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Computer aided parametric-planning (CAPP)

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Computer aided parametric-planning (CAPP)

by

Faramarz Rahbar

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Civil Engineering (Construction Engineering and Management)

Major Professor: Dr. James E. Rowings

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For the Major Program

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For the Graduate College

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ABSTRACT

Today's challenge of fast technological advances and global competition requires a shift in our planning paradigm. The "same old way" simply does not bring about the necessary results. Our paradigm must change to reflect this. Continuous improvement of the planning process is essential to achieve success. Research indicates that the key to project success is to invest quality time in systematic planning at an early stage. Yet, we have relied upon mostly unstructured and manual formation of plans. Existing scientific planning techniques (i.e. Critical Path Method) are scheduling tools for analysis rather than plan generation. They manipulate data provided by planners not the knowledge used in generating project plans. Unlike estimating, where past project data are frequently utilized in formation of quick estimates, planning data from previous jobs are rarely documented or used as a reference.

This study introduces a systematic planning model to guide the end user to conceptualize the planning process and prepare quick and reliable conceptual plans based on similar projects completed in the past. The study provides a framework to capture historical data, synthesize it, and identify the parameters, milestones, and major activities that affect timing, sequencing, and overall planned duration of a project. This framework will serve as the basis for an inference

engine module that can be utilized in linking past project data to the present. The model is based on the *parametric* concept and referred to as *the Computer Aided Parametric Planning* or *CAPP*.

CHAPTER 1: INTRODUCTION

Overview

Research indicates that major causes of project failure are lack of a good project definition and lack of systematic planning at early stages of projects. A study by the Project Management Institute (PMI) using 2600 randomly selected members (46% of whom were project managers) ranked project definition the highest management activity and planning the highest management function (Gobeli and Larson 1990). The results of this study are summarized in Figure 1. The same study pointed out that the majority of problems are related to planning rather than scheduling (see Figure 2). The Construction Industry Institute (CII) identified pre-project planning as an important area for research and indicated that pre-project planning can save as much as 20 percent in costs and reduce the project schedule by as much as 39 percent thus increasing the chance of meeting the project objectives (Planning and Scheduling - Report A-6.1. 1982).

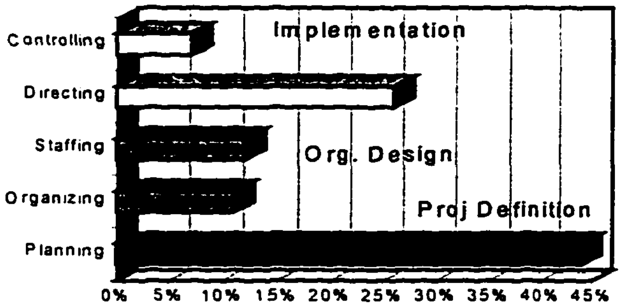


Figure 1. PMI study ranked project definition as the highest task and planning as the highest function of project management.

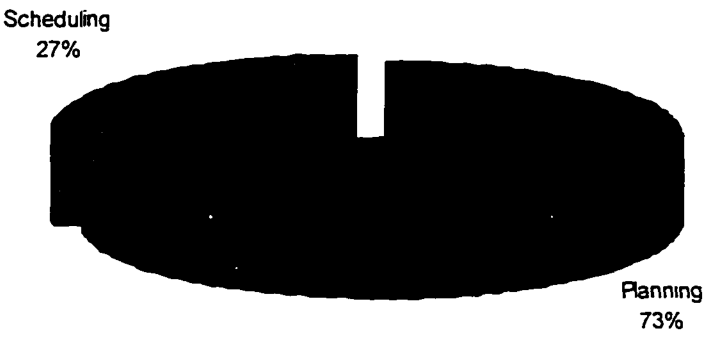


Figure 2. PMI study indicated that most project management problems are related to planning rather than scheduling.

This study also identified lack of industry standards as a major obstacle in the construction industry adopting modern planning techniques and called for extensive research to improve the planning process and techniques used in the construction industry. Studies that followed indicated a positive relationship between project pre-planning, improved productivity, and project success (Nicolas 1986).

Several scheduling tools are available and constantly enhanced, but little has been done in terms of automating or even developing a standard approach to project planning. Current practices rely upon unstructured and manual formation of plans. In fact, few planning tools exist to aid the user to develop plans during the conceptual stage. Studies indicate that despite the substantial developments in planning methods and techniques, there is deep dissatisfaction with the current planning practices (Laufer 1986, Mason 1984). Traditional network-based tools using Critical Path Method (CPM) algorithms can help in analyzing a plan, not in generating it (Kartam and Levitt 1990).

The conceptual phase of a project is the most critical stage where major decisions take place that can affect the entire time and cost of the project (Laufer 1997). Therefore, starting the planning process as early as possible can result in improved solutions and cost savings. Maximum potential for influencing cost is in the definition phases. Cost performance declines dramatically as the project progresses. At project conception, management looks for a plan that is produced quickly to meet the requirements for feasibility, proposals or other conceptual studies. At this stage, the scope of work is not well defined and few details are available. Gathering of information and data analysis to define the scope and planning requirements is the most time-consuming item (Laufer and Tucker 1987). It will be a missed opportunity if the available data from similar projects completed in the past are not utilized to produce conceptual plans.

Significant Contribution

A few studies were undertaken in the recent past to apply the parametric concept to the planning area. However, no attempt was made in establishing the relationships between the parameters, and the activities that affect the timing and overall project duration while focusing on the human aspect of planning. Existing process mostly relies on unstructured and informal plan preparation. This study presents a different paradigm to the process of planning with a "top-down" and "back-to-front" approach which is embedded in the model that is discussed throughout this paper. This innovative and distinct approach will force the planners to use a structured approach to planning while keeping the big picture and project objectives in view throughout the planning process. Although the model is formal in structure, yet it provides great flexibility to the planners to exercise judgment and intuition in developing conceptual plans. The model provides a framework to capture historical data available from past projects, synthesize the data, and identify and rank the parameters, the milestones, and major activities that affect timing, sequencing, and overall duration of a project. This was accomplished through a ruled-based approach for data analysis based on the parametric concept at various levels of a project breakdown structure.

As a result of this study, planners will have the ability to cross over between intuitive and systematic approaches in developing conceptual plans quickly and more accurately at a time when little project information is available. The system has provided the systematic analysis when dealing with the quantitative variables such as project work breakdowns, milestones, activities, durations, and generic logic. On the other hand, planners will have the opportunity to apply judgment, intuition, and creativity at various decision points during this process in a pro-active role.

Furthermore, this study has emphasized the significance of the Internet technology and how it can be used to facilitate the planning process and provide detailed planning information quickly and more accurately through video conferencing, interactive e-mail, and the use of archived progress photos from past jobs. Internet technology is still evolving, however, the use and the integration of the above concepts and techniques to visually simulate construction planning at the conceptual stage of a project, is promising.

A total of 11 case studies consisting of 7 retirement communities and 4 hospital expansion and renovation projects were analyzed. These projects were selected from two prominent contracting firms, the Weitz Company of Des Moines, Iowa, and HCB Contractors of Dallas, Texas. Archived data were collected and entered into a MS-Excel spreadsheet to be synthesized, normalized, and analyzed. The analysis includes a set of rules, directions, and decision points based on the data captured from the case studies which provides the basis for generating an inference engine module to guide the user in producing a quick conceptual plan at the early stages of a project. The inference engine module is an inferring program derived from the analysis of this research and is used in the form of dialogues between the user and the system. Although all the calculations, analysis, and data management are handled by the system, the inference engine allows the user to exercise judgment, and creativity in making important decisions at various decision points built in the system.

Planning Philosophy

Paul Dinsmore (1984) stated that project managers and project team members go about planning largely based on their personal planning postures. Some managers prefer intuitive planning while others use detailed written plans. McKenny and Keen (1974) suggest two distinct and contrasting schools of thought or planning philosophies used in information gathering: the perceptive and receptive. In the perceptive approach, the planner looks for a way to relate the data to existing mental concepts, patterns or systems. Preceptive planners scan data in search of patterns; receptive planners are detail oriented. Receptive planners are concerned with information and tend to withhold judgment until facts are fully examined. McKenny and Keen also state that information is evaluated in one of two ways: intuitively or systematically. Intuitive thinkers examine data in an unstructured way while systematic thinkers study it in a logical organized manner. Therefore, how people think affects how they plan. Preceptive and intuitive planners conduct informal, unstructured planning and avoid formal approaches. Receptive and systematic planners conduct planning on a logical procedural basis.

Dinsmore (1984) also discussed two conflicting planning approaches: behavior oriented versus technocratic. The focus of the behavioral approach is more on the planning process than planning product. Therefore, the behavior oriented approach is more intuitive and planning is performed by those who are ultimately responsible for performing the work. The technocratic approach focuses on the plan itself. The plans are normally prepared by planning experts who usually will not be performing the work and then turned over to those responsible for plan implementation. This is more systematic but less interactive.

This research provides the planners with the ability to cross over between intuitive and systematic planning by focusing on both the planning process as well as the planning product. For example, detailing a project breakdown structure, milestones, and durations, key restraints, etc., is systematic in nature and can be easily captured from past project data, while activity sequencing, integration of resources, overall approaches and application of soft logic is more abstract and requires intuitive and creative thinking. The cross-over between the two is a series of decision points that requires planners judgment to determine the cross-over point.

