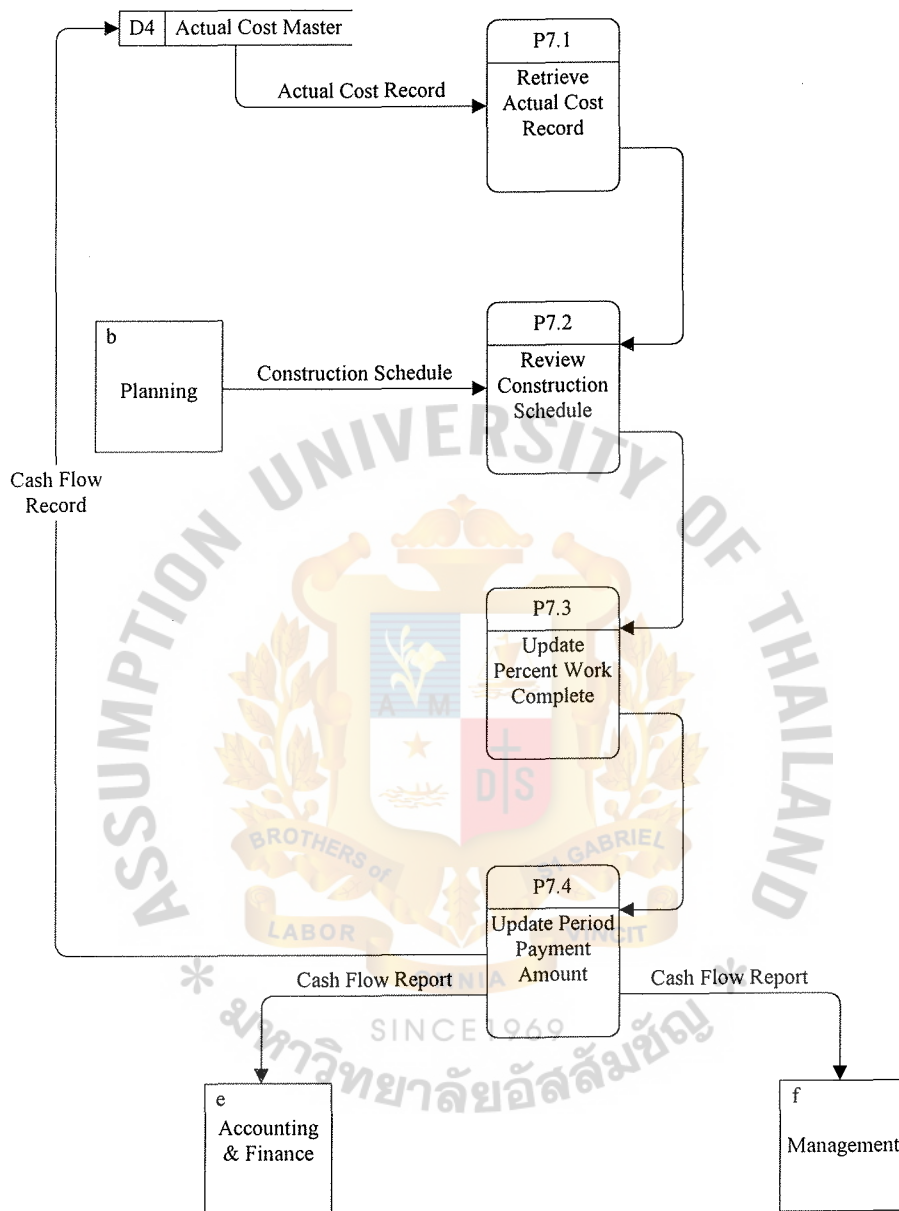
Figure B.9.   Process 7 - Prepare Cash Flow Report.

APPENDIX   C

PROCESS SPECIFICATION

Process Specification

Process 1 to 3 are fundamental elements for the setting up of database for all cost engineering information system at early stage of project. These processes develop items of work for cost information. New and unforeseen work items may be added from time to time when figured out during later stage of the construction project. The project cost code developed in Process 3 is then used as primary key in developing fields for all cost-related information which are mostly numerical data, also key to retrieve the cost item when updating cost data or preparing reports.

Process 4 to 8 involve the development of various reports combining various fields of information from Process 1 to 3. These reports are submitted to management and line manager of mostly Procurement, Construction and Accounting & Finance Departments. They are required to be prepared and revised in regular basis, usually every month.

Process 1   Develop Work Element List

Work Element List of item of all works in the project is fundamental data for cost control and monitoring of Cost Engineering System.

Process 1.1: Review Project Information

Project information to be reviewed are design plan and specifications and design drawings so that generic type of work for the project can be roughly figured out.

Process 1.2: Review Cost Items

Review items of cost from preliminary cost estimate schedule from Estimate Cost Master File which was developed and used in project bidding stage.

Process 1.3: Refer to Master format

Refer to CSI's Master format as guideline to classify and categorize the works of project.

Process 1.4: Determine Cost Element

Rearrange the cost item from cost estimate schedule into work element list according to Master format work division. Then store Work Element List in Work Structure Master File.

Process 2   Develop Work Breakdown Structure

Work Breakdown Structure is numbering system used to describe work element of project.

Process 2.1: Indicate Project Identifier

To identify type or function of the project.

Process 2.2: Indicate Facility Number

Facility number is major division of each work element. This number is used for accounting purpose.

Process 2.3: Indicate Element of Work

To indicate standard element of work, work element detail code and work element detail designator. It consists of 4 numerical characters.

Process 2.4: Indicate Element of Cost

To indicate basic element of cost number and further detail of basic cost number. This number is used for financial purpose.

Process 2.5: Write Word Description

Write description of each work element in lowest but comprehensive details.

Process 2.6: Indicate Reference Code

This is additional information used to refer to responsibility, subcontract, specifications, zone and system of each work element. The numbering system is the

same as used in scheduling program of Planning Department. Then store the work breakdown structure in Work Structure Master File.

Process 3   Develop Project Cost Code

Project Cost Code is used to classify and categorise items of works of project for cost record and control purpose.

Process 3.1: Indicate Project Number

The project number consists of 4 subdivisions in alphanumeric:

- The first two digits are the year when the project starts.

- The third digit is the status of the contract.

- The fourth is the type of the construction work.

- The last two digits indicate sequence of the project taken during that year.

Process 3.2: Indicate Area-Facility Code

Area-facility code is numerical.

This code can be "floor" in case of building, or the division of construction structures to be defined for each individual project.

Process 3.3 : Indicate Work Type Code

Work type code is work division based on Master format. The code is numeric.

Process 3.4: Indicate Distribution Code

Distribution Code identifies the resource components of type of work. It separates the type of work into labour, materials, equipment and subcontract costs to facilitate the preparation of detailed cost estimate and cash flow forecast.

Process 4   Prepare Project Budget Report

Project Budget Report provides budget cost of project used as cost control and monitoring information from early stage of project until the end of project. It is used as basis to the procurement of project resources.

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Process 4.1: Review Estimate Cost Record

Review Cost Estimate Record from Estimate Cost Master File developed during project bidding stage.

Process 4.2: Retrieve Project Cost Code

Retrieve Project Cost Code from Work Structure File (Process 3).

Process 4.3: Update Work Quantity

Update quantity of works referring to Quantity Schedule provided by Planning Department.

Process 4.4: Update Budget Cost

Update budget cost item in relevant Cost Code and according to latest cost and project information. Then store the revised cost in Control Budget Master File.

Process 5   Prepare Resource Schedule

The Resource Schedule is used by Procurement Department to develop plan for purchasing and obtaining project resources i.e. equipment, materials, supplies, services and labour required in the project. It is used to determine the right time to procure resources required in the most economical manner.

Process 5.1: Identify Resource Items

List resource items i.e. equipment, materials, supplies, services and labour from Construction Schedule developed by Planning Department.

Process 5.2: Determine Resource Quantity

Determine quantity of each resource items required for the project based on Construction Schedule.

Process 5.3: Allocate Budget Cost

Allocate budget cost of each resource items based on Project Budget Report.

Process 5.4: Allocate Time Schedule

Allocate Time Schedule of each resource items based on Construction Schedule.

Process 5.5: Enter Market Price

Enter Market Price of each resource items received from Procurement Department. Then submit the Resource Schedule to Procurement Department

Process 6   Prepare Summary Cost Report

Summary Cost Report describes the actual and forecast status of project cost. It commences with the preliminary estimate and ends when the project is complete with all claims, if any, have been settled.

Process 6.1: Retrieve Cost Estimate Summary

Retrieve Cost Estimate Summary from Cost Estimate Master File.

Process 6.2: Update Work at Completion

Update Work at Completion in quantity based on Field Measurement information from Construction Department which reports progress quantity of construction works.

Process 6.3: Update Cost at Completion

Update Total Cost Committed amount based on Income/Expense Report from Accounting & Finance Department.

Process 6.4: Enter Variation Cost

Enter Variations Cost based on Work Variation information from Construction Department (if any) which cause impact on project costs.

Process 6.5: Update Total Cost Committed Amount

Update Total Cost Committed Amount which is the original amount of work plus the amount of Work Variation.

Then store Actual Cost Record in Actual Cost Master File.

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Process 7   Prepare Cash Flow Report

Project Cash Flow Report is used by Accounting & Finance Department and Management for project financial planning and control. The report gives gross cash requirements for expenses throughout the project and also determines working capital requirements for the company and in setting up lines of credit to borrow funds at favorable rates. Cash Flow Reports are regularly prepared to accompany Cost Reports.

Process 7.1: Retrieve Cost Report

Retrieve Cost Report from Actual Cost Master File.

Process 7.2: Review Construction Schedule

Review Construction Schedule developed by Planning Department

Process 7.3: Update Percent Work Complete.

Update Percent Complete of works based on Work at Completion in Summary Cost Report.

Process 7.4: Update Period Payment Amount.

