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**INTEGRATION OF PROJECT COST ESTIMATE AND PROJECT
TIME SCHEDULE: A PROJECT BREAKDOWN STRUCTURE
APPROACH**

**By
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**Master's Research
Plan B**

**Submitted to
Michigan State University
In partial fulfillment of the requirements
For the degree of**

MASTER OF SCIENCE

Department of Agriculture Engineering

1999

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ABSTRACT**INTEGRATION OF PROJECT COST ESTIMATE AND PROJECT TIME SCHEDULE:****A PROJECT BREAKDOWN STRUCTURE APPROACH****by****SYED AQEEL AHMED KAKAKHEL**

The Project Cost Estimate and the Project Time Schedule are the core plans developed during any construction project planning process. In the current tough competitive business environment, the successful completion of a project is highly dependent on how these two plans are realistically prepared and integrated with one another. Because schedulers and estimators view projects differently, the two plans are seldom integrated for information exchange purposes.

Integration is necessary because project costs and time exhibit a complex interdependency: direct costs may increase with a decrease in completion time; on the other hand, indirect costs may decrease.

This research paper presents a scheme, the Project Breakdown Structure (PBS), for the integration of the cost estimate and the time schedule. The PBS is a seven-level common work breakdown structure, which conveniently adapts to popular software. An intelligent activity identification framework has also been developed through extension of the PBS codes. As an added benefit, the PBS is a candidate to become the standardized format for the scheduling.

In order to demonstrate the scheme, a construction schedule and a cost estimate have been generated on the basis of the PBS for a sample project in Primavera Project Planner and Timberline Precision Estimation.

Dedicated to my wife, Shazia

Acknowledgments

I am especially grateful to my mentor and professor, the late Dr. Thomas H. Burkhardt, for his generous assistance in all aspects of my program, beginning with the application and culminating in this research. I will always remember his kindness and integrity. May Allah grant him eternal rest.

The author would like to thank Dr. John Gerrish, who agreed to be my Major advisor after the sad demise of Dr. Thomas H. Burkhardt. His regular, educating and harmonious supervision on the progress of the work helped me to complete this report on time.

The author would like to thank Dr. Matt Syal, for his scholarly suggestions and provision of related literature from his personal library. The author learned the technique of conducting a research from Dr. Syal.

The author appreciates the willingness of Mr. Timothy Hinds, Case Study Center, to act as a committee member.

The author extends his thanks to Dr. Dennis Welch for the timely arrangement of Timberline Precision Estimation, and Means 99 cost database.

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Chapter 1

INTRODUCTION

1.1 OVERVIEW

As time progresses, construction projects are becoming more complex and costly, requiring greater attention to the management of both time and resources [AGC 1994]. Today's owners demand precise execution and control of their projects to satisfy their time and cost constraints [Budeiri 1984]. The construction industry can become proficient by applying the modern techniques of Construction Project Management to complete projects successfully.

The elements of construction project management are shown in Figure 1.1

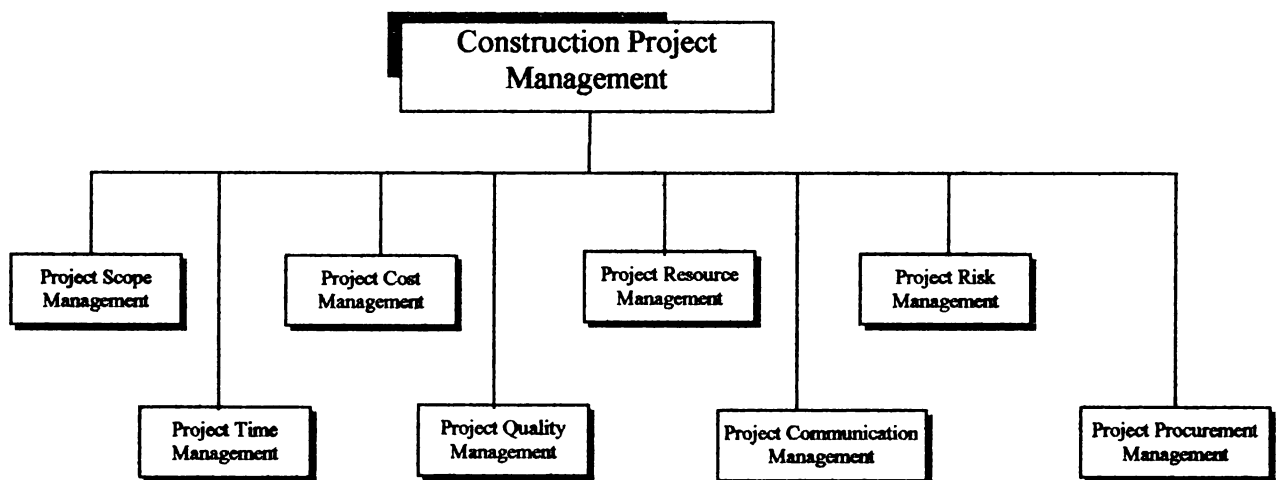


Figure 1.1 Elements of construction project management
(Modified from PMBOK 1996).

Construction project management is an integrative endeavor: an action, or failure to take an action, in one area will usually affect other areas. The interactions may be straightforward and well understood, or they may be subtle and uncertain. [PMBOK 1996]. For example, expediting of a project to produce a tight schedule may result in higher completion costs due to the increase in direct cost of the execution of activities such as overtime wages of crew, renting of additional equipment or loss of productivity due to overcrowding of a construction site.

Project Cost Management (PCM), and Project Time Management (PTM) are the two core elements of construction project management as they ensure the achievement of the main objective, i.e. being on time and within budget. PCM includes the processes required to ensure that a project is completed within the approved budget while PTM consists of the processes required to ensure timely completion of a project. PCM and PTM are composed of component processes, which are shown in Table 1.1.

Table 1.1 Component Processes of PCM and PTM
(Modified from PMBOK 1996).

<u>Project Cost Management</u>	<u>Project Time Management</u>
• Cost Estimating • Cost Budgeting • Cost Control	• Schedule Development • Schedule Implementation • Schedule Control

The different component processes of PCM and PTM are performed at various stages of the project life cycle. The cost estimating and schedule development processes are performed at the construction project planning (CPP) stage. The CPP can be defined as the decision making process which establishes a set of actions needed to successfully progress from the initial stage (i.e. design) of the project to the goal stage (i.e. constructed facility) [Syal 1992].

The project cost estimate is prepared by the estimator(s), whose aim is to forecast an accurate project cost within predefined conditions so that the project's monetary objectives could be achieved. The project construction schedule is prepared by the scheduler(s) whose main objective is to develop a realistic construction plan so that the project could be completed within the contract time constraints.

1.2 PROBLEM AREA

Construction projects exhibit complex relationships between costs and schedules. Although the interdependency between schedule and cost is obvious, it is rare to find project control systems that integrate cost and schedule control functions. Rather, they remain two separate functions that are performed independently of each other [Rasdorf 1991].

In order to facilitate the planning, the project planners decompose the project into manageable components and sub-components utilizing the Work Breakdown Structure (WBS) technique. Although PCM and PTM require similar information from common sources such as drawings, specifications and other contract documents, planners usually use one WBS to generate a cost estimate and a different WBS to generate a construction schedule. The building construction industry in USA uses Construction Specification

Institute's (CSI) MasterFormat system as the basis for a WBS for generation of a cost estimate. The MasterFormat categorizes the construction products and processes into sixteen divisions based on the following attributes. [Spence 1998]

- Location (e.g. division 2: sitework)
- Material (e.g. division 3 : concrete)
- Function (e.g. division 7: thermal and moisture protection)
- Applications (e.g. division 9: finishes)
- Trade (e.g. division 16 : electrical)

The WBS for a cost estimate systematically decomposes a project until the line items are determined.

Unlike the cost estimate, there is no specific format or standard for the preparation of a WBS for the schedule. Schedulers develop a WBS based on their experience and intuition. Even within a given company, different WBS's are adopted to decompose projects for scheduling purposes. A WBS for a schedule is generally based on any of the following:

- By major deliverables such as main building, auxiliary buildings and outbuilding works
- By trades such as concrete work, carpentry, metal, electrical and mechanical
- By major building components such as foundations, walls, columns, floors and roof
- By responsibility of project stakeholders such as owner, architect, engineer, general contractor, and subcontractors.
- By floor levels for high rise buildings such as ground floor, floor 1, floor 2 and so on.
- By construction sequence

A WBS for scheduling ends up with a set of construction activities irrespective of the basis on which it is developed. A construction project schedule is then developed from these activities using the networking technique.

The adaptation of different WBS's, one for the generation of a cost estimate and another for generation of a construction schedule for the same project leads to an information-flow blockage between them and prohibits subsequent data-sharing during the cost control and time control processes. For example, when it is necessary to cost load an activity, such as form work footing for the south wall, the scheduler will have to calculate the work quantity from the drawings for that particular activity and then apply the cost for that portion of form work from the estimate. These additional computations are necessary because the cost estimate presents a cumulative quantity of formwork for the entire project.

The data acquisition relies strongly on the intuition and experience of the cost estimators, schedulers, and project planners and controllers [Kim 1995]. As a consequence, they spend an unreasonable amount of time making adjustments to update and maintain information during the various stages of the project life cycle. For example, quantity of work in the schedule of values for the payment process may not be consistent with the activities, and therefore the actual quantity of work performed must be computed. If the schedule of values and the activities had been developed on the same basis or format, many subsequent computations could have been avoided.

Keeping in view the above discussion, two main problems prevent integration of a cost estimate with a construction schedule:

- a. Non-existence of a standard framework/format for the development of construction schedules.
- b. Adaptation of different WBS formats – one for the generation of cost estimates and another for the generation of construction schedules.

A need, therefore, exists for the development of a common WBS, most appropriately called the Project Breakdown Structure (PBS), which can resolve the above two problems. It means that the proposed PBS (common WBS) should provide:

- A standard format (standard WBS) for the development of a construction schedule, and
- A framework for a schedule (time plan) and a cost estimate (cost plan) generated in an integrated way.

Although the author has chosen to use PBS, the name is not original. It has used to describe other similar schemes. [DOE 1981]

1.3 RESEARCH OBJECTIVES

The primary objective of this research is to develop a project breakdown structure PBS (common WBS) model to serve as a standard format for the generation of a construction schedule, and as framework for the generation of an integrated cost estimate and time schedule.

The secondary objectives of this research are:

- a. To present a process flow diagram depicting the generation of a construction schedule and a cost estimate on the basis of a PBS.
- b. To demonstrate the utility of the PBS model by applying it to a sample project for the generation of an integrated cost estimate and schedule. Timberline Precision

Estimating Extended® Edition and Primavera Project Planner® will be used for the generation of cost estimates and schedules, respectively.

- c. To compare the cost estimate and the time schedule generated for the sample project on the basis of a common PBS and two traditional divergent WBS's in order to highlight the advantages of the PBS.

1.4 RESEARCH SCOPE

The research will focus mainly on a construction building project being executed in a design-build environment. In the design-build delivery system, a single entity (designer-builder) is responsible to the owner for the execution of the entire project from design to construction, and it benefits from the parallel generation of construction schedules and cost estimates. The unified design-build responsibility facilitates the control of project performance [Rizzo 1997]. There is an intense participation by the constructor during the design phase, communication between all participants is facilitated, and interface problems are reduced [Spink 1997].

1.5 RESEARCH METHODOLOGY

The research efforts are divided into the following steps:

- a. A comprehensive review of available literature in the area of project management (specifically dealing with cost estimation, scheduling, and work breakdown structures), construction information classification systems (such as MasterFormat and UniFormat), computer-integrated systems, and construction project planning modeling.

- b. Analysis of the capabilities of the topmost cost estimating software (Timberline Precision Estimating Extended®) and high-ended scheduling software (Primavera Project Planner®) so that the proposed PBS model can be made compatible to the said softwares.
- c. Development of a PBS generic model.
- d. Development of a PBS detailed model.
- e. Development of process flow diagram depicting the generation of a construction schedule and a cost estimate on the basis of PBS.
- f. Application of the common PBS model to a sample project for the generation of a schedule and a cost estimate.
- g. A comparison of a cost estimate and a time schedule generated for the sample project on the basis of a common PBS and two traditional divergent WBS's.

1.6 RESEARCH OUTPUT

The following are the outputs of this research study:

- a. A PBS generic model (Figure 4.1)
- b. PBS detailed model as a hard copy (Table 4.1) and as an electronic file in MS Word, which can serve as a template for the development of PBS for any given project.
- c. Process flow diagram for generation of a construction schedule and a cost estimate on the basis of the PBS. (Figure 4.3)
- d. Construction schedule for the sample project on the basis of a PBS generated in Primavera Project Planner.

- e. Cost estimate for the sample project on the basis of PBS generated in Timberline Precision Estimation software.

1.7 RESEARCH REPORT ORGANIZATION

The research report is composed of six chapters, two appendices and a bibliography. Chapter 1 consists of a brief overview of the construction project management, problem area, research objectives, scope, methodology, and expected output.

The literature review is presented in chapters 2 and 3. Chapter 2 reviews the previous research attempts focusing on the integration of cost estimates and construction schedules.

Chapter 3 covers work breakdown structure, MasterFormat and UniFormat. This chapter also briefly presents the features and capabilities of the topmost cost estimating software (Timberline Precision Estimating Extended®) and high-ended scheduling software (Primavera Project Planner®).

Chapter 4 describes the Project Breakdown Structure and presents a process flow diagram for the generation of a construction schedule and a cost estimate on the basis of the PBS.

Chapter 5 demonstrates the application of the PBS. It consists of a construction schedule and cost estimate for the sample project developed on the basis of the PBS.

Chapter 6 presents the conclusion and recommendations.

Appendix A contains the UniFormat numbering and titles up to level 3 while appendix B presents sketches of the sample project.

Chapter 2

LITERATURE REVIEW – I

2.1 OVERVIEW

Project cost management (PCM) and Project time management (PTM) are the core elements of construction project management as already discussed in section 1.1. A number of models have been proposed by various researchers to integrate the cost plan (cost estimate) and time plan (construction schedule) so that the entire processes of PCM and PTM can be effective and efficient. This chapter presents the following previous research efforts focusing on the integration of cost estimate and construction schedule.

- Teicholz's Model
- Hendrickson's Model
- Ibbs's and Kim Model
- Work- Packaging Model

2.2 TEICHOLZ'S MODEL

Teicholz initially recognized the existence of two data structures, i.e. different work breakdown structures, for the generation of cost estimates and construction schedules [Kim 1995]. The term “Cost breakdown structure” (CBS) was used for the WBS of the cost estimate.

Teicholz's model is shown in Figure 2.1.

Teicholz (1987) proposed a mapping mechanism between the CBS and WBS. The mechanism maps a given cost account to one or more activities that relate to that account. The mapping mechanism employs the concept of percent allocation, where a cost account has a specific percentage for the amount of a given resource (such as labor hours or material quantities) in a cost account on the CBS that should be allocated to a given activity on the WBS. For example, a cost account for the “Strip 20 cm wall” on the CBS (refer to Figure 2.1) corresponds to many tasks on the WBS such as strip 20-cm wall- area A, strip 20-cm wall- area B, strip 20-cm wall- area C.

According to William J. Rasdorf and Osama Y. Abudayyeh [Rasdorf 1991], the percent allocation concept proposed by Teicholz is approximate and based on judgment. Synchronization of two separate views of data is an issue, and no attempt has been made to integrate these views physically. Moreover, maintaining links between the cost-and – schedule-control account creates an extra computational overhead that may affect the efficiency of data processing and reporting.

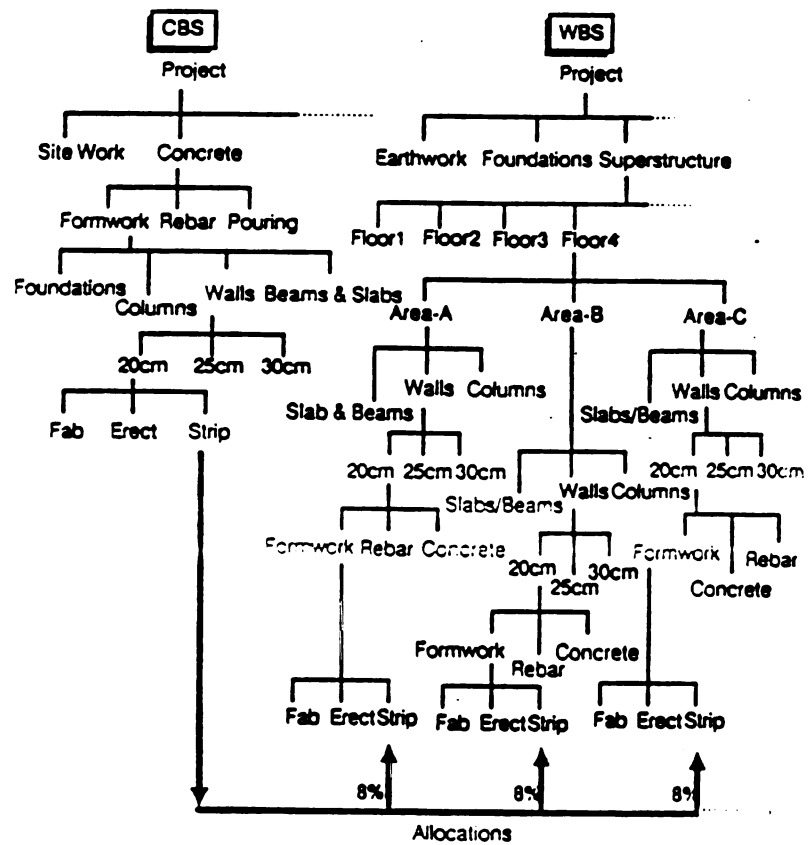
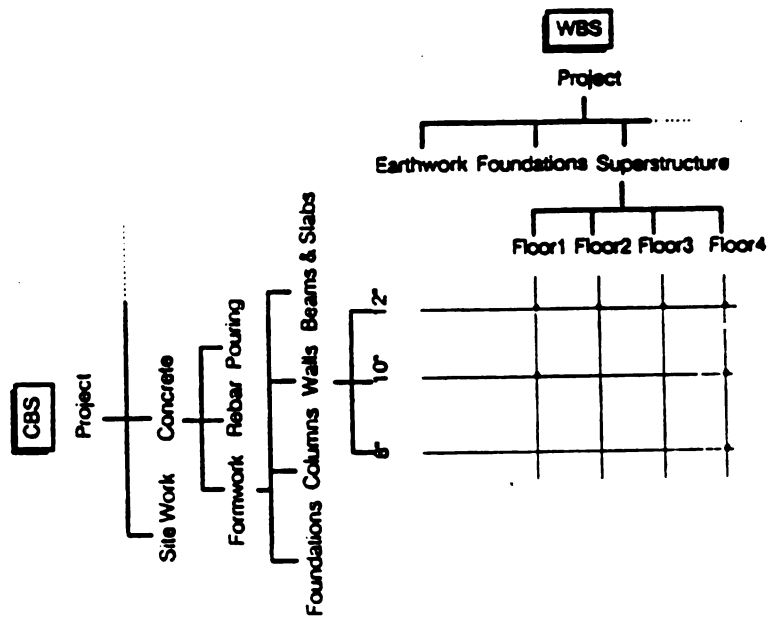


Figure 2.1. Teicholz's model

2.3 HENDRICKSON'S MODEL

Hendrickson and Au [1989] proposed a work-element concept for integrating the cost estimate and construction schedule. Hendrickson's model is shown in Figure 2.2.

A work element is a control account defined by a matrix of work packages from the WBS and a cost account from the CBS. In Hendrickson model, work element is used as a common denominator which provides a link between the WBS and the CBS, where a cost account may relate to one or more activities, and at the same time, an activity may relate to one or more cost accounts. Hendrickson and Au recognized the need for a common denominator for acquiring and maintaining data for effective project control. The success of the Hendrickson model is conditional on developing automated data acquisition and representation methods because of the burden of data collection and storage. Moreover, the model maintains two different views of project data (the CBS and WBS) which creates an extra computational overhead [Rasdorf 1991].



Work Element Matrix

		First Floor	Second Floor	Third Floor	Fourth Floor
Cost Accounts	30cm Walls	X	X	X	X
	25cm Walls	X			X
	20cm Walls				X

X : work element

Figure 2.2 Hendrickson's Model

2.4 IBBS'S AND KIM MODEL

Ibbs's and Kim (Kim 1989) model uses object-oriented programming (OOP) approach. The model is based on BOD, which is defined as the lowest-level construction task needed to build a specific design object. BOD is the entity that provides a linking between a design object and its corresponding construction operation control functions (WBS and CBS). The Model is shown in Figure 2.3.

A BOD has three attributes: a work package on the WBS, a cost account on the CBS, and a design object on the drawing. For example, the following five BODs can be generated for an 8-in (20-cm) concrete wall object of area A on the fourth floor:

- Fabricate formwork
- Erect formwork
- Place rebars
- Pour concrete
- Strip formwork

Each BOD is then linked to one cost account on the CBS and one work package on the WBS.

In this model each BOD is defined at such a refined level that it may be impossible to acquire data to support model. Moreover, Ibbs's and Kim Model still maintains the dual WBS and CBS views, which creates an extra computational overhead [Rasdorf 1991].

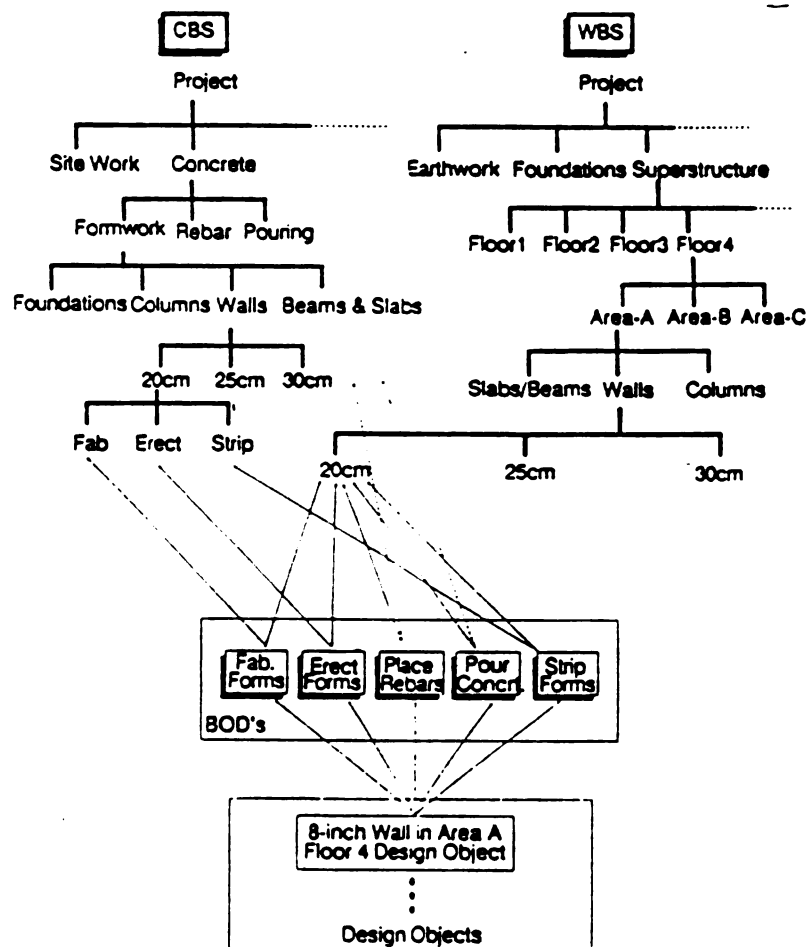


Figure 2.3 Ibbs and Kim Model

2.5 WORK PACKAGING MODEL

Work Packaging (WP) is defined as a method to create common manageable work entities and to interface them with different phases throughout the life cycle of a project, e.g. design, cost estimation, scheduling, and control. Work packages are derived by combining the WBS and Organizational Breakdown Structure (OBS). Figure 2.4 shows a work packaging model. WPs are developed by creating a matrix in which the WBS defines the columns and the OBS defines the rows. WPs at this level are called control accounts. Control accounts are then divided into tasks. Cost budgets, time budgets, and labor resources are then allocated to these tasks [Kim1995].

This model has a very complex control account coding system. Additionally, it does not suggest a breakdown structure for the cost estimation. Furthermore, even a small change in the WBS or OBS would affect the whole model.

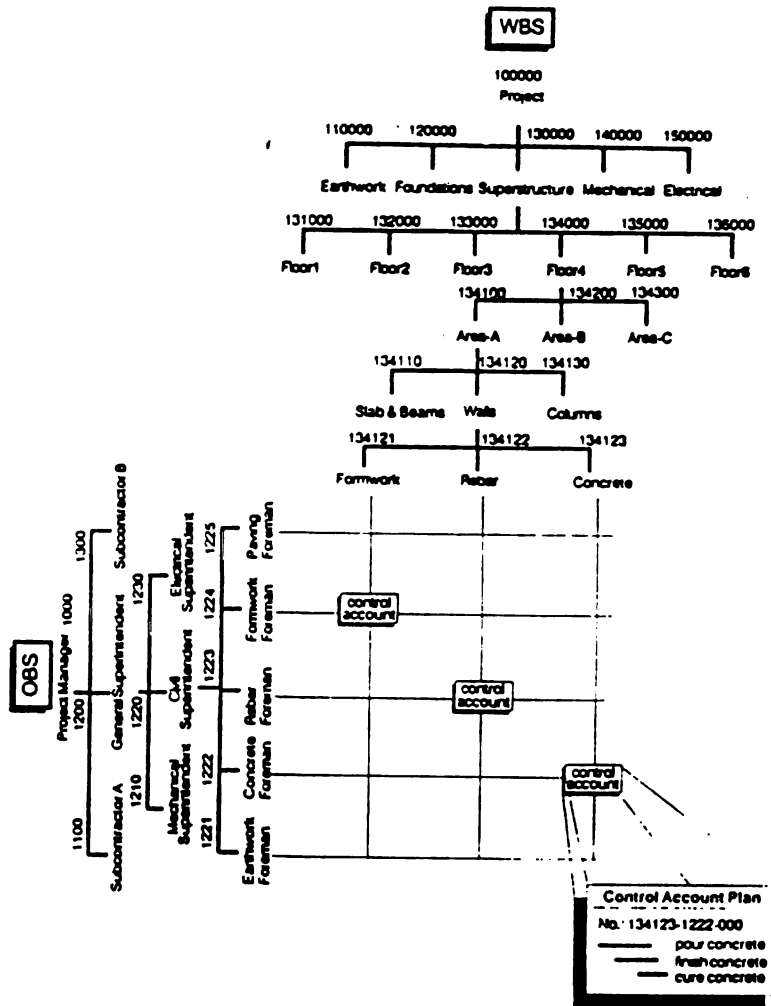


Figure 2.4 Work packaging model

2.6 SUMMARY

The models discussed in the previous sections have proposed to integrate the cost estimate and construction schedule by linking WBS with CBS or WBS with OBS through various mechanisms such as direct mapping (Teichloz's model), work element (Hendrickson's model), BOD (Ibbs's and Kim model), control account (work packaging model). These models maintain the dual view of data, and the synchronization issue is not resolved. Moreover, these models will have to be developed (almost from scratch) for every project, which results in computational overhead.

These models have not addressed the issue of compatibility with the Masterformat classification system, which is being widely used as a standard WBS for the generation of cost estimate by the US construction industry. Nor have these models proposed an activity identification structure.

In the author's view, an efficient and effective integration between the cost estimate and the construction schedule can be achieved only through a common WBS, most appropriately called the Project Breakdown Structure (PBS). The PBS, developed by the author is presented in Chapter four. The PBS approach to integration incorporates WBS (project management technique), Masterformat and Unifomat (construction information classification systems), Primavera Project Planner (construction management and scheduling software), and Timberline Precision Estimation (cost estimation software). Therefore, prior to presenting PBS, these topics will be discussed in Chapter three.

Chapter 3

LITERATURE REVIEW – II

3.1 OVERVIEW

This chapter covers the topics of Work Breakdown Structure (WBS), MasterFormat (MF), and UniFormat (UF). WBS is an effective management technique used for the planning and controlling of projects. MasterFormat and UniFormat are the construction information classification systems developed by the Construction Specification Institute (CSI). This chapter also briefly discusses the related advanced features of the Primavera Project Planner (P3) and Timberline Precision Estimation (TPE).

3.2 WORK BREAKDOWN STRUCTURE

Over time, projects have been getting larger and more complex. This growth in size and complexity resulted in the introduction of a new project management tool, the Work Breakdown Structure (WBS) in the early 1960s [Chimni 1989]. This section presents the basics of the work breakdown structure technique and its uses in construction project management.

3.2.1 WBS definition and development

A WBS is a hierarchical format, which decomposes a project into successively greater levels of detail [Dreger 1992]. A WBS serves as bridge between the end objective and its

supporting efforts. It provides an ordered framework for the planning and controlling of a project [DOE 1981].

The work breakdown structure first decomposes a project (or a product) into major subprojects (or subproducts) which are in turn broken down into smaller, more manageable components and sub-components until the project (or product) is defined in adequate detail for planning, executing, and controlling. This decomposition is carried out systematically into levels, each level providing increasingly detailed definition of the project (or product). The number of levels depends on the scope and complexity of the individual project and the degree of control it warrants [DOE 1981]. Figure 3.1, shows a project broken down to three levels.