Problem Statement

Defining the planning requirements and data gathering is the most time consuming activity at early stages of projects (Laufer and Tucker 1987). The scope of work is not well defined and few details are available. There is large similarity between the process of design and the planning process. Iteration is at the heart of the design process. Architects and engineers use models to solve their design objectives. During the conceptual phase, very little data is available. Designers must rely on assumptions, test these assumptions using various types of models, and make the necessary modifications. It is not uncommon for the designer to copy segments of design from one component to another during this entire process. On the other hand, planners are usually in a reactive mode waiting for information to become available as project scope becomes more clear. Plans are mostly developed informally and in an unstructured manner based on intuition and the planners' personal postures and the available data from past projects are rarely used in generating conceptual plans. What is needed is a systematic, integrative, and disciplined approach to project planning in the early stages of the project without taking away from planners intuitive and creative thinking.

Purpose Of The Study

The purpose of this study is to develop a systematic planning framework, with the help of a computer-aided model, to guide the end user in preparing quick conceptual project plans using identified parameters and past project data. The model will be based on the *parametric* concept and referred to as *the Computer Aided Parametric Planning* or *CAPP*.

Research Questions

1. How can archived planning data from various projects in the past be captured in a consistent format and quickly retrieved, extracted, and re-used as a reference in generating conceptual plans for a similar project at hand?
2. How can a planner's creativity, intuition, and judgment be maintained while automating the planning process through the use of historical data?
3. What parameters, milestones, and activities affect the timing, sequencing, and overall duration of a project?
4. How can the use of advanced information technology facilitate the planning process?

Limitations Of Study

This research has explored the use of the parametric concept in preparing conceptual project plans. The final product is not a computer program, rather a framework of information that can be used in developing such a program. This research provided general specification and technical direction from which such a program can be constructed and tested using user feedback, regression analysis, and simulation.

Not all types of projects are represented. However, the case studies consisted of several components which represent a variety of projects including single and multi-unit residential, small health care, parking garage, clubhouse, site improvement, hospital expansion, and renovation types of projects. Future research can continue with this study to address other types of work.

CHAPTER 2: HISTORICAL BACKGROUND

Project Planning

Definition

Norbert Wiener compared project planning with taking a journey between two points. Figure 3 is an illustration of this analogy where the project is considered as a voyage between points A and B, the method of work is the route to be taken, the road map is the project plan, and the manager is the navigator who will steer the ship. The journey is full of hazards (shown as constraints) imposed on the manager, and the role of the manager is to complete the journey using the available resources within the allocated budget and on-time (Jackson 1986).

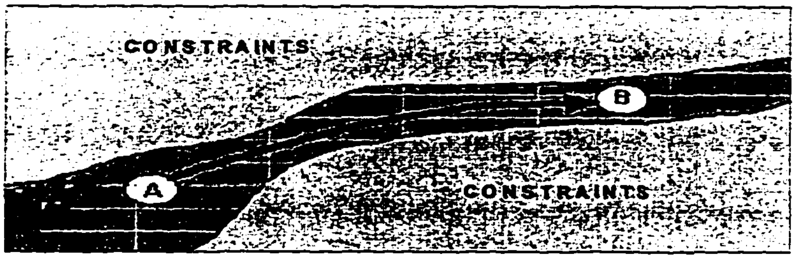


Figure 3. Planning as a Journey

The definition of planning is widely debated. The simplest and most comprehensive one is given by the Construction Industry Institute (CII 1989) which defines planning as: “making decisions today with a view towards the future”.

A similar definition is given by the American Association of Cost Engineers (AACE 1988): “making decisions now with the objective of influencing the future”.

The *Encyclopedia of Terms and Applications related to Project Planning* (Popescu 1995) defines planning as the establishment of project activities and events, their logical relationships and interrelations to each other, and the sequences in which they are to be accomplished.

The National Research Council's Committee on Improving Preliminary Planning (Programming Practices in the Building Process 1986) defined planning as the ongoing process of defining primarily long-term, future mission and objectives and translating them into resource requirements (money, manpower, capital, facilities, equipment, supplies, etc.).

A Working Definition

For the purpose of this research, the author has defined planning as the process of gathering information and preparing activities, events, sequences, and translating these into resources and schedules to meet project objectives and scope of work.

Planning versus Scheduling - a Confusion over Terminology

Planning occupies a central position in the function of the project manager, yet, there is no consistent terminology covering the subject of project planning. The term planning has been subject of debates and controversy which complicates our understanding of planning (Laufer and Tucker 1987, Mason 1984). Furthermore, there seems to be a great confusion between the term planning and scheduling. Scheduling techniques are perceived as synonymous with project planning and sometimes with project management as a whole (Mason 1984; Clough 1975; Callahan, Quackenbush, and Rowings 1992). A clear indication of this problem is the confusion over job titles. Planners are sometimes referred to as schedulers, planning and scheduling engineers, cost and scheduling engineers, project control engineers, cost engineers, CPM schedulers, or scheduling analysts (see Figure 4). The terms "planning" and "scheduling" are often used synonymously. In fact they are quite different yet related (Callahan, Quackenbush, Rowings 1992).

PLANNING: deals *with WHAT, HOW,* and *WHO.* It is not scientific or systematic.

SCHEDULING: deals *with WHEN.* It is fairly systematic and scientific.

ROLE CONFUSION

What is the correct job title?

- *PLANNER*
- *SCHEDULER*
- *PLANNING & SCHEDULING ENGINEER*
- *COST/SCHEDULING ENGINEER*
- *PROJECT CONTROL ENGINEER*
- *COST ENGINEER*
- *SCHEDULER/PLANNER*
- *CPM SCHEDULER*
- *SCHEDULING ANALYST*

Figure 4. Confusion over job titles

Just as there is a difference between planning and scheduling, there is also a difference between planning and the plan. Planning is the process while the plan is a product of planning, or scheduling, or both (Dinsmore 1984). The scheduling process for a construction project is part of planning. Construction planning is the process of selecting the method and order of work from among various methods and possible sequences, while scheduling is the determination of timing for those sequences and to give the overall completion time (Callahan, Quackenbush, and Rowings 1992). Planning provides detail information and basis for estimating time as well as a baseline for project control. *THE SCHEDULE IS A REFLECTION OF THE PLAN.*

Types of Planning

There is no consistency in the definition or types of planning. Literature search (Laufer 1989, MacColum 1995, and CII 1989) shows the following formal types of planning:

- Economic, Social, and Policy Planning
- Urban Community Planning
- Strategic Planning
- Tactical/Operational/Maintenance Planning
- Safety Planning
- Project Planning

Permanent or semi-permanent guidelines and procedures reflecting top management policy are established through policy planning. Urban community planning consist of community and regional planning. Strategic planning establishes corporate objectives and are usually long-term on a macro scale (Kezsbom 1989). Tactical planning is for shorter periods looking at the near-term portion of the strategic plan. Safety planning is designed to facilitate safety compliance and loss prevention. Project planning is a process of establishing activities and sequences to meet the objectives of a project. The focus of this paper is on project specific planning.

Project planners go about planning using various approaches. Dinsmore (1984) discussed two conflicting schools of thought as behavior oriented versus technocratic school. The focus of the behavioral school is more on the process than the product. Therefore, it is more people oriented and planning is performed by the line manager or those who are ultimately responsible for performing the work. Generally, it is more intuitive and less formal. The technocratic school focuses on the plan (as the end product) itself. The plans are normally prepared by planners who normally will not be performing the work. Planning is performed using more of a systematic approach rather than intuitive with less interaction and very little help from others. Both of these strategies have advantages and disadvantages.

The main advantage of the behavioral school is that it does not alienate planners from doers and creates more participation and interactions among the various parties. The main advantage of the technocratic school is the emphasis for systematic solutions which is usually performed by people who are highly skilled in planning techniques. This author believes that the most effective plans are produced when these two apparent conflicting approaches are used to complement each other. This can be accomplished by focusing on both the planning process as well as the plan itself, as a product.

Planning Process

Planning is the means not the end. The process of planning is as important as the plan itself. In fact, plans are the products of a planning process. This process consists of (CII 1989):

- Establishing a set of goals.
- Formulating feasible alternative plans to achieve the goals.
- Establishing criteria for evaluating alternatives.
- Selecting the best alternatives.
- Implementing the selected alternatives.
- Continuous review and evaluation of selected alternatives.

Planning Culture

This has more to do with the attitude and commitment of management to planning than the planners. If top executives play a passive role and do not put their influence behind the planning process, the output will be inefficient and will reflect the values of planners rather than managers. CII (1989) suggested the following premises as a starting point in developing a positive planning attitude:

- Planning activities must be performed by managers who will be ultimately responsible for its implementation.
- Professional planners can facilitate the planning process, but they cannot do the planning itself.
- Creative planning is a group activity.
- Managers must be motivated to spend time on planning through a formalized system.
- The planning process must provide for the development of both qualitative as well as quantitative data bases to facilitate the definition and evaluation of alternatives.

Process of Planning during Conceptual Phase of a Project

The conceptual phase of a project is the early stage where scope of work is not well defined, the project manager is just appointed, and there are many questions than answers as to the many pieces of planning details. Planning activities carried during this phase consist of five components (Neale, 1989):

1. Identifying data sources.
2. Collecting data.
3. Having the proper planning tools and techniques.

4. Plan development.

5. Planning output.

Figure 5 shows these components and the relationships between them. Data is collected after the data source is identified. This component then leads into plan development. Various planning tools and techniques are used to aid the planner in the plan development. The final component is the planning output.