Update Period Payment Amount according to actual payment in Cost Report and determine the projected payment based on work program in Construction Schedule, then store Cash Flow Record in Actual Cost Master File.
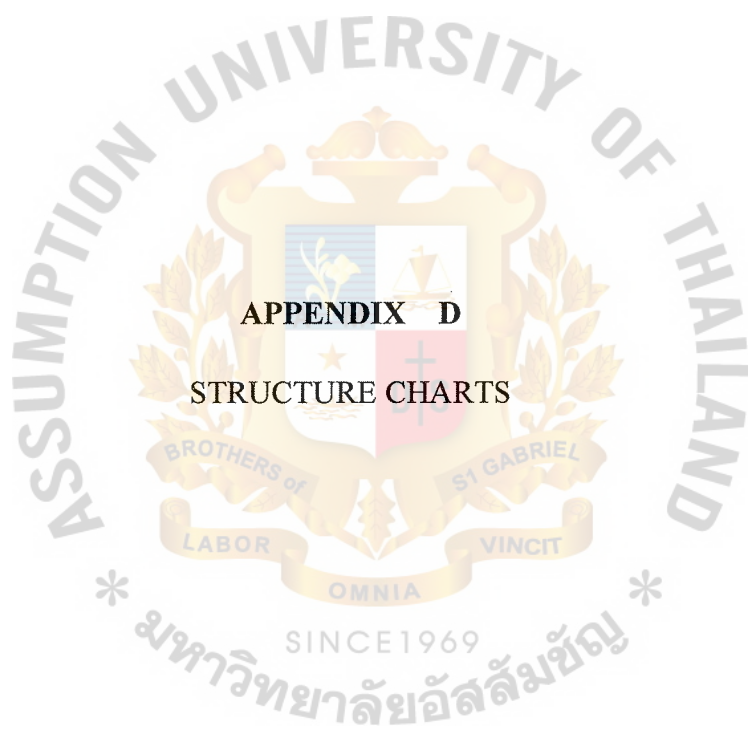
APPENDIX   D