WBS is a hierarchical structure, which can be developed as:

- a. A tree diagram, as shown in Figure 3.1
- b. An indented listing, as shown in Figure 3.2
- c. A table, as shown in Table 3.1

3.2.2 WBS coding

Each module (such as project, subproject, or component) of a WBS is assigned a code to be used for its identification throughout the life of the project. A simple decimal or alphanumeric coding system is applied that logically indicates the level of each module and relates that module to its parent module. In Figures 3.1, 3.2 and Table 3.1, a numerical decimal system is shown for the coding purpose.

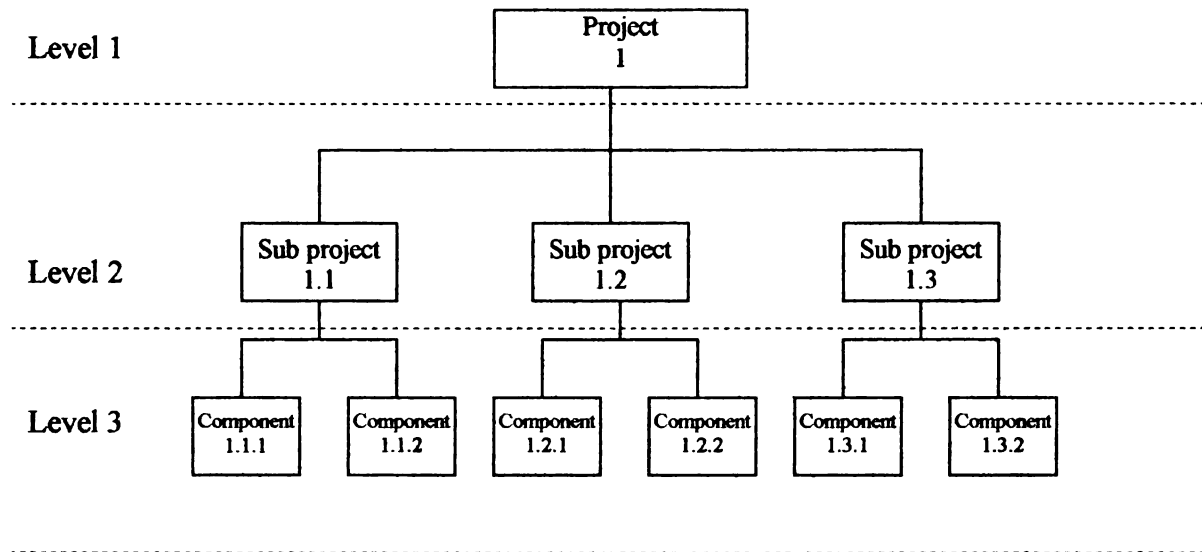


Figure 3.1 WBS graphical representation

1	Project	(Level 1)
1.1	Subproject	(Level 2)
1.1.1	Component	(Level 3)
1.1.2	Component	(Level 3)
1.2	Sub project	(Level 2)
1.2.1	Component	(Level 3)
1.2.2	Component	
1.3	Sub project	
1.3.1	Component	
1.3.2	Component	

Figure 3.2. WBS as indented listing

Table 3.1 WBS in table format

Level 1	Level 2	Level 3
1 Project		
	1.1 Subproject	1.1.1 Component
		1.1.2 Component
	1.2 Subproject	1.2.1 Component
		1.2.2 Component
	1.3 Subproject	1.3.1 Component
		1.3.2 Component

3.2.3 Purposes of WBS

The major WBS purposes are listed below: [Dreger 1992]

- To define total project effort – what the project is
- To define project scope and limit – what the project is not
- To state project objectives as tangible, measurable deliverables
- To structure the work into small, detailed units that define scope and deliverables

According to Kerzner [1995], the WBS is the single most important management tool because it provides a common framework from which:

- The total project can be described as the sum of contributing elements,
- Planning and forecasting may be performed,
- Schedules and budgets can be established,

- Time, cost, and performance can be tracked,
- Objectives can be linked to company resources in a logical manner,
- Schedule status reporting procedures can be established,
- Network construction and control planning can be initiated, and
- Responsibility assignments for each element can be established.

3.2.4 Application of WBS in construction project management

A WBS can be used to provide the basis for: [Kerzner 1995]

- Construction scheduling
- Cost estimation
- Responsibility matrix development
- Risk analysis
- Organizational structure
- Contract administration
- Coordination of objective

Keeping in view the scope of this research, only the WBS's being used for the construction schedule and the cost estimate will be discussed further. Figures 3.3, 3.4 and 3.5 present WBS's developed on different yardsticks such as major deliverables, major processes, and major work categories for planning of a typical house. In order to generate a construction schedule or a cost estimate, these WBS's have to be expanded to the next level of detail, i.e. activities or line items.

The US construction industry uses the MasterFormat classification system as a basis for the WBS of cost estimating, whereas there is no industry-wide standard or format for the WBS of construction scheduling. Schedulers develop WBS based on their individual experience

and intuition. Even within a given company, *ad hoc* WBS's are adopted for the scheduling of particular projects.

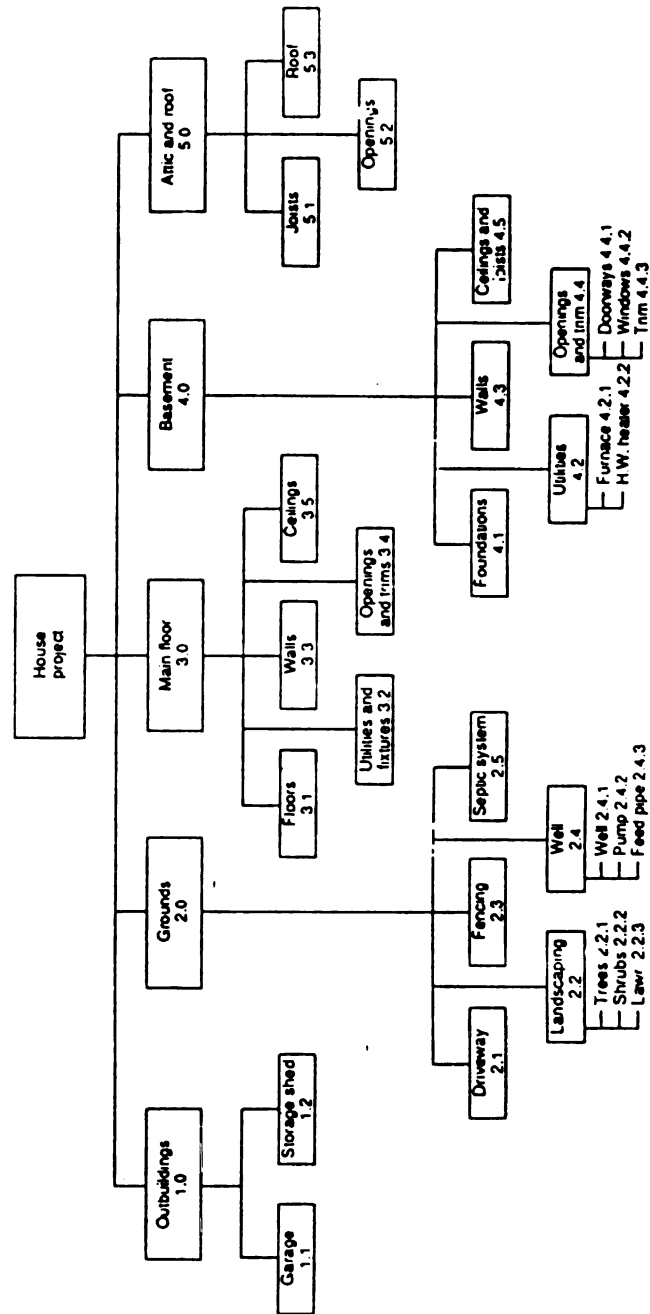


Figure 3.3 WBS by major deliverables
(Source [Dreger 1992])

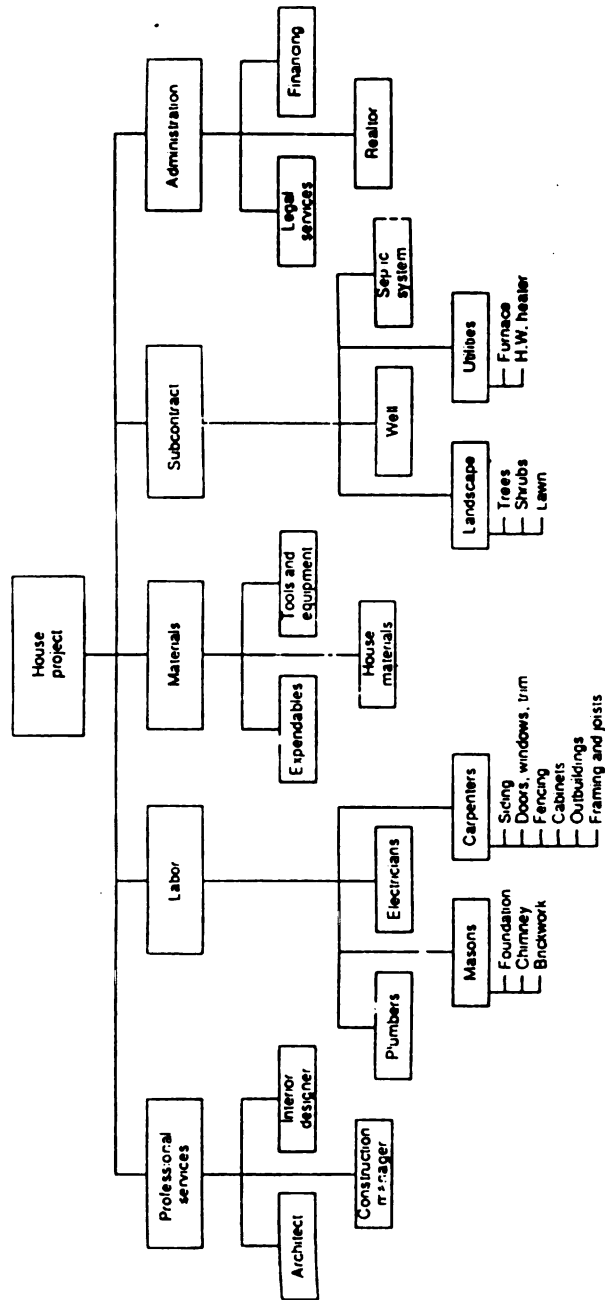


Figure 3.4 WBS by major processes
(Source [Dreger 1992])

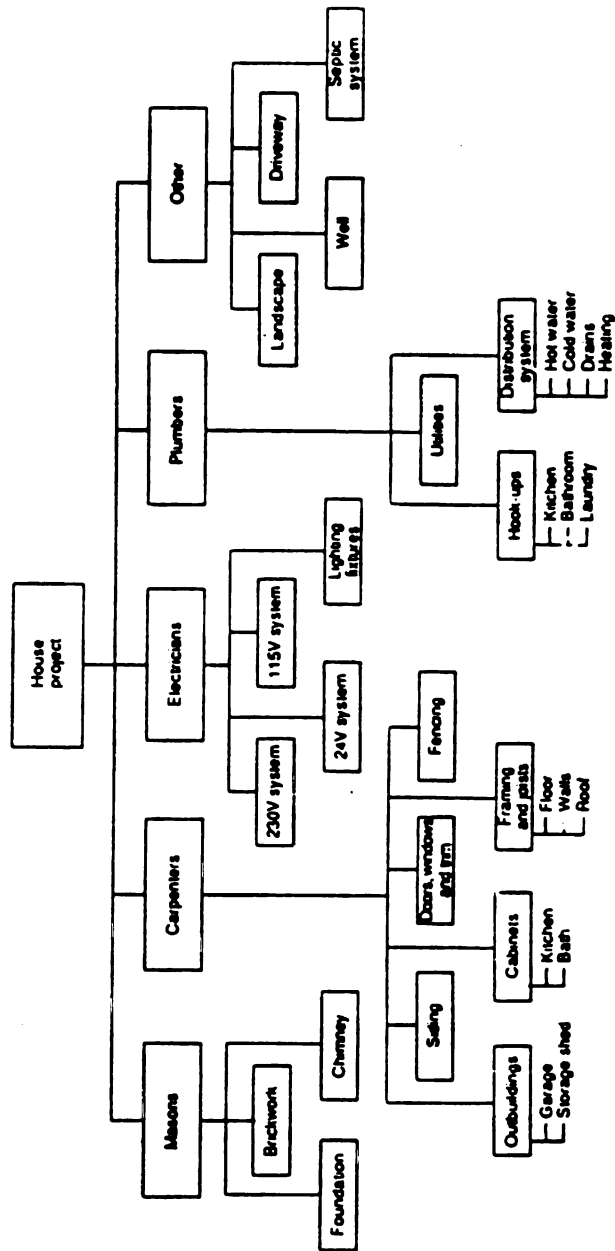


Figure 3.5 WBS by major work categories
(Source [Dreger 1992])

3.3 MASTERFORMAT

MasterFormat is a construction information classification system developed by CSI. MasterFormat categorizes the construction products and processes into sixteen divisions based on the following attributes: [Spence 1998]

- Location (e.g. division 2: sitework)
- Material (e.g. division 3 : concrete)
- Function (e.g. division 7: thermal and moisture protection)
- Applications (e.g. division 9: finishes)
- Trade (e.g. division 16 : electrical)

The term “product” means materials, components, and equipment that a contractor incorporates into a project. Products can be new or existing, may be commodities or manufactured units, can be materials, components, finished assemblies or combinations, for example, masonry bricks, concrete mix, wooden floor joists, metal studs, curtain walls. Products are the basic components of construction.

The term “ process” means a construction method or procedure utilizing a particular crew or material or both, for example, placing of ready-mix concrete of 3000-psi strength with a pump truck or excavation of soil with a backhoe for a utility trench.

The following are the sixteen MasterFormat divisions. These divisions are also called the group phases. [Bledsoe 1992]

- Division 1: General Requirements
- Division 2: Site work
- Division 3: Concrete
- Division 4: Masonry

- Division 5: Metals
- Division 6: Wood and Plastics
- Division 7: Thermal and Moisture Protection
- Division 8: Doors and Windows
- Division 9: Finishes
- Division 10: Specialties
- Division 11: Equipment
- Division 12 Furnishings
- Division 13: Special Construction
- Division 14: Conveying Systems
- Division 15: Mechanical
- Division 16: Electrical

3.3.1 Applications of Masterformat

The Masterformat is used for the following purposes:

- Arranging information within project manuals
- Cataloging of product information by manufacturers and suppliers
- Keynoting for drawings to associate items with specifications
- Arranging of cost databases in books or electronic format such as :
 - RS Means building construction cost data (book), Richardson cost data books.
 - RS Means database, Timberline Commercial GC database and Timberline Residential Home Builder database or a company's proprietary cost database.
- As a WBS for the generation of cost estimates

3.3.2 Application of Masterformat for arranging of cost databases

The various cost databases (electronic and printed) arrange the cost data using the titles and numbering of the MasterFormat. Each MasterFormat division (group phase) is divided into Subdivisions (phases), each Subdivision is divided into Medium Scopes; each Medium Scope is divided into Major Classifications and each Major Classification is divided into line items. [Bledsoe 1992].

For example: The division 2, site work has been arranged as:

Division 2:	Site work
Subdivision 022:	Earthwork
Medium scope 022 200:	Excavation, backfill, and compaction
Major classification 022 238:	Excavating, bulk bank measure, common earth piled
Line item 022 238 0200:	Backhoe, hydraulic, crawler mounted, 1 C.Y cap = 75 C.Y / hr

Line items are the individual cost elements tabulated in cost databases and are the smallest division of work to be analyzed. A Line item may be a product or a process. A 10-digit code based on the CSI MasterFormat is used to uniquely describe the line item. The first six digits are MasterFormat medium scope and major classification codes. The last four digits are optional; in this example, the last four digits are those used by the RS Means to identify various crews, equipment, production rates, etc. This complete item code narrows the work item to the finest detail i.e. excavation with a specific equipment type and size [Bledsoe 1992].

Figure 3.6 shows cost data arranged on the basis of MasterFormat for a portion of division 2.

022 Earthwork										
022 200 Excav./Backfill/Compact.										
			CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	1997 BARE COSTS			
							MAT.	LABOR	EQUIP.	TOTAL
234	0010	DRILLING AND BLASTING Only, rock, open face, under 1500 C.Y.	B-47	225	107	C.Y.	1.58	2.42	2.53	6.53
	0100	Over 1500 C.Y.	*	300	280		1.58	1.82	1.89	5.29
	0300	Bulk drilling and blasting, can vary greatly, average								3.95
	0500	Pits, average								20
	1300	Deep hole method, up to 1500 C.Y.	B-47	50	480		1.58	10.90	11.35	23.83
	1400	Over 1500 C.Y.		66	364		1.58	8.25	8.60	18.43
	1900	Restricted areas, up to 1500 C.Y.		13	346		1.58	42	43.50	87.08
	2000	Over 1500 C.Y.		20	1,200		1.58	27.50	28.50	57.58
	2200	Trenches, up to 1500 C.Y.		22	1,291		4.75	25	26	55.75
	2300	Over 1500 C.Y.		26	323		4.53	21	22	47.53
	2500	Per holes, up to 1500 C.Y.		22	1,291		1.58	25	25	52.58
	2600	Over 1500 C.Y.	↓	31	774		1.58	17.60	18.35	37.53
	2800	Souiders under 1/2 C.Y., loaded on truck, no hauling	B-100	80	150			3.69	5.15	9.84
	2900	Drilled, blasted and loaded on truck, no hauling	B-47	30	300	↓	1.58	18.20	18.95	38.73
	3100	Jackhammer operators with foreman compressor, air tools	B-9	1	40	Day		3.25	.54	9.89
	3300	Track drill, compressor, operator and foreman	B-47	1	24	*		545	570	1,115
	3500	Blasting caps				Ea.	3			3
	3700	Explosives				Lb.	2			2
	3900	Blasting mats, rent, for first day				Ea.	80			80
	4000	Per added day					25			25
	4200	Preblast survey for 6 room house, individual lot, minimum	A-6	2.40	5.567	↓		1.62		1.62
	4300	Maximum	*	1.35	35.2			2.88		2.88
	4500	City block within zone of influence, minimum	A-8	25,200	301	SF		03		03
	4600	Maximum	*	15,100	302	*		05		05

Figure 3.6 Cost data arrangement
(Source RS Means 1997)

3.3.3 Masterformat as WBS for cost estimate

Construction cost estimation consists of two components.

- Quantity takeoff (quantity surveying): it is the process of taking measurements from architectural and engineering drawings and specifications and converting them mathematically into useful and meaningful quantities for cost estimating [Bledsoe 1992].
- Pricing: when the quantities are determined, then prices, or unit costs must be applied to determine the total direct cost. The prices can be obtained from the cost data sources.

The overheads and profit are then added to the total direct costs on the bottom line of the estimate summary [RS Means, 1990]

The US construction industry uses MasterFormat as the basis for the cost estimate. This means that the quantity takeoff and pricing are carried out according to the sequence of the 16 divisions of MasterFormat. Within each division, the components or individual items are identified, listed, and priced. Each item is broken down further into material, labor, and equipment. A sample WBS suitable for a cost estimate on the basis of MasterFormat is shown in Figure 3.7. A few line items from the phases of division 2 and division 3 have been presented for illustration purposes. A complete WBS for a project may contain line items from most of the phases.

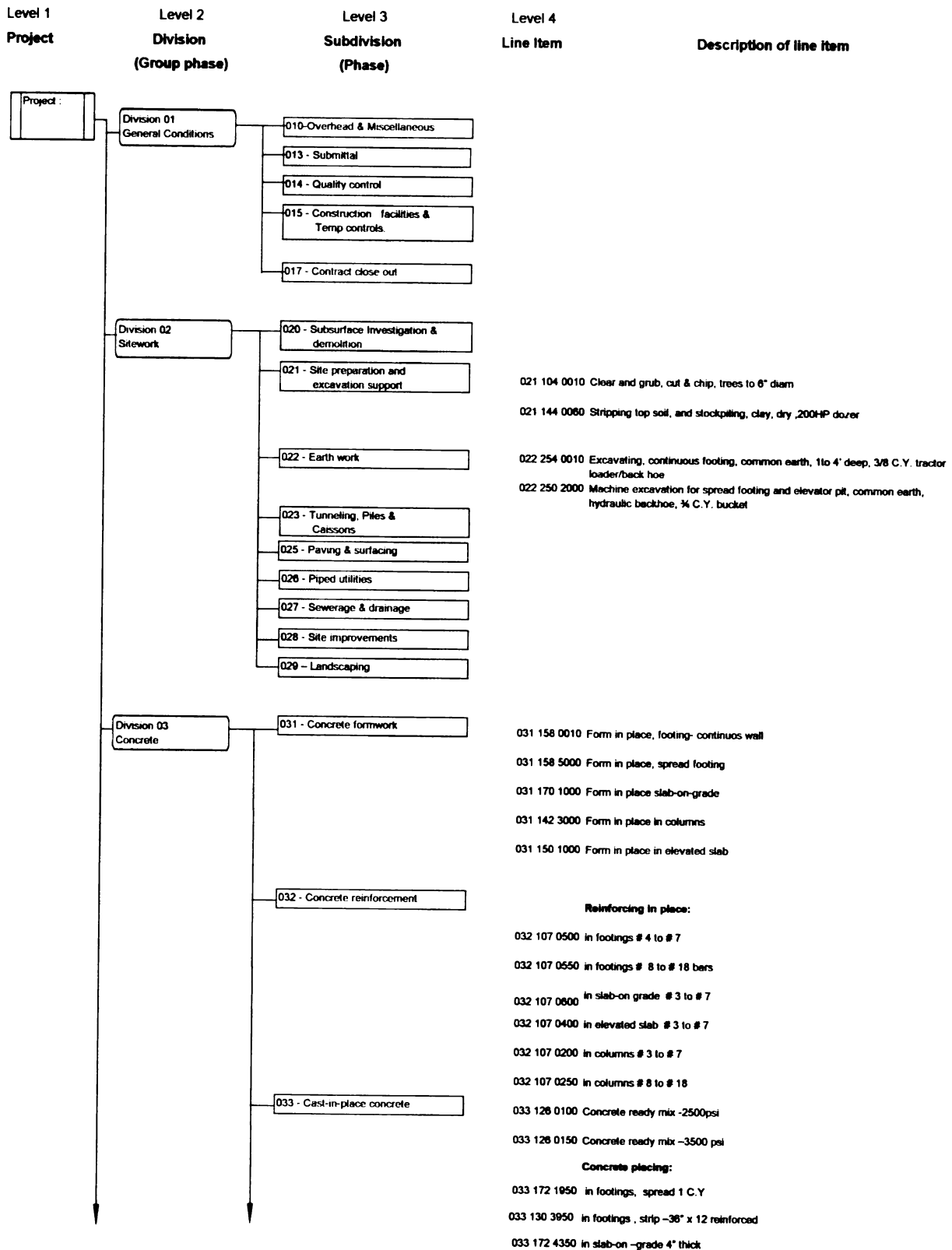


Figure 3.7 WBS for a cost estimate on the basis of MasterFormat

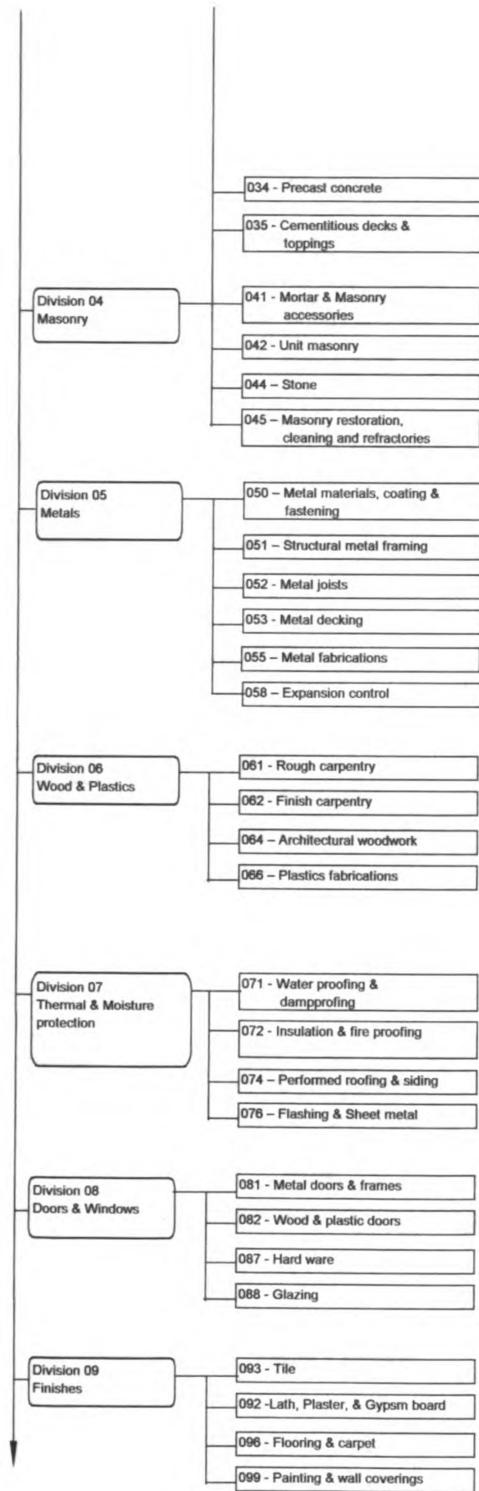


Figure 3.7(cont'd)

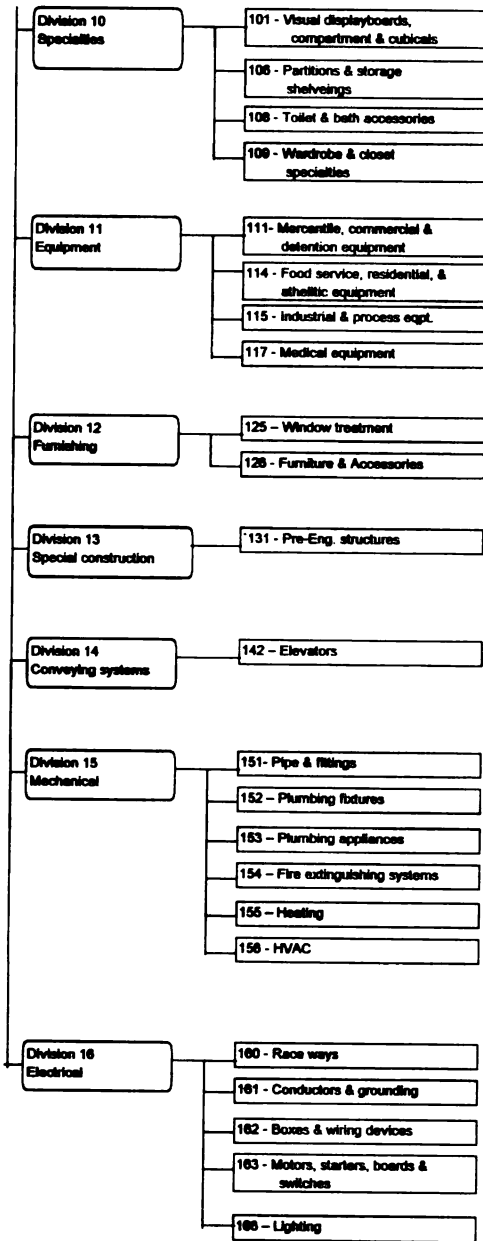


Figure 3.7(cont'd)

3.4 UNIFORMAT

Uniformat [1998] is an arrangement of construction information based on the physical parts of a facility called systems and assemblies. UniFormat has been developed by CSI and CSC (Construction Specification Canada). These systems and assemblies are characterized by their function without identifying the products that compose them. UniFormat covers systems and assemblies for a range of building types and construction related to buildings. Systems and assemblies render a view of a constructed facility that is different from the view rendered by a breakdown of building materials, products, and processes.

The purpose of UniFormat is to achieve consistency in the economic evaluation of projects, enhance reporting of design program information, and promote consistency in filing information for facility management, drawing details, and construction market data.

3.4.1 Organization of Uniformat

Uniformat has a hierarchical structure, which decomposes construction information to five levels, each of increasing detail. The hierarchy comprises the following nine major categories of construction information:

PROJECT DESCRIPTION

- **A SUBSTRUCTURE**
- **B SHELL**
- **C INTERIORS**
- **D SERVICES**
- **E EQUIPMENT AND FURNISHINGS**
- **F SPECIAL CONSTRUCTION AND DEMOLITION**

- G BUILDING SITEWORK
- Z GENERAL

A complete list of the Unifomat titles and numbering from level 1 through level 3 is provided in Appendix A.

The first category “ Project Description” does not have a letter designation because it is not a building system or assembly. Instead, Project Description is a collection of basic information related to the project, e.g., bidding, proposal, and contract requirements. Thus, Unifomat can be used as a stand-alone contracting structure for construction projects especially design-build projects. The letters and titles of Level 1 categories are fixed and should not be changed in any application.