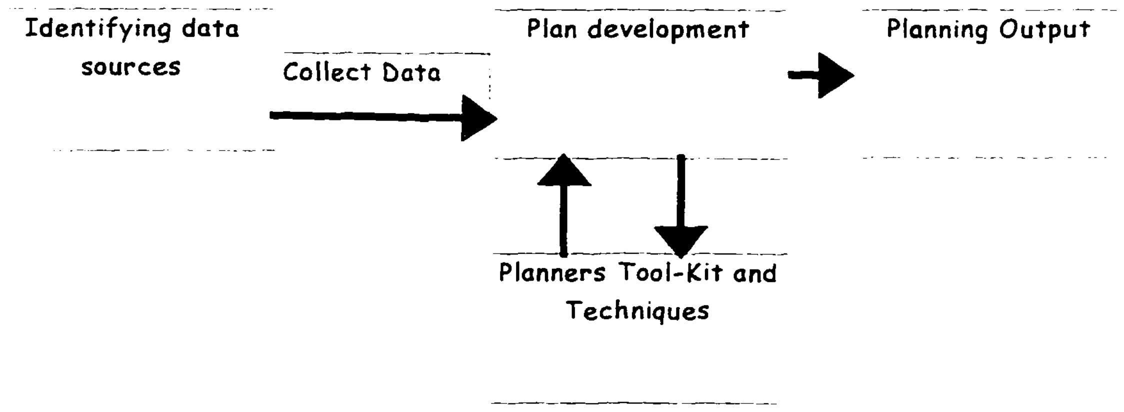


Figure 5. The five components of project planning

Dynamic interaction and brainstorming among the project participants is essential during this process. There is a lot of thought process and judgment exercises during this process. A lack of integration among parties and involvement of line supervisors will lead to plans being ignored or misinterpreted. Therefore, management participation and support during the planning process is essential for its success. The planning process at project conception is extensive and includes organizational, human, and information handling aspects, in addition to the planning and scheduling techniques. It is actually during the process of planning, prior to the start of the project that the groundwork is laid for a successful or unsuccessful project.

The quality of the information is a function of a thorough project organization plan, data collection, and project analysis. Developing a project plan that can accurately reflect the intended plan and project objectives is not a simple process. There are no short cuts. Actual development involves a series of judgments and coordination among the parties involved which requires "people skills," understanding of the work process, and available time (Callahan, Quackenbush, and Rowings 1992). Laufer and Tucker have concluded that the normative process of planning comprises five phases similar to the five components discussed above (see Figure 6).

Phase 1. Planning the Planning Process

The first phase is planning the planning process. During this phase, the project is defined, objectives are identified, and a preliminary scope of work is prepared. Also, long lead procurement items are identified. The results of this phase will be the basis for laying out the planning process. Some of the

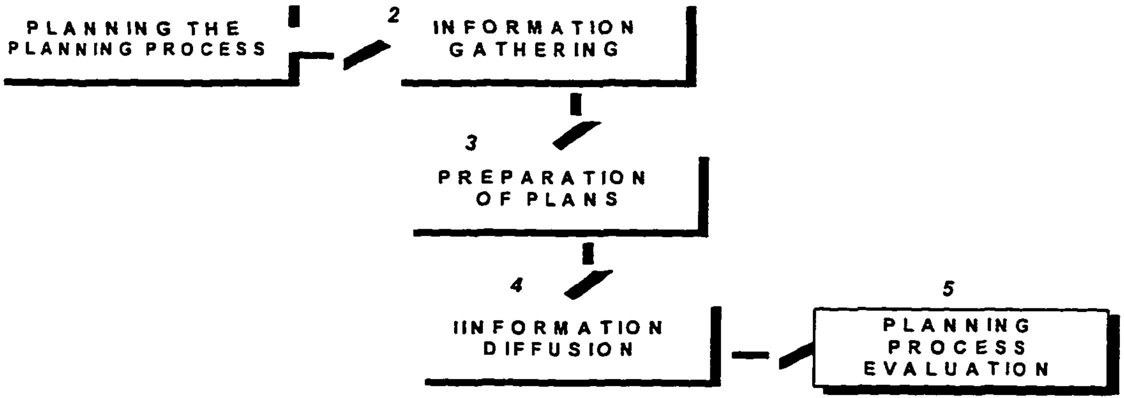


Figure 6. The five phases of project planning

decisions made during this phase may include: the planning technique to be used, level of detail, updating frequency, the method for gathering data, the required resources to develop the plan, and likewise. According to Laufer and Tucker, this phase is rarely used and is normally neglected. Although a few companies prepare planning or project procedures that deal with the above, in general, these procedures are rarely implemented.

Phase 2. Information Gathering

Collecting information and making decisions regarding this information is the core of planning, with the project manager being the nerve center in the midst of this process. According to a study by Laufer and Tucker, a great majority of a manager's time (more than 75%) is spent receiving or imparting information. The information gathering phase is the most time consuming requiring considerable resources. This includes information searches, analysis, processing of data, evaluation of alternatives, and decision making. During the information gathering phase, the project is more precisely defined, scope of work finalized, a master schedule identifying a preliminary critical path is developed, contracting and organization structure is fully set, and procurement activities are planned in detail. Formal and informal data collection methods are employed to search, collect, refine data, and analyze additional information. Data are collected face to face or "one on one", through meetings or by correspondence (mail, telephone, fax, etc.). However, the majority of information is prepared using the planners' or project managers' past experience on similar projects (Laufer and Tucker, 1987).

During the information gathering phase one should expect major problems to be encountered in the approach to uncertainty. According to Laufer and Tucker (1987), planners are more likely to ignore uncertainty than to use extra effort and seek additional information. Planners are usually "passive recipients" of information confined to their office. It is rare to see a planner act like an investigation journalist visiting the field and digging for information. It is more convenient to make one's own assumptions rather than try to find documents or talk to people. Valuable information is lost because key people are not consulted or interviewed. In general, the higher the uncertainty the higher should be the level of detail and more inquiry should be done by planners.

Phase 3. Preparation of Plans

The phase that receives the most attention, and sometimes the only attention, is the preparation of the plan. Once the information is gathered, reviewed, and organized, decisions are made based on the evaluation of the collected data using the Critical Path Method (CPM), Line of Balance (LOB), or the Gantt Chart. But the focus is primarily on CPM/PERT (Laufer and Tucker 1987). During this phase, the information gathered in the previous phase is normally input into a project management software program and the system will perform the scheduling analysis and generate a number of graphics and tabular output as defined by the system and the user. However, the user involvement and interaction with the system is kept at a very minimum. A more detailed discussion on CPM and problems with its application will follow.

Phase 4. Information Diffusion

Information diffusion is the dispersion and communication of plan to the user. The user can be defined as the individual on the line who is responsible for the entire project or any segment of the project being planned (Mason 1984). During this phase it is decided who should get what reports and in what format. Also the frequency of report distribution is decided during this phase. Studies show that planners do not make a realistic assessment of what information is required, when and in what format. Many projects produce horrendous volumes of mostly obsolete, redundant and somewhat incomplete reports that only get filed or thrown away rather than used. A better job of managing and information diffusion is needed. “People problems” are at the heart of this phase which makes it difficult to apply. Project planners should use “people skills” in dealing with “people problems”

This can be done by interviewing each potential user of the system early in the process to determine what information the user needs and to design a report that is tailored for each user.

Phase 5. Planning Process Evaluation

The last phase, evaluating the results of planning is not only difficult to measure, it is conspicuously absent on most projects. Planners are generally skeptical in analyzing the results of planning application and would much rather file the data and go on with a new project. Managers, on the other hand, also do not see an economical justification for spending extra time and effort of analyzing the project after it is done.

The Parametric Approach

The parametric approach is a procedure involving the use of a constant parameter as a reference to generate a cost or time plan from historical or past projects. The purpose of a parametric system is to provide a detailed estimate or plan that can conform to a standard Project Breakdown Structure (PBS). The PBS acts like a vehicle for linking the scope of work with objectives, resources and activities and for integrating cost, schedule, materials and other database information and is used as a common denominator for relating schedule parameters to schedule tasks and milestones.

The application of the parametric concept to produce conceptual estimates has been widely used since the early 1960's. In the last 35 years, several parametric cost estimating models were developed. Before parametric estimating models, conceptual estimates required pricing a quantity take-off. Since the scope of work was not clear, the accuracy of the take-off depended on a great number of assumptions.

Although parametric models for estimating have been widely used for the past 35 years, little is done in terms of developing models based on parametric planning or scheduling. In fact, very limited references are available regarding the application of the parametric concept in this area.

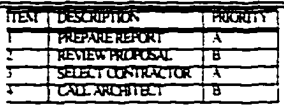
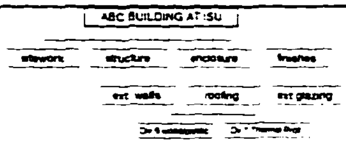
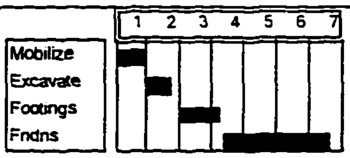
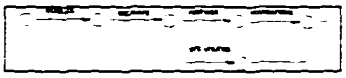
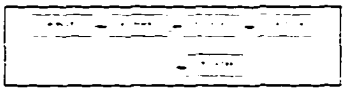
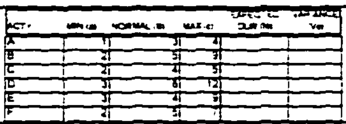
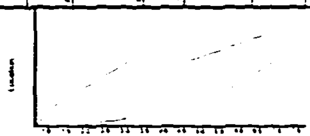
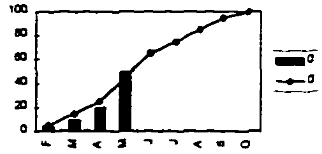
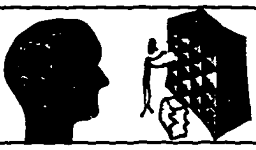
Planning Tools and Techniques

Planning tools and techniques can vary from a simple "Things To Do" list to comprehensive Critical Path Method (CPM) plans, to more sophisticated Knowledge-Based Expert Systems (KBES). Table 1 is a summary of the planning tools and techniques along with a list of their main features. It should be noted that most of the tools and techniques presented in this section are not stand alone techniques and indeed are inter-related.