STRUCTURE CHARTS
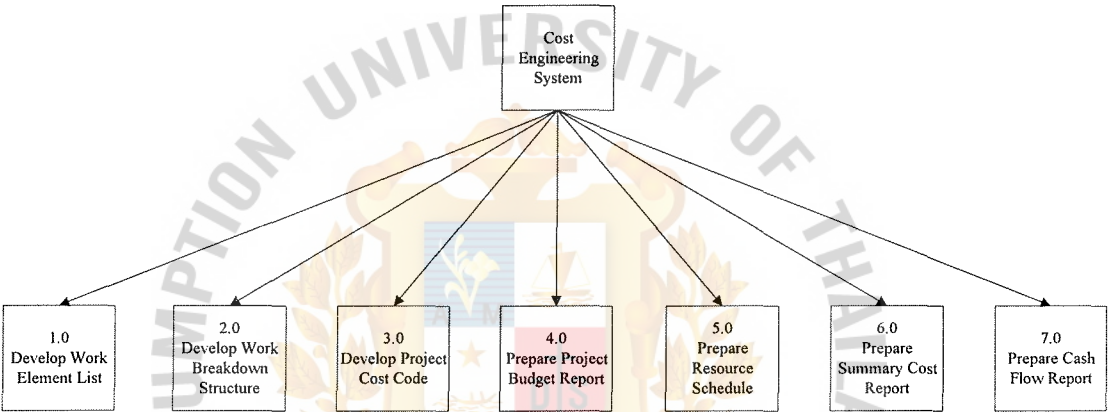
Figure D.1.   Structure Chart - Overview System.
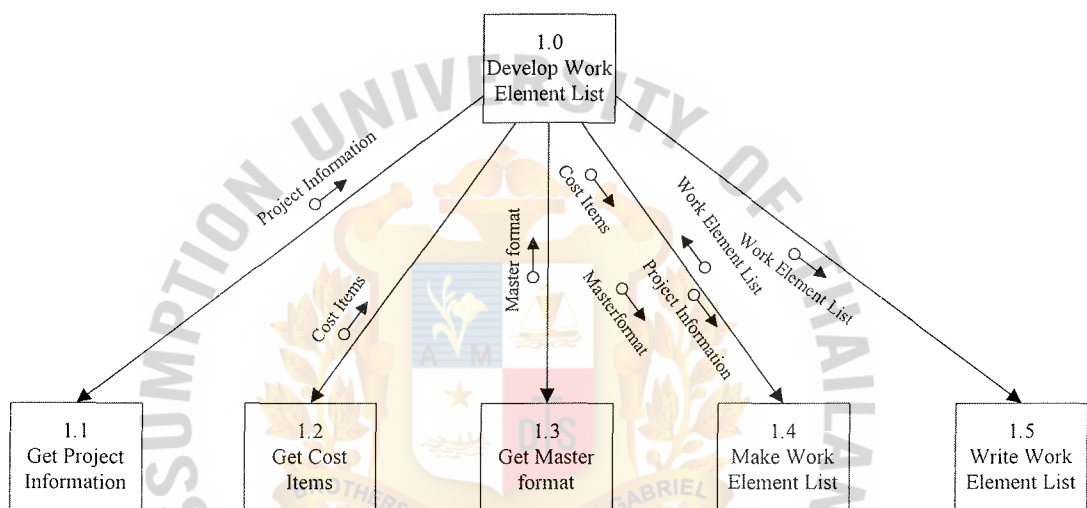
Figure D.2.   Structure Chart - Process 1.
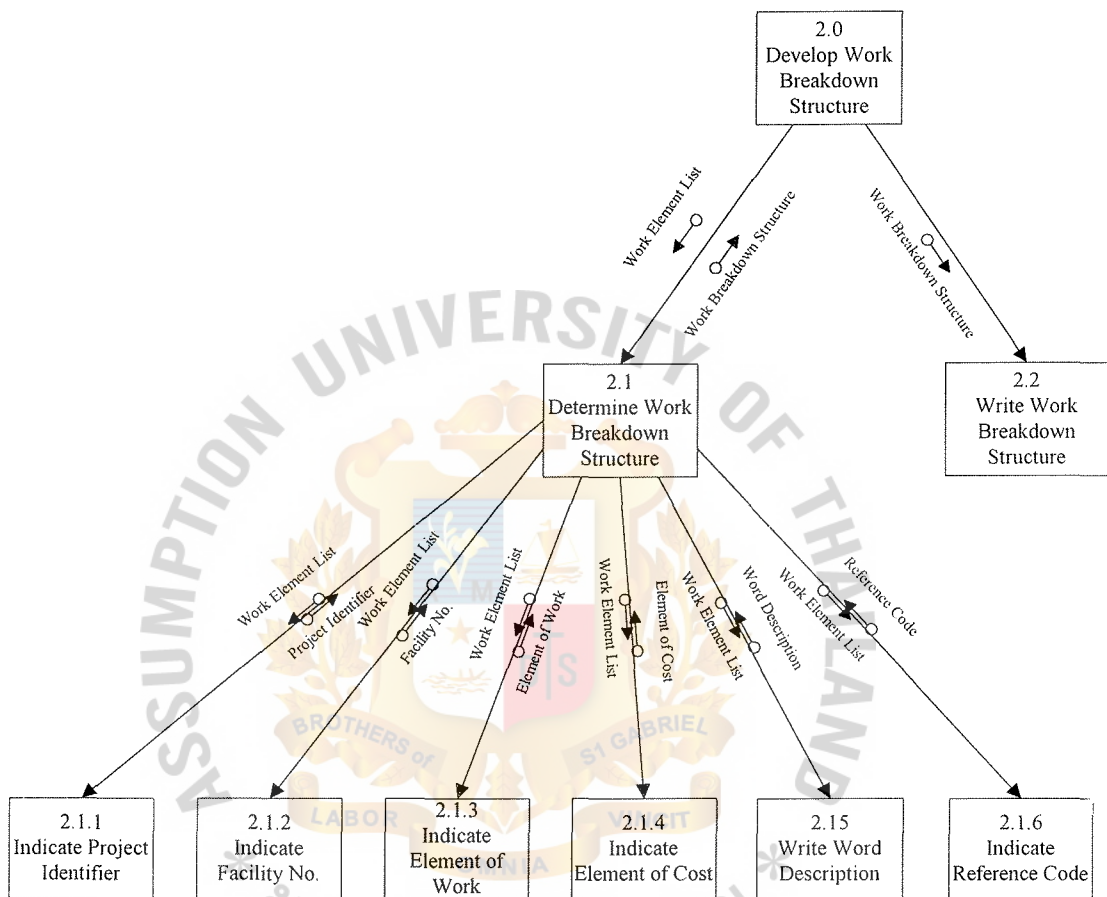
Figure D.3. Structure Chart - Process 2.
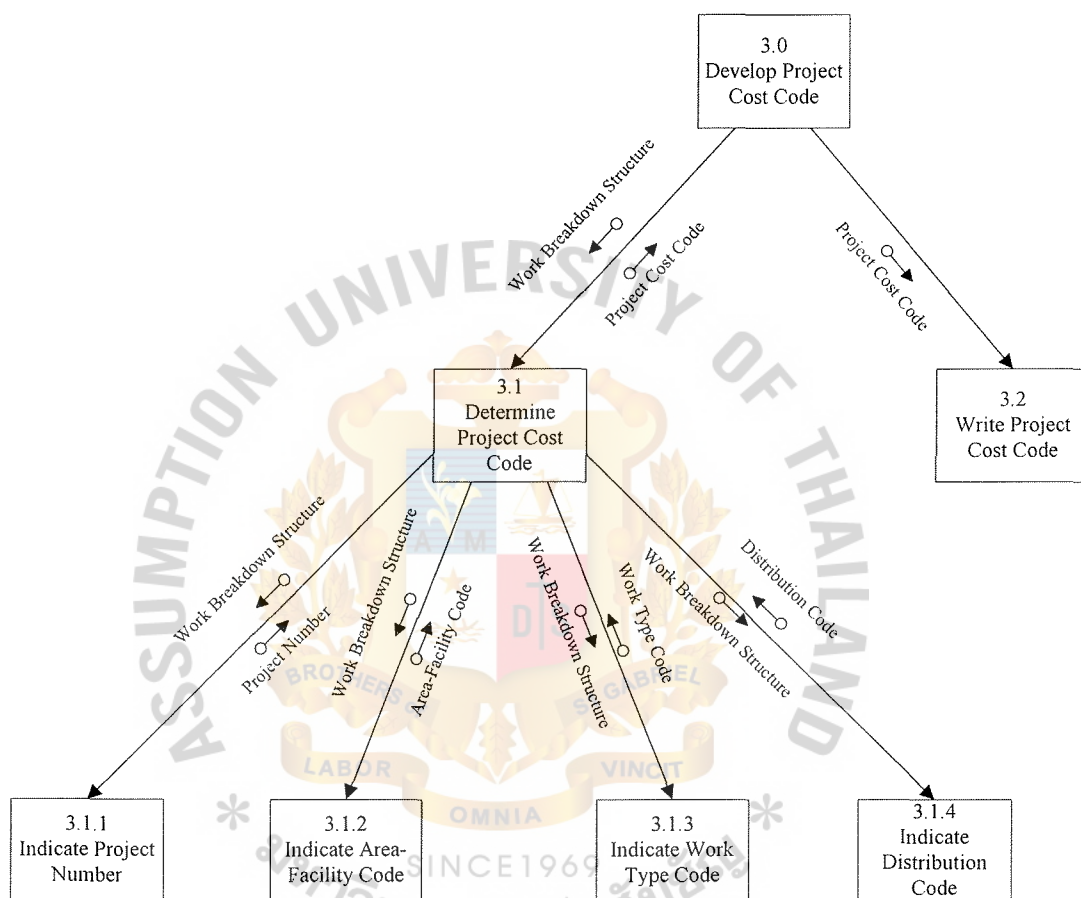
Figure D.4.   Structure Chart - Process 3.
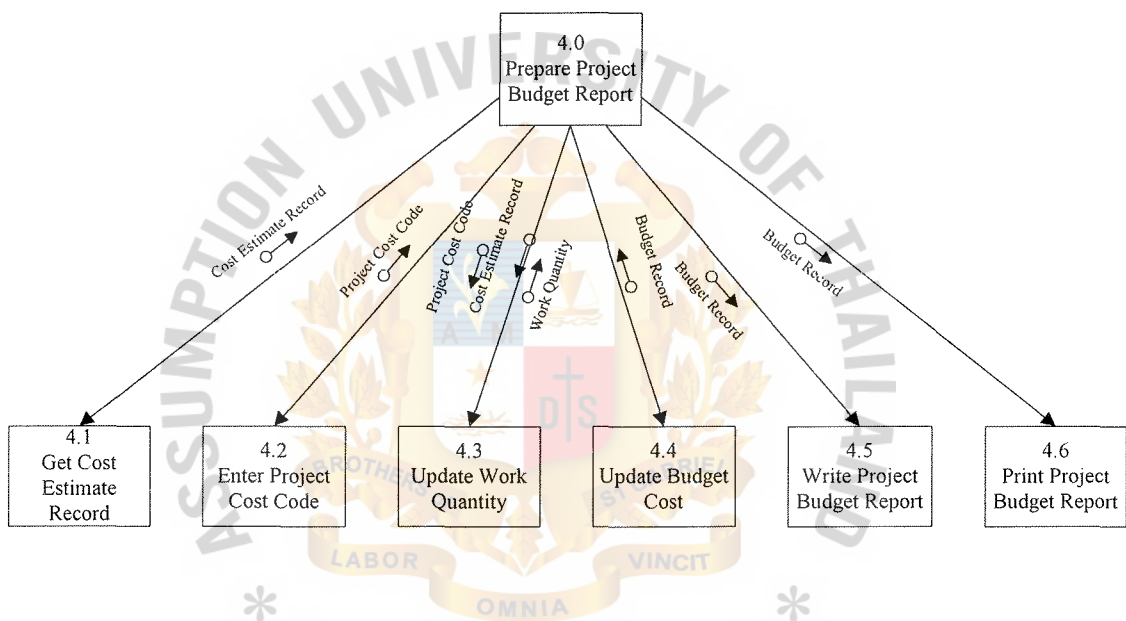
Figure D.5.   Structure Chart - Process 4.
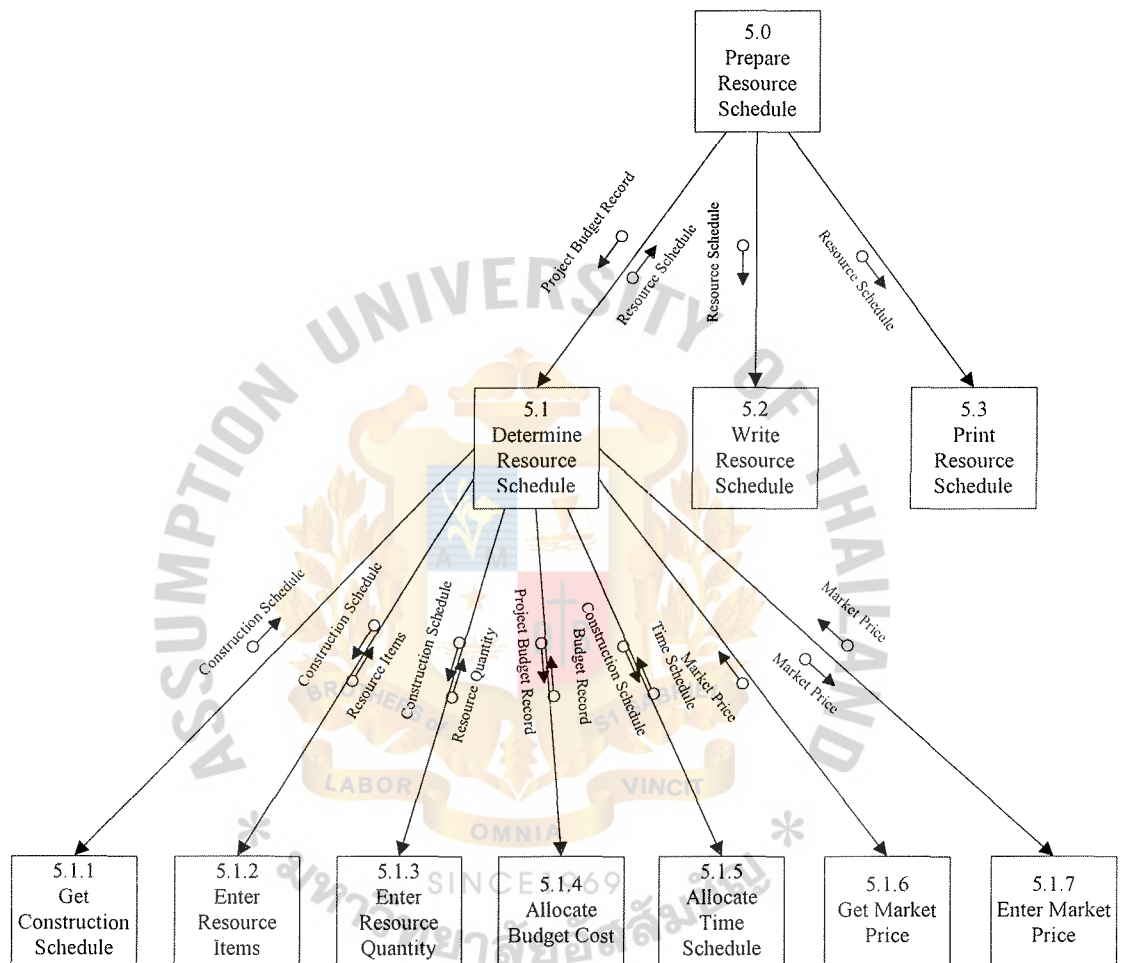
Figure D.6.   Structure Chart - Process 5.
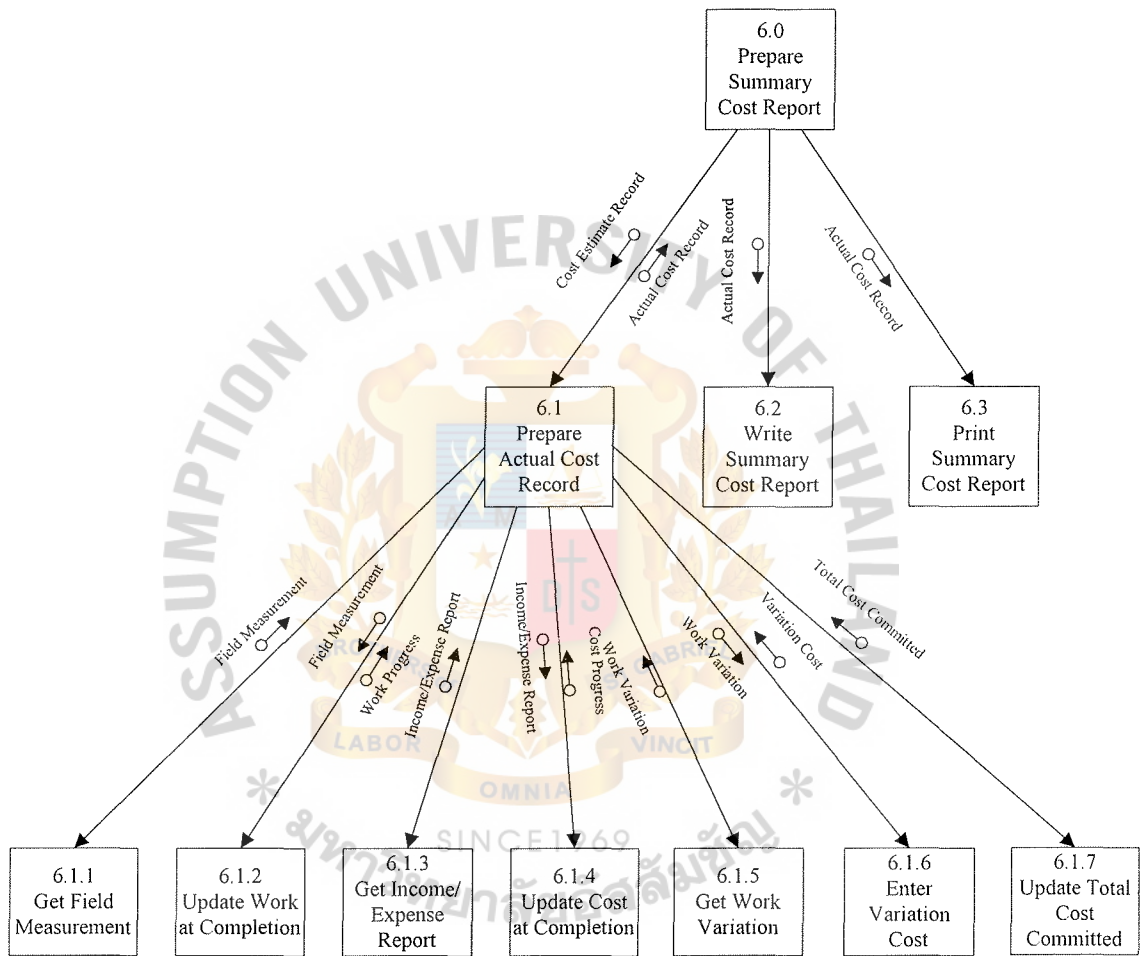
Figure D.7.   Structure Chart - Process 6.
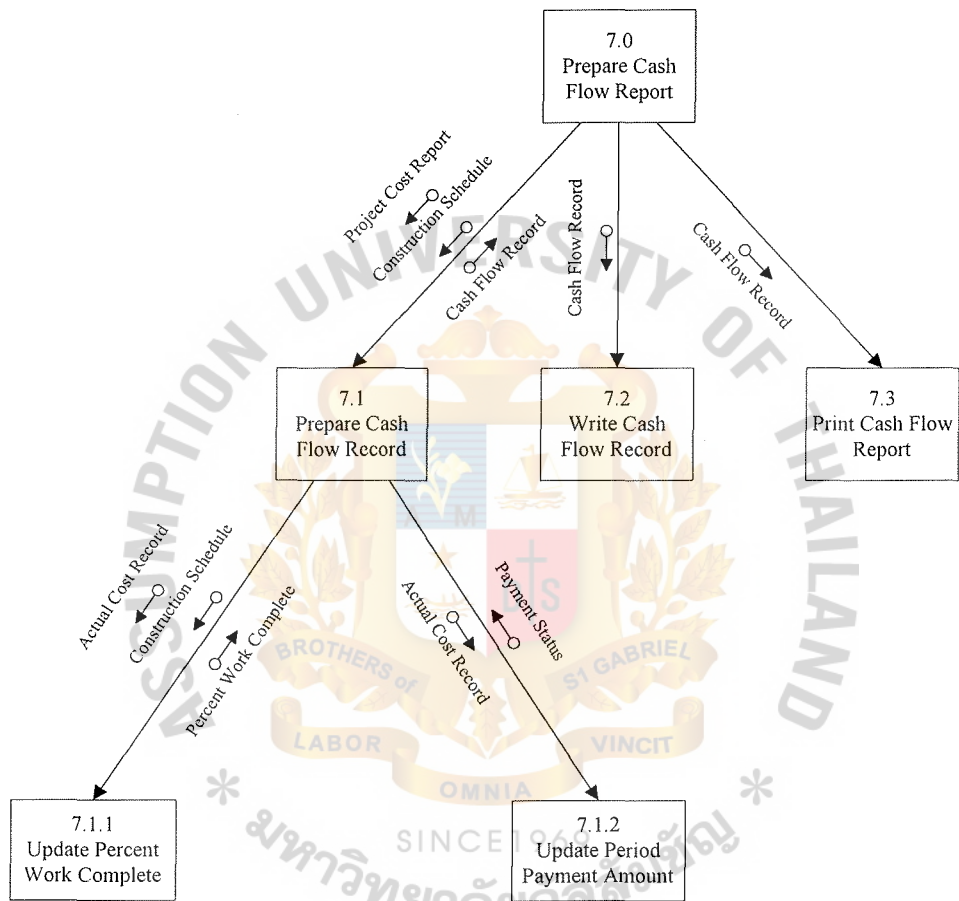
Figure D.8.   Structure Chart - Process 7.