Unifomat divides each Level 1 category into classes of information. At Level 2, classes carry the letter of their parent category, plus a two-digit number e.g. A 10. Levels 3 and 4 are developed by further subdividing Level 2 classes. These subclasses carry the alphanumeric designation of their parent category and class, plus a two-digit number e.g. A1010. Alphanumeric designations and titles of Level 2 and Level 3 subclasses are fixed and should not be changed in application.

Alphanumeric designations for Level 4 are unassigned within a group of Level 3 subclasses, and number extensions are assigned by the user. The user-assigned number should carry the alphanumeric designation of the parent Level 3 subclass, plus a two-digit number (as illustrated below by the XX), or the corresponding Masterformat number.

Titles presented below Level 4 are Level 5 subclasses, developed by presenting specialized design solutions of their parent Level 4 subclasses. Particular materials may be identified

(e.g., concrete and steel) to differentiate one specialized solution from another. Titles at Level 5 are examples of information included in their Level 4 subclass.

Level 5, and sometimes Level 4 titles, correspond to Masterformat numbers and titles.

The numbering system is as follows:

Level 1:	A	Substructure
Level 2:	A10	Foundations
Level 3:	A1010	Standard Foundations
Level 4:	A1010.XX	Wall Foundations
Level 5:	A1010.XX	Column Foundations

The Unifomat numbering system is expandable, allows additional numbers, and titles at any level if needed. User-defined numbers and titles that fit within the established framework of Unifomat can be added.

Titles in Levels 1 through 3 can be applied to most project descriptions and preliminary cost estimates. Levels 4 and 5 are available for use on detailed, complex projects. Level 4 and 5 titles and detailed listings provide a checklist to ensure comprehensive and complete application of Unifomat.

3.4.2 Comparison of Unifomat and Masterformat

The primary difference between Unifomat and Masterformat lies in how each system divides construction information for its intended application. The Unifomat has nine major categories while Masterformat has sixteen divisions. Each views the same construction information or base of data from a different perspective. Unifomat and Masterformat titles suggest complementary views of construction products and performance requirements:

Uniformalt names systems and assemblies that have a determinable function whereas Masterformat names components that have specifiable characteristics. [Uniformalt 1998]:

3.4.3 Application of Uniformalt

As suggested by CSI, Uniformalt can be used for the following purposes: Uniformalt [1998]

3.4.3.1 Arranging Cost Information

Cost information can be organized according to Uniformalt and may be reported in varying degrees of detail, which can be refined as design decisions are made. The presentation of cost information on the basis of UniFormat facilitates the comparison of various building elements, particularly during early design phases. A cost estimate organized on the basis of UniFormat can evolve along with a cost estimate organized according to Masterformat.

These two models of cost estimating present a different view of the same project and provide details appropriate for different requirements. For example, a cost model organized by UniFormat can provide information about the cost of a concrete structure compared with a steel structure, even though there will be more concrete and steel on the project. However, a cost model organized according to MasterFormat can provide information about the cost of all the concrete and steel on a project regardless of the structural system chosen.

UniFormat is most suitable for value analysis, which requires assigning a cost to a particular use or facility function rather than to particular products and activities.

3.4.3.2 Arranging Preliminary Project Descriptions

A logical sequence of systems and assemblies is provided by Uniformalt to describe a project before all construction materials and methods have been determined. This helps the owners to understand various components and systems proposed by the designer. UniFormat can be

adopted to organize, and serves as a checklist for preparing, preliminary project descriptions at various levels of detail. As the design progresses, both descriptions and the estimate of probable construction cost can be refined.

3.4.3.3 Arranging Project Manuals

Organizing project manuals, or portions of them, according to UniFormat is well suited for the projects employing Performance Specifying. UniFormat can be used to organize performance specifications for elements crossing Masterformat section and division boundaries. Performance specifying can be used at many levels, from a single product to major subsystems or entire projects. It allows the owner to access a range of options, from existing technology to innovative systems and developing technologies.

3.4.3.4 Organizing Drawings

UniFormat numbers and titles can be used for organizing architectural and engineering drawings.

3.4.3.5 Arranging Facilities Management Information

UniFormat can be used for organizing maintenance and operation programs, and data.

3.4.3.6 Arranging Information for Design-Build Applications

UniFormat classification system can be used for the communication of functional performance in a design-build project delivery. Owners can communicate project performance requirements organized according to UniFormat to design-build entities in requests for proposals. In turn, design-build contractors must use performance requirements to communicate their proposals.

3.5 PRIMAVERA PROJECT PLANNER

Primavera Project Planner (P3) is a project management and scheduling software developed by Primavera Systems Inc. (www.primavera.com). P3 is designed to handle large-scale, intricate and multifaceted projects. The following are some P3 (version 2.0 b) features/capabilities: [Primavera 1997]

- Can handle 100,000 activities per project.
- Unlimited project groups, projects and target plans can be set.
- Scheduling and resource leveling can be performed at the project group and/or project level.
- 20-level user definable WBS dictionary.
- 24 user-definable activity codes for selection and sorting.
- 10-character user-definable intelligent activity ID codes.
- Summarization of multiple project groups.
- What-if analyses for schedule dates and resource planning.
- Earned value analyses.
- Merge multiple projects in a project group.
- 31 activity-calendars per project.
- Time units in hours, days, weeks and months.
- 10 types of schedule constraints (e.g., start-no-earlier-than, finish-no-later-than, etc.)
- 9 types of activities for more precise schedule modeling (e.g., task, meeting, independent, milestone, hammock, flags, etc.)
- Resource calendars and variable availability
- Unlimited resources per project and activity.

- Activity splitting, stretching and crunching during leveling and smoothing.
- Variable resource pricing and availability.
- Resource-driven activity durations.
- Unlimited cost accounts per project with intelligent 12-character codes.
- Track budget, actual cost this period, actual cost to date, percent complete, earned value, cost to complete, cost at completion.
- Autocost feature for user-defined rules for planning and updating cost.
- Unlimited presentation layouts.
- Hierarchical project outlining organized by any combination of activity codes, resources, cost accounts, and WBS.
- Summarize and group activities and compare to targets by WBS.
- Multiple levels of sort and selection (filter)

In addition to the above features/capabilities, P3 has an electronic interface with the following software:

- Expedition (contract control)
- Monte Carlo (risk analysis)
- Sure Track (scheduling)
- MS Project (scheduling)
- Timberline Precision Estimation (cost estimation)
- Pro Log Manager (Construction management and document control)

3.6 TIMBERLINE PRECISION ESTIMATION

Timberline Precision Estimation (TPE) is cost estimation software developed by Timberline Software Corporation [Timberline 1998]. It has two main parts: a database, and a spreadsheet.

The database stores all the standard cost items required to prepare an estimate including labor, material, and equipment items and prices, takeoff formulas, productivity factors, assemblies and more. A database can be built from scratch or an industry-standard model can be purchased and customized to suit company needs.

The spreadsheet presents the items, quantities, and dollar amounts that make up an estimate in a format designed specifically for estimating.

In the estimate creation process, the information is pulled from the database into the spreadsheet. The dimensions of a structure or quantities are then entered manually or through a digitizer. The TPE finalizes (computes) the costs in a spreadsheet. The database and spreadsheet are stored in separate files. The changes made in the spreadsheet stay in the estimate and affect neither the database nor other estimates.

The following are some of the features/capabilities of Timberline Precision Estimation (extended version):

- There are four methods of takeoff: Quick takeoff, item takeoff, assembly takeoff and one-time takeoff.
- Location code: can indicate where items are shown on plans, or where items will be used on the job site.

- **WBS codes:** Up to 12 WBS codes can be defined in the database. Within each WBS code, numerous WBS values can be defined to which items can be assigned. TPE allows sorting out estimate items based on the user-defined WBS.
- **Four additional spreadsheet sequences** (besides Phase/item, takeoff order and assembly) can be defined for an estimate.

In addition to Spreadsheet and Standard Estimate report in various layouts, TPE's can generate the following reports:

- **Estimate Details Report**
- **Takeoff Unit Cost Report**
- **Unit Price Review Report**
- **Bill of Materials Report**
- **Quote Sheet Report**
- **Crew Report**
- **Crew Analysis Report**
- **Comparison Report**
- **Variance Report**
- **Bill of Quantities**
- **Unit Price Analysis Report**

Chapter 4

PROJECT BREAKDOWN STRUCTURE

4.1 OVERVIEW

Chapter 4 presents the Project Breakdown Structure (PBS), developed by the author as a result of the research effort. This chapter includes the explanation of the PBS, a generic PBS model (Figure 4.1), PBS detail model (Table 4.1), and a process flow diagram (Figure 4.3) depicting the development of both a Construction Schedule and a Cost Estimate on the basis of the PBS.

4.2 PBS MODEL

Project Breakdown Structure (PBS) is a common work breakdown structure (WBS), which can be adopted:

- As a standard format for the generation of a construction schedule and,
- As a framework for the generation of an integrated construction schedule and cost estimate. It decomposes a construction project into the following seven levels, each of increasing detail. Each of these levels is described in the next few pages.
 - Level 1: Project
 - Level 2: Element
 - Level 3: Class
 - Level 4: Subclass

- Level 5: Area
- Level 6: Activity
- Level 7: Cost line item

A PBS format/framework is shown in Figure 4.1. A detailed PBS model is shown in Table 4.1. The elements and their associated classes and subclasses divide a building project into its basic parts, each part characterized by its function. The PBS first subdivides a project into major elements which, in turn, are decomposed into smaller, more manageable components until the elements are defined in adequate detail so that a project could be planned, executed, and controlled efficiently. Each element is decomposed to its constituent activities at level 6 of the PBS. At level 7 of the PBS, cost line items are assigned to each activity for estimation purposes. The UniFormat classification system's levels 1, 2, and 3 have been adopted for the levels 2, 3, and 4 of the PBS respectively. Other than that the PBS scheme is the author's contribution. CSI has suggested many applications (discussed in section 3.4.3) for UniFormat except for schedule development. Some of the reasons for incorporating the UniFormat into the PBS are listed below:

- UniFormat covers systems and assemblies for a range of building types and construction related to buildings.
- UniFormat provides a logical sequence of systems and assemblies to describe a construction project before all materials and methods have been determined. Therefore, it can be adopted at the initial planning stages.
- UniFormat titles and numbering are generic and are expandable to meet specific requirements. For example, level 6 of the PBS has been developed by grouping the related activities within corresponding subclasses.

the first of these is the fact that the system is not a simple one, but a complex one, in which the various parts are interrelated and interdependent. The second is that the system is not a static one, but a dynamic one, in which the parts are constantly changing and evolving. The third is that the system is not a closed one, but an open one, in which the parts are constantly interacting with the environment. The fourth is that the system is not a linear one, but a non-linear one, in which the parts are constantly interacting with each other in a non-linear fashion. The fifth is that the system is not a deterministic one, but a probabilistic one, in which the parts are constantly interacting with each other in a probabilistic fashion. The sixth is that the system is not a simple one, but a complex one, in which the parts are interrelated and interdependent. The seventh is that the system is not a static one, but a dynamic one, in which the parts are constantly changing and evolving. The eighth is that the system is not a closed one, but an open one, in which the parts are constantly interacting with the environment. The ninth is that the system is not a linear one, but a non-linear one, in which the parts are constantly interacting with each other in a non-linear fashion. The tenth is that the system is not a deterministic one, but a probabilistic one, in which the parts are constantly interacting with each other in a probabilistic fashion.

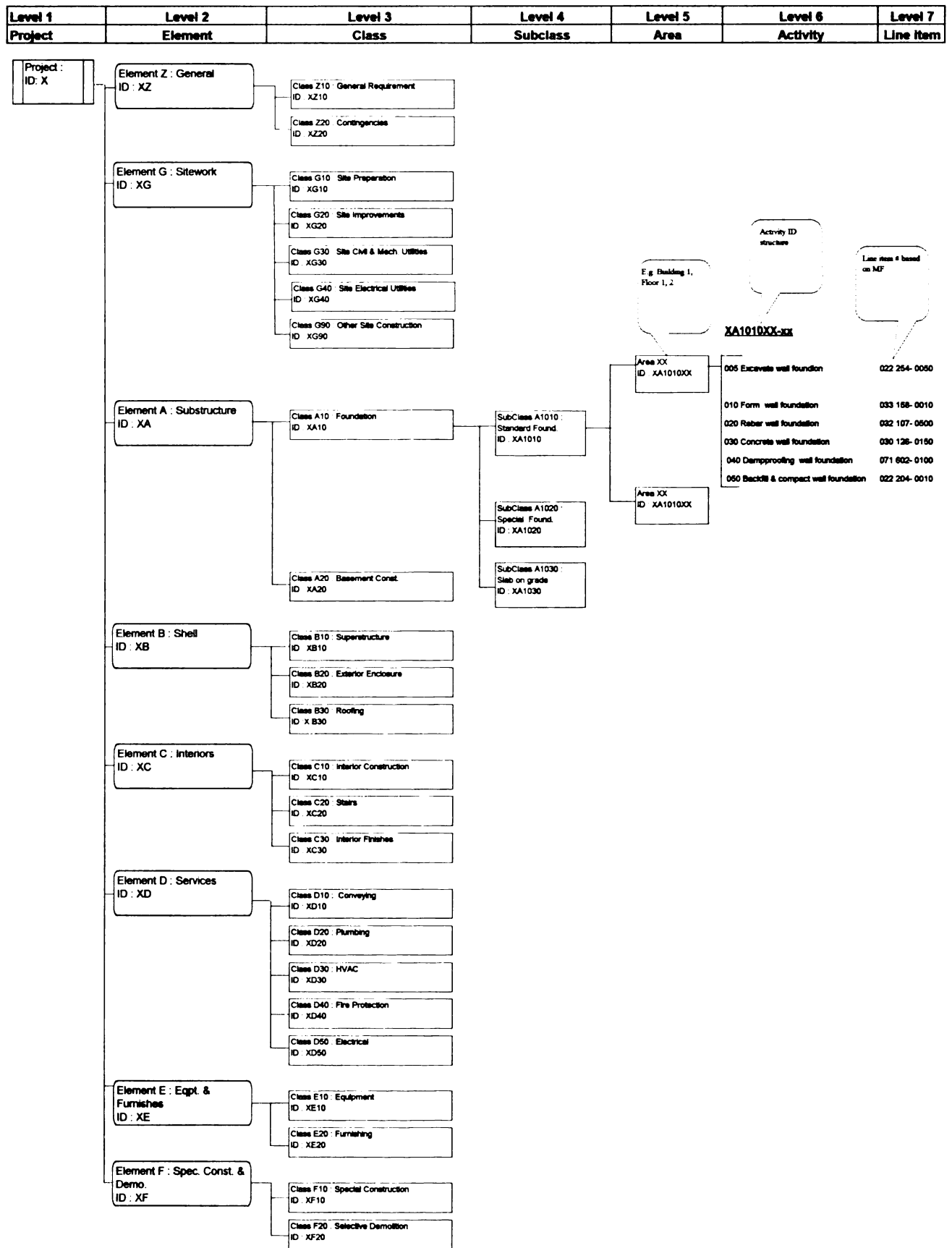


Figure 4.1: PBS Generic Model

Table 4.1: Project Breakdown Structure (PBS)
(Detailed Model)

Note: Underline words shows the code of a component

Level 1: PROJECT	Level 2: ELEMENT	Level 3: CLASS	Level 4: SUBCLASS	Level 5: AREA	Level 6: ACTIVITY	Level 7: LINE ITEM
Project <u>X</u>						
	<u>Element Z GENERAL</u> <u>XZ</u>					
		Z10 General Requirements <u>XZ10</u>	Z1010 Administration <u>XZ1010</u>	Area (s) XX <u>XZ1010XX</u> e.g. Floor 1	Activity (s) xx <u>XZ1010XXxx</u> e.g. - 05 Site supervision	Line Item (s) On Master Format basis)
			Z1020 Quality Requirements <u>XZ1020</u>	Area (s) XX <u>XZ1020XX</u>	Activity (s) xx <u>XZ1020XXxx</u>	Line Item (s)
			Z1030 Temporary Facilities <u>XZ1030</u>	Area (s) XX <u>XZ1030XX</u>	Activity (s) xx <u>XZ1030XXxx</u> e.g. - 03 Provision of temp. electricity - 05 Provision of temp. water - 07 Provision of temp. roads - 11 provision of field offices and sheds	Line Item (s)
			Z1040 Project Closeout <u>XZ1040</u>	Area (s) XX <u>XZ1040XX</u>	Activity (s) xx <u>XZ1040XXxx</u>	Line Item (s)
			Z1050 Permits, Insurance, And Bonds <u>XZ1050</u>	Area (s) XX <u>XZ1050XX</u>	Activity (s) xx <u>XZ1050XXxx</u>	Line Item (s)
			Z1060 Fee <u>XZ1060</u>	Area (s) XX <u>XZ1060XX</u>	Activity (s) xx <u>XZ1060XXxx</u>	Line Item (s)
		Z20 Contingencies <u>XZ20</u>	Z2010 Design Contingency <u>XZ2010</u>	Area (s) XX <u>XZ2010XX</u>	Activity (s) xx <u>XZ2010XXxx</u>	Line Item (s)
			Z2020 Escalation Contingency <u>XZ2020</u>	Area (s) XX <u>XZ2020XX</u>	Activity (s) xx <u>XZ2020XXxx</u>	Line Item (s)
			Z2030 Construction Contingency <u>XZ2030</u>	Area (s) XX <u>XZ2030XX</u>	Activity (s) xx <u>XZ2030XXxx</u>	Line Item (s)
	<u>Element G BUILDING SITEWORK</u> <u>XG</u>					
		G10 Site Preparation <u>XG10</u>	G1010 Site Clearing <u>XG1010</u>	Area (s) XX <u>XG1010XX</u>	Activity (s) xx <u>XG1010XXxx</u>	Line Item (s)
			G1020 Site Demolition & Relocation <u>XG1020</u>	Area XX <u>XG1020XX</u>	Activity (s) xx <u>XG1020XXxx</u>	Line Item (s)

			G1030 Site Earthwork <u>XG1030</u>	Area XX <u>XG1030XX</u>	Activity (s) xx <u>XG1030XXxx</u>	Line Item (s)
			G1040 Hazardous Waste Remediation <u>XG1040</u>	Area XX <u>XG1040xx</u>	Activity (s) xx <u>XG1040XXxx</u>	Line Item (s)
			G2010 Roadways <u>XG2010</u>	Area XX <u>XG2010XX</u>	Activity (s) xx <u>XG2010XXxx</u>	Line Item (s)
			G2020 Parking Lots <u>XG2020</u>	Area XX <u>XG2020XX</u>	Activity (s) xx <u>XG2020XXxx</u>	Line Item (s)
			G2030 Pedestrian Paving <u>XG2030</u>	Area XX <u>XG2030XX</u>	Activity (s) xx <u>XG2030XXxx</u>	Line Item (s)
			G2040 Site Development <u>XG2040</u>	Area XX <u>XG2040</u>	Activity (s) xx <u>XG2040XXxx</u>	Line Item (s)
			G2050 Landscaping <u>XG2050</u>	Area XX <u>XG2050XX</u>	Activity (s) xx <u>XG2050XXxx</u>	Line Item (s)
			G3010 Water Supply <u>XG3010</u>	Area XX <u>XG3010XX</u>	Activity (s) xx <u>XG3010XXxx</u>	Line Item (s)
			G3020 Sanitary Sewer <u>XG3020</u>	Area XX <u>XG3020XX</u>	Activity (s) xx <u>XG3020XXxx</u>	Line Item (s)
			G3030 Storm Sewer <u>XG3030</u>	Area XX <u>XG3030XX</u>	Activity (s) xx <u>XG3030XXxx</u>	Line Item (s)
			G3040 Heating Distribution <u>XG3040</u>	Area XX <u>XG3040XX</u>	Activity (s) xx <u>XG3040XXxx</u>	Line Item (s)
			G3050 Cooling Distribution <u>XG3050</u>	Area XX <u>XG3050XX</u>	Activity (s) xx <u>XG3050XXxx</u>	Line Item (s)
			G3060 Fuel Distribution <u>XG3060</u>	Area XX <u>XG3060XX</u>	Activity (s) xx <u>XG3060XXxx</u>	Line Item (s)
			G3090 Other Site Mechanical Utilities <u>XG3090</u>	Area XX <u>XG3090XX</u>	Activity (s) xx <u>XG3090XXxx</u>	Line Item (s)
			G4010 Electrical Distribution <u>XG4010</u>	Area XX <u>XG4010</u>	Activity (s) xx <u>XG4010xx</u>	Line Item (s)
			G4020 Site Lighting <u>XG4020</u>	Area XX <u>XG4020XX</u>	Activity (s) xx <u>XG4020XXxx</u>	Line Item (s)
			G4030 Site Communications & Sec. <u>XG4030</u>	Area XX <u>XG4030XX</u>	Activity (s) xx <u>XG4030XXxx</u>	Line Item (s)
			G20 Site Improvements <u>XG20</u>			
			G30 Site Civil & Mech. Utilities <u>XG30</u>			
			G40 Site Electrical Utilities <u>XG40</u>			

			G-090 Other Site Electrical Utilities XG4090	Area XX XG4090XX	Activity (s) xx XG4090XXxx	Line Item (s)
		G90 Other Site Construction XG290	G9010 Service Tunnels XG9010 G9090 Other Site Systems XG9090	Area XX XG9010XX Area XX XG9090XX	Activity (s) xx XG9010XXxx Activity (s) xx XG9090XXxx	Line Item (s) Line Item (s)
		Element A SUBSTRUCTURE XA				
		A10 Foundations A10	A1010 Standard Foundations XA1010	Area XX XA1010XX	Activity (s) xx XA1010XXxx e.g. - 03 Excavate wall foundation - 05 Form wall foundation - 07 Rebar wall foundation - 09 Pour concrete wall foundation - 11 Dump proofing wall foundation - 12 Backfill & compact wall foundation	Line Item (s)
			A1020 Special Other Foundations XA1020 A1030 Slab On Grade XA1030	Area XX XA1020XX Area XX XA1030XX	Activity (s) xx XA1020XXxx Activity (s) xx XA1030XXxx	Line Item (s) Line Item (s)
		A20 Basement Construction A20	A2010 Basement Excavation XA2010 A2020 Basement Walls XA2020	Area XX XA2010XX Area XX XA2020XX	Activity (s) xx XA2010XXxx Activity (s) xx XA2020XXxx	Line Item (s) Line Item (s)
		Element B SHELL XB				
		B10 Superstructure XB10	B1010 Floor Construction XB1010 B1020 Roof Construction XB1020	Area XX XB1020XX Area XX XB1020XX Area XX XB2010XX	Activity (s) xx XB1020XXxx Activity (s) xx XB1020XXxx Activity (s) xx XB2010XXxx	Line Item (s) Line Item (s) Line Item (s)
		B20 Exterior Enclosure XB20	B2010 Exterior Walls XB2010 B2020 Exterior Windows XB2020 B2030 Exterior Doors XB2030	Area XX XB2020XX Area XX XB2030XX	Activity (s) xx XB2020XXxx Activity (s) xx XB2030XXxx	Line Item (s) Line Item (s) Line Item (s)

		B30 Roofing B30	B3010 Roof Coverings B3010	Area XX XB3010XX	Activity (s) xx XB3010XXxx	Line Item (s)
			B3020 Roof Openings B3020	Area XX XB3020XX	Activity (s) xx XB3020XXxx	Line Item (s)
	Element C INTERIORS XC					
		C10 Interior Construction XC10	C1010 Partitions XC1010	Area XX XC1010XX	Activity (s) xx XC1010XXxx	Line Item (s)
			C1020 Interior Doors XC1020	Area XX XC1020XX	Activity (s) xx XC1020xx	Line Item (s)
			C1030 Fittings Specialties XC1030	Area XX XC1030XX	Activity (s) xx XC1030xx	Line Item (s)
		C20 Stairs XC20	C2010 Stair Construction XC2010	Area XX XC2010XX	Activity (s) xx XC2010XXxx	Line Item (s)
			C2020 Stair Finishes XC2020	Area XX XC2020XX	Activity (s) xx XC2020xx	Line Item (s)
		C30 Interior Finishes XC30	C3010 Wall Finishes XC3010	Area XX XC3010 XX	Activity (s) xx XC3010 XXxx	Line Item (s)
			C3020 Floor Finishes XC3020	Area XX XC3020XX	Activity (s) xx XC3020XXxx	Line Item (s)
			C3030 Ceiling Finishes XC3030	Area XX XC3030 XX	Activity (s) xx XC3030 XXxx	Line Item (s)
	Element D SERVICES XD					
		D10 Conveying XD10	D1010 Elevators And Lifts XD1010	Area XX XD1010XX	Activity (s) xx XD1010XXxx	Line Item (s)
			D1020 Escalators And Moving Walks XD1020	Area XX XD1020XX	Activity (s) xx XD1020XXxx	Line Item (s)
			D1090 Other Conveying Systems XD1090	Area XX XD1090XX	Activity (s) xx XD1090XXxx	Line Item (s)
		D20 Plumbing XD20	D2010 Plumbing Fixtures XD2010	Area XX XD2010XX	Activity (s) xx XD2010XXxx	Line Item (s)
			D2020 Domestic Water Distribution XD2020	Area XX XD2020XX	Activity (s) xx XD2020XXxx	Line Item (s)
				Area XX	Activity (s) xx	Line Item (s)

			D2030 Sanitary Waste XD2030	XD2030XX	XD2030XXxx	Line Item (s)
			D2040 Rain Water Drainage XD2040	Area XX XD2040XX	Activity (s) xx XD2040XXxx	Line Item (s)
			D2090 Other Plumbing Systems XD2090	Area XX XD2090XX	Activity (s) xx XD2090XXxx	Line Item (s)
			D3010 Energy Supply XD3010	Area XX XD3010XX	Activity (s) xx XD3010XXxx	Line Item (s)
			D3020 Heat Generation XD3020	Area XX XD3020XX	Activity (s) xx XD3020XXxx	Line Item (s)
			D3030 Refrigeration XD3030	Area XX XD3030XX	Activity (s) xx XD3030XXxx	Line Item (s)
			D3040 HVAC Distribution XD3040	Area XX XD3040XX	Activity (s) xx XD3040XXxx	Line Item (s)
			D3050 Terminal And Packaged Units XD3050	Area XX XD3050XX	Activity (s) xx XD3050XXxx	Line Item (s)
			D3060 HVAC Instrumentation And Controls XD3060	Area XX XD3060XX	Activity (s) xx XD3060XXxx	Line Item (s)
			D3070 Testing, Adjusting, And Balancing XD3070	Area XX XD3070XX	Activity (s) xx XD3070XXxx	Line Item (s)
			D3090 Other Special HVAC Systems And Eqp XD3090	Area XX XD3090XX	Area XX XD3090XXxx	Line Item (s)
			D4010 Fire Protection XD4010	Area XX XD4010XX	Area XX XD4010XXxx	Line Item (s)
			D4020 Standpoints XD4020	Area XX XD4020XX	Area XX XD4020XXxx	Line Item (s)
			D4030 Fire Protection Spec. XD4030	Area XX XD4030XX	Area XX XD4030XXxx	Line Item (s)
			D4090 Others Fire Protection Systems XD4090	Area XX XD4090XX	Area XX XD4090XXxx	Line Item (s)
			D5010 Electrical Service And Distributio XD5010	Area XX XD5010XX	Activity (s) xx XD5010XXxx	Line Item (s)
			D5020 Lighting And Branch Wiring XD5020	Area XX XD5020XX	Activity (s) xx XD5020XXxx	Line Item (s)

			D5030 Communications And Security <u>XD5030</u>	Area XX <u>XD5030XX</u>	Activity (s) xx <u>XD5030XXxx</u>	Line Item (s)
			D5090 Other Electrical Systems <u>XD5030</u>	Area XX <u>XD5030XX</u>	Activity (s) xx <u>XD5030XXxx</u>	Line Item (s)
			Element E EQUIPMENT & FURNISHINGS <u>XE</u>			
		E10 Equipment <u>XE10</u>	E1010 Commercial Equipment <u>XE1010</u>	Area XX <u>XE1010 XX</u>	Activity (s) xx <u>XE1010 XXxx</u>	Line Item (s)
			E1020 Institutional Equipment <u>XE1020</u>	Area XX <u>XE1012 XX</u>	Activity (s) xx <u>XE1020 XXxx</u>	Line Item (s)
			E1030 Vehicular Equipment <u>XE1030</u>	Area XX <u>XE1030XX</u>	Activity (s) xx <u>XE1030XXxx</u>	Line Item (s)
			E1090 Other Equipment <u>XE1090</u>	Area XX <u>XE1090XX</u>	Activity (s) xx <u>XE1090XXxx</u>	Line Item (s)
		E20 Furnishings <u>XE20</u>	E2010 Fixed Furnishings <u>XE2010</u>	Area XX <u>XE2010XX</u>	Activity (s) xx <u>XE2010XXxx</u>	Line Item (s)
			E2020 Moveable Furnishings <u>XE2020</u>	Area XX <u>XE2020XX</u>	Activity (s) xx <u>XE2020XXxx</u>	Line Item (s)
			Element F SPECIAL CONSTRUCTION & DEMOLITION <u>XF</u>			
		F10 Special Construction <u>XF10</u>	F1010 Special Structures <u>XF1010</u>	Area XX <u>XF1010XX</u>	Activity (s) xx <u>XF1010XXxx</u>	Line Item (s)
			F1020 Integrated Construction <u>XF1020</u>	Area XX <u>XF1020XX</u>	Activity (s) xx <u>XF1020XXxx</u>	Line Item (s)
			F1030 Special Construction Systems <u>X1030</u>	Area XX <u>X1030XX</u>	Activity (s) xx <u>X1030XXxx</u>	Line Item (s)
			F1040 Special Facilities <u>XF1040</u>	Area XX <u>XF1040 XX</u>	Activity (s) xx <u>XF1040 XXxx</u>	Line Item (s)
			F1050 Special Controls And Instrumentation <u>XF1050</u>	Area XX <u>XF1050XX</u>	Activity (s) xx <u>XF1050XXxx</u>	Line Item (s)
		F20 Selective Demolition <u>XF20</u>	F2010 Building Elements Demolition <u>XF2010</u>	Area XX <u>XF2010 XX</u>	Activity (s) xx <u>XF2010 XXxx</u>	Line Item (s)
			F2020 Hazardous Components Abatement <u>XF2020</u>	Area XX <u>XF2020XX</u>	Activity (s) xx <u>XF2020XXxx</u>	Line Item (s)

A PBS also provides a hierarchical coding system that corresponds to each level and components within a level. Each PBS component (such as project, element, class, subclass, area, and activity) is assigned a code for identification throughout the life of the project. This code will be used in the Primavera Project Planner (P3) and Timberline Precision Estimation (TPE) for the development of a schedule and an estimate for a sample project.