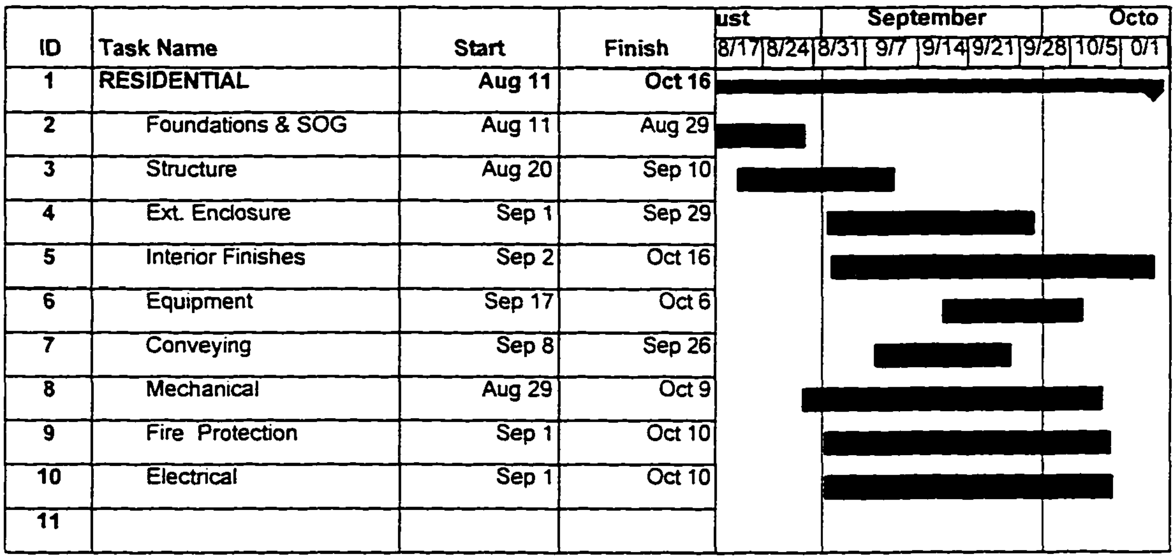
Bar Chart

The first scientific planning technique can be traced to World War I when Henry L. Gantt and Frederick W. Taylor developed the Gantt Chart or Bar Chart technique for production planning (O'Brian 1993).

Table 1. Planning tools and techniques

	Tool	Sample	Features
1	Action Item Lists or Things to Do Lists or Activity Lists	 ITEM DESCRIPTION PRIORITY 1 PREPARE REPORT A 2 REVIEW PROPOSAL B 3 SELECT CONTRACTOR A 4 CALL ARCHITECT B	-Simple -Easy to prepare -Can be used as stand alone or in conjunction with other tools.
2	Work Breakdown Structure (WBS)		-Graphic display of scope -!st step in planning -A tool to integrate cost/schedule
3	Bar Chart		-Simple and highly visual -User directly involved -Does not display restraints -Not used for what-if analysis
4	CPM: ADM PDM	 	-Demonstrates Critical Path -Forces user to think in detail -Does not allow overlap - Displays activity overlap - Includes all ADM benefits
5	PERT	 ACT NORMAL MAX Var A 1 3 4 B 2 3 3 C 2 4 5 D 3 6 12 E 3 4 9 F 2 5 7	- Used for Risk Analysis - Gives probability assessment - Too complex for construction
6	LINEAR METHODS Line Of Balance Vertical Production Method Linear Scheduling Method		- Used on repetitive work - Best applied on small non-complex projects.
7	PROGRESS CURVE (Earned Value Technique)		- Good complement to CPM - Shows overall picture - Gives cumulative and incremental rate of progress
9	KNOWLEDGE BASED EXPERT SYSTEMS		- Simulates human judgement - Integrated tools - Too complex to implement

The Bar Chart (Figure 7) was readily accepted for planning and scheduling of construction projects. The Bar Chart approach enjoys wide use today due to its simplicity and ease of use. However, the Bar Chart does not show activity dependencies clearly.



ID	Task Name	Start	Finish
1	RESIDENTIAL	Aug 11	Oct 16
2	Foundations & SOG	Aug 11	Aug 29
3	Structure	Aug 20	Sep 10
4	Ext. Enclosure	Sep 1	Sep 29
5	Interior Finishes	Sep 2	Oct 16
6	Equipment	Sep 17	Oct 6
7	Conveying	Sep 8	Sep 26
8	Mechanical	Aug 29	Oct 9
9	Fire Protection	Sep 1	Oct 10
10	Electrical	Sep 1	Oct 10
11			

Figure 7. Bar Chart or Gantt Chart is still popular and most widely used

CPM and PERT

In 1956 a group of researchers lead by E.I. du Pont Company started a project to study application of new management techniques including the use of mathematical logic to the area of planning which resulted in the development of the Critical Path Method (CPM) technique in 1958. Today this is being referred to as Arrow Diagramming Method (ADM) (Figure 8) in contrast with the Precedence

Diagramming Method (PDM) which was developed later. A parallel development by the U.S. Navy Polaris program lead to the development of the Program Evaluation and Review Technique (PERT) in 1958.

In the early 1960s Professor John Fondahl of Stanford University while working on a project for the Navy's Bureau of Yards and Docks developed a somewhat variation of the initial CPM model called the Precedence Diagramming Method or PDM (Figure 9).

The Associated General Contractors of America (AGC) endorsed the CPM technique in 1963 (AGC 1976). During the 1970's and 1980's CPM found wide use in the construction industry and many engineering schools added CPM planning to their undergraduate curricula.

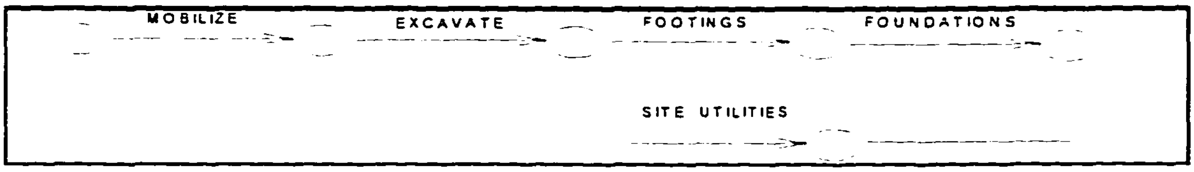


Figure 8. An example of an Arrow Diagramming Method (ADM)

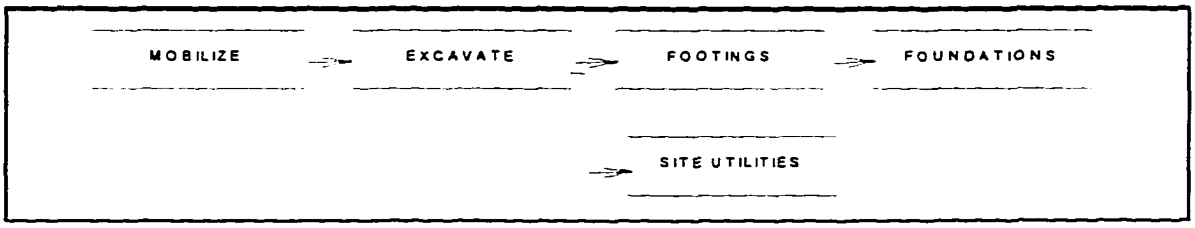


Figure 9. An example of an Precedence Diagramming Method (PDM)

During this period planners mostly used mainframe computers. The author recalls some of the more prominent mainframe computer programs as Project/2, MSCS, PREMIS, ARTEMIS, and a few others. With the advancement of Personal Computers (PCs) in the 1980s, a major shift from mainframe computer programs to PC based programs took place. Hundreds of PC based scheduling programs were introduced. However, according to this author only a few programs such as PRIMAVERA, OPENPLAN, MS-Project, etc., performed most of same functions of the mainframe programs more efficiently and at a much lesser cost. Most of the Mainframe programs mentioned above also introduced their own PC versions of the programs. It is important to note that although the end product of these software programs is the generation of plans and schedules, they are more of a scheduling tool than planning. They still require the user to input all the required data which is normally prepared manually during the planning process.

Knowledge Based Expert Systems (KBES)

The 1990s witnessed a number of research projects in the area of Knowledge Based Expert Systems (KBES) for construction planning and scheduling. The objective of these systems were mainly to automatically generate plans and schedules by applying planning and scheduling knowledge stored in the knowledge base of an expert system and to automate many of the decisions that are normally carried out by the planner (Kahkonen 1994). One among the KBES is Construction PLANEX developed under an NSF grant by Carlos Zozaya-Gorostiza of Carnegie Mellon University, PA (Zozaya-Gorostiza 1989). PLANEX can generate project activity networks, cost estimates, duration estimates for the foundation and frame construction of a modular building. It also has a menu driven interface and a knowledge source acquisition module. PLANEX is the first knowledge-based system that emulates the complete construction planning process (Chen 1994). Other research work in this area include "Know-Plan" by A. Morad (1994), "SIPE" by Nabil Kartam (1990), "MDA Planner" by Adina Jagbeck (1994), and "Object-Oriented" models (work done by Annette Stumpf (1996) is worth mentioning). These systems will be analyzed in more detail.