APPENDIX E

ENTITY-RELATIONSHIP DIAGRAM
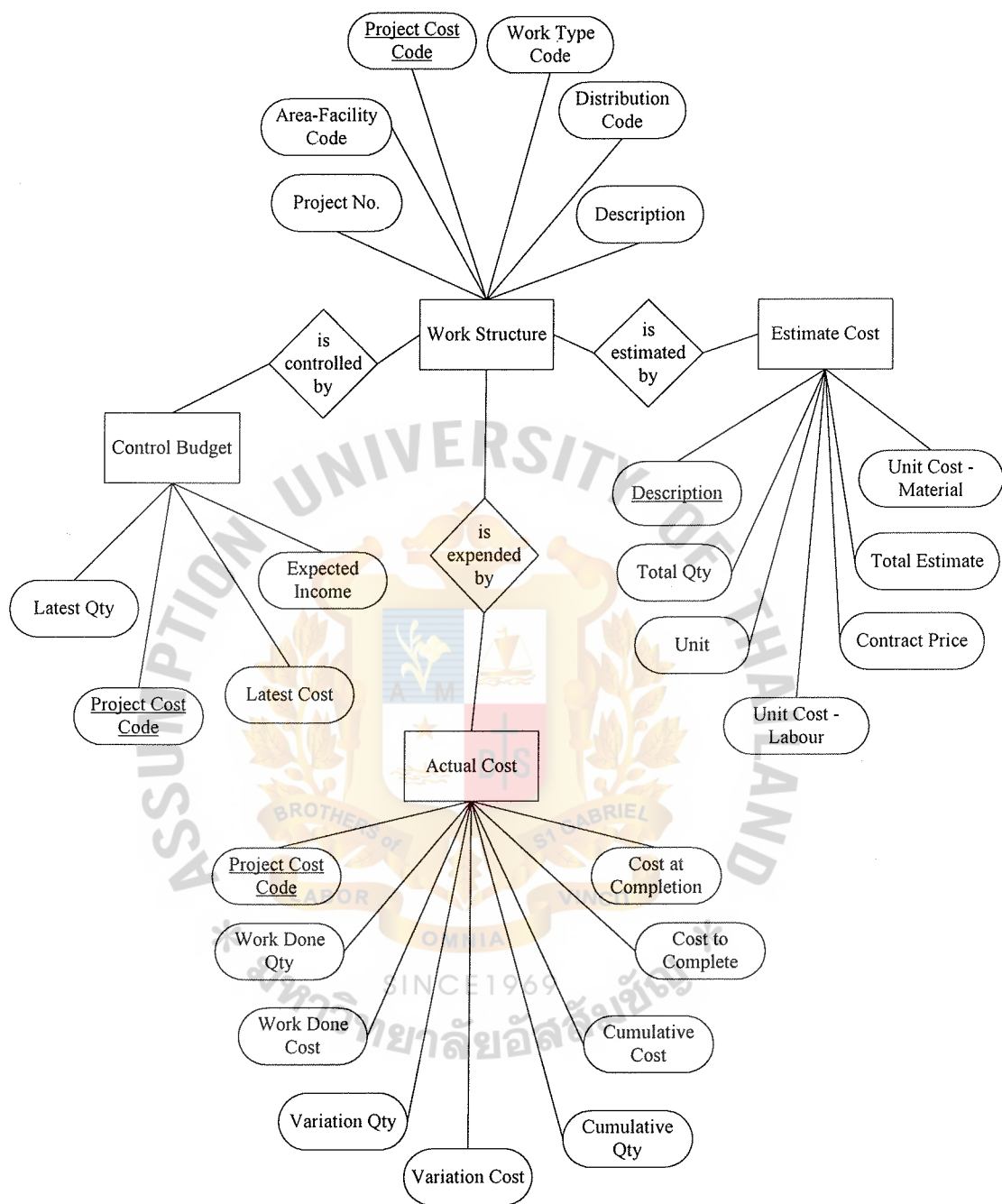
Figure E.1.   Entity-Relationship Diagram.

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APPENDIX   F

DATA DICTIONARY

Data Dictionary

Object Name	Object Type	Definition	Description
Accounting & Finance	External Entity	N/A	Accounting & Finance Department
Construction	External Entity	N/A	Construction Department
Design	External Entity	N/A	Design Department
Management	External Entity	N/A	Personnel in Management Level including departmental manager, project manager, members of board of committee
Planning	External Entity	N/A	Planning Department
Procurement	External Entity	N/A	Procurement Department
Project Information	Data Flow	N/A	Information about particular construction project e.g. design drawing, design specification, contract document,
Actual Cost Record	Data Flow	Project Cost Code, Word Description, Work at Completion, Cost at Completion, Variation Cost (optional)	Record of actual cost status of construction project
Cash Flow Record	Data Flow	Project Cost Code, Estimate Cost, Percent Work Complete, Expense Amount	Record of estimates expense for projected period of construction project
Cash Flow Report	Data Flow	Word Description, Estimate Cost, Percent Work Complete - Period, Percent Work Complete – Cumulative, Expense Amount –	Report used for project financial planning and control by Accounting & Finance Department and the Management

Object Name	Object Type	Definition	Description
		Period, Expense Amount - Cumulative	
Construction Schedule	Data Flow	Word Description, Work Quantity, Resources Required, Time Period	Schedule of construction project as planned to meet completion in efficient manner. Mostly in form of table, bar chart, Gantt chart.
Cost Estimate Record	Data Flow	Word Description, Work Quantity, Unit Cost, Amount	Record of cost estimate of work items prepared during project bidding stage.
Cost Items	Data Flow	Word Description	Items of work in particular construction project as determined in cost estimate prepared during project bidding stage.
Field Measurement	Data Flow	Word Description, Total Work Quantity, Completed Work Quantity	Construction work progress as measured at site.
Income /Expense Report	Data Flow	Word Description, Expense, Payment Received,	Report on income and expense of construction project prepared by Accounting & Finance Department
Market Price	Data Flow	Word Description, Cost Amount	Price of all construction material, equipment, subcontracted works and other supplies for construction project
Project Budget Record	Data Flow	Project Cost Code, Word Description, Budget Amount, Expected Income	Record of budget cost of work items for monitoring cost status of construction project
Project Budget Report	Data Flow	Word Description, Work Quantity, Contract Price, Budget Amount,	Report on project budget as information for monitoring and controlling cost status.