The various PBS levels are explained below.

4.2.1 Level 1: Project

An entire construction project is at the level 1 of the PBS (refer to Figure 4.1). A project is subdivided into components at the other levels. A project is a temporary endeavor undertaken to create a unique product or service. Temporary means that every project has a definite beginning and a definite end. Unique means that the product or service is different in some distinguishing way from all the similar products or services [PMBOK 1996]. For the scope of this research, the project being considered is a construction project and the product is a facility such as a commercial building complex. The owner provides the scope of the product (e.g., its intended purpose, financial limits, and completion time requirements) and broad performance specifications.

In the PBS, a project has a one-character unique identification (ID). It may be a number, or letter, for example, 1, 2, A, B. In figure 4.1 the project ID is shown as X. The project ID identifies a given project with an organization (company).

4.2.2 Level 2:Element

At Level 2 of the PBS, the project is broken down into “Elements”. Level 2 of the PBS is based on the titles and numbering system of level 1 of the UniFormat [1998]. There are nine categories at level 1 of the UniFormat, but only eight of them are incorporated at level two of

the PBS. These eight categories and their associated classes and subclasses define the basic parts of a constructed facility, and each basic part is characterized by its function.

The first category at the level 1 of the UniFormat is “ Project Description” which is not adopted in the PBS because it is not a physical part of facility, but rather, it is a related project information classification.

The element “Z: General”, which is the last category at level 1 of the Unifomat, is also not a physical part of the facility, instead, it contains the titles under which the project pre-construction activities such as mobilization and provision of temporary facilities could be grouped. “Z: General” is placed first at level 2 of the PBS because it includes the tasks/activities that are performed at the initiation of a project.

Similarly, the element “G: Site Work” is placed second at level 2 of the PBS because the activities it are executed at the start of the project, i.e., after the element Z activities.

Elements A through F are placed in alphabetical order at level 2 of the PBS.

The letters and titles of level 2 should not be changed so as preserve consistency in a coding system within an organization for various projects.

The elements of the PBS with the designation letters are listed as below:

- Element Z: GENERAL
- Element G: BUILDING SITEWORK
- Element A: SUBSTRUCTURE
- Element B: SHELL
- Element C: INTERIORS
- Element D: SERVICES
- Element E: EQUIPMENT AND FURNISHINGS

1. The first step in the process of the scientific method is to make an observation or ask a question. For example, a scientist might observe that a plant grows better in one type of soil than another.

2. Next, the scientist forms a hypothesis, which is a prediction or an educated guess about the outcome of an experiment. For example, the scientist might hypothesize that the plant will grow taller in soil A than in soil B.

3. The third step is to design and conduct an experiment to test the hypothesis. This involves setting up a controlled experiment where only one variable is changed at a time. In this case, the scientist would plant the same type of plant in two different soils and measure their growth.

4. After the experiment is completed, the scientist collects data and analyzes the results. This might involve measuring the height of the plants at regular intervals and comparing the growth rates.

5. Finally, the scientist draws a conclusion based on the data. If the data supports the hypothesis, the scientist might conclude that soil A is better for growing the plant. If the data does not support the hypothesis, the scientist might revise the hypothesis and repeat the experiment.

The scientific method is a systematic approach to investigating natural phenomena. It allows scientists to test their ideas and make discoveries about the world around us.

- Element F: SPECIAL CONSTRUCTION AND DEMOLITION

4.2.3 Level 3:Class

At level 3 of the PBS, each element is decomposed into classes. Level 3 of the PBS is based on the titles and numbering system of level 2 of the UniFormat. There are a total of twenty-five classes at level 3 in the eight elements of the PBS (refer to table 4.1). A four-character alphanumeric ID designates each class within the PBS; e.g., X A 10. The first character “X”, is the project ID (refer section 4.2.1), while the second character (alpha) comes from the parent element to which the class belongs and the last two characters (numeric) are added as an ID for the class within a particular element.

For Example:

Level 1 Project: A building construction project (X)

Level 2 Element A: Substructure (X A)

Level 3 Class A 10: Foundation (X A 10)

The letters and titles of level 3 (except the project ID) should not be changed so as to maintain consistency in coding a system within an organization for various projects.

4.2.4 Level 4:Subclass

At level 4 of the PBS, each class is further decomposed into subclasses. Level 4 of the PBS is based on the titles and numbering system of level 3 of the UniFormat. The twenty-five classes at level 3 of the PBS are divided into eighty-eight subclasses at level 4 (refer to Table 4.1). A six-character alphanumeric ID designates each subclass e.g. X A 10 10.

For Example:

Level 1 Project: A building construction project (X)

Level 2 Element A: Substructure (X A)

THE UNIVERSITY OF CHICAGO PRESS

THE UNIVERSITY OF CHICAGO PRESS 1

THE UNIVERSITY OF CHICAGO PRESS 1

THE UNIVERSITY OF CHICAGO PRESS 1

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THE UNIVERSITY OF CHICAGO PRESS 1

THE UNIVERSITY OF CHICAGO PRESS 1

1

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Level 3 Class A 10: Foundation (X A 10)

Level 4 Subclass A1010: Standard foundations (X A 10 10)

The letters and titles of level 4(except project ID) should not be changed so as to maintain consistency in coding a system within an organization for various projects.

4.2.5 Level 5: Area

At level 5 of the PBS, each subclass is assigned to its area of execution or the area where the items of a subclass finally belong. For Example, Subclass “A1010 Standard Foundation” can be assigned to building No.1, 2 or 3. Similarly, for a multi-story building, the columns and beams can be assigned to Floor No 1, 2, or 3.

In the PBS, “Area” has a two-character unique identification (ID). It may be numbers, letters or a combination, for example, 12, B1, or F1. In figure 4.1(PBS generic model), the Area ID is shown by XX.

4.2.6 Level 6: Activity

At level 6 of the PBS, the project is extended to the activity level. An activity is a single work step that has a recognizable beginning and end. Activities are time-consuming and resource-consuming tasks. The time that an activity requires to complete is called its duration [CQR 1992]. One of the main purposes of the PBS is to break down the project successively and systematically to the activity level so that an efficient and practical schedule can be developed. The quantities computed during the takeoff (quantity surveying) are then allocated to corresponding activities, and subsequent pricing for each activity is carried out to generate the cost estimate.

The size of each activity may vary depending on the type of work involved and the importance of the activity to project completion. No activity, however, should be so small as

1. The first part of the paper is devoted to the study of the properties of the function $f(x)$ defined by the equation

$$f(x) = \int_0^x \frac{1}{1+t^2} dt, \quad (1)$$

where x is a real number. It is well known that this function is increasing and concave down on the interval $(-\infty, \infty)$.

2. In the second part, we consider the function $g(x)$ defined by the equation

$$g(x) = \int_0^x \frac{1}{1+t^4} dt, \quad (2)$$

where x is a real number. It is well known that this function is increasing and concave down on the interval $(-\infty, \infty)$.

3. In the third part, we consider the function $h(x)$ defined by the equation

$$h(x) = \int_0^x \frac{1}{1+t^6} dt, \quad (3)$$

where x is a real number. It is well known that this function is increasing and concave down on the interval $(-\infty, \infty)$.

4. In the fourth part, we consider the function $k(x)$ defined by the equation

$$k(x) = \int_0^x \frac{1}{1+t^8} dt, \quad (4)$$

where x is a real number. It is well known that this function is increasing and concave down on the interval $(-\infty, \infty)$.

5. In the fifth part, we consider the function $l(x)$ defined by the equation

$$l(x) = \int_0^x \frac{1}{1+t^{10}} dt, \quad (5)$$

where x is a real number. It is well known that this function is increasing and concave down on the interval $(-\infty, \infty)$.

6. In the sixth part, we consider the function $m(x)$ defined by the equation

$$m(x) = \int_0^x \frac{1}{1+t^{12}} dt, \quad (6)$$

where x is a real number. It is well known that this function is increasing and concave down on the interval $(-\infty, \infty)$.

7. In the seventh part, we consider the function $n(x)$ defined by the equation

$$n(x) = \int_0^x \frac{1}{1+t^{14}} dt, \quad (7)$$

where x is a real number. It is well known that this function is increasing and concave down on the interval $(-\infty, \infty)$.

8. In the eighth part, we consider the function $o(x)$ defined by the equation

$$o(x) = \int_0^x \frac{1}{1+t^{16}} dt, \quad (8)$$

where x is a real number. It is well known that this function is increasing and concave down on the interval $(-\infty, \infty)$.

9. In the ninth part, we consider the function $p(x)$ defined by the equation

$$p(x) = \int_0^x \frac{1}{1+t^{18}} dt, \quad (9)$$

where x is a real number. It is well known that this function is increasing and concave down on the interval $(-\infty, \infty)$.

to unnecessarily complicate or lengthen the schedule, or so large that the work cannot be controlled. For example, a construction schedule activity should never be as small as the units of reach, move, turn or release, etc. A construction schedule activity should be not as large as a major phase of a construction project, such as “interior finish”, or “electrical work” because such major activities themselves consist of smaller activities. By preparing a schedule with major activities, the dependency among minor activities is not disclosed [CQR 1992].

The activities will be the main focus in the PBS approach because their completion achieves the objective and goals of the project. An activity is the main planning unit in the PBS. Beside the essential attributes (activity ID, description, and duration), the following attributes will be assigned to each activity so that the schedule can be used as an efficient project management tool for the planning and controlling of time, cost, and resources.

- Cost
- Responsibility for the execution
- Resources required
- Location of execution
- Type of activity, i.e. milestone, task, independent, meeting , hammock

Each activity has a unique ID (extended systematically from level 1 through level 6) so that it can be identified during the various phases of the project. Similarly the ID will facilitate the filtering and sorting in the computer system. At present, there is no standard or code for specifying activity ID's. The PBS provides an efficient and systematic activity ID structure (see Fig 4.2) that could be adopted for all building projects. The activity ID should not

exceed 10 characters so that it could be used in P3, which allows only ten characters for an activity ID.

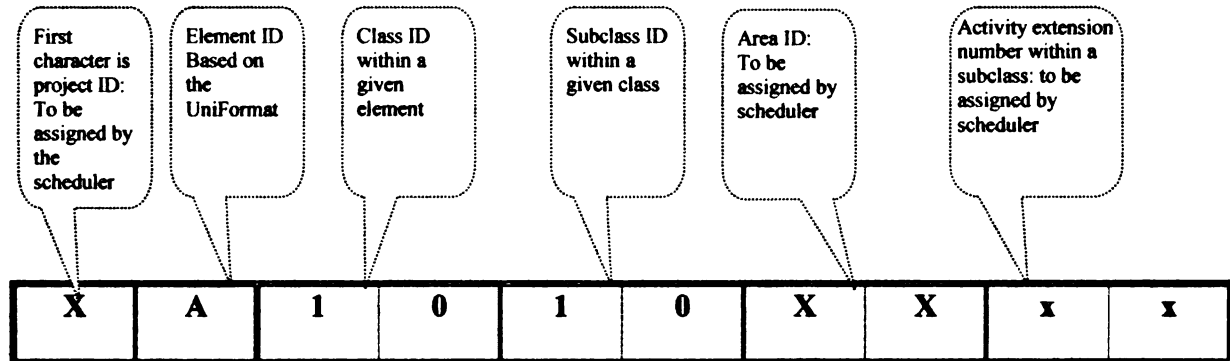


Figure 4.2 Activity ID Structure

For example, the activity “Excavate wall foundation” of building No. 1 in a project “P” will have the following ID:

P A 10 10 B1 05

Where “P” is the project ID, “A” is the ID of element substructure, the first “10” is the ID of the class foundation, the second “10” is the ID of the subclass within a class, B1 is the area ID and 05 is the specific activity number within a subclass.

The activity ID will also be assigned to cost line items in the cost estimate so as to facilitate tracking of activity cost. TPE do not have a provision for assigning activity ID to the cost line items; therefore the “location field” of the TPE will be used for this purposes.

4.2.7 Level 7: Cost Line Item

At level 6 of the PBS, each activity is decomposed into its cost line items for estimation purposes. The line item is an individual cost component. Cost line items are the smallest division of the work to be analyzed [Bledsoe 1992]. It may be a material such as 3000-psi ready- mix concrete, a process such as back filling of earth or combination of material and

process such as installation of a door. The CSI MasterFormat system is widely used in the United States for the classification of construction products and process. Refer to section 3.2.2 for more details.

4.3 STEPS FOR GENERATION OF CONSTRUCTION SCHEDULE AND COST ESTIMATE ON BASIS OF PBS

The steps suggested by the author for the generation of construction schedule and cost estimate on the basis of PBS have been presented in the form of a process flow diagram (PFD) as shown in Figure 4.3. PFD has been developed by the author on the basis of his eight years practical experience in managing construction projects, and the knowledge he gained during the Masters Program. The PFD depicts generation of construction schedule and cost estimate on the basis of PBS in a design-build environment, but it can be easily modified for fast track projects, in which the design is finalized in steps along with execution of the construction work.

Besides design-built environment, PBS can also be used for the development of construction schedule and cost estimate in other contract delivery arrangements such as design-bid-build and Construction Management environments.

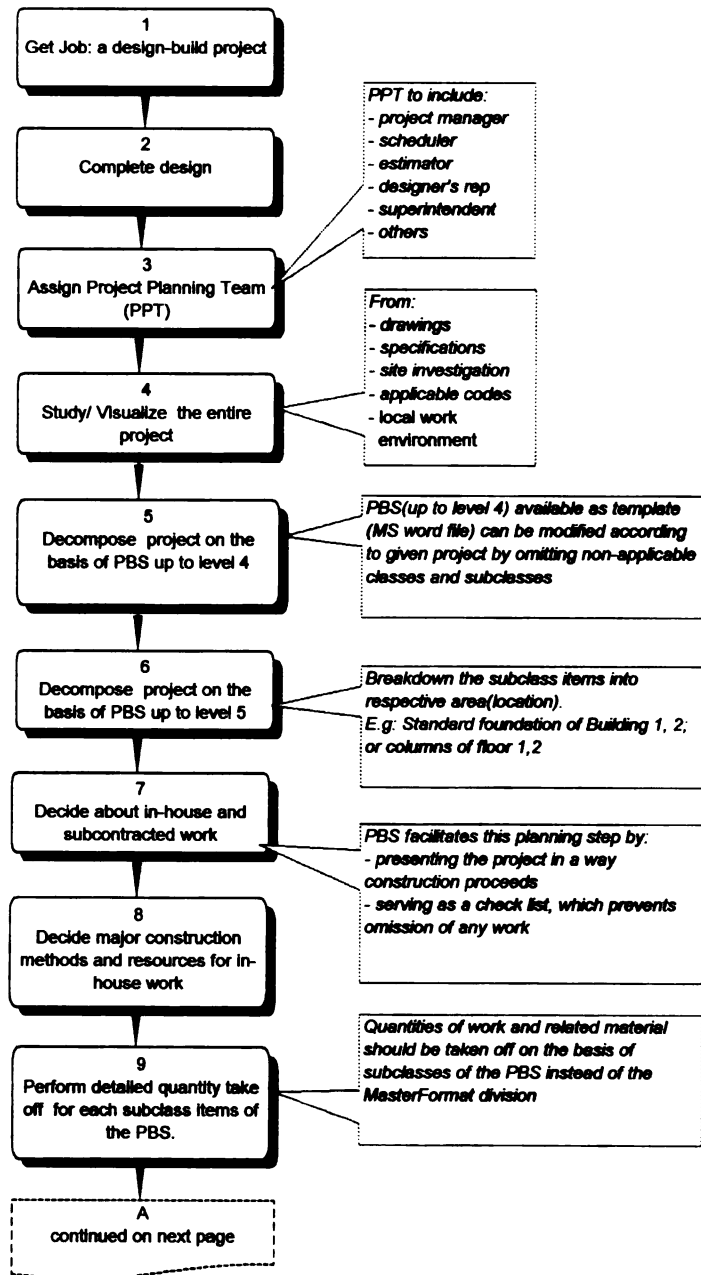


Figure 4.3 : Process Flow diagram for generation of schedule and cost estimate on basis of PBS

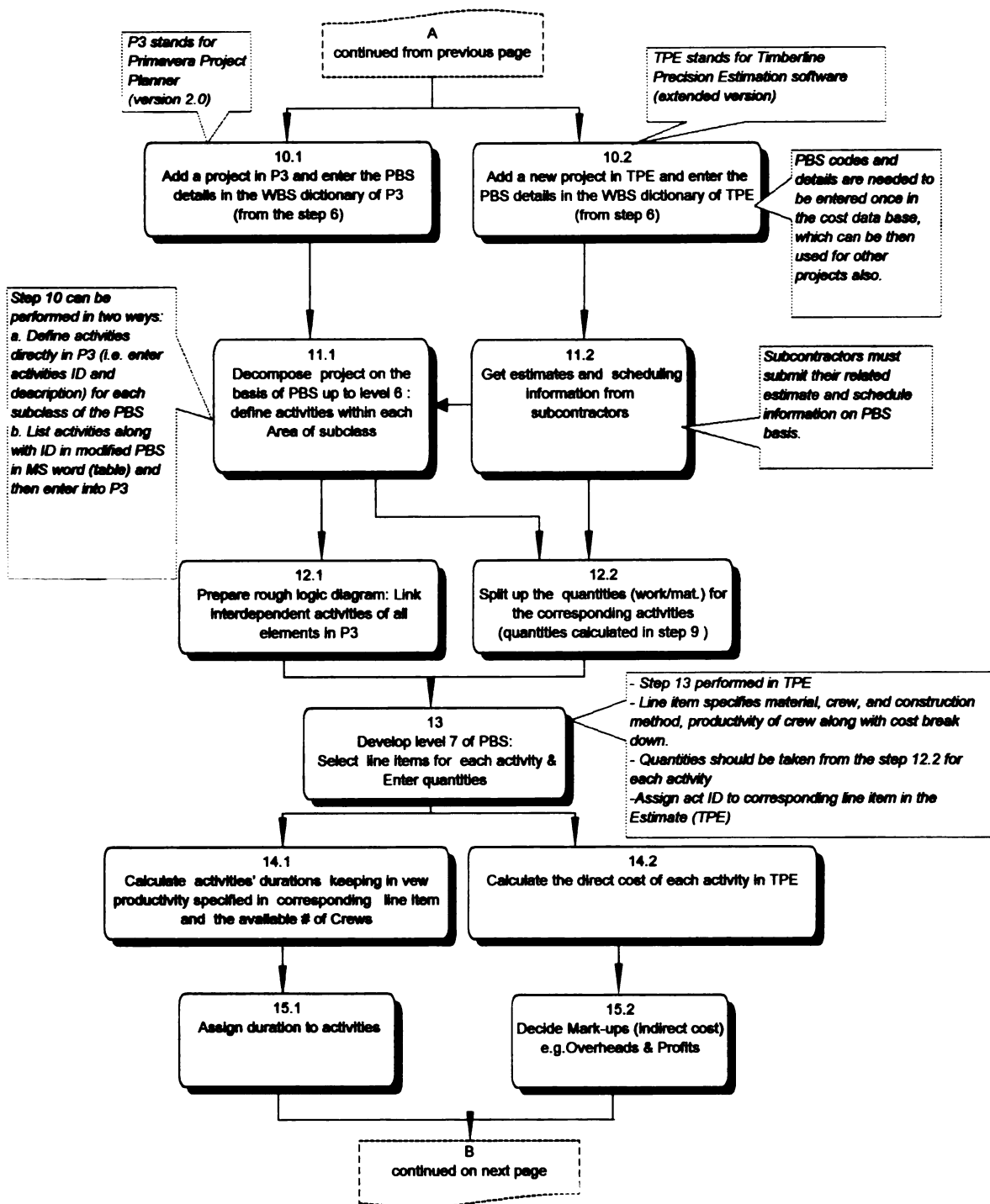


Figure 4.3 (cont'd)

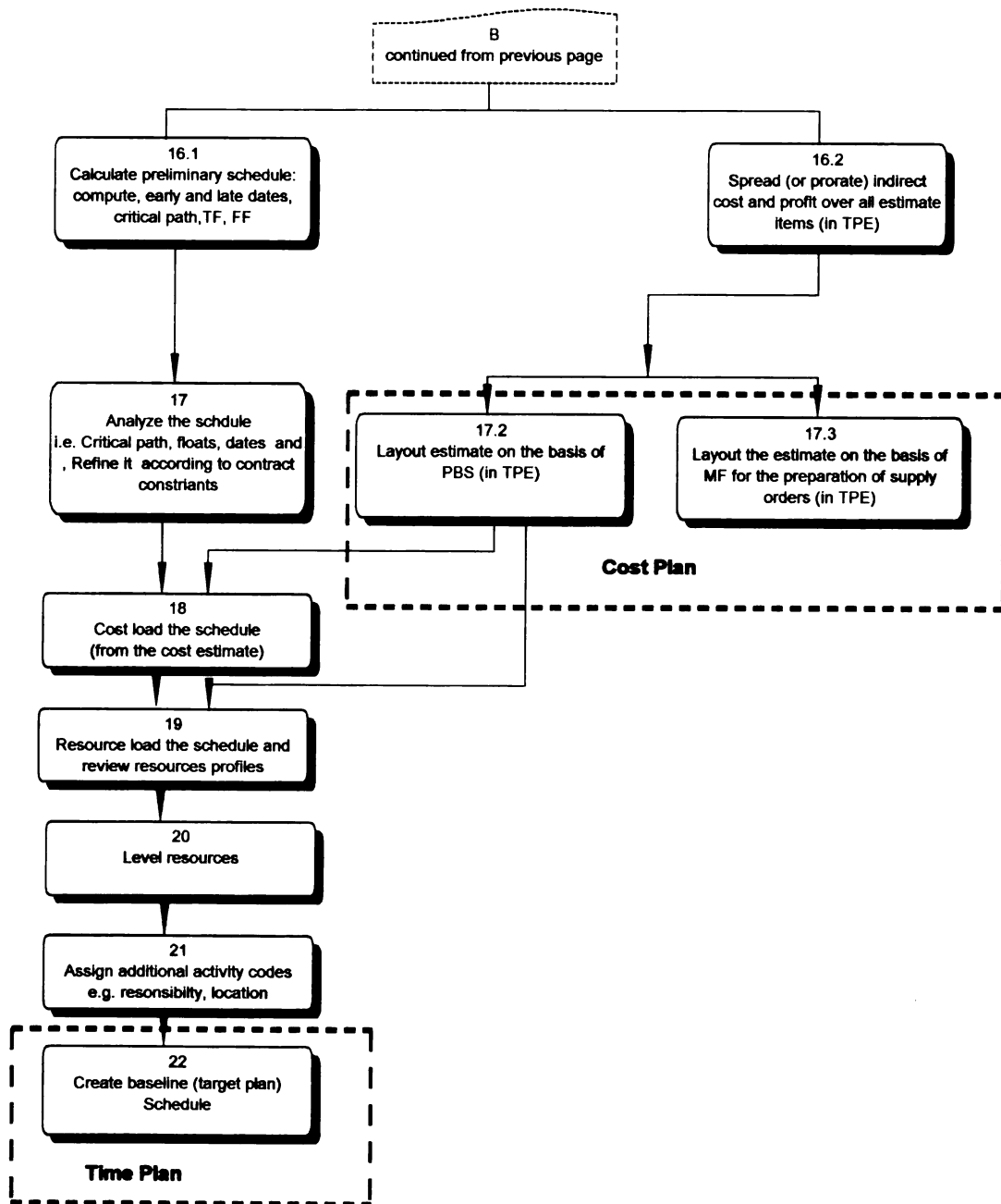


Figure 4.3 (cont'd)

4.4 ADVANTAGES OF PBS

The advantages of the PBS are listed below:

- a. The PBS provides a standard WBS for development of construction schedule for building projects. This relieves the scheduler of deciding how to breakdown each project for scheduling purposes.
- b. The PBS can be adopted as WBS for the development of cost estimate. This cost estimate will provide a cost breakdown of a project on the basis of its major building component, such as foundation, shell (walls, columns, roof) or interiors. In this way, the PBS will facilitate value engineering. The cost estimate developed on the basis of the PBS can be easily presented (without re-entering of the data) on the basis of Masterformat, which is the default WBS in TPE.
- c. As the PBS provides the development of a construction schedule and cost estimate on a common format and thus integration can be achieved through it. Information exchange between the two can be performed without manipulation. For example, costs from line items in the estimate can be readily assigned to corresponding activities in the schedule; activity durations for the schedule can be calculated from the crew productivity used in the cost estimate. Similarly, the crews adopted in the cost estimate can be assigned to the corresponding activities in the schedule. The resource leveling and smoothing can be then carried out in the scheduling.
- d. The PBS can be adopted for any building project. The schedule developed on the basis for a given project can be used as a template for the development of similar other projects.

- e. The PBS is not a theoretical model. It is adaptable both in P3 and TPE. Construction schedule and cost estimate for the sample project “SYED” (presented in chapter 5) has been developed on the basis of PBS in the P3 and TPE, respectively.
- f. The PBS provides a systematic and intelligent activity ID structure that can be easily customized for a given project. This activity ID structure allows the insertion/deletion of activities at the later stages. This activity ID structure can be used for filtering and sorting purposes and thus facilitates in schedule analysis and resource planning. The same activity ID can be assigned to cost line items in the TPE in the “location field”, so that activity costs can be tracked in the cost estimate. (The TPE do not have any provision for attributing the activity ID with the cost line items. Therefore, author utilized the “location field” for that purpose.)
- g. PBS provides a specific place for each activity within a schedule. For example, the foundation activities are placed in the “subclass XA1010: standard foundation” and “subclass XA1020: Special foundation”. Similarly the slab on grade activities are placed in the “ subclass XA1030: Slab on Grade”.
- h. As the activity ID structure has two-character sub-ID for “Area” (see section 4.2.5), this allows the filtering/sorting of the activities for a particular portion of the project. For example, the activities of a multistory building project can be assigned the following sub-ID’s for each floor :

Floor 1: F1

Floor 2: F2

Common over all project activities: OP

Similarly if a project consists of more than one building, sub-codes can be assigned as B1, B2, etc.

- i. The PBS serves as checklist while preparing schedules and cost estimates.
- j. The PBS can be used for the development of a schedule for project group within a company and in this way the different projects can be integrated. This integrated schedule for various projects will facilitate resource planning and control.

Chapter 5

PBS APPLICATION

5.1 OVERVIEW

This chapter presents a construction schedule and a cost estimate developed on the basis of PBS for a sample project named as “SYED”. The construction schedule and cost estimate were developed in parallel by exchanging the project information with one another as shown in the process flow diagram (PFD) in Figure 4.3.

Project “SYED” consists of construction of a two-storied concrete structure building of 4800 SF floor area. Site layout, building plan and building cross section are provided in appendix B. Only the site work and structure activities are presented for illustration purposes.

The integration between the construction schedule and cost estimate is achieved through the following:

- a. Common work breakdown structure, i.e. PBS
- b. A unique activity ID for each activity.

Both the schedule and estimate are laid out by the PBS, and activity ID’s are assigned to each line item in the cost estimate besides activities in the schedule.

This chapter also presents a traditional construction schedule and a cost estimate for the sample project for the comparison purposes.

5.2 CONSTRUCTION SCHEDULE ON BASIS OF PBS

The construction schedule was generated in P3. PBS codes were entered into the WBS code

dictionary of P3. Besides PBS, activity codes were entered into the activity code dictionary, which can be used in conjunction with PBS for advance filtering and sorting. Intelligent activity ID's (discussed in section 4.2.6) were assigned to the activities.