Most of the literature on parametric models relates to cost estimating. In fact, the author was only able to locate two dissertations and articles that directly or indirectly discussed the application of parametric models to the planning or scheduling area. These include the work of Dr. Joseph Orczyk of Purdue (1989) and that of Wei-Tong Chen of University of Florida (1994). These are discussed in detail under the topic of Parametric Models.

Project Breakdown Structure (PBS)

PBS is the top down logical structuring of project work that defines and displays all of the work to be done in accomplishing the project objectives. The PBS can graphically display the work to be done, whether it is a division of engineering, procurement, or construction, and helps to correlate tasks, schedules, estimates, performance, and technical interfaces (Humphreys 1993). PBS is synonymous with Work Breakdown Structure (WBS) although the former is project oriented.

PBS is the first step in project planning. A PBS is developed by dividing the project into discrete and logical tasks using an outline structure (Davies 1995). It partitions the project into manageable elements of work for which costs, budgets, and schedules can be established. The integration of a project's organization structure with the PBS helps the project manager to assign responsibility for various technical tasks to specific project personnel (Popescu 1995). The PBS is a tool that helps one get started by breaking down and organizing the work. It removes the complexity of the job so that work is nothing more than large number of small tasks. The PBS is structured in levels of work detail, beginning with the final product, and then separated into identifiable work elements. A PBS consist of three components: work items, levels, and work packages.

PBS Level

PBS level refers to the management scope, which divides the project into defined elements. A typical PBS may contain five to seven levels although a more detailed PBS is possible. The PBS example of Figure 10 consist of four levels. The first level is "construction", second are major components such as residential, health center, etc. Third are sub-components such as "apartments, townhomes, etc. The fourth level includes are detail milestones related to all the components and sub-components.

PBS can be prepared by following a few steps and simple rules as follows:

Step 1: Start with the project as level one. Level 1 is the end product.

Step 2: Define all <u>Major Components</u> to support level 1.

Step 3: Define all the sub-components to support level 2.

Step 4: Continue this process until all major PBS elements leading to a specific deliverable are defined.

Rule 1:PBS at each level must be comparable.

Rule 2: Each PBS must have a definable output or a specific product

Rule 3: Each PBS must have a start and end point

Rule 4: Each PBS must roll up to the next higher level

The PBS consists of two sections: definition and execution. The definition section is used to define the scope and establish initial cost estimates and schedules that will be used as a baseline against which actual and forecast information will be measured. The execution section defines the strategy selected for a particular project. A PBS is the heart of any project integration effort. Project managers use it to ensure that all tasks are identified and fit together properly to complete the project (Davies 1995).

PROJECT BREAKDOWN STRUCTURE (PBS)

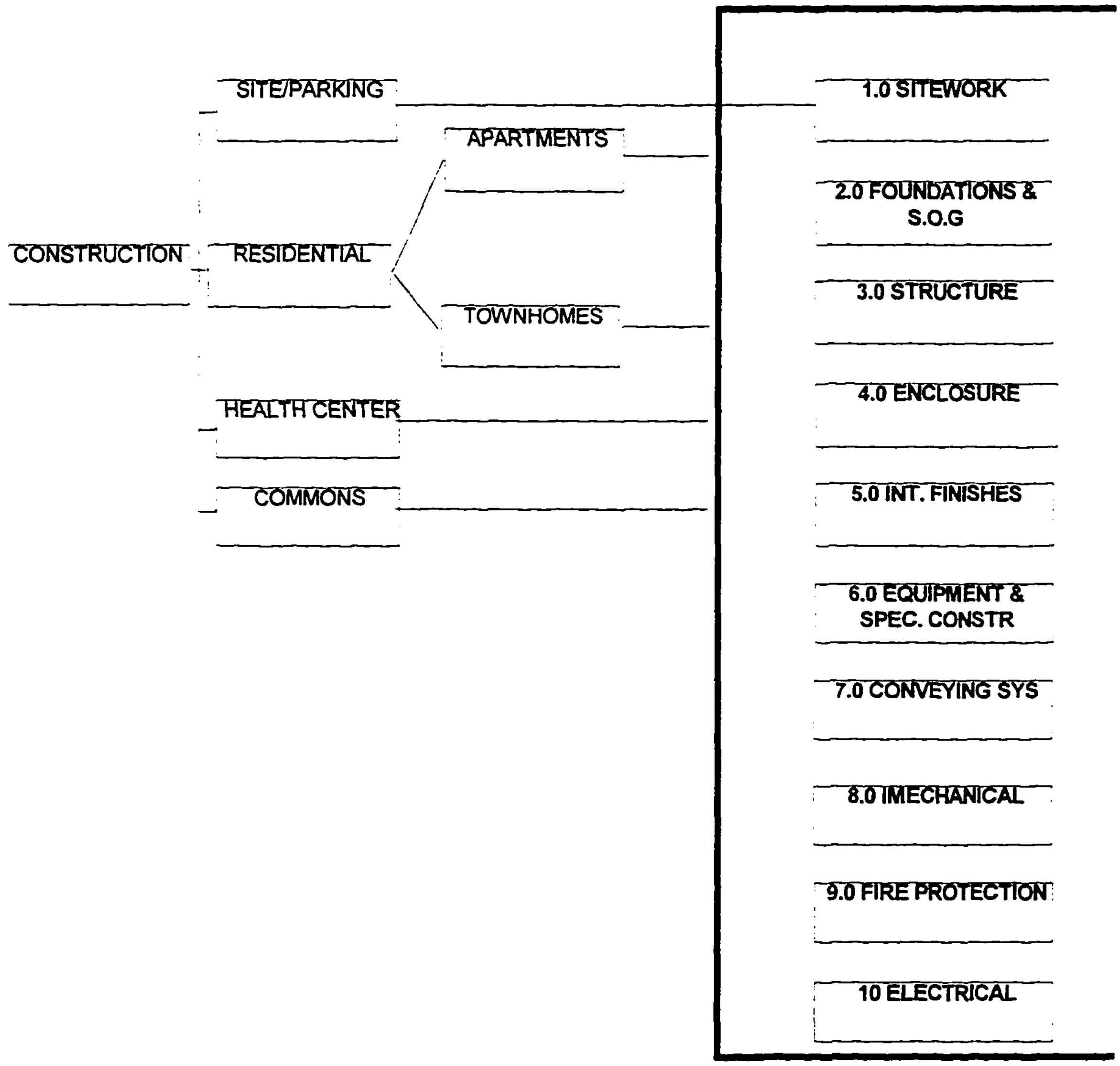


Figure 10. An example of a Project Breakdown Structure (PBS)

CPM as a Planning Model

CPM and project network scheduling made significant contribution to planning and successful completion of construction projects. CPM has continually evolved since its development in the late 1950s. Industry expanded its use to perform a number of analysis such as resource loading, resource leveling, cash flow analysis, etc. The advent of CPM coincided with advent of the computer and the term CPM and computer soon became synonymous (Mason 198). The computer was used widely to manipulate data and make the basic calculations. For a number of years CPM users were totally dependent on Mainframe Systems. The data processing aspects of schedule preparations consumed more time and effort than constructive planning. In many cases, the computer program, and not the CPM plan became the focus of attention. Planners and schedulers were either tied down to learn the programming instructions or spend a majority of their time depending on systems people to solve their problems. Consequently, this contributed to the alienation of planners from the end user (Mason 1984). The planners usually dictate system requirements on the end user in a form that is hard to digest by the users.

Numerous scholars and practitioners including Birrell, 1980; Fondahl, 1982; Mason, 1984; Jaafari, 1984; White, 1985 have criticized the conventional CPM model. Only some of the major CPM shortcomings are briefly discussed here:

Problem of Logic

Mason argues that CPM is suitable for "sequential" operations. It is not suitable for "bulk" operations which is typical of installation type of work, where detailed sequencing of activities is often irrelevant. Besides, most projects today may be more driven by logistics rather than logic examples of which include projects that are driven by resources due to resource limitations such as mechanical piping and ductwork, or electrical conduits, trays, etc. Other examples include material procurements, weather, plant shutdowns, strikes, etc., where the start of an activity is more restrained by these logistics than the logic ties to its predecessors.

Mismatch of Summary versus Detail and Level of Detail

Most projects prepare several levels of project plans such as master, milestones, control, detail engineering, and construction plans. These are prepared independently or at different time intervals. Hence, they do not relate to each other, or at times, may contain incorrect or outdated information. Showing the right level of detail in CPM is another problem. This is particularly applicable to design and procurement activities where literally thousands of drawings, specifications, studies, stock items, direct charges, purchase requests, and purchase orders may be involved. To show all this detail in CPM would turn the CPM model into a planner's nightmare. It is practically beyond the ability of CPM model to cope with this amount of data (Mason 1984).

Planning Accuracy Problems

One of the false hypothesis of the CPM model is assuming that interferences and variability rarely occur in a project. In fact, randomness and uncertainty exist in construction everywhere (Laufer and Tucker 1987). To build in an element of risk, some companies impose the use of statistical or simulation techniques such as Monte Carlo Simulations, etc. The primary statistical measures are the expected project duration and the project standard deviation. These are used to compute the probability of completing the project within a specific amount of time. Although this may seem logical in theory, there are many problems in practice. For example, many of these modules assume working with one project, allowing one resource per activity, and assuming that there is only one critical path per project (Woodworth 1993). Even so, the models are not only complex and hard to understand by the layman, but suffer from their own problems such as insufficient data parameters and inconclusive results (Laufer and Tucker 1987).