Object Name	Object Type	Definition	Description
		Expected Income	
Project Cost Code	Data Flow	Project No., Area-Facility Code, Work-Type Code, Distribution Code	Classification and categorization of all items of work or cost pertaining to a particular construction project.
Quantity Schedule	Data Flow	Word Description, Work Quantity, Time Period	Schedule of material and equipment required for each cost items in construction project.
Resource Schedule	Data Flow	Word Description, Total Work Quantity, Quantity Allocation, Time Period	Schedule of all resources required for construction project including materials, equipment, labour, supplies prepared based on construction schedule.
Summary Cost Report	Data Flow	Word Description, Estimate Cost, Contract Price, Variation Cost (optional), Estimated Cost to Complete, Estimate Cost at Completion, (Under) or Over Budget	Report that provides actual and forecast cost status of construction project for cost monitoring and control.
Work Breakdown Structure	Data Flow	Project Identifier, Facility No., Element of Work, Element of Cost, Word Description	Numbering system used to describe work element of construction project in logical hierarchy for management control activities.
Work Element Information	Data Flow	Word Description, Work Quantity, Resources Required	Information about construction work element of particular project, its description, type, quantity, materials and equipment used as prepared by Planning Department after construction contract award
Work Element	Data Flow	Word	Items of work in particular

Object Name	Object Type	Definition	Description
List		Description	construction project prepared by Cost Engineering Department based on Project Information
Work Variation	Data Flow	Word Description, Work Quantity	Change to the construction work e.g. additional work, change due to design, new requirements that cause additional construction cost
Allocate Budget Cost	Data Process	N/A	Allocate budget cost for each resource item according to Project Budget Record
Allocate Time Schedule	Data Process	N/A	Allocate time duration required for each resource item.
Determine Cost Element	Data Process	N/A	Determine cost element and write to Work Structure master file
Determine Resource Quantity	Data Process	N/A	Determine quantity of resources required in particular project
Develop Project Cost Code	Data Process	N/A	Develop Project Cost Code used for cost record purpose.
Develop Work Element List	Data Process	N/A	Develop list of work element of particular construction project to be classified in Work Breakdown Structure
Enter Market Price	Data Process	N/A	Enter actual Market Price for each resource item as provided by Procurement Department
Enter Variation Cost (optional)	Data Process	N/A	Enter cost of work variation from original contract requirements
Identify Resource Items	Data Process	N/A	Identify items of resources required for particular project e.g. labour, material and equipment
Indicate Area-Facility Code	Data Process	N/A	Indicate area or facility that categorize physical or geographical features in particular project.
Indicate Distribution Code	Data Process	N/A	Indicate distribution code that break out the resource components of various types of work, separating out

Object Name	Object Type	Definition	Description
			labour, material, equipment and subcontract costs.
Indicate Elements of Cost	Data Process	N/A	Indicate basic element of cost and its further detail as part of Work Breakdown Structure to be used for financial record purpose. The number consists of 2 digits. Format: X X
Indicate Elements of Work	Data Process	N/A	Indicate standard element of work code, work element detail code and work element detail designator code as part of Work Breakdown Structure to be used for accounting record purpose. The number consists of 4 digits. Format: X XX X
Indicate Facility No.	Data Process	N/A	Indicate facility/area code, subfacility/subarea code and subfacility/subarea detail code as part of Work Breakdown Structure to be used for accounting record purpose. The number consists of 4 digits. Format: X X XX
Indicate Project Identifier	Data Process	N/A	Indicate project identifier as part of Work Breakdown Structure. This is optional field used only on multiproject program.
Indicate Project Number	Data Process	N/A	Indicate number for a particular project consisting of start year, type of project, type of contract and sequence with other projects that start that year.
Indicate Reference Code	Data Process	N/A	Indicate the code that is used to identify responsibility, subcontract, specification, zones and systems as part of Work Breakdown Structure. The number consists of 9 digits.

Object Name	Object Type	Definition	Description
			Format: XXXXXXXXX
Indicate Work Type Code	Data Process	N/A	Indicate work-type code using Master format numbering standard
Prepare Cash Flow Report	Data Process	N/A	Prepare Cash-flow Report to be used for project financial planning & control by Accounting & Finance and Management
Prepare Project Budget Report	Data Process	N/A	Prepare Project Budget Report for monitoring and control cost status of project
Prepare Resource Schedule	Data Process	N/A	Prepare Resource Schedule to be used in planning the procurement of resources required in project
Prepare Summary Cost Report	Data Process	N/A	Prepare Summary Cost Report to provide actual and forecast cost status information of project to the Management
Refer to Master format	Data Process	N/A	Refer to Master format for construction work classification number.
Retrieve Actual Cost Record	Data Process	N/A	Retrieve Actual Cost Record form Actual Cost master file.
Retrieve Project Budget	Data Process	N/A	Retrieve Project Budget Record from Control Budget master file
Retrieve Project Cost Code	Data Process	N/A	Retrieve Project Cost Code from Work Structure master file.
Review Construction Schedule	Data Process	N/A	Review Construction Schedule to see work trend and forecast
Review Cost Estimate	Data Process	N/A	Review Cost Estimate Record from Estimate Cost master file to use as guideline
Review Cost Items	Data Process	N/A	Review cost items from Estimate Cost master file
Review Project Information	Data Process	N/A	Review project information in terms of cost aspects
Update Budget Cost	Data Process	N/A	Update Budget Cost of each work element item by item according to current Quantity Schedule
Update Cost at	Data Process	N/A	Update Cost at Completion

Object Name	Object Type	Definition	Description
Completion			based on Income/Expense Report provided by Accounting and Finance Department
Update Percent Work Completed	Data Process	N/A	Update percentage of work completed according to Construction Schedule.
Update Period Payment Amount	Data Process	N/A	Update Period Payment Amount according to Income Report
Update Total Cost Committed Amount	Data Process	N/A	Update Total Cost Committed Amount based on actual work progress and cost progress of the project.
Update Work at Completion	Data Process	N/A	Update Work at Completion based on Field Measurement provided by Construction Department.
Update Work Quantity	Data Process	N/A	Update Work Quantity based on current Quantity Schedule prepared by Planning Department.
Write Word Description	Data Process	N/A	Write word description of work element in short but comprehensive detail.
Actual Cost Master File	Data Store	Project Cost Code, Work Done Quantity, Work Done Cost, Variation Quantity, Variation Cost, Cumulative Quantity, Cumulative Cost, Cost to Complete, Cost at Completion,	File that keeps all cost information according to actual work progress and cost incurred in work operation
Control Budget Master File	Data Store	Project Cost Code, Latest Quantity, Latest Cost, Expected Income	File that keeps the budget cost of project in which work quantity and relevant cost are regularly updated according to actual Quantity Schedule
Estimate Cost Master File	Data Store	Word Description, Prelim. Total	File that keeps cost estimate information of work items of particular construction project

Object Name	Object Type	Definition	Description
		Quantity, Unit, Unit Cost - Labour, Unit Cost - Material, Total Estimate, Contract Price	prepared during project bidding.
Work Structure Master File	Data Store	Project Cost Code, Project Number, Area-Facility Code, Work-Type Code, Distribution Code, Word Description	File that keeps work elements of project in categorized numbering system of area/facility, work type (Master format), means of cost distribution and combined into Project Cost Code.
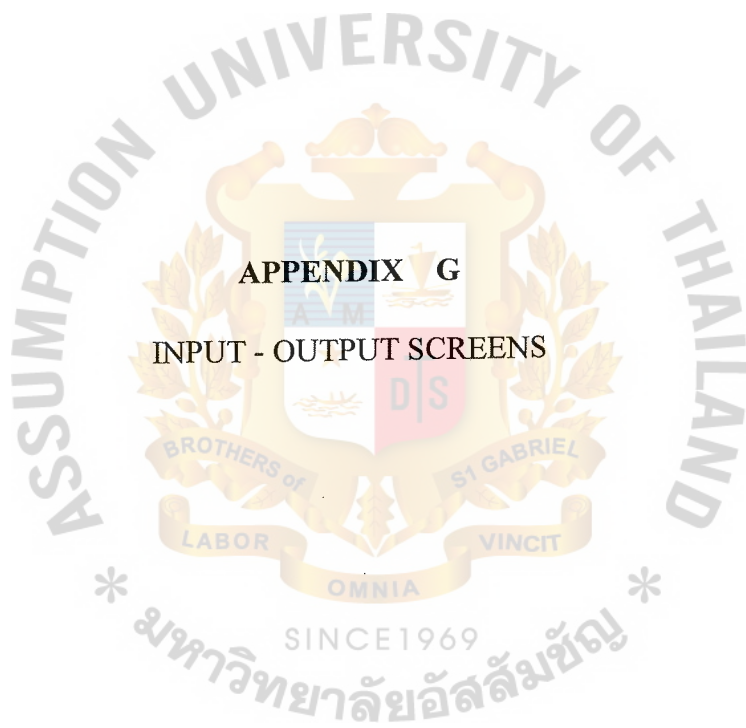
APPENDIX   G

INPUT - OUTPUT SCREENS

Figure G.1.   Input Screen for Work Structure File .

Figure G.2.   Input Screen for Estimate Cost File.

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Figure G.3.   Input Screen for Control Budget File.

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Figure G.4.   Input Screen for Actual Cost File.