The following reports/layouts were generated in P3 for the sample project.

- PBS code report (Table 5.1)
- Activity codes report (Table 5.2)
- Detailed PBS layout (Figure 5.1)
- Summary PBS Layout- PBS (Figure 5.2)
- Classic Schedule Layout (Figure 5.3)
- Formwork Activities Layout (Figure 5.4)

5.2.1 Detailed PBS Layout

This layout (Figure 5.1): depicts the entire project activities grouped systematically into the various PBS levels. A different color is used for each PBS level. Every activity has a specified place in the PBS. E.g., all foundations-related activities are placed in the Class “Foundation” (code SA10). Similarly, activities related to columns and beams are placed in the Class “Superstructure” (code SB10). This layout also presents the blank PBS level so that activities can be added if needed. E.g. Class “Interior Construction” (code SC10), Class “Plumbing” (code SD20). The activity costs and resources (crews) were assigned to activities from the cost estimate. Similarly the activities’ durations were calculated on the basis of the productivity specified in the line items of the cost estimate. This layout is primarily meant for the site project managers and field superintendents who need detailed information about every aspect of the project such as activities scheduled dates or crew requirement for a given activity on a particular date. This layout can be used as “Schedule of Values” for progress

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5.2.2 Summary bars Layout- PBS up to level 3

This layout (Figure 5.2) is generated in P3 on the basis of PBS by summarizing the detailed PBS layout (Figure 5.1) to level 3. This layout does not show activities' details but instead presents information about a certain major portion of a project. For example, time required for the completion of superstructure, its scheduled start and finished dates, and the associated cost. This layout is very helpful for the top management who needs summarized information of all the projects in their control. This layout can be further rolled up to the next higher level of PBS such as level 2 and level 1. It is very useful for the site managers for the analysis, planning and control of a project; they often need to see the broader view of the project. The information presented in this layout can facilitate financial planning. Owners would know how much money is needed during a particular phase of the project.

5.2.3 Classic Schedule layout

This layout (Figure 5.3) presents all the project activities sorted on the basis of early start and total float. The intelligent activity ID's in combination with activity codes can be used for the filtering and sorting purposes.

5.2.4 Formwork Activities Layout

This layout (Figure 5.4) presents formwork and scaffolding activities of the second floor of the superstructure. This layout was generated from a classic schedule layout (figure 5.3) by utilizing the filtering feature of P3. Similar other useful layouts for specific purposes can be generated, such as concreting activities for the entire project or for a particular portion of a project.

Table 5.1 PBS Code Report

PRIMAVERA PROJECT PLANNER

PROJECT BREAKDOWN STRUCTURE (PBS)
(Common WBS)

SYED - Sample project for research thesis

WBS Code	Title
1S	Project Syed
1S.Z	Element Z:General
1S.Z.10	Class Z10:General requirement
1S.Z.10.30	Subclass Z1030:Temporary facilities
1S.Z.10.30.OP	Area OP:Temp.facilities- Over all project
1S.Z.10.40	Subclass Z1040: Project close out
1S.Z.10.40.OP	Area OP:Project close out-Over all project
1S.Z.20	Class Z20:Contegencies
2S	Project Syed
2S.G	Element G:Building sitework
2S.G.10	Class G10:Site preparation
2S.G.10.10	Subclass G1010:Site clearing
2S.G.10.10.OP	Area OP:Site clearing-Over all project
2S.G.10.30	Subclass G1030:Site earthwork
2S.G.10.30.OP	Area OP:Site work-Over all project site
2S.G.20	Class G20:Site improvements
2S.G.20.20	Subclass G2020:parking lots
2S.G.20.20.OP	Area OP:Parking lots-over all project site
2S.G.20.40	Subclass G2040:site development
2S.G.20.40.OP	Area OP:Site development- over all project
2S.G.30	Class G30:Site civil & mech. utilities
2S.G.40	Class G40:Site electrical utilities
3S	Project Syed
3S.A	Element A:Substructure
3S.A.10	Class A10:Foundations
3S.A.10.10	Subclass A1010:Standard foundations
3S.A.10.10.OP	Area OP:Stad.foundation Over all project site
3S.A.10.30	Subclass A1030:Slab on grade
3S.A.10.30.F1	Area A:Slab on garde-Floor 1
3S.A.20	Class A20:Basement construction
4S	Project Syed
4S.B	Element B:Shell
4S.B.10	Class B10:Superstructure
4S.B.10.10	Subclass B1010:Floor construction
4S.B.10.10.F1	Area F1:Floor const.-Floor 1
4S.B.10.10.F2	Area F2:Floor const.-Floor 2
4S.B.10.20	Subclass B1020:Roof construction
4S.B.10.20.RF	Area RF:Roof const.-Roof
4S.B.20	Class B20:Exterior enclosure
4S.B.20.10	Subclass B2010:Exterior walls
4S.B.20.10.F1	Area F1:Exterior walls-Floor 1
4S.B.20.10.F2	Area F2:Exterior walls-Floor 2
4S.B.20.20	Subclass B2020:Exterior windows
4S.B.20.20.F1	Area F1:Exterior windows-Floor 1
4S.B.20.20.F2	Area F2:Exterior windows-Floor 2
4S.B.20.30	Subclass B2030:Exterior doors
4S.B.20.30.F1	Area F1:Exterior doors-Floor 1

- 4S.B.30 Class B30:Roofing
 - 4S.B.30.10 Subclass B3010:Roof coverings
 - 4S.B.30.10.RF Area RF:Roof coverings-Roof
- 5S Project Syed
 - 5S.C Element C:Interiors
 - 5S.C.10 Class C10:Interior construction
 - 5S.C.10.10 Subclass C1010:Partitions
 - 5S.C.10.10.F1 Area F1:Partitions-Floor 1
 - 5S.C.10.10.F2 Area F2:Partitions-Floor 2
 - 5S.C.20 Class C20:Stairs
 - 5S.C.20.10 Subclass C2010:Stairs construction
 - 5S.C.20.10.OP Area OP:Stairs const.-Over all project site
 - 5S.C.30 Class C30:Interior finishes
 - 5S.C.30.10 Subclass 3010:Wall finishes
 - 5S.C.30.10.F1 Area F1:Wall finishes-Floor 1
 - 5S.C.30.10.F2 Area F2:Wall finishes-Floor 2
- 6S Project Syed
 - 6S.D Element D:Services
 - 6S.D.10 Class D10:Conveying
 - 6S.D.10.10 Subclass D1010:Elevators and lifts
 - 6S.D.10.10.OP Area OP:Elevators & lifts-Over all project
 - 6S.D.20 Class D20:Plumbing
 - 6S.D.30 Class D30:HVAC
 - 6S.D.50 Class D50:Electrical
- 7S Project Syed
 - 7S.E Element E:Eqpt.& furnishes
 - 7S.E.10 Class E10:Equipment
 - 7S.E.20 Class E20:Furnishing
- 8S Project Syed
 - 8S.F Element F:Special construction & demolition
 - 8S.F.10 Class F10:Special construction
 - 8S.F.20 Class F20:Selective demolition

Table 5.2:Activity Codes Report

PRIMAVERA PROJECT PLANNER

ACTIVITY CODES DICTIONARY

SYED - Sample project for research thesis

CODE	VALUE	TITLE	SEQUENCE
Activity Codes:			
JOB	Job Type		
	MOBLI	Mobilization & Start up	1
	EARTH	Earth Work	2
	FORMW	Form work and Scaffolding	3
	MASON	Masonry Work	4
	REBAR	Rebarring	5
	CONCR	Concreting	6
	WATER	Water proofing and Thermal insulation	7
	MECHE	Mechanical	8
	ELECT	Electrical	9
	DOORS	Doors and Window installation	10
	FINIS	Finishes	11
	METAL	Metal work	12
	DEMOB	Demobilization & Handing over	13
AREA	Area		
	OP	Overall Project	1
	F1	First Floor	2
	F2	Second Floor	3
	RF	Roof Floor (top roof)	4
	HD	Head Office	5

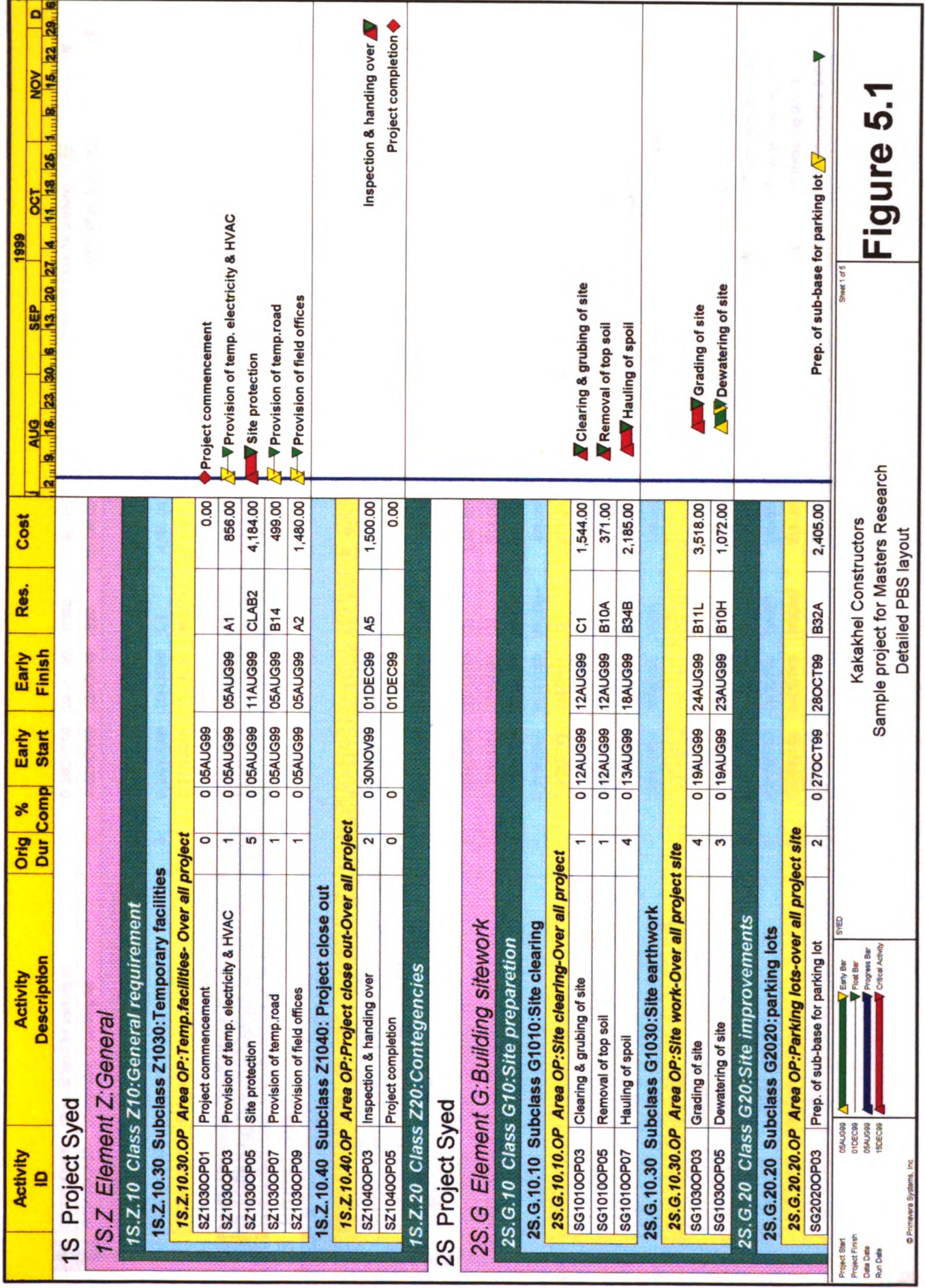
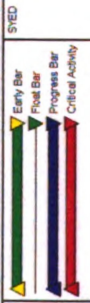


Figure 5.1

Kakakhel Constructors
Sample project for Masters Research
Detailed PBS layout



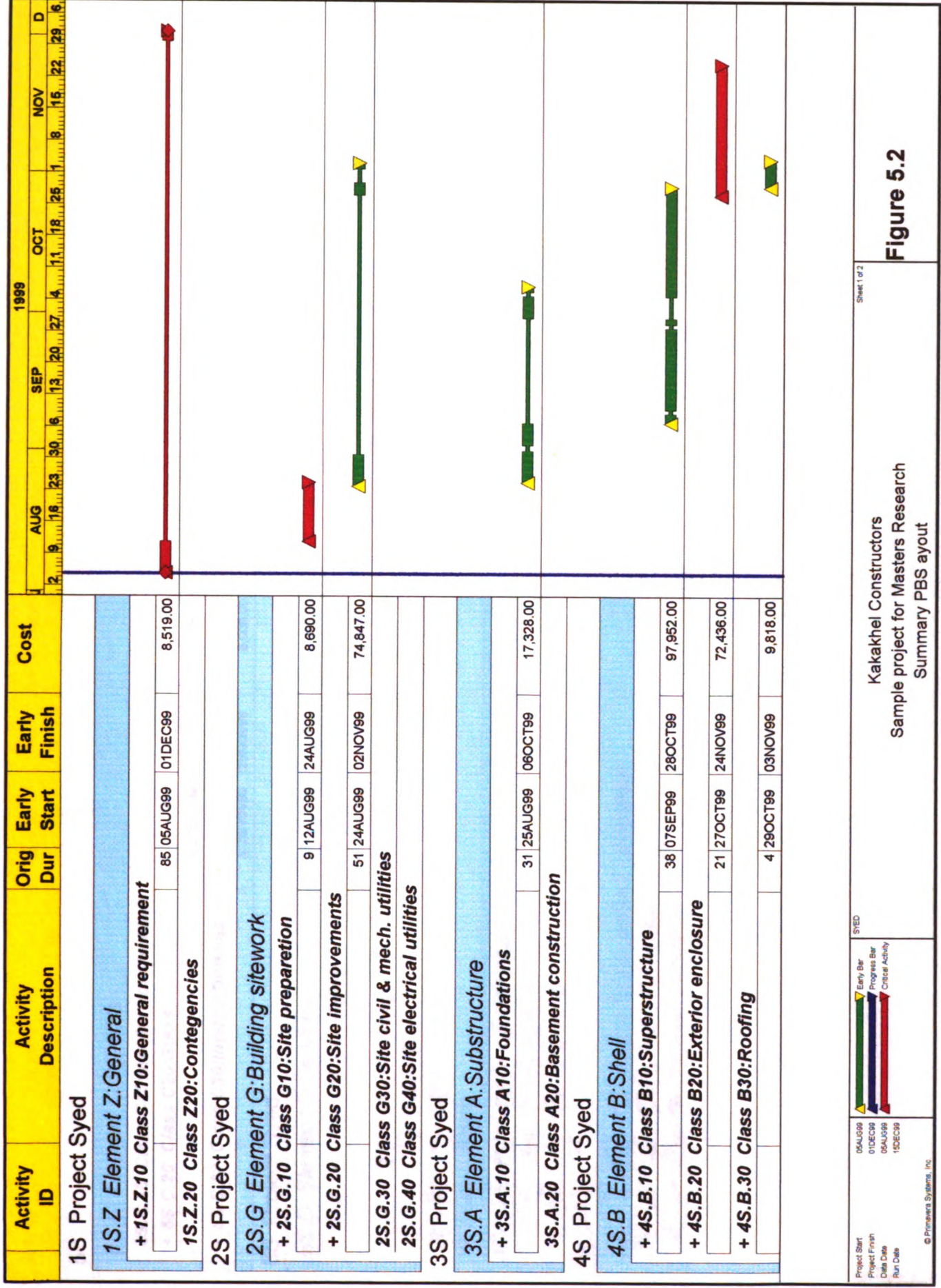
										1999 AUG SEP OCT NOV D											
Activity ID	Activity Description	Orig Dur	% Comp	Early Start	Early Finish	Res.	Cost														
SG2020OP05	Prep. of base for parking lot	1	0	29OCT99	29OCT99	B36B	8,908.00														
SG2020OP07	Concreting of parking lot	1	0	02NOV99	02NOV99	B26	55,796.00														
2S.G.20.40 Subclass G2040:site development																					
2S.G.20.40.OP Area OP:Site development- over all project																					
SG2040OP03	Formwork retaining wall	3	0	24AUG99	26AUG99	C1	4,052.00														
SG2040OP05	Rebaring retaining wall	1	0	27AUG99	27AUG99	RODM4	1,669.00														
SG2040OP07	Concreting of retaining wall	1	0	30AUG99	30AUG99	C20	2,017.00														
2S.G.30 Class G30:Site civil & mech. utilities																					
2S.G.40 Class G40:Site electrical utilities																					
3S Project Syed																					
3S.A Element A:Substructure																					
3S.A.10 Class A10:Foundations																					
3S.A.10.10 Subclass A1010:Standard foundations																					
3S.A.10.10.OP Area OP:Stad.foundation Over all project site																					
SA1010OP03	Excavate wall found.	1	0	25AUG99	25AUG99	B11C	251.00														
SA1010OP13	Excavate column found.	2	0	25AUG99	26AUG99	CLAB1	386.00														
SA1010OP05	Formwork wall found.	3	0	26AUG99	30AUG99	C1	3,391.00														
SA1010OP15	Formwork column found.	1	0	27AUG99	27AUG99	C1	514.00														
SA1010OP17	Rebar column foundation	1	0	30AUG99	30AUG99	RODM4	564.00														
SA1010OP07	Rebar wall found.	1	0	31AUG99	31AUG99	RODM4	438.00														
SA1010OP09	Concreting wall found.	1	0	02SEP99	02SEP99	C20	2,271.00														
SA1010OP19	Concreting column found.	1	0	02SEP99	02SEP99	C6	492.00														
SA1010OP11	Damp proofing wall found.	1	0	03SEP99	03SEP99	G2	2,623.00														
SA1010OP21	Damp proofing column found.	1	0	03SEP99	03SEP99	G2	384.00														
SA1010OP23	Back fill/compt. wall & column found.	1	0	06SEP99	06SEP99	B10A	179.00														
3S.A.10.30 Subclass A1030:Slab on grade																					
3S.A.10.30.F1 Area A:Slab on garde-Floor 1																					
SA1030F103	Preparation of base for S.O.G	1	0	30SEP99	30SEP99	B11L	250.00														
SA1030F105	Formwork for S.O.G	2	0	01OCT99	04OCT99	C1	1,426.00														
SA1030F107	Damp proofing S.O.G	1	0	01OCT99	01OCT99	CARP1	210.00														
SA1030F109	Rebaring S.O.G	1	0	04OCT99	04OCT99	RODM2	616.00														
SA1030F111	Concreting S.O.G	1	0	06OCT99	06OCT99	C6	3,333.00														

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Activity ID	Activity Description	Orig Dur	% Comp	Early Start	Early Finish	Res.	Cost	
3S.A.20 Class A20:Basement construction								
4S Project Syed								
4S.B Element B:Shell								
4S.B.10 Class B10:Superstructure								
4S.B.10.10 Subclass B1010:Floor construction								
4S.B.10.10.F1 Area F1:Floor const.-Floor 1								
SB1010F103	Formwork for columns C1	2	0	07SEP99	08SEP99	C1	3,143.00	Formwork for columns C1 Rebaring of column C1 Concreting of column C1
SB1010F105	Rebaring of column C1	2	0	07SEP99	08SEP99	RODM4	1,610.00	
SB1010F107	Concreting of column C1	1	0	10SEP99	10SEP99	C20	655.00	
4S.B.10.10.F2 Area F2:Floor const.-Floor 2								
SB1010F203	Formwork for beams B2 & slab S2	6	0	13SEP99	20SEP99	C2	23,359.00	Formwork for beams B2 & slab S2 Rebaring of beam B2 & slab S2 Concreting of beams B2 & slab S2 Formwork for column C2 Rebaring of column C2 Concreting of column C2
SB1010F205	Rebaring of beam B2 & slab S2	5	0	21SEP99	27SEP99	RODM4	8,918.00	
SB1010F207	Concreting of beams B2 & slab S2	1	0	29SEP99	29SEP99	C20	5,309.00	
SB1010F209	Formwork for column C2	2	0	05OCT99	06OCT99	C1	3,143.00	
SB1010F211	Rebaring of column C2	1	0	05OCT99	05OCT99	RODM4	1,610.00	
SB1010F213	Concreting of column C2	1	0	07OCT99	07OCT99	C20	655.00	
4S.B.10.20 Subclass B1020:Roof construction								
4S.B.10.20.RF Area RF:Roof const.-Roof								
SB1020RF03	Formwork for beams B3 & roof slab S3	6	0	08OCT99	15OCT99	C2	30,917.00	Formwork for beams B3 & roof slab S3 Rebaring of beams B3 & roof slab S3 Concreting of beams B3 & roof slab S3 Damp proofing of roof slab S3
SB1020RF05	Rebaring of beams B3 & roof slab S3	6	0	18OCT99	25OCT99	RODM4	10,910.00	
SB1020RF07	Concreting of beams B3 & roof slab S3	1	0	26OCT99	26OCT99	C20	5,309.00	
SB1020RF09	Damp proofing of roof slab S3	2	0	27OCT99	28OCT99	G1	2,414.00	
4S.B.20 Class B20:Exterior enclosure								
4S.B.20.10 Subclass B2010:Exterior walls								
4S.B.20.10.F1 Area F1:Exterior walls-Floor 1								
SB2010F103	Scaffolding for ext.walls F1	2	0	27OCT99	28OCT99	CARP3	1,554.00	Scaffolding for ext.walls F1 Masonry ext walls F1 Water proofing ext.walls F1
SB2010F105	Masonry ext walls F1	7	0	29OCT99	08NOV99	D8	11,752.00	
SB2010F107	Water proofing ext.walls F1	9	0	09NOV99	19NOV99	D1	4,012.00	
4S.B.20.10.F2 Area F2:Exterior walls-Floor 2								
SB2010F203	Scaffolding for ext.walls F2	3	0	29OCT99	02NOV99	CARP3	1,554.00	Scaffolding for ext.walls F2 Masonry for ext. walls F2 Water proofing ext walls F2
SB2010F205	Masonry for ext. walls F2	7	0	03NOV99	11NOV99	D8	11,752.00	
SB2010F207	Water proofing ext walls F2	9	0	12NOV99	24NOV99	D1	4,012.00	
4S.B.20.20 Subclass B2020:Exterior windows								
4S.B.20.20.F1 Area F1:Exterior windows-Floor 1								
SB2020F103	Inst. of ext.windows F1	2	0	22NOV99	23NOV99	SSWK2	12,499.00	Inst. of ext.windows F1

Activity ID	Activity Description	Orig Dur	% Comp	Early Start	Early Finish	Res.	Cost
4S.B.20.20.F2 Area F2:Exterior windows-Floor 2							
SB2020F203	Inst. of ext. windows F2	2	0	12NOV99	15NOV99	SSWK2	14,582.00
4S.B.20.30 Subclass B2030:Exterior doors							
4S.B.20.30.F1 Area F1:Exterior doors-Floor 1							
SB2030F103	Inst. of ext. doors F1	3	0	22NOV99	24NOV99	E3+	10,719.00
4S.B.30 Class B30:Roofing							
4S.B.30.10 Subclass B3010:Roof coverings							
4S.B.30.10.RF Area RF:Roof coverings-Roof							
SB3010RF03	Thermal insul.of roof slab	2	0	29OCT99	01NOV99	SKW1	5,476.00
SB3010RF05	Membrane roofing of roof slab.	2	0	02NOV99	03NOV99	SKW1	4,342.00
5S Project Syed							
5S.C Element C:Interiors							
5S.C.10 Class C10:Interior construction							
5S.C.10.10 Subclass C1010:Partitions							
5S.C.10.10.F1 Area F1:Partitions-Floor 1							
5S.C.10.10.F2 Area F2:Partitions-Floor 2							
5S.C.20 Class C20:Stairs							
5S.C.20.10 Subclass C2010:Stairs construction							
5S.C.20.10.OP Area OP:Stairs const.-Over all project site							
SC2010OP03	Inst. of metal stairs	1	0	27OCT99	27OCT99	G3	5,535.00
5S.C.30 Class C30:Interior finishes							
5S.C.30.10 Subclass 3010:Wall finishes							
5S.C.30.10.F1 Area F1:Wall finishes-Floor 1							
SC3010F103	Wall finishing F1	2	0	25NOV99	26NOV99	L4	3,841.00
5S.C.30.10.F2 Area F2:Wall finishes-Floor 2							
SC3010F203	Wall finishes F2	3	0	25NOV99	29NOV99	L4	4,168.00
6S Project Syed							
6S.D Element D:Services							
6S.D.10 Class D10:Conveying							
6S.D.10.10 Subclass D1010:Elevators and lifts							
6S.D.10.10.OP Area OP:Elevators & lifts-Over all project							
SD1010OP03	Inst. of elevator	10	0	27OCT99	09NOV99	ELEV2	32,104.00

Activity ID	Activity Description	Orig Dur	% Comp	Early Start	Early Finish	Res.	Cost	1999	AUG	SEP	OCT	NOV	D
6S.D.20	Class D20:Plumbing												
6S.D.30	Class D30:HVAC												
6S.D.50	Class D50:Electrical												
7S	Project Syed												
7S.E	Element E:Eqpt. & furnishes												
7S.E.10	Class E10:Equipment												
7S.E.20	Class E20:Furnishing												
8S	Project Syed												
8S.F	Element F:Special construction & demolition												
8S.F.10	Class F10:Special construction												
8S.F.20	Class F20:Selective demolition												



Activity ID	Activity Description	Orig Dur	Early Start	Early Finish	Cost	
1999						
AUG SEP OCT NOV D						
2 9 16 23 30 6 13 20 27 4 11 18 25 1 8 15 22 29 6						
5S Project Syed						
5S.C Element C:Interiors						
5S.C.10 Class C10:Interior construction						
+ 5S.C.20 Class C20:Stairs		1	27OCT99	27OCT99	5,535.00	
+ 5S.C.30 Class C30:Interior finishes		3	25NOV99	29NOV99	8,009.00	
6S Project Syed						
6S.D Element D:Services						
+ 6S.D.10 Class D10:Conveying		10	27OCT99	09NOV99	32,104.00	
6S.D.20 Class D20:Plumbing						
6S.D.30 Class D30:HVAC						
6S.D.50 Class D50:Electrical						
7S Project Syed						
7S.E Element E:Eqpt. & furnishes						
7S.E.10 Class E10:Equipment						
7S.E.20 Class E20:Furnishing						
8S Project Syed						
8S.F Element F:Special construction & demolition						
8S.F.10 Class F10:Special construction						
8S.F.20 Class F20:Selective demolition						

Figure 5.3

Activity ID	Activity Description	Orig Dur	% Comp	Early Start	Early Finish	Res.	Budgeted Cost	1999											
								AUG	SEP	OCT	NOV	D	8	15	22	29	5	12	19
SZ1030OP01	Project commencement	0	0	05AUG99			0.00												
SZ1030OP05	Site protection	5	0	05AUG99	11AUG99	CLAB2	4,184.00												
SZ1030OP03	Provision of temp. electricity & HVAC	1	0	05AUG99	05AUG99	A1	856.00												
SZ1030OP07	Provision of temp. road	1	0	05AUG99	05AUG99	B14	499.00												
SZ1030OP09	Provision of field offices	1	0	05AUG99	05AUG99	A2	1,480.00												
SG1010OP03	Clearing & grubbing of site	1	0	12AUG99	12AUG99	C1	1,544.00												
SG1010OP05	Removal of top soil	1	0	12AUG99	12AUG99	B10A	371.00												
SG1010OP07	Hauling of spoil	4	0	13AUG99	18AUG99	B34B	2,185.00												
SG1030OP03	Grading of site	4	0	19AUG99	24AUG99	B11L	3,518.00												
SG1030OP05	Dewatering of site	3	0	19AUG99	23AUG99	B10H	1,072.00												
SG2040OP03	Formwork retaining wall	3	0	24AUG99	26AUG99	C1	4,052.00												
SA1010OP03	Excavate wall found.	1	0	25AUG99	25AUG99	B11C	251.00												
SA1010OP13	Excavate column found.	2	0	25AUG99	26AUG99	CLAB1	386.00												
SA1010OP05	Formwork wall found.	3	0	26AUG99	30AUG99	C1	3,391.00												
SA1010OP15	Formwork column found.	1	0	27AUG99	27AUG99	C1	514.00												
SG2040OP05	Rebaring retaining wall	1	0	27AUG99	27AUG99	RODM4	1,669.00												
SA1010OP17	Rebar column foundation	1	0	30AUG99	30AUG99	RODM4	564.00												
SG2040OP07	Concreting of retaining wall	1	0	30AUG99	30AUG99	C20	2,017.00												
SA1010OP07	Rebar wall found.	1	0	31AUG99	31AUG99	RODM4	438.00												
SA1010OP09	Concreting wall found.	1	0	02SEP99	02SEP99	C20	2,271.00												
SA1010OP19	Concreting column found.	1	0	02SEP99	02SEP99	C8	492.00												
SA1010OP11	Damp proofing wall found.	1	0	03SEP99	03SEP99	G2	2,623.00												
SA1010OP21	Damp proofing column found.	1	0	03SEP99	03SEP99	G2	384.00												
SA1010OP23	Back fill/compt. wall & column found.	1	0	06SEP99	06SEP99	B10A	179.00												
SB1010F103	Formwork for columns C1	2	0	07SEP99	08SEP99	C1	3,143.00												
SB1010F105	Rebaring of column C1	2	0	07SEP99	08SEP99	RODM4	1,610.00												
SB1010F107	Concreting of column C1	1	0	10SEP99	10SEP99	C20	655.00												
SB1010F203	Formwork for beams B2 & slab S2	6	0	13SEP99	20SEP99	C2	23,359.00												
SB1010F205	Rebaring of beam B2 & slab S2	5	0	21SEP99	27SEP99	RODM4	8,918.00												
SB1010F207	Concreting of beams B2 & slab S2	1	0	29SEP99	29SEP99	C20	5,309.00												
SA1030F103	Preparation of base for S.O.G	1	0	30SEP99	30SEP99	B11L	250.00												
SA1030F105	Formwork for S.O.G	2	0	01OCT99	04OCT99	C1	1,426.00												
SA1030F107	Damp proofing S.O.G	1	0	01OCT99	01OCT99	CARP1	210.00												
SA1030F109	Rebaring S.O.G	1	0	04OCT99	04OCT99	RODM2	616.00												