Information Preparation Problems

Perhaps a more serious problem under-emphasized by the planning profession and not addressed at all by the software companies is how to go about preparing the required input for the CPM model. Traditionally, project managers and schedulers rush to develop project schedules based on past experience and intuition, developed in a crisis mode, with little time to analyze the plan prior to its execution. Little thought is given to the role of the owner, architect/engineer, contractors, material suppliers, and other parties involved (Cunningham 1994). These parties have different contractual terms with various and conflicting objectives. Over the past two decades, construction projects have become very complex with literally thousands of separate, yet interdependent, operations involving numerous parties across the globe.

Often schedules are developed while project scope is not well defined and the objectives are short range (Pincus 1982). The basis for a good plan is a good description of the scope of work. Project scope forms the baseline for control. If the scope is not well defined, it is difficult to accurately define material and work requirements, determine quantity of work, staffing, and other resource requirements. Rather than concentrating on identifying and formalizing project scope of work, contractual and other commitments, long lead items and materials requirements (i.e. "real" planning issues), emphasis has been on developing and processing the CPM schedule. Therefore, CPM schedules are developed without considering major planning issues. The result of this "hit and miss" approach is "wacky" schedules that are not reflective of project scope and objectives, client requirements, contract milestones, etc., and provide very little information as far as schedule basis, qualifications and assumptions. A schedule which is inaccurate or does not demonstrate the "intended" project plan will most likely be a detriment to the project (Callahan, Quackenbush, Rowings 1992).

Need for a CPM Supplement Model

Regardless of the criticism and limitations of the CPM model, so long as better models are not available, CPM is still applicable to most projects. The industry is constantly bombarded with "latest/best" computerized planning systems that, when analyzed objectively, rarely offer substantial improvements over existing CPM processors (Mason 1984). The problem is not the CPM technique, but what is input into the CPM. "Garbage-in Garbage out" is the expression used that best describe this (see Figure 11).

Project planning can be improved by focusing on the planning as a whole, rather than only on planning technique (Cohenca, Laufer, Ledbetter 1989). Most planning textbooks have explained the CPM technique in great detail. Extensive time is taken up reviewing, learning, and struggling with new scheduling techniques and computer software, but very few have addressed the planning process and what must be done to improve it (Laufer, Tucker 1987).

Knowledge Based Expert Systems (KBES)

Knowledge Based Expert Systems (KBES) are examples of Artificial Intelligence (AI) technology. AI technology enables computers to emulate functions carried out by humans and bring reasoning process into the program (Morad, Beliveau 1994). AI research related to project planning goes back to the early 1970's. The first generation of AI planning started with Stanford Research

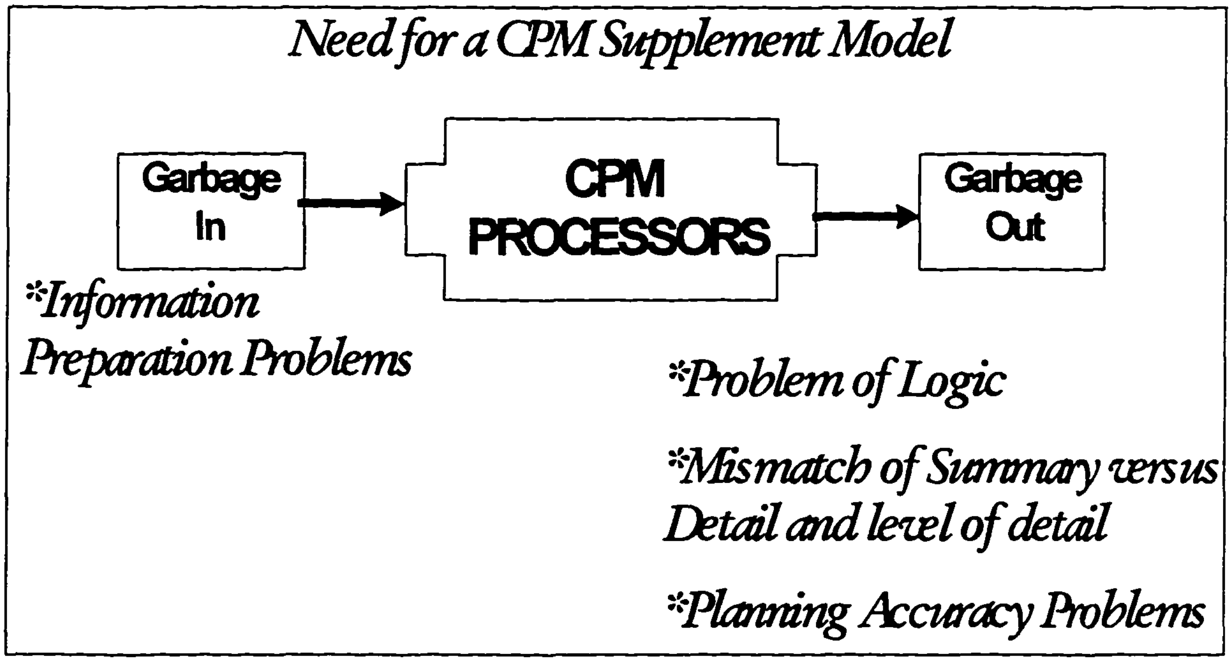


Figure 11. The problem is not the CPM technique, but what is input into the CPM.

Institute Planning Systems (STRIPS) in 1971. This study by Nilsson and Fikes (Kartam, Levitt 1990) assumed that planning is linear with no allowance for parallel actions. The practicality of this research was indeed questionable since construction activities include both linear and non-linear types. In fact most construction projects with exception of transportation, pipeline, vertical and some of the repetitive type construction are considered as non-linear. The second generation of AI planners used the “least commitment” approach in the Nets Of Action Hierchies (NOAH) developed by Sacredoti in 1975 and used non-linear plans to delay ordering decisions (Kartam, Levitt 1990). In 1989 Wilkins developed System for Interactive Planning Execution (SIPE). The research funded by NSF and Stanford Construction Institute is based on hierarchical non-linear plans and uses deductive rules. SIPE is based on the concept of robotics and uses generic operators to generate plans. It employs object hierarchies defined on CAD and is based on a multi-story construction modeling (Kartam, Levitt 1990).

Zozaya-Gorostiza and Hendrickson developed PLANEX in 1989. The activities with required resources are linked into a process planning network. All information on the planning process is stored in the form of objects. PLANEX uses a set of rules resembling a decision table. Durations are estimated by domain operators which are stored in a domain operator schema. Control is provided using control operators and a control panel which acts as a user interaction mechanism (Zozaya, Henderickson, Rehak 1989). In 1989 Rowings and Wagner introduced the concept of Alternative Logic Scheduling Theory (ALST) which uses an optimization technique capitalizing on the concept of soft logic or alternative logic. Alternative logic is often selected on the basis of resource constraints, cost and schedule objective, personal preference, or traditional sequencing methods. ALST builds on the strengths of traditional CPM and attempts to incorporate the flexible characteristics of dynamic site conditions. The definition of absolute and preferential logic and their application are at the root of ALST. ALST is a modification of CPM and does not affect the output (Wagner, 1989).

From the above research it is obvious that a great deal of effort has been spent in automating the planning process. However, CII has emphasized the need for further research particularly in the following grossly overlooked areas (CII 1994):

- Timing of planning and the timing of transition from one stage to the next.
- Steering the process through its progress

CII suggests development of traditional planning tools to improve understanding of the actual process of planning. It also recommended the application of Artificial Intelligence (AI) models to simulate the traditional process based on human decision making. Nonetheless, the study warns that for planning to become more effective, information gathering methods should be changed, the roll of planning and scheduling should be modified, and schedule assumptions should be taken into serious consideration. Project management needs a planning model that quickly and economically develops a quality summary construction schedule from parametric elements of the project (Orczyk, Chang 1990).

The Parametric Technique

A parameter as defined by Webster is "any of a set of physical properties whose values determine the characteristics of something". Examples of parameters for a construction project include: floor area, building volume, capacity, location, type of construction, etc.

Background

The literature review of the parametric technique begins with its application to cost estimating and then moves to the planning and scheduling area. In fact most of the parametric applications are in the cost estimating area but many of the parameters that are used to generate conceptual cost estimates also apply in producing conceptual plans. Under the parametric estimating models, project cost estimates are derived from cost histories on prior similar programs. The origins of parametric cost estimating date back to World War II. The war caused a demand for military aircraft in numbers and models that far exceeded anything the aircraft industry had manufactured before. While there had been some rudimentary work from time to time to develop parametric techniques for predicting cost, there was no widespread use of any cost estimating technique beyond a laborious buildup of labor-hours and materials. A type of statistical estimating had been suggested in 1936 by T. P. Wright in the *Journal of Aeronautical Science*. Wright provided equations which could be used to predict the cost of airplanes over long production runs, a theory which came to be called the learning curve.

In the late 1940's, the Department of Defense (DoD), and, especially, the United States Air Force began a study of multiple scenarios concerning how the country should proceed into the age of jet aircraft, missiles and rockets (Scott

1995). The Military saw a need for a stable, highly skilled cadre of analysts to help with the evaluation of such alternatives. Around 1950, the Military established the Rand Corporation in Santa Monica, California, as a civil "think-tank" for independent analysis. Over the years, Rand's work represents some of the earliest and most systematic studies of cost estimating in the airplane industry (Scott 1995). The first assignments given to Rand concerned studies of first and second generation ICBM's, jet fighters and jet bombers. While the learning curve technique still proved useful for predicting the behavior of recurring cost, there were still no techniques other than detailed labor-hour and material estimating for projecting what the first unit cost might be (a key input to learning curve equation). Worse still, no methods were available for quickly estimating the non-recurring costs associated with research, development, testing and evaluation (RDTE). In the defense business in the early to mid 1950's, RDTE had suddenly become a much more important consideration. There were two reasons for that fact. First, a shrinking defense budget (between World War II and the Korean War) had cut the number of production units for most military programs, and second, the cost of new technology had greatly magnified the cost of development. The inability to quickly, and accurately, estimate RDTE and first unit production costs had become a distinct problem.