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Project	Area-Facility	Work Type	Distribution	Project Cost Code	Description
99AB09	00	02010	0	99AB0900020100	Subsurface investigation
99AB09	00	02011	0	99AB0900020110	Demolition
99AB09	00	02100	0	99AB0900021000	Site preparation
99AB09	00	02150	0	99AB0900021500	Shoring and underpinning
99AB09	00	02200	0	99AB0900022000	Tunneling
99AB09	00	02350	0	99AB0900023500	Pile and caisson
99AB09	00	02660	0	99AB0900026600	Water distribution
99AB09	00	02700	0	99AB0900027000	Sewerage and drainage
99AB09	00	02780	0	99AB0900027800	Power and communications
99AB09	00	02800	0	99AB0900028000	Site improvement
99AB09	00	02900	0	99AB0900029000	Landscaping
99AB09	00	03100	0	99AB0900031000	Concrete formwork
99AB09	00	03200	0	99AB0900032000	Concrete reinforcement
99AB09	00	03250	0	99AB0900032500	Concrete reinforcement
99AB09	00	03300	0	99AB0900033000	Cast-in-place concrete
99AB09	00	03370	0	99AB0900033700	Concrete curing
99AB09	00	03400	0	99AB0900034000	Precast concrete
99AB09	00	03500	0	99AB0900035000	Cementitious decks and toppings
99AB09	00	03600	0	99AB0900036000	Grout
99AB09	00	03700	0	99AB0900037000	Concrete restoration and cleaning
99AB09	00	05010	0	99AB0900050100	Metal materials
99AB09	00	05030	0	99AB0900050300	Metal coatings

Figure G.5.   Work Structure Table.

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Description	Total Qty	Unit	Unit Cost - Labour	Unit Cost - Material	Total Estimate	Contract Price
Concrete restoration and cleaning	15,000	m2	25	-	375,000	431,250
Construction facilities and temporary controls	N/A	LS			3,441,000	3,957,150
Coordination	N/A	LS			5,736,000	6,596,400
Demolition	1	LS	35,000	100,000	135,000	155,250
Door opening assemblies		ea.	750	1,250	-	-
Electrical testing		LS			350,000	402,500
Elevators	9	ea.	50,000	2,500,000	22,950,000	26,392,500
Entrances and storefronts	3	ea.	2,500	35,000	112,500	129,375
Exterior wall assemblies	12,500	m2	350	750	13,750,000	15,812,500
Fabrics		LS			450,000	517,500
Facility startup/commissioning	N/A	LS			1,448,350	1,665,603
Field engineering	N/A	LS			1,594,800	1,834,020
Finish carpentry	2,000	m2	20	150	340,000	391,000
Fire protection	86,000	m2	50	65	9,890,000	11,373,500
Fire protection specialties		LS			1,200,000	1,380,000
Fire suppression and supervisory systems		LS			850,000	977,500
Fireproofing	25,000	m2	215	650	21,625,000	24,868,750
Firestopping	5,000	m2	200	1,000	6,000,000	6,900,000
Flashing and sheet metal	2,500	m2	300	2,500	7,000,000	8,050,000
Fluid waste treatment and disposal equipment		LS			100,000	115,000
Food service equipment		LS			125,000	143,750
Furniture and accessories		LS			35,000,000	40,250,000

Figure G.6.   Estimate Cost Table.

Figure G.7.   Control Budget Table.

Project Cost Code	Work Done Qty	Work Done Cost	Variation Qty	Variation Cost	Cumulative Qty	Cumulative Cost	Cost to Complete	Cost at Completion
99AB0900014000		2,690,000				2,690,000	7,177,000	9,867,000
99AB0900015000		1,685,000				1,685,000	1,756,000	3,441,000
99AB0900016000		5,894,000				5,894,000	5,603,160	11,497,160
99AB0900016500		1,145,600				1,145,600	302,750	1,448,350
99AB0900018000		259,600				259,600	3,024,800	3,284,400
99AB0900020100		36,000				36,000	4,000	40,000
99AB0900020110		115,400				115,400	19,600	135,000
99AB0900021000	750	63,750			2,500	40,000	148,750	212,500
99AB0900021500	555	305,250			1,850	29,600	712,250	1,017,500
99AB0900023500	156	16,926,000			520	8,320	39,494,000	56,420,000
99AB0900026600						-	50,000	50,000
99AB0900027000						-	48,500	48,500
99AB0900027800						-	300,000	300,000
99AB0900028000						-	110,000	110,000
99AB0900029000	660	1,749,000	274	726,100	2,474	39,584	4,081,000	5,830,000
99AB0900031000	3,705	30,195,750			12,350	197,600	70,456,750	100,652,500
99AB0900032000	3,600	54,000,000	2,500	37,500,000	14,500	232,000	126,000,000	180,000,000
99AB0900033000	7,500	12,750,000	1,200	2,040,000	26,200	419,200	29,750,000	42,500,000
99AB0900033700	7,500	1,200,000	1,150	184,000	26,150	418,400	2,800,000	4,000,000
99AB0900034000	3,150	6,457,500			10,500	168,000	15,067,500	21,525,000
99AB0900035000	240	307,200			800	12,800	716,800	1,024,000
99AB0900036000	30	60,000			100	1,600	140,000	200,000

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Datasheet View

Figure G.8.   Actual Cost Table.

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Figure G.9. Query for Contract Price of Concrete Work Items.

Figure G.10.   Query for Contract Price of Steel Work Items.

APPENDIX   H

EXAMPLE REPORTS

Preliminary Cost Estimate Summary				
Project: Livewell Condominium				
Item	Description	Labour Hours	Total Direct Cost	Overhead & Fee	Total
1	Site earthwork	4520	9,147,826	1,372,174	10,520,000
2	Foundation	32450	42,565,217	6,384,783	48,950,000
3	Building structures	35820	202,260,870	30,339,130	232,600,000
4	Structural steel	16230	349,565,217	52,434,783	402,000,000
5	Precast walls	6520	16,486,957	2,473,043	18,960,000
6	Plumbing & HVAC	7520	19,625,217	2,943,783	22,569,000
7	Fire protection	3650	6,643,478	996,522	7,640,000
8	Electrical	4780	28,433,043	4,264,957	32,698,000
9	Roofing	3450	7,391,304	1,108,696	8,500,000
10	Building finish	28650	163,147,826	24,472,174	187,620,000
	Total	143,590	845,266,956	126,790,043	972,057,000
	Contingency @ 5 %				48,602,850
	Total Estimate (Baht)				1,020,659,850

Figure H.1.   Preliminary Cost Estimate Summary.

	Detailed Cost Estimate Summary				
Project: Livewell Condominium					
Item	Description	Labour Hours	Total Direct Cost	Overhead & Fee	Total
1	Site earthwork	4520	9,147,826	1,372,174	10,520,000
2	Foundation	32450	42,782,609	6,417,391	49,200,000
3	Building structures	35820	207,208,696	31,081,304	238,290,000
4	Structural steel	16230	356,164,348	53,424,652	409,589,000
5	Precast walls	6520	20,530,435	3,079,565	23,610,000
6	Plumbing & HVAC	7520	19,625,217	2,943,783	22,569,000
7	Fire protection	3650	6,643,478	996,522	7,640,000
8	Electrical	4780	30,779,130	4,616,870	35,396,000
9	Roofing	3450	7,391,304	1,108,696	8,500,000
10	Building finish	28650	181,921,739	27,288,261	209,210,000
	Total	143,590	882,194,783	132,329,217	1,014,524,000
	Contingency @ 5 %				50,726,200
	Total Estimate (Baht)				1,065,250,200

Figure H.2.   Detailed Cost Estimate Summary.

Cost Comparison Summary

| Project: Livewell Condominium |

Item	Description	Contract Price	Prelim. Estimate	Detailed Estimate	Over (Under) Pre. Est.	Over (Under) Det. Est.	
1	Site earthwork	11,689,000	10,520,000	10,520,000	1,169,000	1,169,000	
2	Foundation	53,257,000	48,950,000	49,200,000	4,307,000	4,057,000	
3	Building structures	252,400,000	232,600,000	238,290,000	19,800,000	14,110,000	
4	Structured steel	468,900,000	402,000,000	409,589,000	66,900,000	59,311,000	
5	Precast walls	21,500,000	18,960,000	23,610,000	2,540,000	(2,110,000)	
6	Plumbing & HVAC	25,000,000	22,569,000	22,569,000	2,431,000	2,431,000	
7	Fire protection	11,373,500	7,640,000	7,640,000	3,733,500	3,733,500	
8	Electrical	39,540,000	32,698,000	35,396,000	6,842,000	4,144,000	
9	Roofing	11,526,000	8,500,000	8,500,000	3,026,000	3,026,000	
10	Building finish	206,850,000	187,620,000	209,210,000	19,230,000	(2,360,000)	
	Total (Baht)	1,102,035,500	972,057,000	1,014,524,000	129,978,500	87,511,500	
	To Date	Cumul.	Cumul.	Cumul.	Cumul.	Cumul.	
1	Site earthwork	11,689,000	10,520,000	10,520,000	1,169,000	1,169,000	
2	Foundation	64,946,000	59,470,000	59,720,000	5,476,000	5,226,000	
3	Building structures	317,346,000	292,070,000	298,010,000	25,276,000	19,336,000	
4	Structured steel	786,246,000	694,070,000	707,599,000	92,176,000	78,647,000	
5	Precast walls	807,746,000	713,030,000	731,209,000	94,716,000	76,537,000	
6	Plumbing & HVAC	832,746,000	735,599,000	753,778,000	97,147,000	78,968,000	
7	Fire protection	844,119,500	743,239,000	761,418,000	100,880,500	82,701,500	
8	Electrical	883,659,500	775,937,000	796,814,000	107,722,500	86,845,500	
9	Roofing	895,185,500	784,437,000	805,314,000	110,748,500	89,871,500	
10	Building finish	1,102,035,500	972,057,000	1,014,524,000	129,978,500	87,511,500	

Cost comparison before contingency.