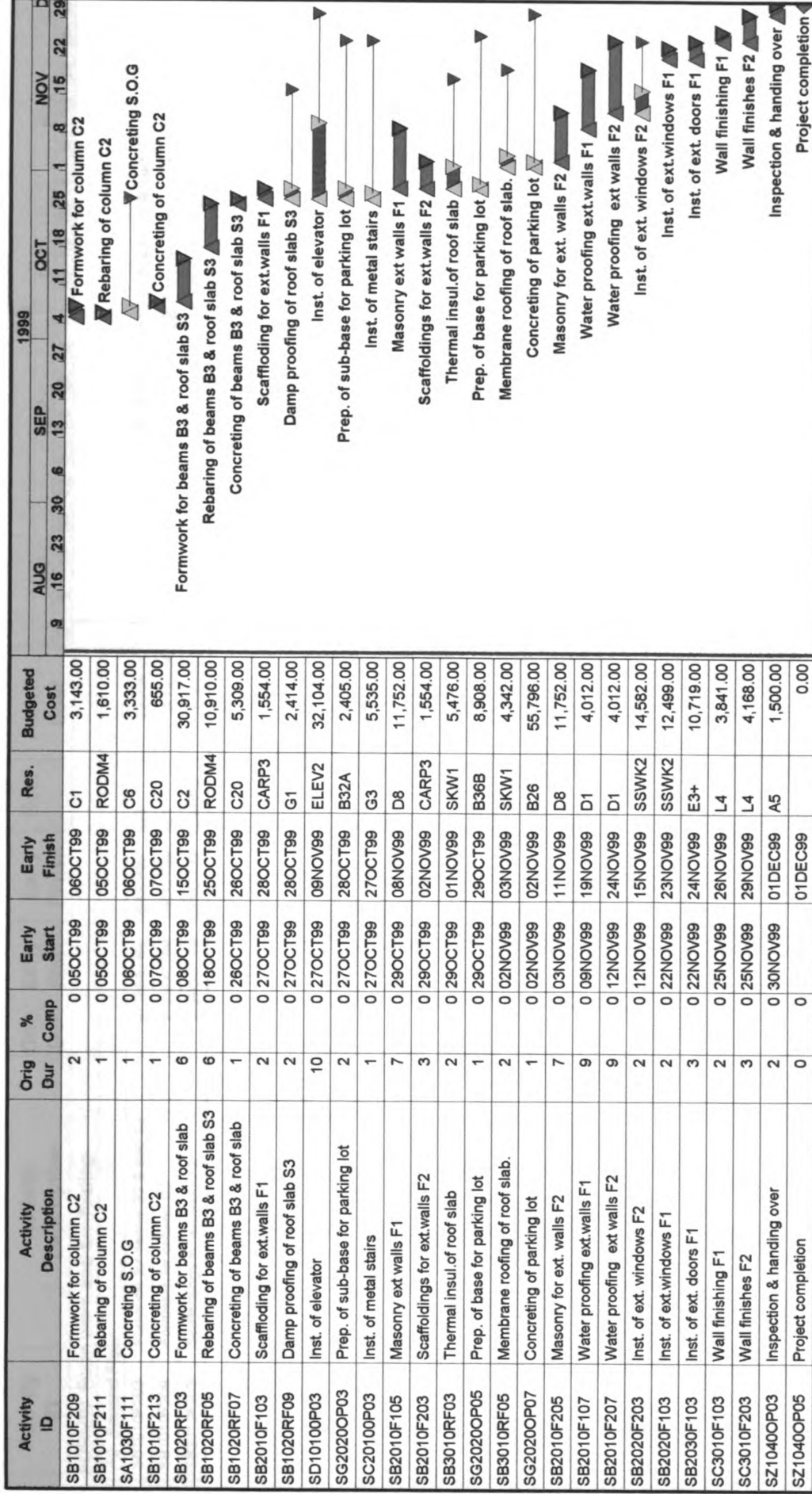
Project Start
Project Finish
Date Code
Run Code

SYED

Kakakhel Constructors
Sample project for Masters Research
Classic Schedule Layout

Figure 5.3

Sheet 1 of 2



Project completion

Project Start

06AUG99

Project Finish

01DEC99

Date Delta

06AUG99

Run Date

15DEC99

Early Bar

Float Bar

Progress Bar

Critical Activity

Kakakhel Constructors
Sample project for Masters Research
Classic Schedule Layout

Sheet 2 of 2

Figure 5.3

5.3 COST ESTIMATE ON BASIS OF PBS

A Cost estimate for a sample project on the basis of PBS was generated in an extended version of Timberline Precision Estimation (TPE). Activity ID's were assigned to each line item (utilizing the "Location" field) so that cost for every activity could be tracked. Prior to developing the cost estimate, PBS was incorporated into the WBS section of the RS Means cost database 99. The WBS section of the RS Means Cost Database was blank and is meant for insertion of a user-defined WBS. The following two reports are presented:

- Spreadsheet Report on the basis of the PBS
- Spreadsheet Report on the basis of MasterFormat

5.3.1 Spreadsheet Report on the basis of PBS

This report (Table 5.3) lays out the cost estimate on two PBS levels, i.e. PBS level 4 (subclass) and PBS level 6(activity). Similarly any other two levels can be used for laying out the estimate. This report shows the cost and crews for each activity so that then can be assigned directly to activities in the schedule without additional computations. This is one of the main advantages of presenting the cost estimate on basis of the PBS that information can be exchanged between the schedule and the cost estimate. This report can facilitate planning, analyzing and controlling, as the project managers would have all the information available to them for each activity. For example, for the activity "Formwork for columns C1" (Act ID: SB1010F103) the following information is provided: MasterFormat Phase and line item number, quantity of formwork, crew type, productivity and cost, materials type and cost, and overall cost of the activity.

The cost estimate based on the PBS presents costs for various portions and constituent components of a project. For example, to get the cost for Slab on Grade of the sample project, all the line items from various MasterFormat divisions (division 2, 3 and 7) are grouped in one place and the total cost of the Slab on Grade is appears in one place.

5.3.2 Spreadsheet Report on the basis of MasterFormat:

This report (Table 5.4) lays out the cost estimate for the sample project on the basis of the MasterFormat divisions and phases (default WBS of the cost databases), which is the traditional way of preparing cost estimate with the exception of assigning activity ID's to each line item. This report can be generated without re-entering the project data.

Table 6.3 Spreadsheet Report on basis of PBS

Location Column shows activity ID

SYED

PBS L-4	Location	Phase	Item	Description	Takeoff Quantity	Crew	Labor Productivity	Labor Amount	Material Price	Material Amount	Sub Amount	Expt. Producty	Equip. Price	Equip. Amount	Total Cost/Unit	Total Amount
03.SZ1030-																
Temporary Facilities																
SZ1030OP03	100.34	100.34	—	100 Field office expense, field office lights & HVAC installation	7.00 mo 1.00 ea	A1	1.000	172	88.00	616	-	1.000	-	-	88.00	616
								<u>172</u>	<u>172</u>	<u>616</u>	<u>69</u>	<u>856</u>				
SZ1030OP05	153.04	153.04	—	10 Fencing, 11 ga. chain link, 5' high	500.00 lf	CLAB2	0.160	1,922	4.04	2,262	-	-	-	7.47	4,184	
								<u>1,922</u>	<u>2,262</u>	<u>2,262</u>	<u>4,184</u>					
SZ1030OP07	155.52	155.52	—	50 Roads, temporary, roads, gravel fill, NO surfacing, 4" gravel depth	170.00 sy	B14	0.087	280	1.10	187	-	0.011	27.35	52	2.93	499
								<u>260</u>	<u>187</u>	<u>52</u>	<u>499</u>					
SZ1030OP09	159.04	159.04	—	350 Office trailer, furnished, no hookups, 32' x 6', rent per month	7.00 ea	A5	1.585	-	158.00	1,108	-	-	0.00	0	158.00	1,108
								<u>172</u>	<u>1,136</u>	<u>2,262</u>	<u>344.35</u>	<u>480</u>				
SZ1040OP03	171.04	209.90	—	100 Cleanup, floor area, final	25.00 mcf 1.00 day	A5	1.585	841	2.63	66	-	0.174	21.49	93	39.99	1,000
								<u>841</u>	<u>841</u>	<u>93</u>	<u>500.00</u>	<u>1,500</u>				
10.SG1010-																
Site Clearing																
SG1010OP03	211.04	211.04	—	150 Clear & grub, grubbing, ideal conditions, grub stumps & remove	1.42 acre	B30	12.000	412	-	-	-	12.000	68.55	1,132	1,099.00	1,544
								<u>412</u>	<u>1,132</u>	<u>1,132</u>	<u>1,544</u>					
SG1010OP05	211.44	211.44	—	20 Shipping, topsoil & stockpiling, sandy loam, 200 HP dozer, ideal cond	740.00 cy	B10B	0.005	101	-	-	-	0.003	104.87	270	0.50	371
								<u>101</u>	<u>270</u>	<u>371</u>	<u>371</u>					
SG1010OP07	222.66	222.66	—	450 Hauling, heavy haulers, 12 CY, 3 mi round trip, 1.9 beds/hr	600.00 cy	B34B	0.047	624	-	-	-	0.047	55.28	1,561	3.64	2,185
								<u>624</u>	<u>1,561</u>	<u>2,185</u>	<u>2,185</u>					
SG1030OP03	251.22	251.22	—	10 Fine grade area to BE paved with grader, small area	1,444.44 sy	B11L	0.040	1,440	-	-	-	0.020	71.94	2,078	2.44	3,518
								<u>1,440</u>	<u>2,078</u>	<u>2,078</u>	<u>3,518</u>					
SG1030OP05	214.04	214.04	—	800 Dewatering, pumping 8 hr, 8 hrs attended, 2" diaphragm pump	3.00 day	B10H	12.000	939	-	-	-	32.000	1.39	133	357.44	1,072
								<u>939</u>	<u>1,072</u>	<u>1,072</u>	<u>1,072</u>					

Table 5.3 Spreadsheet Report on basis of PBS

SYED

Location Column shows activity ID

PBS L-4	Location	Phase	Item	Description	Takeoff Quantity	Crew	Labor Productivity	Labor Amount	Material Price	Material Amount	Sub Amount	Eqpt. Productivity	Equip. Price	Equip. Amount	Total Cost/Unit	Total Amount
	SA1010OP13	222.50	10	Excavating, structural, hand, pile to 6' deep, sandy soil	16.00 cy	CLAB1	1.000	386	-	-	-	-	-	-	21.45	386
	SA1010OP15	311.56	7000	Forms in place, spread footings, platins, 1 use	90.00 sfca	C1	0.128	288	2.40	216	-	-	-	-	5.71	514
	SA1010OP17	321.07	500	Reinforcing in place, footings, #4 to #7	0.58 km	RODM4	15.238	289	510.00	296	-	-	-	-	973.24	564
	SA1010OP19	331.26 331.72	150 2400	Concrete ready mix, regular weight 3000 psi Placing conc. footings, spread, under 1 CY, direct chule	6.00 cy 6.00 cy	C6	0.873	118	61.00	366	-	0.291	4.68	-	61.00 21.06	366 128
	SA1010OP21	714.52	20	Continuous waterproofing, 1/8" application, sprayed on	166.00 sf	G2	0.024	92	1.50	252	-	0.006	29.41	40	2.29	364
	SA1010OP23	222.04	400	Backfill, by hand, compaction in 6" layers, roller comp over walking.	44.00 cy	B10A	0.120	136	-	-	-	0.060	11.63	41	4.06	179
	SA1010OP23			32.SA1010-Slab Formed Standard Foundation				138						41		179
	SA1010OP23			Slab on Grade				4.487		9.484				592		11.483
34.SA1030-	SA1030F103	251.22	1100	Fine grade, for slab on grade, machine	266.67 sy	B11L	0.015	102	-	-	-	0.006	71.94	146	0.94	250
	SA1030F105	311.70	4000	Forms in place, SOG, edge, slab blockouts, to 12" high, wood, 1 use	300.00 lf	C1	0.160	1,240	0.62	186	-	-	-	-	4.75	1,426
	SA1030F107	719.22	900	Building paper, polyethylene vapor barrier, std, .005" thick	24.00 sq	CARP1	0.216	142	2.66	69	-	-	-	-	6.76	210
	SA1030F109	322.07 0322.07	- 0100	Placing of WMF Welded wire fabric, sheets, 6 x 6 - W1.4 x W1.4 (10 x 10) 21 BrC8F	24.00 cdf 24.00 cdf	ROOM2	50.000	117 334	6.90	166	-	50.000	-	-	4.86 20.80	117 499
	SA1030F111	331.72 0331.26	4600 0150	Placing conc. slab on grade, slab over 6" thick, direct chule Concrete ready mix, regular weight 3000 psi	46.00 cy 46.00 cy	C6	0.291	322	-	-	-	0.097	4.68	22	7.02	344
	SA1030F111							322	61.00	2,989	-	-	-	-	61.00	2,989
	SA1030F111							322		2,989	-	-	-	22		3,333

POS L-4	Location	Phase	Item	Description	Takeoff Quantity	Crew	Labor Productivity Wty	Labor Amount	Material Price	Material Amount	Sub Amount	Eqpt. Productivity	Equip. Price	Equip. Amount	Total Cost/Unit \$	Total Amount
37.SB1010-5 on G. Slab on Grade																
Floor Construction																
37.SB1010-5 on G. Slab on Grade								2,224	3,492							
37.SB1010-	SB1010F103	311.42	7800	Forms in place, columns, steel framed plywood, 4 w/straps, rent, 12" x 12"	720.00 sfca	C1	0.006	1,609	2.13	1,534	-	-	-	-	4.37	3,143
	SB1010F103							1,609		1,534						3,143
	SB1010F105	321.07	200	Reinforcing in place, A615 Gr 60, columns, #3 to #7	1.36 ton	ROOM4	21.333	862	535.00	726	-	-	-	-	1,183.54	1,610
	SB1010F105							862		726						1,610
	SB1010F107	331.26	150	Concrete ready mix, regular weight 3000 psi	6.70 cy			-	61.00	409	-	-	-	-	61.00	409
		331.72	400	Placing conc, columns, squarearound, 12" thick, pumped	6.70 cy	C20	1.067	165	-	-	-	0.400	30.02	80	36.71	246
	SB1010F107							165		409				80		655
	SB1010F203	311.38	500	Forms in place, beam & girder, ext expanded, plywood, 12" wide, 1 use	1,360.00 sfca	C2	0.213	7,734	2.28	3,114	-	-	-	-	7.98	10,849
		311.50	1000	Forms in place, elev slabs, flat plate plywood to 15' high, 1 use	2,400.00 sf	C2	0.102	6,534	2.46	5,976	-	-	-	-	5.21	12,510
	SB1010F203							14,268		9,090						23,359
	SB1010F205	321.07	100	Reinforcing in place, A615 Gr 60, beams and girders, #3 to #7	4.00 ton	ROOM4	20.000	2,432	535.00	2,140	-	-	-	-	1,143.00	4,572
		321.07	400	Reinforcing in place, A615 grade 60, elevated slabs, #4 to #7	4.80 ton	ROOM4	11.034	1,610	570.00	2,736	-	-	-	-	905.45	4,346
	SB1010F205							4,042		4,876						8,918
	SB1010F207	331.26	160	Concrete ready mix, regular weight 3000 psi	64.00 cy			-	61.00	3,904	-	-	-	-	61.00	3,904
		331.72	50	Placing conc, beams, email, elev, pumped	19.00 cy	C20	1.067	469	-	-	-	0.400	30.02	228	36.71	697
		331.72	1400	Placing conc, elev slabs, less than 6" thick, pumped	45.00 cy	C20	0.457	476	-	-	-	0.171	30.02	232	15.73	709
	SB1010F207							946		3,904				450		5,309
	SB1010F209	311.42	7800	Forms in place, columns, steel framed plywood, 4 w/straps, rent, 12" x 12"	720.00 sfca	C1	0.006	1,609	2.13	1,534	-	-	-	-	4.37	3,143
	SB1010F209							1,609		1,534						3,143
	SB1010F211	321.07	200	Reinforcing in place, A615 Gr 60, columns, #3 to #7	1.36 ton	ROOM4	21.333	862	535.00	726	-	-	-	-	1,183.54	1,610
	SB1010F211							862		726						1,610
	SB1010F213	331.26	150	Concrete ready mix, regular weight 3000 psi	6.70 cy			-	61.00	409	-	-	-	-	61.00	409
		331.72	400	Placing conc, columns, squarearound, 12" thick, pumped	6.70 cy	C20	1.067	165	-	-	-	0.400	30.02	80	36.71	246
	SB1010F213							165		409				80		655
	37.SB1010-Floor Cast Floor Construction							24,592		23,310				80		24,692
Roof Construction																
38.SB1020-	SB1020RF03															

Table 5.3 Spreadsheet Report on basis of PBS
SYED

Location Column shows activity ID

PBS L-4	Location	Phase	Item	Description	Takeoff Quantity	Crew	Labor Productivity	Labor Amount	Material Price	Material Amount	Sub Amount	Eqpt. Prody	Equip Price	Equip Amount	Total Cost/Unit	Total Amount
	SC3010F203	0991.24	---	Painting lab charges	10,000.00 sf	L4	1,500.000	1,368				1,500.000				1,368
				SC3010F203				3,818		350						4,168
				<u>49.SC3010-Wall Fin. Wall Finishes</u>				<u>7,389</u>		<u>620</u>						<u>8,009</u>
52.SD1010-				Elevators & Lifts												
	SD1010OP03	1420.14	410	Elevators, hoiless hyd passenger, 2000 lb cap, 2 story	1.00 ea	ELEV2	160.000	5,304	26,800.00	26,800					32,104.00	32,104
				SD1010OP03				5,304		26,800						32,104
				<u>52.SD1010-Elev/Lift Elevators & Lifts</u>				<u>5,304</u>		<u>26,800</u>						<u>32,104</u>

Estimate Totals

Labor	115,219		
Material	204,969		
Equipment	14,551		
Other	500		
Total	335,239		

	1,111,217	ch
	341,126	ch

Location Column shows activity ID

Table 5.4 Spreadsheet Report on basis of MasterFormat
SYED

Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prody	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Location
100.00	100.34		OVERHEAD													
		180	Field office expense	7.00 mo					88.00	616	-	-	-	88.00	616	SZ1030OP03
		—	Field office expense, field office lights & HVAC installation	1.00 ea	A1	1.000	171.60	172	172	616	-	69	-	240.25	856	SZ1030OP03
			Field office expense					172	172	616	-	69	-		856	
150.00	152.54		OVERHEAD													
			CNST FCLT AND TMPR CNTRLs													
		90	Scaffolding, steel tubular, bldg ext wall face, 1 use per mo, 1 to 5 stor	30.00 ctf	CARP3	1.000	27.30	819	24.50	735	-	-	-	51.80	1,554	SB2010F103
		90	Scaffolding, steel tubular, bldg ext wall face, 1 use per mo, 1 to 5 stor	30.00 ctf	CARP3	1.000	27.30	819	24.50	735	-	-	-	51.80	1,554	SB2010F203
			Scaffold					1,638		1,470					3,108	
153.04			Fencing													
		10	Fencing, 11 ga, chain link, 5' high	560.00 lf	CLAB2	0.160	21.45	1,922	4.04	2,262	-	-	-	7.47	4,184	SZ1030OP06
			Fencing					1,922		2,262					4,184	
155.52			Roads and sidewalks													
		50	Roads, temporary, roads, gravel fill, NO surfacing, 4" gravel depth	170.00 sy	B14	0.067	22.74	260	1.10	187	-	52	-	2.93	499	SZ1030OP07
			Roads and sidewalks					260		187		52			499	
159.04			Office													
		350	Office trailer, furnished, no hookups, 32' x 8', rent per month	7.00 ea					158.00	1,106	-	0	-	158.00	1,106	SZ1030OP09
		800	Office, trailer, furnished, for delivery, add per mile installation etc.	20.00 mile					1.50	30	-	-	-	1.50	30	SZ1030OP09
		—	Office	1.00 ea	A2	1.000	172.40	172	172	1,136	-	172	-	344.36	1,480	SZ1030OP09
			Office					172		1,136		172			1,480	
			CNST FCLT AND TMPR CNTRLs					3,892		5,053		224			9,271	
170.00			CONTRACT CLOSEOUT													
	171.04		Cleaning up													
		100	Cleanup, floor area, final	25.00 msf	A5	1.565	21.48	841	2.63	66	-	93	-	39.99	1,000	SZ1040OP03
			Cleaning up					841		66		93			1,000	
			CONTRACT CLOSEOUT					841		66		93			1,000	
200.00	208.90		SB8RF INVSTG&SITE DEMOLTN													
			Osha testing													
		110	Osha testing, certified technician, maximum	1.00 day					-	-	-	-	-	500	500	SZ1040OP03
			Osha testing											500	500	
			SB8RF INVSTG&SITE DEMOLTN													
210.00	211.04		SITE PREPARATION													
			Clear and grub													
		150	Clear & grub, grubbing, ideal conditions, grub stumps & remove	1.42 acre	B30	12.000	24.20	412	-	-	-	1,132	-	1,089.00	1,544	SG1010OP03
			Clear and grub					412		-		1,132			1,544	
211.44			Stripping													
		20	Stripping, topsoil & stockpiling, sandy loam, 200 HP dozer, ideal cond	740.00 cy	B10B	0.005	26.08	101	-	-	-	270	-	0.50	371	SG1010OP05
			Stripping					101		-		270			371	
214.04			Dewatering													
		800	Dewatering, pumping 8 hr, 8 hrs attended, 2" diaphragm pump	3.00 day	B10H	12.000	26.08	939	-	-	-	133	-	357.44	1,072	SG1030OP06

Location Column shows activity ID

Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prodty	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Location		
220.00	222.04	Dewatering						9.39				133			1,072			
		SITE PREPARATION						1,452					1,536			2,987		
	EARTHWORK																	
	Backfill																	
	400 Backfill, by hand, compaction in 6" layers, roller comp over walking.	44.00 cy	B10A	0.120	26.08	138	-	-	-	-	-	-	41	-	4.06	179	SA1010OP23	
	Backfill																	
	138												41		1/9			
	222.50	Excavating, structural																
	10 Excavating, structural, hand, pits to 6' deep, sandy soil	18.00 cy	CLAB1	1.000	21.45	386	-	-	-	-	-	-	-	-	21.45	386	SA1010OP13	
	Excavating, structural																	
222.54	Excavating, trench																	
80 Excavate trench, cont fig, no shoring, 1-4'D, 3/8 CY tractor loader	81.00 cy	B11C	0.107	24.93	162	-	-	-	-	-	-	89	-	4.12	251	SA1010OP03		
Excavating, trench																		
162															2/1			
220.00	222.66	Hauling																
		450 Hauling, hwy haulers, 12 CY, 3 mi round trip, 1 load/hr	600.00 cy	B34B	0.047	22.10	624	-	-	-	-	-	-	1,561	-	3.64	2,185	SG1010OP07
	Hauling																	
	624															2,185		
	223.04	Base																
	10 Base, prepare & roll sub-base, small areas to 2500 SY	2,222.22 sy	B32A	0.016	26.08	927	-	-	-	-	-	-	1,478	-	1.08	2,405	SG2020OP03	
	Base																	
	927															2,405		
	250.00	223.08	Base course															
			50 Base course, large areas, crushed 3/4" stone, compacted, 3' deep	2,222.22 sy	B36B	0.012	25.28	691	-	-	-	-	-	-	1,394	-	4.01	8,908
Base course																		
691																8,908		
EARTHWORK																14,314		
PAVING AND SURFACING																		
Concrete pavement																		
200 Concrete pavement, fix form, 12' pass, unreinforced, 6" thick		2,222.22 sy	B26	0.035	24.14	1,888	-	-	-	-	-	-	1,686	-	25.11	55,796	SG2020OP07	
Concrete pavement																		
1,888																55,796		
310.00	251.22	Fine grade																
		10 Fine grade area to BE paved with grader, small area	1,444.44 sy	B11L	0.040	24.93	1,440	-	-	-	-	-	-	2,078	-	2.44	3,518	SG1030CP03
	Fine grade																	
	1100 Fine grade, for slab on grade, machine	266.67 sy	B11L	0.015	24.93	102	-	-	-	-	-	-	148	-	0.94	250	SA1030F103	
	Fine grade																	
	1,542															3,768		
	PAVING AND SURFACING																	
	CONCRETE FORMWORK																	
	52,222															59,564		
	311.00	311.38	Flip beams and girders															
500 Forms in place, beam & girder, ext spandrel, plywood, 12' wide, 1 use			1,360.00 sfca	C2	0.213	26.66	7,734	-	-	-	-	-	-	-	-	7.98	10,849	SB1010F203
500 Forms in place, beam & girder, ext spandrel, plywood, 12' wide, 1 use		1,360.00 sfca	C2	0.213	26.66	7,734	-	-	-	-	-	-	-	-	7.98	10,849	SB1020RF03	
Flip beams and girders																		
15,469																21,697		
311.42		Forms in place, columns																
		7600 Forms in place, columns, steel framed plywd, 4 used/mo, rent, 12' x 12'	720.00 sfca	C1	0.088	25.84	1,609	-	-	-	-	-	-	-	-	4.37	3,143	SB1010F103