Fortunately, within Rand, a cost analysis department had been started in 1950. This group proved to be prolific contributors to the art and science of cost analysis—so much so that the literature of aerospace cost estimating of the 1950's and 1960's is dominated by the scores of Rand cost studies that were published during that time. In the mid 1950's, Rand developed the most basic tool of the cost estimating discipline, the Cost Estimating Relationship (CER), and merged the CER with the learning curve to form the foundation of parametric aerospace estimating. This estimating approach is still used today.

By 1951, Rand derived CER's for aircraft cost as a function of such variables as speed, range, and altitude. Acceptable statistical correlation were observed. When the data was segregated by aircraft types (e.g., fighters, bombers, cargo aircraft, etc.), families of curves were discovered. Each curve corresponded to different levels of product or program complexity. This Parametric stratification especially helped clarify development cost trends. Eventually, a useable set of predictive equations were derived which were quickly put to use in Air Force planning activities.

The use of CER's and data stratification were basic breakthroughs in cost estimating, especially for RDTE and first unit costs. For the first time, cost analysts saw the promise of being able to estimate relatively quickly and accurately the cost of proposed new systems. Rand extended the methods throughout the 1950's, and by the early 1960's, the techniques were being applied to all phases of aerospace systems.

The state-of-the-art in parametric estimating has been steadily improving by an explosive growth in the number of practitioners, important methodological improvements, and greatly expanded databases. All of the major aerospace contractors and government aerospace organizations have dedicated staffs of parametricians who maintain and expand databases, develop parametric cost models, and utilize the tools of parametrics to make estimates of new and ongoing programs. NASA and the DoD routinely use parametric estimates to form the basis of new project cost commitments to Congress. The contractor community also routinely uses parametric cost models, especially during product concept definition. These estimates are used for decision making regarding bid strategies and are used as submittals to the government. It is only at the production and full scale development phase that parametrics are not commonly utilized for official proposal submissions (although contractors still frequently use parametrics to generate target costs and cross-checks on the labor-material/buildup estimates).

A parametric cost model is defined as, a group of cost estimating relationships used together to estimate entire cost proposals or significant portions thereof. These models are often computerized and may include many inter-related CER's, both cost-to-cost and cost-to-noncost. Some models use a very limited number of independently estimated values and a series of Parametric inter-related cost-to-cost and cost-to-noncost estimating relationships to predict complex proposal cost structures.

The parametric cost estimating is a technique used by both contractors and the Government in planning, budgeting, and performance stages of the acquisition process. The technique is used by contractors to expedite the development of cost estimates when discrete estimating techniques would require inordinate amounts of time and resources and would produce similar results. Reliance on properly developed and carefully evaluated CER's and parametric cost models to produce realistic cost estimates can save both Industry and the Government time and resources in the evaluation and definitization cycle of the proposal or contract.

The concept includes the use of cost-to-cost CER's such as engineering labor overhead rates and material overhead rates which when reviewed using traditional evaluation criteria, are considered valid estimators by the government. However, the technique also uses cost-to-noncost CER's which require additional analysis to determine their validity and acceptability as estimating tools.

Parametric techniques focus on the cost drivers, not the miscellaneous details. The drivers are the controllable system design or planning characteristics and have a predominant effect on system cost. Parametrics uses the few important parameters that have the most significant cost impact on the product(s), hardware or software, being estimated.

Over the past several years industry and professional estimating associations (e.g., International Society of Parametric Analyst (ISPA), Society of Cost Estimating and Analysis (SCEA), and the Space Systems Cost Analysis

Group (SSCAG)) have been actively working with both Defense Contract Management Command (DCMC) and Defense Contract Audit Agency (DCAA) to explore the expanded opportunities for the use of parametric cost estimating techniques in firm business proposals. ISPA was formed in 1978 when a parametric estimating user's group evolved into a more generic Society.

Although the Rand Corporation was a pioneer in developing parametric estimating models, many parametric cost estimating models have been developed by others as well (Black 1984). More recent studies include the work done by Gallagher (1982), Dell'Isola and Kirk (1981), Parker (1994), Gosselin and McMullan (1989), Tom Mendel (1989), and a few others.

Gallagher (1982) mentions four parametric facets as data bank, new product definition, estimating methods, and probability techniques. The purpose of the data bank is to provide parameters and values from previous jobs to be used in estimating new jobs. New product definition must also be in terms that apply to the elements used in estimating methods. He mentions five estimating methods using system parameters, unit of function parameters, parameters for budgeting resources, parameters by type of work, and parameters for modular work measurement. Probability techniques are used for final evaluations and to enlist full management participation.

James Black (1984) demonstrated a seven step parametric procedure as;

1. Problem Definition: Define the problem and determine the objectives.

2. Data Collection: Collect all the relative data.
3. Data Normalization: Make sure data is on the same basis. Adjust for time, location, inflation, learning curve, and technological progress.
4. Interdependencies Determination: Look for characteristics of the item related to cost. Use regression analysis to determine relationship between the parameters and the cost.
5. CER Derivation: Derive Cost Estimating Relationship.
6. Limitations: Establish the limits of variables.
7. Documentation: Document all of the assumptions and limitations.

Donald Parker (1994) of General Services Administration (GSA) has identified seven key parametric cost drivers as: Functional Areas, Number of Occupants, Configuration, Design Parameters, Special Systems, Geographical Location, and Schedule. He argues that this method allows the owner to ask "what if" questions and see what is included or excluded in the budget and the budget documentation can be given to the designer for execution.

Gosselin and Leslie (1989) designed a parametric system which integrates process design information, project description files, and economic analysis. In this way the estimator will have more time to devote to qualitative analysis. They mentioned that the parametric technique provides feedback from the accumulation of the data bank and additional curve-fit observations and can be used to simulate cost based on varying degrees of design information.

Tom Mendel (1989) of the American Association of Cost Engineers (AACE) has mentioned that the parametric technique has a wide range of applications to any industry with repeatable design concepts. The accuracy of estimate using this technique range from 5% to 25% which demonstrates that computer models can simulate manual conceptual estimates with greater speed and better accuracy. Mendel has mentioned that the system's development has been a rewarding experience and demonstrated that parametric estimating can be an accurate estimating tool.

Parametric Planning Models

The current research in the application of the parametric technique to the planning and scheduling area is very limited. The author found only two studies in this area. The first study was conducted by Dr. Joseph Orczyk of Pudue in 1989-1990 (the study was part of his dissertation) which discussed the application of parametric technique to milestones. The second study was conducted by Dr. Wei-Tng Chen, University of Florida in 1994 (Ph. D. Dissertation) and discussed the application of parametric technique in estimating contract duration for highway construction.

Orczyk's Study

This study identified the most important parameters and milestones for a parametric scheduling model. This study which is based on a survey of users including owners, designers, and builders, identifies standard milestones and the parameters that affect timing of the milestones and overall project duration by building type. Although the research was focused on low rise office buildings, the result of the study can be applied to other types of projects as well.

Table 2 is a list of parameters and milestones extracted from this study based on user survey and ranking for a low rise commercial building project. The milestones are listed on the left-hand column while the parameters are shown on the right-hand column. However, there is no relationships shown between the parameters and milestones.

The study also identified average durations for some of the milestones associated with a low rise commercial building. These durations are shown in Table 3 as number of weeks from start of construction for each of the milestones.

Tables 4, 5, and 6 list typical milestones and parameters for highway and bridge, environmental, and power/process construction projects. Orczyk's study provides a good reference for future research. The milestones and parameters that are identified in this research should be included in the development of future scheduling models.

Table 2. Typical Milestones and Parameters for a Building Construction

TYPE: BUILDING CONSTRUCTION		
MILESTONES (START-FINISH)	**PARAMETERS**	
◊ CERT. SUBST. COMPLETION		
◊ FRAME ERECTION	TYPE OF STRUCT. FRAME	TOTAL SITE AREA
◊ ELEVATOR	OWNER'S SCHEDULE	TONS OF HVAC
◊ EXTERIOR CLADDING	SUBSURFACE CONDITION	BUILDING CODE CLASS
◊ ELECTRICAL WORK	EXTERIOR CLADDING TYPE	ROOF AREA
◊ FOUNDATIONS	NUMBER OF FLOORS	TYPE OF CONTRACT
◊ NOTICE TO PROCEED	MONTH CONSTRUCTION BEGINS	LENGTH/TYPE OF PARTITIONS
◊ PLUMBING	AVAILABILITY OF LABOR	CONNECTED POWER LOAD
◊ GLAZING	TYPE OF FOUNDATION	TYPE OF ROOFING
◊ HVAC	VOLUME OF CUT/FILL	PRESENCE OF SPRINKLERS
◊ INTERIOR FINISH	TOTAL FLOOR AREA	AREA OF PAVING
◊ ROOFING	QUALITY OF LABOR	TYPE OF DOORS
◊ CONCRETE TOPPING	LOCATION	AREA OF LANDSCAPING
◊ PUNCHLISTS	SUPPORTED FLOOR AREA	NUMBER OF OCCUPANTS
◊ U/G UTILITIES	EXTERIOR WALL AREA	TYPE OF CEILING FINISH
INTERIOR PARTITIONS	LENGTH OF PARAMETER	R-VALUE OF EXT. WALLS
	STORY HEIGHT	TYPE OF INT. WALL FINISH