Figure H.3.   Cost Comparison Summary Between Preliminary Design
and Detailed Design Stages.

Project Budget

Division: Bangkok   Date: 18-Feb-99   Project No. 548

Facility: Livewell Condominium   Prepared by: ASD

Location: Bangkok   Approved by TP

Description:

45,000 square metre of 24 story residential building with sport complex and car park.

Item	Allocation	Amount Requested	Total
1.	Architect/Engineer		4,500,000
2.	Site work	10,520,000	
3.	Building and utilities	915,230,000	
4.	Repair and maintenance	4,570,000	
5.	Other owner's cost	5,982,000	
6.	Subtotal (item 2 - 5)	936,302,000	
7.	Contingency	46,815,100	
8.	Total building cost		983,117,100
9.	Operating and process equip.	18,596,000	
10.	Repair and maintenance	5,967,000	
11.	Other owner's cost	1,647,000	
12.	Subtotal equipment	26,210,000	
13.	Contingency	1,310,500	
14.	Total equipment cost		27,520,500
15.	Total land cost		15,000,000
16.	Total Estimated Cost (Baht)		1,030,137,600

Figure H.4.   Project Budget Report.

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colspan Summary Cost Report							

Summary Cost Report

Project: Livewell Condominium (As of October 1998)

Control Account Number	Description	Contract Price	Variation Cost	Cumulative Cost	Cost to Complete	Cost at Completion	Budget	(Under) or Over Estimate
1	Site earthwork	11,689,000		13,698,000		13,698,000	10,520,000	3,178,000
2	Foundation	53,257,000	250,000	49,862,000		49,862,000	48,950,000	912,000
3	Building structure	252,400,000		185,900,000	45,960,000	231,860,000	232,600,000	(740,000)
4	Structured steel	468,900,000	(7,589,000)	259,600,000	137,956,000	397,556,000	402,000,000	(4,444,000)
5	Precast walls	21,500,000		7,890,000	9,786,000	17,676,000	18,960,000	(1,284,000)
6	Plumbing & HVAC	25,000,000			23,590,000	23,590,000	22,569,000	1,021,000
7	Fire protection	11,373,500			10,687,000	10,687,000	7,640,000	3,047,000
8	Electrical	39,540,000			30,689,000	30,689,000	32,698,000	(2,009,000)
9	Roofing	11,526,000			7,854,000	7,854,000	8,500,000	(646,000)
10	Building finish	206,850,000		8,756,000	177,985,000	186,741,000	187,620,000	(879,000)
	Total Direct Cost	1,102,035,500	(7,339,000)	525,706,000	444,507,000	970,213,000	972,057,000	(1,844,000)
11	Field general conditions	15,690,000		18,956,000	2,040,000	20,996,000	22,560,000	(1,564,000)
12	Office fixed fee	12,698,000		9,568,000	5,803,000	15,371,000	20,680,000	(5,309,000)
	Total Indirect Cost	28,388,000	-	28,524,000	7,843,000	36,367,000	43,240,000	(6,873,000)
	Estimated Total Cost	1,130,423,500	(7,339,000)	554,230,000	452,350,000	1,006,580,000	1,015,297,000	(8,717,000)
	Contingency	98,000,000			48,000,000	48,000,000	98,000,000	(50,000,000)
	Total (Baht)	1,228,423,500		554,230,000	500,350,000	1,054,580,000	1,113,297,000	(58,717,000)

Note : Control budget is based upon preliminary estimate. At completion estimates are based upon contract awards, detailed estimates and preliminary estimates.

Figure H.5.   Summary Cost Report - Early Stages.

Summary Cost Report								
Project: Livewell Condominium							(As of May 1999)	
Control Account Number	Description	Contret Price	Variation Cost	Cumulative Cost	Cost to Complete	Cost at Completion	Budget	(Under) or Over Estimate
1	Site earthwork	11,689,000		13,698,000		13,698,000	10,520,000	3,178,000
2	Foundation	53,257,000	250,000	49,862,000		49,862,000	49,200,000	662,000
3	Building structure	252,400,000	5,690,000	236,980,000		236,980,000	238,290,000	(1,310,000)
4	Structured steel	468,900,000	(7,589,000)	398,560,000		398,560,000	409,589,000	(11,029,000)
5	Precast walls	21,500,000	4,650,000	24,965,000		24,965,000	23,610,000	1,355,000
6	Plumbing & HVAC	25,000,000		24,596,000		24,596,000	22,569,000	2,027,000
7	Fire protection	11,373,500		7,568,000		7,568,000	7,640,000	(72,000)
8	Electrical	39,540,000	2,698,000	34,589,000		34,589,000	35,396,000	(807,000)
9	Roofing	11,526,000		4,569,000	1,560,000	6,129,000	8,500,000	(2,371,000)
10	Building finish	206,850,000	21,590,000	159,840,000	3,689,000	163,529,000	209,210,000	(45,681,000)
	Total Direct Cost	1,102,035,500	27,289,000	955,227,000	5,249,000	960,476,000	1,014,524,000	(54,048,000)
11	Field general conditions	15,690,000		19,860,000		19,860,000	22,560,000	(2,700,000)
12	Office fixed fee	12,698,000		13,695,000	15,692,000	29,387,000	20,680,000	8,707,000
	Total Indirect Cost	28,388,000	-	33,555,000	15,692,000	49,247,000	43,240,000	6,007,000
	Estimated Total Cost	1,130,423,500	27,289,000	988,782,000	20,941,000	1,009,723,000	1,057,764,000	(48,041,000)
	Contingency	98,000,000		21,568,000	25,000,000	46,568,000	98,000,000	(51,432,000)
	Total (Baht)	1,228,423,500		1,010,350,000	45,941,000	1,056,291,000	1,155,764,000	(99,473,000)

Note : Control budget is based upon preliminary estimate. At completion estimates are based upon contract awards, detailed estimates and preliminary estimates.

Figure H.6.   Summary Cost Report - Late Stages.

Project Cost Summary

Project: Livewell Condominium (As of August 1999)

Control Account Number	Description	Recorded Costs		Variation	Cumulative Total Recorded & Committed	Estimated Cost		Budget	Under or Over Budget
		Current Period	Cumulative to Date			Cost To Complete	Cost At Completion		
	Direct Cost								
1000.0000	Site development and improvement	-	13,698,000		13,698,000		13,698,000	10,520,000	3,178,000
2000.0000	Buildings and structures	1,580,000	807,789,000	24,466,000	832,255,000	1,458,620	833,713,620	905,680,000	(71,966,380)
3000.0000	Process equipment and systems	589,200	10,897,000		10,897,000	1,578,900	12,475,900	8,597,000	3,878,900
4000.0000	Utilities distribution	2,590,000	42,897,000	2,698,000	45,595,000	1,894,000	47,489,000	57,865,000	(10,376,000)
6000.0000	Distributable directs	120,000	5,987,000	125,000	6,112,000	258,900	6,370,900	2,489,000	3,881,900
	Total Direct Cost	4,879,200	881,268,000	27,289,000	908,557,000	5,190,420	913,747,420	985,151,000	(71,403,580)
									-
	Indirect Cost								
7100.0000	Contractor field services		19,860,000		19,860,000		19,860,000	22,560,000	(2,700,000)
7200.0000	Construction plant	2,690,000	25,890,000		25,890,000	1,589,000	27,479,000	19,785,000	7,694,000
7300.0000	Construction equipment	20,531	27,894,000		27,894,000	1,259,000	29,153,000	31,578,900	(2,425,900)
	Total Indirect Cost	2,710,531	73,644,000	-	73,644,000	2,848,000	76,492,000	73,923,900	2,568,100
	Total Construction Cost	7,589,731	954,912,000	27,289,000	982,201,000	8,038,420	990,239,420	1,059,074,900	(68,835,480)
					-				-
8100.0000	Engineering, supervision and procurement	2,698,000	15,987,000		15,987,000	2,548,000	18,535,000	31,589,000	(13,054,000)
8900.0000	Contingency	1,598,700	22,589,000	-	22,589,000	5,890,000	28,479,000	48,311,100	(19,832,100)
9000.0000	Clearings	1,489,000	10,547,800		10,547,800	3,259,800	13,807,600	16,789,000	(2,981,400)
	Total Project (Baht)	13,375,431	1,004,035,800	27,289,000	1,031,324,800	19,736,220	1,051,061,020	1,155,764,000	(104,702,980)

monthly summary of cost, estimate and comparison to budget prepared for distribution.

Figure H.7.   Project Cost Summary - Classifying Direct Costs and Indirect Costs.