Table 5.4 Spreadsheet Report on basis of MasterFormat

SYED

Location Column shows activity ID

Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prody	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Location	
311.42		7600	Forms in place, columns	720.00 sfca	C1	0.086	25.84	1,609	2.13	1,534	-	-	-	4.37	3,143	SB1010F209	
			Forms in place, columns, steel framed plywd, 4 use/mo, rent, 12' x 12"													6,285	
			Forms in place, columns						3,218		3,067						
			Forms in place, elev slabs, flat plate plywd to 15' high, 1 use	2,400.00 sf	C2	0.102	26.66	6,534	2.49	5,976	-	-	-	6.21	12,510	SB1010F203	
			Forms in place, elev slabs, flat plate plywd to 15' high, 1 use	3,850.00 sf	C2	0.102	26.66	10,482	2.49	9,587	-	-	-	5.21	20,068	SB1020RF03	
			Forms in place, elev slabs						17,016		15,563					32,579	
			Forms in place, footings	980.00 sfca	C1	0.085	25.84	2,161	1.93	1,891	-	-	-	4.14	4,052	SG2040OP03	
			Forms in place, footings, continuous wall, plywood, 1 use	820.00 sfca	C1	0.085	25.84	1,808	1.93	1,583	-	-	-	4.14	3,391	SA1010OP05	
			Forms in place, footings, continuous wall, plywood, 1 use	90.00 sfca	C1	0.128	25.84	298	2.40	216	-	-	-	5.71	614	SA1010OP15	
			Forms in place, footings						4,266		3,690					7,956	
311.70		4000	Forms in place, slab grade	300.00 lf	C1	0.160	25.84	1,240	0.62	186	-	-	-	4.75	1,426	SA1030F105	
			Forms in place, SOG, edge, slab blockouts, to 12" high, wood, 1 use						1,240		186					1,426	
			Forms in place, slab grade														
			Forms in place, slab grade						41,209		28,735					69,944	
			Forms in place, slab grade														
			Forms in place, slab grade														
			Forms in place, slab grade														
			Forms in place, slab grade														
			Forms in place, slab grade														
			Forms in place, slab grade														
321.07		100	Reinforcing in place	4.00 ton	RODM4	20.000	30.40	2,432	535.00	2,140	-	-	-	1,143.00	4,572	SB1010F205	
			Reinforcing in place, A615 Gr 60, beams and girders, #3 to #7	4.00 ton	RODM4	20.000	30.40	2,432	535.00	2,140	-	-	-	1,143.00	4,572	SB1020RF05	
			Reinforcing in place, A615 Gr 60, beams and girders, #3 to #7	1.36 ton	RODM4	21.333	30.40	882	535.00	728	-	-	-	1,183.54	1,610	SB1010F105	
			Reinforcing in place, A615 Gr 60, columns, #3 to #7	1.36 ton	RODM4	21.333	30.40	882	535.00	728	-	-	-	1,183.54	1,610	SB1010F211	
			Reinforcing in place, A615 Gr 60, columns, #3 to #7	4.80 ton	RODM4	11.034	30.40	1,610	570.00	2,736	-	-	-	905.45	4,346	SB1010F205	
			Reinforcing in place, A615 grade 60, elevated slabs, #4 to #7	7.00 ton	RODM4	11.034	30.40	2,348	570.00	3,990	-	-	-	905.45	6,338	SB1020RF05	
			Reinforcing in place, footings, #4 to #7	0.45 ton	RODM4	15.238	30.40	208	510.00	230	-	-	-	973.24	438	SA1010OP07	
			Reinforcing in place, footings, #4 to #7	0.58 ton	RODM4	15.238	30.40	269	510.00	296	-	-	-	973.24	564	SA1010OP17	
			Reinforcing in place, walls, #3 to #7	2.00 ton	RODM4	10.667	30.40	649	510.00	1,020	-	-	-	834.27	1,669	SG2040OP05	
			Reinforcing in place						11,712		14,007					25,718	
322.07		---	Welded wire fabric	24.00 ccf	RODM2	50.000	243.20	117			-	-	-	4.86	117	SA1030F109	
			Placing of WWF					117								117	
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
331.26		150	Concrete ready mix, regular weight 3000 psi	24.85 cy					61.00	1,516	-	-	-	61.00	1,516	SG2040OP07	
			Concrete ready mix, regular weight 3000 psi	30.00 cy						61.00	1,830	-	-	-	61.00	1,830	SA1010OP09
			Concrete ready mix, regular weight 3000 psi	6.00 cy						61.00	366	-	-	-	61.00	366	SA1010OP19
			Concrete ready mix, regular weight 3000 psi	64.00 cy						61.00	3,904	-	-	-	61.00	3,904	SB1010F207
			Concrete ready mix, regular weight 3000 psi	64.00 cy						61.00	3,904	-	-	-	61.00	3,904	SB1020RF07
			Concrete ready mix, regular weight 3000 psi	6.70 cy						61.00	409	-	-	-	61.00	409	SB1010F107
			Concrete ready mix, regular weight 3000 psi							61.00		-	-	-	61.00		
			Concrete ready mix, regular weight 3000 psi							61.00		-	-	-	61.00		
			Concrete ready mix, regular weight 3000 psi							61.00		-	-	-	61.00		
			Concrete ready mix, regular weight 3000 psi							61.00		-	-	-	61.00		
330.00		---	Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
			Welded wire fabric														
331.26		150	Concrete ready mix, regular weight 3000 psi	24.85 cy					61.00	1,516	-	-	-	61.00	1,516	SG2040OP07	
			Concrete ready mix, regular weight 3000 psi	30.00 cy						61.00	1,830	-	-	-	61.00	1,830	SA1010OP09

Location Column shows activity ID

Table 5.4 Spreadsheet Report on basis of MasterFormat
SYED

Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prody	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Location
331.26			Concrete, ready mix	6.70 cy				-	61.00	409	-	-	-	61.00	409	SB1010F213
		150	Concrete ready mix, regular weight 3000 psi					-	61.00	409	-	-	-	61.00	409	SB1010F213
331.72			Concrete, ready mix							12,337					12,337	
			Placing concrete													
		50	Placing conc, beams, small, elev, pumped	19.00 cy	C20	1.067	23.16	469	-	-	-	228	-	36.71	687	SB1010F207
		50	Placing conc, beams, small, elev, pumped	19.00 cy	C20	1.067	23.16	469	-	-	-	228	-	36.71	687	SB1020RF07
		400	Placing conc, columns, square/round, 12" thick, pumped	6.70 cy	C20	1.067	23.16	165	-	-	-	80	-	36.71	246	SB1010F107
		400	Placing conc, columns, square/round, 12" thick, pumped	6.70 cy	C20	1.067	23.16	165	-	-	-	80	-	36.71	246	SB1010F213
		1400	Placing conc, elev slabs, less than 6" thick, pumped	45.00 cy	C20	0.457	23.16	476	-	-	-	232	-	15.73	708	SB1010F207
		1400	Placing conc, elev slabs, less than 6" thick, pumped	45.00 cy	C20	0.457	23.16	476	-	-	-	232	-	15.73	708	SB1020RF07
		1950	Placing conc, footings, continuous, pumped	30.00 cy	C20	0.427	23.16	286	-	-	-	144	-	14.68	441	SA1010OP09
		2400	Placing conc, footings, spread, under 1 CY, direct chute	6.00 cy	C6	0.873	22.57	118	-	-	-	8	-	21.06	126	SA1010OP19
		4600	Placing conc, slab on grade, slab over 6" thick, direct chute	49.00 cy	C6	0.261	22.57	322	-	-	-	22	-	7.02	344	SA1030F111
		5100	Placing conc, walls, 12" thick, pumped	25.00 cy	C20	0.562	23.16	337	-	-	-	164	-	20.02	501	SG2040OP07
420.00			Placing concrete					3,295		12,337		1,419		4,714	17,051	
			CAST-IN-PLACE CONCRETE					3,295		12,337		1,419				
423.10			UNIT MASONRY													
			Concrete block, exterior													
		250	Conc blk ext, reinf, tooled ft 2sides, styrofoam ins, reg, 8"x16"x10"thk	2,300.00 sf	D8	0.113	25.20	6,531	2.27	5,221	-	-	-	5.11	11,752	SB2010F105
		250	Conc blk ext, reinf, tooled ft 2sides, styrofoam ins, reg, 8"x16"x10"thk	2,300.00 sf	D8	0.113	25.20	6,531	2.27	5,221	-	-	-	5.11	11,752	SB2010F206
			Concrete block, exterior					13,062		10,442				23,504	23,504	
710.00			UNIT MASONRY													
			WATPRFNG&DAMPPOOFING													
			Membrane waterproofing													
711.04		10	Membrane waterproofing on slabs, 1 ply, felt, mopped	3,500.00 sf	G1	0.019	22.67	1,481	0.13	455	-	477	-	0.69	2,414	SB1020RF09
			Membrane waterproofing					1,481		455		477			2,414	
714.52		20	Cementitious waterproofing, 1/8" application, sprayed on	1,148.00 sf	G2	0.024	22.92	631	1.50	1,722	-	270	-	2.29	2,623	SA1010OP11
		20	Cementitious waterproofing, 1/8" application, sprayed on	168.00 sf	G2	0.024	22.92	92	1.50	252	-	40	-	2.29	384	SA1010OP21
			Cementitious waterproofing					724		1,974		310			3,007	
718.02		100	Cement parging	2,300.00 sf	D1	0.064	24.60	3,621	0.17	391	-	-	-	1.74	4,012	SB2010F107
		100	Cement parging, 2 coats, waterproofed Portland cement	2,300.00 sf	D1	0.064	24.60	3,621	0.17	391	-	-	-	1.74	4,012	SB2010F207
			Cement parging					782		782					8,024	
719.22		900	Building paper, polyethylene vapor barrier, std, 006" thick	24.00 sq	CARP1	0.216	27.30	142	2.86	69	-	-	-	8.76	210	SA1030F107

Table 5.4 Spreadsheet Report on basis of MasterFormat
SYED

Location Column shows activity ID

Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prody	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Location
830.00	836.52	1000	Building paper					142		69					210	
			<u>WATERPROOFING</u>					<u>9,589</u>		<u>3,289</u>		<u>787</u>			<u>13,655</u>	
			<u>SPECIAL DOORS</u>													
			Telescoping steel doors													
			Telescoping stl dr, baked enamel finish, ovnd, 03" th, elec opt, 10x10H	1.00 ea	E3	30.000	31.27	938	8,500.00	8,500	-	103	-	9,540.96	9,541	8B2020F203
850.00	837.52	1050	<u>Telescoping steel doors</u>					938		8,500		103			9,541	
			Double acting													
			Double acting, W/vislon pnl, FR, closer&hwe, 063" alum, 7'-0" H, 6'-8" W	2.00 pr	CARP2	4.000	27.30	218	480.00	960	-	-	-	569.20	1,178	8B2020F203
			Double acting					218		960					1,178	
			<u>SPECIAL DOORS</u>					<u>1,158</u>		<u>9,460</u>		<u>103</u>			<u>10,719</u>	
851.04	851.04	1000	<u>METAL WINDOWS</u>													
			Steel windows													
			Steel windows, custom units, double hung, 2'-8" x 4'-6" opening	24.00 ea	SSWK2	1.333	30.60	979	480.00	11,520	-	-	-	520.80	12,499	8B2020F103
			Steel windows, custom units, double hung, 2'-8" x 4'-6" opening	28.00 ea	SSWK2	1.333	30.60	1,142	480.00	13,440	-	-	-	520.80	14,562	8B2020F203
			<u>METAL WINDOWS</u>					2,122		24,960					27,082	
0320.00	0322.07	0100	<u>CONCRETE REINFORCEMENT</u>					<u>2,122</u>		<u>24,960</u>					<u>27,082</u>	
			Welded wire fabric													
			Welded wire fabric, sheets, 6 x 6 - W1.4 x W1.4 (10 x 10) 21 lb/CSF	24.00 csf			13.90	334	6.90	166	-	-	-	20.80	499	SA1030F109
			<u>CONCRETE REINFORCEMENT</u>					334		166					499	
			<u>CAST-IN-PLACE CONCRETE</u>					<u>334</u>		<u>166</u>					<u>499</u>	
0330.00	0331.26	0150	<u>CONCRETE REINFORCEMENT</u>													
			Concrete, ready mix													
			Concrete ready mix, regular weight 3000 psi	49.00 cy			-	-	61.00	2,989	-	-	-	61.00	2,989	SA1030F111
			Concrete, ready mix							2,989					2,989	
			<u>CAST-IN-PLACE CONCRETE</u>					<u>2,989</u>		<u>2,989</u>					<u>2,989</u>	
0550.00	0551.04	0100	<u>METAL FABRICATIONS</u>													
			Stair													
			Stair, stl, sfty neg, stl stringers, grtg trd, pipe ring, 4'-0" wide	40.00 tr			33.00	1,320	92.00	3,680	-	110	-	127.74	5,110	SC2010OP03
			Installation	40.00 tr	G3	20.000	212.80	426		3,680	-	110	-	10.64	426	SC2010OP03
			<u>METAL FABRICATIONS</u>					<u>1,746</u>		<u>3,680</u>		<u>110</u>			<u>5,535</u>	
0720.00	0721.15	0600	<u>INSULATION</u>													
			Sprayed													
			Sprayed insul, foam type on roof, urethane, 3#/CF density, 1" T, R3.8	3,500.00 sf			0.71	2,485	0.42	1,470	-	1,085	-	1.44	5,040	SB3010RF03
			Installation	3,500.00 sf	SKWK1	1,800.000	224.40	436		1,470	-	1,085	-	0.13	436	SB3010RF03
			<u>INSULATION</u>					<u>2,921</u>		<u>1,470</u>		<u>1,085</u>			<u>5,476</u>	
0760.00	0751.02		<u>MEMBRANE ROOFING</u>													
			Built-up roofing					<u>2,921</u>		<u>1,470</u>		<u>1,085</u>			<u>5,476</u>	

Location Column shows activity ID

Table 5.4 Spreadsheet Report on basis of MasterFormat
SYED

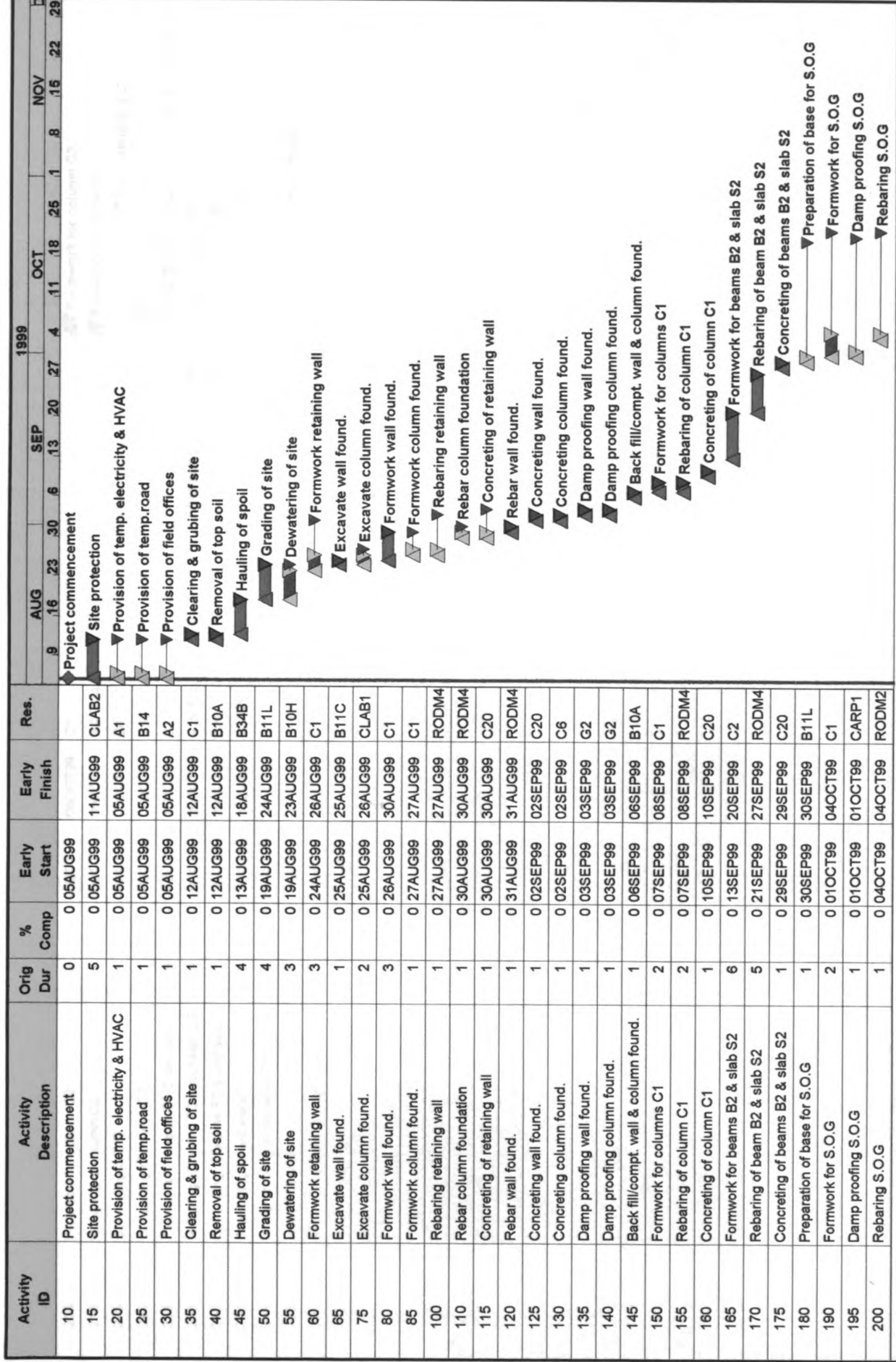
Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prody	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Other Amount	Total Cost/Unit	Total Amount	Location
0990.00	0751.02		Built-up roofing													
		0200	BUR, asph flood ct w/grd surf, base sheet, 3 plies #15 felt, mippd installation	35.00 sq			57.50	2,013	35.50	1,243	-	-	651	-	111.60	3,906 SB3010RF06
		--	Built-up roofing	35.00 sq	SKWK1	18,000	224.40	436		1,243	-	-	651	-	12.47	436 SB3010RF06
								2,449		1,243			651			4,342
								2,449		1,243			651			4,342
	0991.24		MEMBRANE ROOFING													
			PAINTING & WALL COVERINGS													
		0370	Paint, walls masonry	4,500.00 sf			0.31	1,395	0.03	135	-	-	-	-	0.34	1,530 SC3010F103
			latex, first coat													
		0370	Paint, walls, masonry, CMU, smooth, burshwork, latex, first coat	5,000.00 sf			0.31	1,550	0.03	150	-	-	-	-	0.34	1,700 SC3010F203
1420.00		0380	Paint, Walls, CMU, smooth, burshwork, latex, second coat	4,500.00 sf			0.21	945	0.03	135	-	-	-	-	0.24	1,080 SC3010F103
		0400	Paint, walls, CMU, smooth, burshwork, latex, waterproof sealer, second	5,000.00 sf			0.18	900	0.04	200	-	-	-	-	0.22	1,100 SC3010F203
		--	Painting lap charges	8,000.00 sf	L4	1,500,000	205.20	1,231							0.14	1,231 SC3010F103
		--	Painting lap charges	10,000.00 sf	L4	1,500,000	205.20	1,368							0.14	1,368 SC3010F203
								7,389		620						8,009
								7,389		620						8,009
			PAINTING & WALL COVERINGS													
			ELEVATORS													
	1420.14		Passelvehdraul# -stp fpm													
		410	Elevators, noless hyd passenger, 2000 lb cap, 2 story	1.00 ea	ELEV2	160,000	33.15	5,304	26,800.00	26,800	-	-	-	-	32,104.00	32,104 SD1010OP03
1420.00			Passelvehdraul# -stp fpm													
								5,304		26,800						32,104
								5,304		26,800						32,104

Estimate Totals

Labor	115,219	
Material	204,969	ch
Equipment	14,551	ch
Other	500	
Total	335,239	

5.4 COMPARISON OF TRADITIONAL AND PBS BASED SCHEDULE

In order to prepare a traditional schedule, the scheduler adopts a WBS for decomposition of the project according to his own experience and intuition. The WBS is often used only for the preliminary determination of the Major Milestone activities, and is not used for final presentation of schedule. Similarly activity ID's are incremented by a certain number such as 5 or 10 and, certain activity codes such as responsibility or department are assigned to the activities. No intelligence is built into activity ID's. As a different WBS is usually adopted for each project, so there is no uniformity in schedules for various projects of a company. A traditional schedule for the sample project is presented in (Figure 5.5) where the activities ID's are incremented by 5. By comparing this layout (Figure 5.5) with the layout of Figure 5.1, which is developed on the basis of PBS one would find that the data in the latter is presented in a more meaningful way for analysis, planning and control. Unlike the PBS based layout the traditional layout cannot be summarized to various levels. The addition of activities in a PBS-based schedule is very convenient because every activity has a specific place. Similarly, sequencing and linking/de-linking of activities in a traditional schedule is very cumbersome, especially during the execution a stage of project when activities are removed or added. The PBS, however, facilitates this process. Activities can be filtered on the various PBS levels or components within a level; filtered lists can be and analyzed instead of analyzing the activities of the entire project at a time.

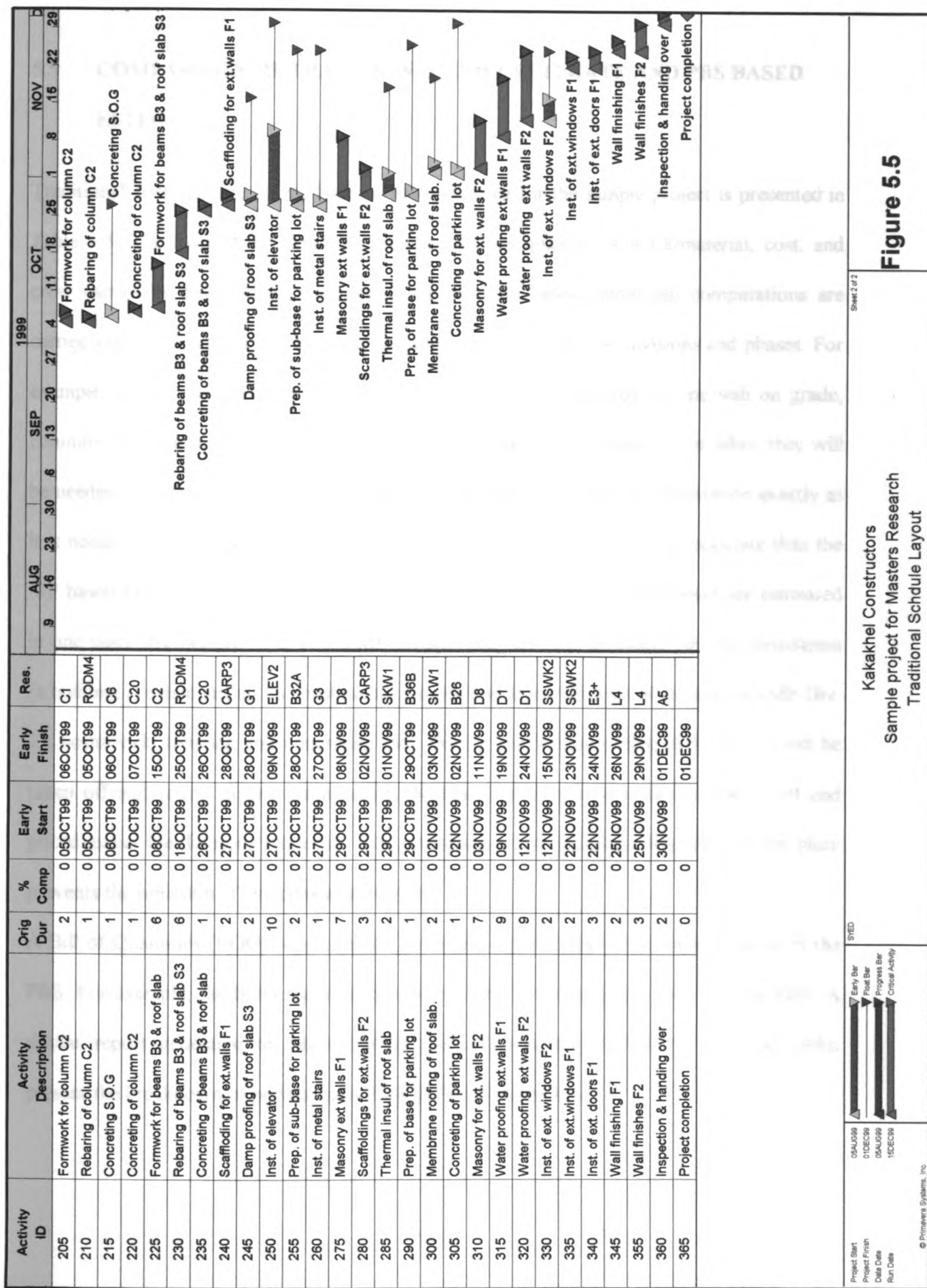


Project Start: 05AUG99
 Project Finish: 01OCT99
 Data Date: 05AUG99
 Run Date: 15DEC99

STED

Kakakhel Constructors
 Sample project for Masters Research
 Traditional Schedule Layout

Figure 5.5



5.5 COMPARISON OF TRADITIONAL COST ESTIMATE AND PBS BASED ESTIMATE

Traditional cost estimate on the basis of MasterFormat for the sample project is presented in Table 5.5. The information from this estimate such as quantity of work/material, cost, and crew cannot be assigned to activities in the schedule unless additional computations are carried out. The various line items are grouped into MasterFormat divisions and phases. For example, all the quantities for concrete (3000-psi strength) required for the slab on grade, columns and beams of various floors are totaled in one place irrespective of when they will be needed at the site. In contrast, the PBS-based schedule provides the information exactly as it is needed for assigning to the activities. PBS based estimate will be more accurate than the MF based estimate as all the required constituents any for building component are estimated in one place irrespective of in which MF division they fall. For example, for wall foundation (a building component) all its constituents process and materials such as excavation (MF Div. 2); Formwork, rebaring and concreting (MF Div.3); and waterproofing (MF Div. 7) will be taken off and priced in one place unlike MF based estimate where they are taken off and priced as per the divisions sequence. The estimating of any building component at one place prevents the omission of any constituents' item.

A Bill of Quantities (BOQ) report can be generated on the basis of the various levels of the PBS. For example, the BOQ report presented in Table 5.6 is based on level 4 of the PBS. A similar report generated on MasterFormat basis is presented in Table 5.7. These tables present the breakdown of project costs from different perspectives.

Table 5.5 Traditional Estimate on basis of MF

SYED

Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prody	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Total Cost/Unit	Total Amount
100.00	100.34		OVERHEAD											
	100.34	---	100 Field office expense, field office lights & HVAC installation	7.00 mo 1.00 ea	A1	1.000	171.80	172	88.00	616	-	-	88.00	616
								<u>172</u>		<u>616</u>			240.25	240
150.00			OVERHEAD											<u>88</u>
	152.54		CNST FCLT AND TMPR CNTRL											
			*90 Scaffolding, steel tubular, bldg ext wall face, 1 use per mo, 1 to 5 stor	60.00 csf	CARP3	1.000	27.30	1,638	24.50	1,470	-	-	51.80	3,108
	153.04		10 Fencing, 11 ga, chain link, 5' high	560.00 lf	CLAB2	0.160	21.45	1,922	4.04	2,262	-	-	7.47	4,184
	155.52		50 Roads, temporary, roads, gravel fill, NO surfacing, 4" gravel depth	170.00 cy	B14	0.067	22.74	260	1.10	187	-	52	2.93	499
	159.04		350 Office trailer, furnished, no hookups, 32' x 8', rent per month	7.00 ea					158.00	1,106	-	0	158.00	1,106
	159.04		800 Office, trailer, furnished, for delivery, add per mile installation etc.	20.00 mile 1.00 ea	A2	1.000	172.40	172	1.50	30	-	-	1.50	30
170.00	171.04		CNST FCLT AND TMPR CNTRL											
			CONTRACT CLOSEOUT					<u>3,992</u>		<u>5,055</u>		<u>224</u>		<u>9,271</u>
200.00	171.04		CONTRACT CLOSEOUT											
			100 Cleanup, floor area, final	25.00 msf	A5	1.565	21.48	841	2.63	66	-	93	39.99	1,000
210.00	208.90		CONTRACT CLOSEOUT					<u>841</u>		<u>66</u>				<u>1,000</u>
			SBSRF INVSTG&SITE DEMOLTN											
			110 Osha testing, certified technician, maximum	1.00 day									500.00	500
			SBSRF INVSTG&SITE DEMOLTN											<u>600</u>
210.00			SITE PREPARATION											
	211.04		150 Clear & grub, grubbing, ideal conditions, grub stumps & remove	1.42 acre	B30	12.000	24.20	412	-	-	-	1,132	1,089.00	1,544
	211.44		20 Stripping, topsoil & stockpiling, sandy loam, 200 HP dozer, ideal cond	740.00 cy	B108	0.006	26.06	101	-	-	-	270	0.50	371
	214.04		800 Dewatering, pumping 8 hr, 8 hrs attended, 2" diaphragm pump	3.00 day	B10H	12.000	26.06	939	-	-	-	133	357.44	1,072
			SITE PREPARATION					<u>1,452</u>				<u>1,536</u>		<u>2,987</u>
220.00			EARTHWORK											
	222.04		400 Backfill, by hand, compaction in 6" layers, roller comp oper walking	44.00 cy	B10A	0.120	26.06	138	-	-	-	41	4.06	179
	222.50		10 Excavating, structural, hand, pits to 6' deep, sandy soil	18.00 cy	CLAB1	1.000	21.45	386	-	-	-	-	21.45	386
	222.54		50 Excavate trench, cont fig, no sh/dewatering, 1-4'D, 3/8 CY tractor loader	61.00 cy	B11C	0.107	24.93	162	-	-	-	89	4.12	251
	222.66		450 Hauling, hwy haulers, 12 CY, 3 mi round trip, 1.9 loads/hr	600.00 cy	B34B	0.047	22.10	624	-	-	-	1,561	3.64	2,185