Cash-Flow Schedule

Project: Livewell Condominium

	Estimate Cost	% Complete		Payments	
		Period	Cumul.	Period	Cumul.
Design & site investigation	17,895,600				
May-98		3	3	536,868	536,868
Jun-98		5	8	894,780	1,431,648
Jul-98		8	16	1,431,648	2,863,296
Aug-98		8	24	1,431,648	4,294,944
Sep-98		10	34	1,789,560	6,084,504
Oct-98		10	44	1,789,560	7,874,064
Nov-98		15	59	2,684,340	10,558,404
Dec-98		15	74	2,684,340	13,242,744
Jan-99		10	84	1,789,560	15,032,304
Feb-99		8	92	1,431,648	16,463,952
Mar-99		5	97	894,780	17,358,732
Apr-99		2	99	357,912	17,716,644
May-99		1	100	178,956	17,895,600
Construction (all costs)	1,030,890,000				
May-98		2	2	20,617,800	20,617,800
Jun-98		3	5	30,926,700	51,544,500
Jul-98		5	10	51,544,500	103,089,000
Aug-98		7	17	72,162,300	175,251,300
Sep-98		8	25	82,471,200	257,722,500
Oct-98		8	33	82,471,200	340,193,700
Nov-98		10	43	103,089,000	443,282,700
Dec-98		10	53	103,089,000	546,371,700
Jan-99		12	65	123,706,800	670,078,500
Feb-99		15	80	154,633,500	824,712,000
Mar-99		10	90	103,089,000	927,801,000
Apr-99		5	95	51,544,500	979,345,500
May-99		3	98	30,926,700	1,010,272,200
Jun-99		1	99	10,308,900	1,020,581,100
Jul-99		1	100	10,308,900	1,030,890,000
Equipment	53,249,900				
May-98		3	3	1,597,497	1,597,497
Jun-98		5	8	2,662,495	4,259,992
Jul-98		5	13	2,662,495	6,922,487
Aug-98		5	18	2,662,495	9,584,982
Sep-98		8	26	4,259,992	13,844,974
Oct-98		8	34	4,259,992	18,104,966
Nov-98		10	44	5,324,990	23,429,956
Dec-98		10	54	5,324,990	28,754,946
Jan-99		9	63	4,792,491	33,547,437
Feb-99		8	71	4,259,992	37,807,429
Mar-99		8	79	4,259,992	42,067,421
Apr-99		7	86	3,727,493	45,794,914
May-99		7	93	3,727,493	49,522,407
Jun-99		4	97	2,129,996	51,652,403
Jul-99		3	100	1,597,497	53,249,900
Total project cost (Baht)	1,102,035,500				
May-98		2	2	22,752,165	22,752,165
Jun-98		3	5	34,483,975	57,236,140
Jul-98		5	10	55,638,643	112,874,783
Aug-98		7	17	76,256,443	189,131,226
Sep-98		8	25	88,520,752	277,651,978
Oct-98		8	33	88,520,752	366,172,730
Nov-98		10	43	111,098,330	477,271,060
Dec-98		10	53	111,098,330	588,369,390
Jan-99		12	65	130,288,851	718,658,241
Feb-99		15	80	160,325,140	878,983,381
Mar-99		10	90	108,243,772	987,227,153
Apr-99		5	95	55,629,905	1,042,857,058
May-99		3	98	34,833,149	1,077,690,207
Jun-99		1	99	12,438,896	1,090,129,103
Jul-99		1	100	11,906,397	1,102,035,500

Figure H.8.   Project Cash Flow Report.

APPENDIX   I

CSI'S MASTER FORMAT

CSI Master format

This Appendix contains the Master format for construction classifications, as published by the Construction Specifications Institute (CSI), 601 Madison Street, Alexandria, Virginia. It is applicable to organizing specifications sections, drawings, cost codes, materials information, office correspondence and other aspects of design, procurement and construction.

Bidding Requirements, Contract Forms and Conditions of the Contract

00010   Pre-bid information

00100   Instructions to bidders

00200   Information available to bidders

00300   Bid forms

00400   Supplements to bid forms

00500   Agreement to bid forms

00600   Bonds and certificates

00700   General conditions

00800   Supplementary conditions

00900   Addenda

Specifications

Division 1 - General requirements

01010   Summary of work

01020   Allowances

01025   Measurement and payment

01030   Alternates/alternatives

01035   Modification procedures

01040 Coordination

01050 Field engineering

01060 Regulatory requirements

01070 Identification systems

01090 References

01100 Special project procedures

01200 Project meetings

01300 Submittals

01400 Quality control

01500 Construction facilities and temporary controls

01600 Material and equipment

01650 Facility startup/commissioning

01700 Contract close-out

01800 Maintenance

Division 2 - Sitework

02010 Subsurface investigation

02050 Demolition

02100 Site preparation

02140 Dewatering

02150 Shoring and underpinning

02160 Excavation support systems

02170 Cofferdams

02200 Earthwork

02300 Tunneling

02350   Paving and surfacing

02600   Utility piping materials

02660   Water distribution

02680   Fuel and steam distribution

02700   Ponds and reservoirs

02780   Power and communications

02800   Site improvements

02900   Landscaping

Division 3 - Concrete

03100   Concrete formwork

03200   Concrete reinforcement

03250   Concrete accessories

03300   Cast-in-place concrete

03370   Concrete curing

03400   Precast concrete

03500   Cementitious decks and toppings

03600   Grout

03700   Concrete restoration and cleaning

03800   Mass concrete

Division 4 - Masonry

04100   Mortar and masonry grout

04150   Masonry accessories

04200   Unit masonry

04400   Stone

04500 Masonry restoration and cleaning

04550 Refractories

04600 Corrosion resistant masonry

04700 Simulated masonry

Division 5 - Metals

05010 Metal materials

05030 Metal coatings

05050 Metal fastening

05100 Structural metal framing

05200 Metal joists

05300 Metal decking

05400 Cold formed metal framing

05500 Metal fabrications

05580 Sheet metal fabrications

05700 Ornamental metal

05800 Expansion control

05900 Hydraulic structures

Division 6 - Wood and plastics

06050 Fasteners and adhesives

06100 rough carpentry

06130 Heavy timber construction

06150 Wood and metal systems

06170 Prefabricated structural wood

06200 Finish carpentry

06300   Wood treatment

06400   Architectural woodwork

06500   Structural plastics

06600   Plastic fabrications

06650   Solid polymer fabrications

Division 7 - Thermal and moisture protection

07100   Waterproofing

07150   Dampproofing

07180   Water repellents

07190   Vapor retarders

07195   Air barriers

07200   Insulation

07240   Exterior insulation and finish systems

07250   Fireproofing

07270   Firestopping

07300   Shingles and roofing tiles

07400   Manufactured roofing and siding

07480   Exterior wall assemblies

07500   Membrane roofing

07570   Traffic coatings

07600   Flashing and sheet metal

07700   Roof specialties and accessories

07800   Skylights

07900   Joint sealers

Division 8 - Doors and windows

08100 Metal doors and frames

08200 Wood and plastic doors

08250 Door opening assemblies

08300 Special doors

08400 Entrances and storefronts

08500 Metal windows

08600 Wood and plastic windows

08650 Special windows

08700 Hardware

08800 Glazing

08900 Glazed curtain walls

Division 9 - Finishes

09100 Metal support systems

09200 Lath and plaster

09250 Gypsum board

09300 Tile

09400 Terrazzo

09450 Stone facing

09500 Acoustic treatment

09540 Special wall surfaces

09545 Special ceiling surfaces

09550 Wood flooring

09600 Stone flooring

09630 Unit masonry flooring

09650 Resilient flooring

09680 Carpet

09700 Special flooring

09800 Special coatings

09900 Painting

09950 Wall coverings

Division 10 - Specialties

10100 Visual display board

10150 Compartment and cubicles

10200 Louvers and vents

10240 Grilles and screens

10250 Service wall systems

10260 Wall and corner guards

10270 Access flooring

10290 Pest control

10300 Fireplaces and stoves

10340 Manufactured exterior specialties

10350 Flagpoles

10400 Identifying devices

10450 Pedestrian control devices

10500 Lockers

10520 Fire protection specialties

10530 Protective covers

10550 Postal specialties

10600 Partitions

10650 Operable partitions

10670 Storage shelving

10700 Exterior protection devices for openings

10750 Telephone specialties

10800 Toilet and bath accessories

10880 Scales

10900 Wardrobe and closet specialties

Division 11 - Equipment

11010 Maintenance equipment

11020 Security and vault equipment

11030 Teller and service equipment

11040 Ecclesiastical equipment

11050 Library equipment

11060 Theatre and stage equipment

11070 Instrumental equipment

11080 Registration equipment

11090 Checkroom equipment

11100 Mercantile equipment

11110 Commercial laundry and dry cleaning equipment

11120 Vending equipment

11130 Audio-visual equipment

11140 Vehicle service equipment

11150 Parking control equipment

11160 Loading dock equipment

11170 Solid waste handling equipment

11190 Detention equipment

11200 Water supply and treatment equipment

11280 Hydraulic gates and valves

11300 Fluid waste treatment and disposal equipment

11400 Food service equipment

11450 Residential equipment

11460 Unit kitchens

11470 Darkroom equipment

11480 Athletic, recreational and therapeutic equipment

11500 Industrial and process equipment

11600 Laboratory equipment

11650 Planetarium equipment

11660 Observatory equipment

11680 Office equipment

11700 Medical equipment

11780 Mortuary equipment

11850 Navigation equipment

11870 Agricultural equipment

Division 12 - Furnishings

12050 Fabrics

12100 Artwork

12300 Manufactured casework

12500 Window treatment

12600 Furniture and accessories

12700 Multiple seating

12800 Interior plants and planters

Division 13 - Special construction

13010 Air supported structures

13020 Integrated assemblies

13030 Special purpose rooms

13080 Sound, vibration and seismic control

13090 Radiation protection

13100 Nuclear reactors

13120 Pre-engineered structures

13150 Aquatic facilities

13175 Ice rinks

13180 Site constructed incinerators

13185 Kennel and animal shelters

13200 Liquid and gas storage tank

13220 Filter underdrains and media

13240 Oxygenation systems

13260 Sludge conditioning systems

13300 Utility control systems

13400 Industrial and process control systems

13500 Recording instrumentation

13550   Transportation control instrumentation

13600   Solar energy systems

13700   Wind energy systems

13750   Cogeneration systems

13800   Building automation systems

13900   Fire suppression and supervisory systems

13950   Special security construction

Division 14 - Conveying systems

14100   Dumbwaiters

14200   Elevators

14300   Escalators and moving walks

14400   Lifts

14500   Material handling systems

14600   Hoists and cranes

14700   Turn-tables

14800   Scaffolding

14900   Transportation systems

Division 15 - Mechanical

15050   Basic mechanical materials and methods

15250   Mechanical insulation

15300   Fire protection

15400   Plumbing

15500   Heating, ventilating and air conditioning

15550   Heat generation

15650 Refrigeration

15750 Heat transfer

15850 Air handling

15880 Air distribution

15950 Controls

15990 Testing, adjusting and balancing

Division 16 - Electrical

16050 Basic electrical materials and methods

16200 Power generation - built-up systems

16300 Medium voltage distribution

16400 Service and distribution

16500 Lighting

16600 Special systems

16700 Communications

16850 Electric resistance heating

16900 Controls

16950 Testing

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