Table 5.5 Traditional Estimate on basis of MF
SYED

Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prody	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Total Cost/Unit	Total Amount
220.00														
			EARTHWORK											
223.04		10	Base, prepare & roll sub-base, small areas to 2500 SY	2,222.22 sy	B32A	0.016	26.06	927	-	-	-	1,478	1.08	2,405
223.06		50	Base course, large areas, crushed 3/4" stone, compacted, 3" deep	2,222.22 sy	B36B	0.012	25.26	661	3.07	6,822	-	1,364	4.01	8,908
			EARTHWORK					2,928		6,822		4,863		14,314
250.00														
			PAVING AND SURFACING											
251.20		200	Concrete pavement, fix form, 12" pass, unreinforced, 9" thick	2,222.22 sy	B26	0.035	24.14	1,868	23.50	52,222	-	1,696	25.11	55,796
251.22		10	Fine grade area to BE paved with grader, small area	1,444.44 sy	B11L	0.040	24.93	1,440	-	-	-	2,078	2.44	3,518
251.22		1100	Fine grade, for slab on grade, machine	266.67 sy	B11L	0.015	24.93	102	-	-	-	148	0.94	250
			PAVING AND SURFACING					3,430		52,222		3,912		59,564
310.00														
			CONCRETE FORMWORK											
311.36		*500	Forms in place, beam & girder, ext spandrel, plywood, 12" wide, 1 use	2,720.00 sfca	C2	0.213	26.86	15,469	2.29	6,229	-	-	7.98	21,697
311.42		*7600	Forms in place, columns, steel framed plywd, 4 use/mo, rent, 12" x 12"	1,440.00 sfca	C1	0.066	25.84	3,218	2.13	3,067	-	-	4.37	6,285
311.50		*1000	Forms in place, elev slabs, flat plate plywd to 15' high, 1 use	6,250.00 sf	C2	0.102	26.86	17,016	2.49	15,563	-	-	5.21	32,579
311.58		*10	Forms in place, footings, continuous wall, plywood, 1 use	1,800.00 sfca	C1	0.065	25.84	3,969	1.93	3,474	-	-	4.14	7,443
311.58		7000	Forms in place, spread footings, plinths, 1 use	80.00 sfca	C1	0.128	25.84	298	2.40	216	-	-	5.71	514
311.70		4000	Forms in place, SOG, edge, slab blockouts, to 12" high, wood, 1 use	300.00 lf	C1	0.160	25.84	1,240	0.62	186	-	-	4.75	1,426
			CONCRETE FORMWORK					41,209		28,738				69,947
320.00														
			CONCRETE REINFORCEMENT											
321.07		*100	Reinforcing in place, A615 Gr 60, beams and girders, #3 to #7	8.00 ton	RODM	20.000	30.40	4,864	535.00	4,280	-	-	1,143.00	9,144
321.07		*200	Reinforcing in place, A615 Gr 60, columns, #3 to #7	2.72 ton	RODM	21.333	30.40	1,764	535.00	1,455	-	-	1,183.53	3,219
321.07		*400	Reinforcing in place, A615 grade 60, elevated slabs, #4 to #7	11.80 ton	RODM	11.034	30.40	3,958	570.00	6,726	-	-	905.45	10,684
321.07		*500	Reinforcing in place, footings, #4 to #7	1.03 ton	RODM	15.238	30.40	477	510.00	525	-	-	973.24	1,002
321.07		700	Reinforcing in place, walls, #3 to #7	2.00 ton	RODM	10.867	30.40	649	510.00	1,020	-	-	834.27	1,069
322.07		—	Placing of WWF	24.00 ccf	RODM2	50.000	243.20	117	-	-	-	-	4.86	117
			CONCRETE REINFORCEMENT					11,822		14,007				25,829
330.00														
			CAST-IN-PLACE CONCRETE											
331.26		*150	Concrete ready mix, regular weight 3000 psi	202.25 cy			-	-	61.00	12,337	-	-	61.00	12,337
331.72		*50	Placing conc, beams, small, elev, pumped	38.00 cy	C20	1.067	23.16	939	-	-	-	456	36.71	1,395

Table 5.5 Traditional Estimate on basis of MF

SYED

Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prody	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Total Cost/Unit	Total Amount
330.00	331.72	*400	CAST-IN-PLACE CONCRETE Placing conc, columns, square/round, 12" thick, pumped	13.40 cy	C20	1.067	23.16	331	-	-	-	161	36.71	492
	331.72	*1400	Placing conc, elev slabs, less than 6" thick, pumped	90.00 cy	C20	0.457	23.16	953	-	-	-	463	15.73	1,416
	331.72	1950	Placing conc, footings, continuous, pumped	30.00 cy	C20	0.427	23.16	296	-	-	-	144	14.68	441
	331.72	2400	Placing conc, footings, spread, under 1 CY, direct chute	6.00 cy	C6	0.873	22.57	118	-	-	-	8	21.06	126
	331.72	4600	Placing conc, slab on grade, slab over 6" thick, direct chute	49.00 cy	C6	0.291	22.57	322	-	-	-	22	7.02	344
	331.72	5100	Placing conc, walls, 12" thick, pumped	25.00 cy	C20	0.582	23.16	337	-	-	-	164	20.02	501
420.00			CAST-IN-PLACE CONCRETE					3,295		12,337		1,419		17,051
			UNIT MASONRY											
	423.10	*250	Conc blk, ext, reinf, tooled j 2 side, styrofoam ins, reg, 8"x16"x10" thick	4,600.00 sf	D8	0.113	25.20	13,062	2.27	10,442	-	-	5.11	23,504
710.00			UNIT MASONRY					13,062		10,442				23,504
			WATPRFNG&DAMPPOOFING											
	711.04	10	Membrane waterproofing on slabs, 1 ply, felt, mopped	3,500.00 sf	G1	0.019	22.87	1,481	0.13	455	-	477	0.69	2,414
	714.52	*20	Cementitious waterproofing, 1/8" application, sprayed on	1,316.00 sf	G2	0.024	22.92	724	1.50	1,974	-	310	2.29	3,007
	718.02	*100	Cement parging, 2 coats, waterproofed Portland cement	4,600.00 sf	D1	0.064	24.80	7,242	0.17	782	-	-	1.74	8,024
	719.22	900	Building paper, polyethylene vapor barrier, std, .006" thick	24.00 sq	CARP1	0.216	27.30	142	2.86	69	-	-	8.76	210
830.00			WATPRFNG&DAMPPOOFING					9,692		3,282		787		13,695
			SPECIAL DOORS											
	836.52	1000	Telescoping sl dr, beled enamel finish, ovhd, .03" thk, elec opr, 10'x10'H	1.00 ea	E3	30.000	31.27	938	8,500.00	8,500	-	103	9,540.95	9,541
850.00	837.52	1050	Dr acting, W/Vision pnl, FR, closer&holve, .063" alum, 7'-0" H, 6'-8" W	2.00 pr	CARP2	4.000	27.30	218	480.00	960	-	-	588.20	1,178
			SPECIAL DOORS					1,155		9,460		103		10,719
			METAL WINDOWS											
0320.00	851.04	*1000	Steel windows, custom units, double hung, 2'-8" x 4'-6" opening	52.00 ea	SSWK2	1.333	30.60	2,122	480.00	24,960	-	-	520.80	27,082
			METAL WINDOWS					2,122		24,960				27,082
			CONCRETE REINFORCEMENT											
0320.00	0322.07	0100	Welded wire fabric, sheets, 6 x 6 - W1.4 x W1.4 (10 x 10) 21 lbCSF	24.00 csf			13.90	334	6.90	166	-	-	20.80	499

Table 5.5 Traditional Estimate on basis of MF
SYED

Group	Phase	Item	Description	Takeoff Quantity	Crew	Lab Prody	Labor Price	Labor Amount	Material Price	Material Amount	Sub Amt	Equip Amount	Total Cost/Unit	Total Amount
<u>CONCRETE REINFORCEMENT</u>														
0330.00			<u>CAST-IN-PLACE CONCRETE</u>					334		168				492
0331.28		0150	Concrete ready mix, regular weight 3000 psi	49.00 cy					81.00	2,989	-	-	81.00	2,989
			<u>CAST-IN-PLACE CONCRETE</u>							2,989				2,989
0550.00			<u>METAL FABRICATIONS</u>											
0551.04		0100	Stair, stl, sfty neg, stl stringers, grtg trd, pipe ring, 4'-0" wide	40.00 riser			33.00	1,320	92.00	3,680	-	110	127.74	5,110
0551.04		---	Installation	40.00 riser	G3	20.000	212.80	426		3,680	-	110	10.64	426
			<u>METAL FABRICATIONS</u>					1,746						5,636
0720.00			<u>INSULATION</u>											
0721.15		0600	Sprayed insul, foam type on roof, urethane, 3#/CF density, 1" T, R3.8	3,500.00 sf			0.71	2,485	0.42	1,470	-	1,085	1.44	5,040
0721.15		---	Installation	3,500.00 sf	SKWK1	1,800.000	224.40	436		1,470	-	1,085	0.13	436
			<u>INSULATION</u>					2,921						5,476
0750.00			<u>MEMBRANE ROOFING</u>											
0751.02		0200	BUR, esph flood ct w/grvl surf, base sheet, 3 piles #15 felt, mppd	35.00 sq			57.50	2,013	35.50	1,243	-	651	111.60	3,906
0751.02		---	Installation	35.00 sq	SKWK1	18.000	224.40	436		1,243	-	651	12.47	436
			<u>MEMBRANE ROOFING</u>					2,449						4,342
0990.00			<u>PAINTING & WALL COVERINGS</u>											
0991.24		0370	Paint, walls, masonry, CMU, smooth, brushwork, latex, first coat	9,500.00 sf			0.31	2,945	0.03	285	-	-	0.34	3,230
0991.24		0380	Paint, Walls, CMU, smooth, brushwork, latex, second coat	4,500.00 sf			0.21	945	0.03	135	-	-	0.24	1,080
0991.24		0400	Paint, walls, CMU, smooth, brushwork, latex, waterproof sealer, second	5,000.00 sf			0.18	900	0.04	200	-	-	0.22	1,100
0991.24		---	Painting lab charges	9,000.00 sf	L4	1,500.000	205.20	1,231			-	-	0.14	1,231
0991.24		---	Painting lab charges	10,000.00 sf	L4	1,500.000	205.20	1,368			-	-	0.14	1,368
			<u>PAINTING & WALL COVERINGS</u>					7,389		920				8,009
1420.00			<u>ELEVATORS</u>											
1420.14		410	Elevators, hoiless hyd passenger, 2000 lb cap, 2 story	1.00 ea	ELEV2	160.000	33.15	5,304	29,800.00	29,800	-	-	32,104.00	32,104
			<u>ELEVATORS</u>					5,304		29,800				32,104

Estimate Totals

Labor	115,219	ch
Material	204,999	
	1,111,222	

Table 5.5 Traditional Estimate on basis of MF
SYED

Estimate Totals

Equipment	14,551	341,129	ch
Other	500		
Total	335,239		

SYED

	Description	Quantity	Unit	Price	Amount	
					Dollars	Cents
	Temporary Facilities (Page 2)				7,019	48
	Project Closeout (Page 3)				1,489	84
	Site Clearing (Page 4)				4,099	94
	Site Earthwork (Page 5)				4,590	82
	Parking Lot (Page 6)				67,108	91
	Site Development (Page 7)				7,737	13
	Standard Foundation (Page 8)				11,482	73
	Slab on Grade (Page 9)				5,835	15
	Floor Construction (Page 10)				48,400	12
	Roof Construction (Page 11)				49,550	13
	Exterior Walls (Page 12)				34,636	10
	Exterior Windows (Page 13)				27,081	59
	Exterior Doors (Page 14)				10,719	35
	Roof Covering (Page 15)				9,818	66
	Stairs Construction (Page 16)				5,535	20
	Wall Finishes (Page 17)				8,009	20
	Elevators & Lifts (Page 18)				32,104	00
	<u>Estimate Total</u>				336,238	36

Table 5.7 Summary BOQ Report on Basis of MasterFormat

SYED

	Description	Quantity	Unit	Price	Amount	
					Dollars	Cents
	OVERHEAD (Page 2)				856	25
	CNST FCLT AND TMR CNTRL (Page 3)				9,271	23
	CONTRACT CLOSEOUT (Page 4)				999	84
	SBSRF INVSTG&SITE DEMOLTN (Page 5)				500	00
	SITE PREPARATION (Page 6)				2,987	34
	EARTHWORK (Page 7)				14,313	78
	PAVING AND SURFACING (Page 8)				59,564	22
	CONCRETE FORMWORK (Page 9)				69,943	58
	CONCRETE REINFORCEMENT (Page 10)				25,835	21
	CAST-IN-PLACE CONCRETE (Page 11)				17,051	39
	UNIT MASONRY (Page 12)				23,503	87
	WATRPRFNG&DAMPPROOFING (Page 13)				13,655	45
	SPECIAL DOORS (Page 14)				10,719	35
	METAL WINDOWS (Page 15)				27,081	59
	CONCRETE REINFORCEMENT (Page 16)				499	20
	CAST-IN-PLACE CONCRETE (Page 17)				2,989	00
	METAL FABRICATIONS (Page 18)				5,535	20
	INSULATION (Page 19)				5,476	33
	MEMBRANE ROOFING (Page 20)				4,342	33
	PAINTING & WALL COVERINGS (Page 21)				8,009	20
	ELEVATORS (Page 22)				32,104	00
	<u>Estimate Total</u>				335,238	36

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The PBS developed by the author provides a standard WBS for schedule generation, and a common framework for the development of integrated schedule and cost estimate in design-build environments. It can be also used as stand-alone WBS for the generation of either in other contract delivery arrangements.

A process flow diagram was presented in Figure 4.3 depicting the steps for the generation of an integrated construction schedule and cost estimate using the PBS.

I have demonstrated the usefulness of the PBS scheme by applying it to a sample project of 2400 SF floor area requiring about four months for construction with an estimated cost of \$335,000.

I have shown that the use of separate WBS's for cost and time produces documents that do not map easily to each other. The integration between the estimate and schedule has been achieved through a PBS (common WBS) and activity ID.

In the view of the author the PBS scheme is easily adaptable as it incorporates the information classifications system (UF and MF) and construction management software already in vogue in the construction industry. Moreover, the coding system is not complex to understand and, once entered in the computer system for the first project, it can be very easily used for other future projects.

6.2 RECOMMENDATIONS AND SUGGETIONS FOR FURTHER STUDY

The author used two different computer programs for the generation of a construction schedule and cost estimate and therefore the project data had to be entered twice. The author feels that there is a dire need for the development of common construction management software, which can perform both of the two functions. The software should be capable of linking line items from a cost database to their corresponding activities. The use of the proposed single software will increase efficiency by avoiding double entry of the data. Accuracy will be also achieved, as there will be fewer chances to forget any data input.

The author also recommends that the PBS scheme should be applied to a completed project in retrospective to check its applicability and usefulness in the real world situation.

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APPENDIX A
UNIFORMAT

UniFormat™ LEVELS ONE THRU THREE NUMBERS AND TITLESProject DescriptionConstruction Systems and Assemblies**PROJECT DESCRIPTION**

10	PROJECT DESCRIPTION
1010	PROJECT SUMMARY
1020	PROJECT PROGRAM
1030	EXISTING CONDITIONS
1040	OWNER'S WORK
1050	FUNDING
20	PROPOSAL, BIDDING, AND CONTRACTING
2010	DELIVERY METHOD
2020	QUALIFICATIONS REQUIREMENTS
2030	PROPOSAL REQUIREMENTS
2040	BID REQUIREMENTS
2050	CONTRACTING REQUIREMENTS
30	COST SUMMARY
3010	ELEMENTAL COST ESTIMATE
3020	ASSUMPTIONS AND QUALIFICATIONS
3030	ALLOWANCES
3040	ALTERNATES
3050	UNIT PRICES

CONSTRUCTION SYSTEMS AND ASSEMBLIES

ELEMENT	A	SUBSTRUCTURE
A10		FOUNDATIONS
A1010		STANDARD FOUNDATIONS
A1020		SPECIAL OTHER FOUNDATIONS
A1030		SLAB ON GRADE
A20		BASEMENT CONSTRUCTION

A2010 **BASEMENT EXCAVATION**
A2020 **BASEMENT WALLS**

ELEMENT **B** **SHELL**

B10 **SUPERSTRUCTURE**
 B1010 **FLOOR CONSTRUCTION**
 B1020 **ROOF CONSTRUCTION**

B20 **EXTERIOR ENCLOSURE**
 B2010 **EXTERIOR WALLS**
 B2020 **EXTERIOR WINDOWS**
 B2030 **EXTERIOR DOORS**

B30 **ROOFING**
 B3010 **ROOF COVERINGS**
 B3020 **ROOF OPENINGS**

ELEMENT **C** **INTERIORS**

C10 **INTERIOR CONSTRUCTION**
 C1010 **PARTITIONS**
 C1020 **INTERIOR DOORS**
 C1030 **FITTINGS SPECIALTIES**

C20 **STAIRS**
 C2010 **STAIR CONSTRUCTION**
 C2020 **STAIR FINISHES**

C30 **INTERIOR FINISHES**
 C3010 **WALL FINISHES**
 C3020 **FLOOR FINISHES**
 C3030 **CEILING FINISHES**

ELEMENT **D** **SERVICES**

D10 **CONVEYING**

D1010 ELEVATORS AND LIFTS
D1020 ESCALATORS AND MOVING WALKS
D1090 OTHER CONVEYING SYSTEMS

D20 PLUMBING
D2010 PLUMBING FIXTURES
D2020 DOMESTIC WATER DISTRIBUTION
D2030 SANITARY WASTE
D2040 RAIN WATER DRAINAGE
D2090 OTHER PLUMBING SYSTEMS

D30 HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)
D3010 ENERGY SUPPLY
D3020 HEAT GENERATION
D3030 REFRIGERATION
D3040 HVAC DISTRIBUTION
D3050 TERMINAL AND PACKAGED UNITS
D3060 HVAC INSTRUMENTATION AND CONTROLS
D3070 TESTING, ADJUSTING, AND BALANCING
D3090 OTHER SPECIAL HVAC SYSTEMS AND EQUIPMENT

D40 FIRE PROTECTION
D4010 SPRINKLERS
D4020 STANDPIPES
D4030 FIRE PROTECTION SPECIALTIES
D4090 OTHER FIRE PROTECTION SYSTEMS

D50 ELECTRICAL
D5010 ELECTRICAL SERVICE AND DISTRIBUTION
D5020 LIGHTING AND BRANCH WIRING
D5030 COMMUNICATIONS AND SECURITY
D5090 OTHER ELECTRICAL SYSTEMS

ELEMENT **E** **EQUIPMENT AND FURNISHINGS**

E10 EQUIPMENT

E1010	COMMERCIAL EQUIPMENT
E1020	INSTITUTIONAL EQUIPMENT
E1030	VEHICULAR EQUIPMENT
E1090	OTHER EQUIPMENT

E20	FURNISHINGS
E2010	FIXED FURNISHINGS
E2020	MOVEABLE FURNISHINGS

ELEMENT F **SPECIAL CONSTRUCTION AND DEMOLITION**

F10	SPECIAL CONSTRUCTION
F1010	SPECIAL STRUCTURES
F1020	INTEGRATED CONSTRUCTION
F1030	SPECIAL CONSTRUCTION SYSTEMS
F1040	SPECIAL FACILITIES
F1050	SPECIAL CONTROLS AND INSTRUMENTATION

F20	SELECTIVE DEMOLITION
F2010	BUILDING ELEMENTS DEMOLITION
F2020	HAZARDOUS COMPONENTS ABATEMENT

ELEMENT G **BUILDING SITEWORK**

G10	SITE PREPARATION
G1010	SITE CLEARING
G1020	SITE DEMOLITION AND RELOCATIONS
G1030	SITE EARTHWORK
G1040	HAZARDOUS WASTE REMEDIATION

G20	SITE IMPROVEMENTS
G2010	ROADWAYS
G2020	PARKING LOTS
G2030	PEDESTRIAN PAVING
G2040	SITE DEVELOPMENT
G2050	LANDSCAPING

G30 SITE CIVIL/MECHANICAL UTILITIES
G3010 WATER SUPPLY
G3020 SANITARY SEWER
G3030 STORM SEWER
G3040 HEATING DISTRIBUTION
G3050 COOLING DISTRIBUTION
G3060 FUEL DISTRIBUTION
G3090 OTHER SITE MECHANICAL UTILITIES

G40 SITE ELECTRICAL UTILITIES
G4010 ELECTRICAL DISTRIBUTION
G4020 SITE LIGHTING
G4030 SITE COMMUNICATIONS AND SECURITY
G4090 OTHER SITE ELECTRICAL UTILITIES

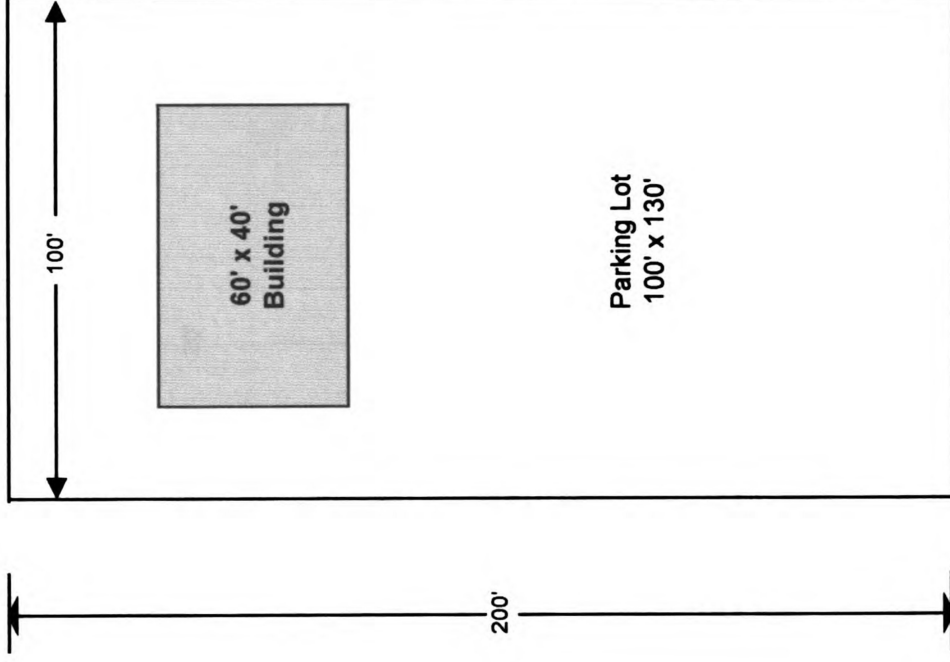
G90 OTHER SITE CONSTRUCTION
G9010 SERVICE TUNNELS
G9090 OTHER SITE SYSTEMS

ELEMENT Z

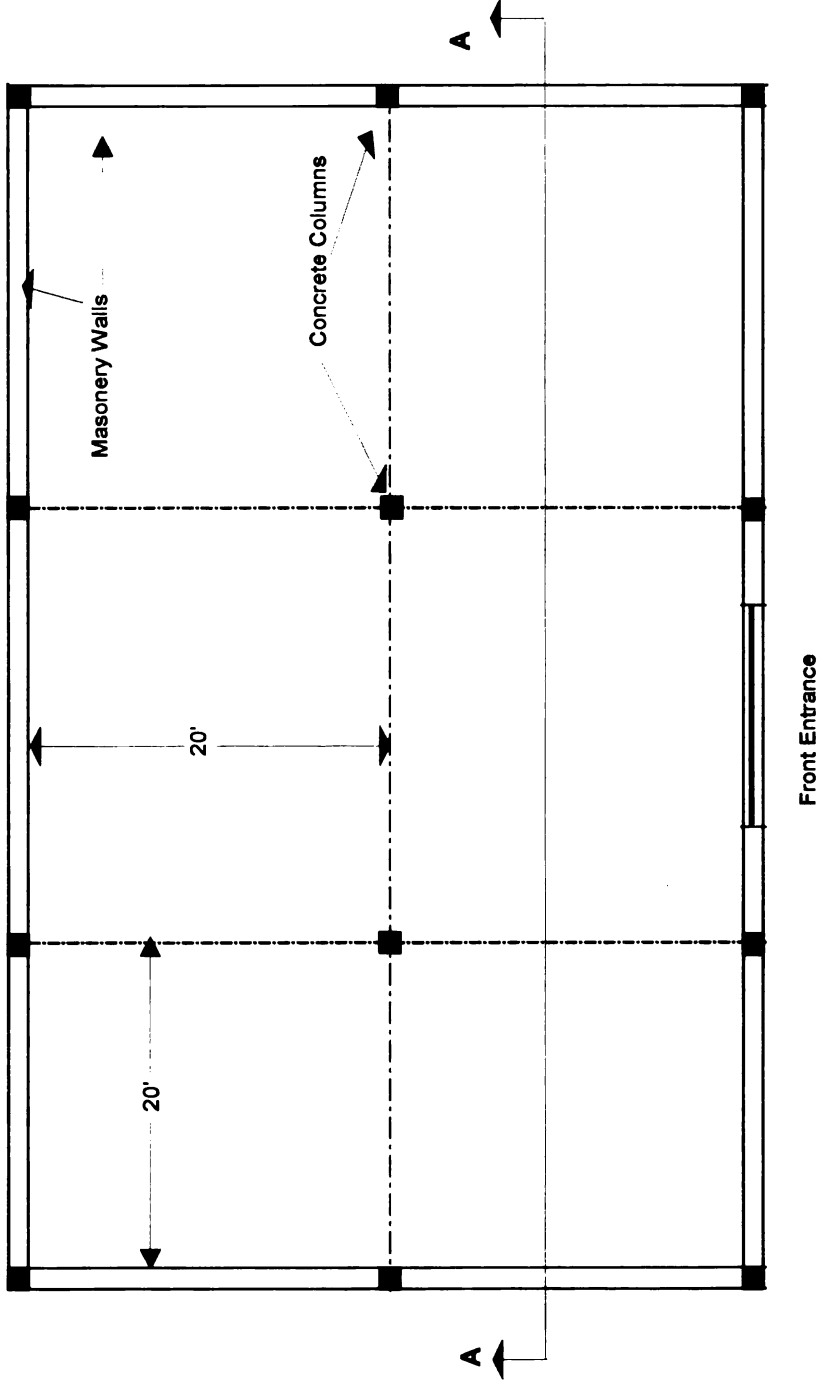
GENERAL

Z10 GENERAL REQUIREMENTS
Z1010 ADMINISTRATION
Z1020 QUALITY REQUIREMENTS
Z1030 TEMPORARY FACILITIES
Z1040 PROJECT CLOSEOUT
Z1050 PERMITS, INSURANCE, AND BONDS
Z1060 FEE

Z20 CONTINGENCIES
Z2010 DESIGN CONTINGENCY
Z2020 ESCALATION CONTINGENCY
Z2030 CONSTRUCTION CONTINGENCY



Sample project layout



Sample project Plan of Building

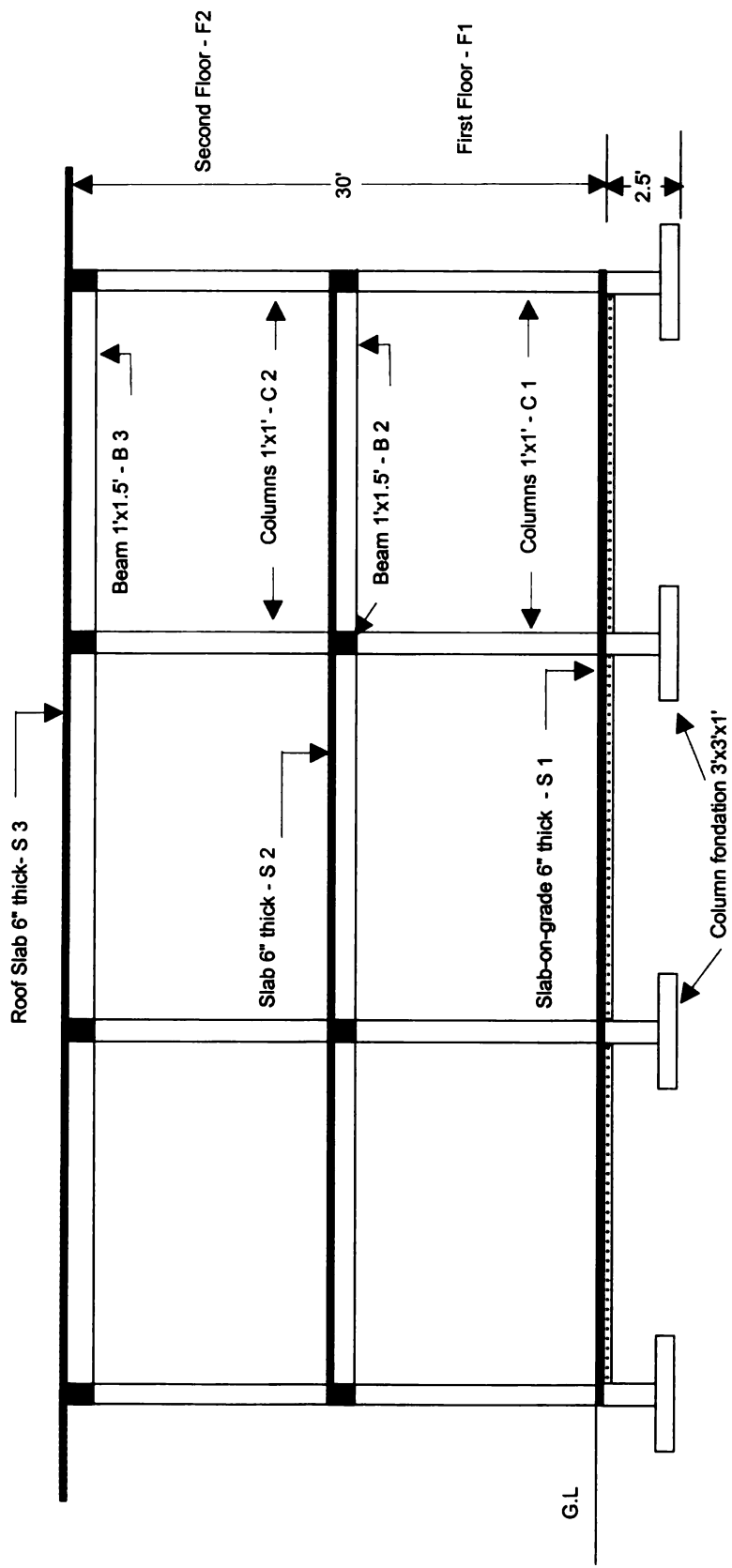


Figure 5.3 Sample project : X - Section @ AA

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