Table 3. Typical Milestones and Durations for a Building Construction

MILESTONE	DURATIONS (in weeks from start of construction)	
NOTICE OF SUBST. COMPLETION	52.3 WEEKS FROM START OF CONSTRUCTION	
NOTICE TO PROCEED	-2 WEEKS	
FOUNDATIONS	START: 3.7 WEEKS (7%)	FINISH: 11.5 WEEKS (22%)
STR. FRAME	START: 12.1 WEEKS (23%)	FINISH: 20.2 WEEKS (39%)
EXTERIOR CLADDING	START: 21.5 WEEKS (41%)	FINISH: 33.7 WEEKS (64%)
ELEVATORS	START: 26.2 WEEKS (50%)	FINISH: 46.3 WEEKS (88%)
COMPLETE ROOFING		FINISH: 26.0 WEEKS (50%)
COMPLETE GLAZING		FINISH: 38.7 WEEKS (74%)
COMPLETE INTERIOR FINISHES		FINISH: 46.8 WEEKS (89%)
COMPLETE ELECTRICAL		FINISH: 47.7 WEEKS (91%)
COMPLETE PLUMBING		FINISH: 46.2 WEEKS (88%)
COMPLETE HVAC		FINISH: 48.6 WEEKS (93%)

Table 4. Milestones and Parameters for Highway and Bridge Construction

TYPE: HIGHWAY and BRIDGE CONSTRUCTION	
MILESTONES	**PARAMETERS**
◊ COMPLETE SUB-GRADE ◊ COMPLETE PAVING ◊ COMPLETE SUBSTRUCTURE ◊ COMPLETE SUPERSTRUCTURE ◊ COMPLETE BRIDGE DECK ◊ DELIVER STEEL ◊ TRAFFIC SHUTDOWN ◊ RE-OPEN TO TRAFFIC ◊ FINAL REVIEW and ACCEPT. ◊ COMPLETE LANE STRIPPING ◊ COMPLETE PLACING BASE MATERIAL	◆ VOLUME OF CUT/FILL ◆ WEATHER ◆ CYDS OF CONCRETE ◆ NEW WORK OR REHAB ◆ LOCATION ◆ LOCAL UNION RULES ◆ TRAFFIC VOLUME ◆ TRAFFIC SCOPE ◆ MAINTENANCE

Table 5. Milestones and Parameters for Environmental Construction

TYPE: ENVIRONMENTAL CONSTRUCTION	
MILESTONES	**PARAMETERS**
◊ MAJOR MATERIAL DELIVERY ◊ COMPLETE ELECTRICAL ◊ OBTAIN PERMITS ◊ COMPLETE MECHANICAL ◊ COMPL. CONCRETE	◆ SUBSURFACE CONDITIONS ◆ MATERIAL LEAD TIME ◆ WEATHER

Table 6. Milestones and Parameters for Power/Process Construction

TYPE: POWER/PROCESS CONSTRUCTION	
MILESTONES	**PARAMETERS**
◊ MAJOR EQUIPMENT DELIVERY ◊ TEST/START-UP ◊ NOTICE TO PROCEED ◊ SET UP MAJOR EQUIPMENT ◊ ENERGIZE SWITCHGEAR ◊ BOILER BLOWOUT(FOSSIL) ◊ TURBINE ROLL ◊ GRID TIE-IN ◊ HYDROTEST (BOILER)	◆ MATERIAL LEAD TIMES ◆ LICENSING/PERMITS ◆ FINANCING ◆ WEATHER ◆ ELECTR. CONDUIT ◆ WIRE/CABLE ◆ LARGE BORE PIPE ◆ SMALL BORE PIPE ◆ NO. OF ELECTR CONNECTIONS

Wei-Tng Chen Study (1994)

This study introduced a parametric time estimating module which utilizes various related project parameters to describe contract duration. The user enters the cost and related project characteristics such as location, traffic handling, and project terrains. As a supplement to the time estimating module, a production rate data base is created to store major work production rates organized by type of work. A template is then formed (using 1-2-3 spreadsheet) to gather related information input by user. The model utilizes "Decision Trees" to graphically convert the obtained information. An example of the decision tree is shown in Figure 7. The system utilizes several rules in order to execute the program. The study gives several case studies to validate the parametric module.

Dzeng's Research (1995)

Ren-Jye Dzeng developed a planning and scheduling model at the University of Michigan named CasePlan, that automates the planning and scheduling process through the use of experience encoded in cases. CasePlan is a decision support tool that enables the user to search for cases with similar design and re-uses parts of the schedules whose associate designs are most similar to the present project. The research used two types of construction, a boiler erection and a Kit-of-Parts post office due to design repetitiveness of these types of projects.

CasePlan utilizes a three step in solving problems:

1. Retrieving the most useful cases
2. Reusing the retrieved cases to solve the new problem
3. Storing the new problem and solution as a case.

Pitfalls in Using a Parametric Model

When a parametric model is applied to values outside its database range, the credibility of the resulting estimate becomes questionable. In cost estimating, one rarely finds large, directly applicable databases, and the source document has to be evaluated to determine if the parametric can be applied to the current estimate. However, it is possible to develop parametric tools that relate cost based on generic complexity values or tables. Such generalized parameters, can be related to the task at hand resulting in a good cost model, but a parametric model always needs to make sense for the present estimate.

Additionally, and before using, one should validate models based on expert opinion. This is accomplished first by obtaining some actual, historical data points (technical, schedule, and cost) on completed programs similar to the current program. With this data in hand, apply the model to the actual technical and schedule information and see how well the parametric model predicts the known cost. If the model estimated the actual costs with an acceptable margin of error, validate the model for programs that are similar to the historical data point. Careful validation will help insure that cost models are appropriately used.

Many times a parametric model needs to be adjusted if the new system has cost drivers and/or requirements that are not reflected in the parametric's database. In some of these cases, a combination of parametric methodology with an approach taken from the analogy methodology can be used to develop an estimate by adjusting the results of the parametric approach with scaling or complexity factors that reflect any unique requirements. For example, parametrics and analogy approaches could be effectively combined to estimate the costs of a new program for which technology advancement is anticipated. First, either develop or use an existing parametric model, based on similar data points, to estimate the cost of the program, without technology advancement.

Second, address the technology advancement by consulting with functional experts to obtain a most-likely range for a relative scaling factor that will reflect any advancements in technology. The relative scaling or complexity factor is applied to the result of the parametric estimate, and adjusts it for the impact of technology advancement. This is a solid and valid estimating approach for assessing the cost impacts of technology advancement, or other "complexity" differences.

In such cases, the parametric model has to be adjusted so that it makes sense vis-à-vis the current estimate. If there exist no realistic estimates for the independent variable values for the product or effort being estimated, then parametric models should not be used. The level of uncertainty in the estimate will be considerable, and the validity of the estimate questionable. In cases such as this, parametrics can only be used as a benchmark.

As stated previously, it is very difficult for functional specialists to provide a single point estimate. Moreover, a single point estimate does not reflect the uncertainty inherent in any functional expert's opinions. Consider requesting most likely range values rather than point estimates, if possible.

Summary and Critique Of Existing Research

The research confirms the importance of conceptual planning and its positive impact on productivity and project success. Alexandar Laufer, R.L. Tucker, Derek Mason, and others are among the leading researchers pointing out that too much was being stressed on the scheduling tools rather than the planning process. As a result of their concern several research projects by CII, U.S. Army (USACERL), Stanford University, Carnegie Mellon, NSF, and other institutions were launched during the past few years to improve the planning process. Most of these studies call for automating the planning process, activity durations, and sequencing by applying Knowledge-Based Expert systems. Unfortunately, only a few of the researchers addressed the problem of applying the parametric approach by using past project information and knowledge in generating present plans. Research done by Joe Orczyk at Purdue (Orczyk 1989), Wei-Tong Chen at the

University of Florida (Chen 1994), and Ren-Jye Dzeng (1995) at the University of Michigan is promising.

Orczyk applied the parametric technique in producing milestone schedules on low-rise buildings. The parameters and milestones were based on a survey of 54 large and small contractors, designers, and owners who ranked the parameters and milestones most frequently used on low rise buildings. These milestones and parameters should be included in the development of parametric based planning. Chen used the parametric technique in describing contract durations for highway projects. His research included the use of a simple spreadsheet to capture user input and a “Decision Tree” to convert this information. Chen’s work addressed calculation of schedule durations and production rates but did not address the planning process. Dzeng presented a model named CasePlan, that automates the planning and scheduling process through the use of experience encoded in cases. CasePlan is a decision support tool that enables the user to search for cases with similar design and re-uses parts of the schedules whose associate designs are most similar to the present project. The research was limited to two types of construction, a boiler erection and a Kit-of-Parts post office. CasePlan utilizes a “reasoning” capability which if extended can be applied to other types of construction as well. This should be included when developing future models. Another limitation of the CasePlan is the storing of data and cases.

Previous research focused on automating the planning process while disregarding the important human aspect of planning. There is no formula for cranking a project plan. Plans are prepared by people using judgment and prior experience. Historical data can be retrieved and used as a reference. Planning is much more than developing a network logic and assigning durations and sequences of work. Part of this process is the interaction and brainstorming among the project team as well as any other entity that is involved in a project. The process contributes to the understanding of the project team regarding their project, the goals and objectives, the scope of work, and how they can work together as a cohesive team to meet the objectives. Planners need a system that would facilitate this process but not to replace it.

Teamwork and communication are critical to the success of the planning process. Activities at the beginning of a project are hectic by nature and may be perceived as undefined. Time is seldom available for all team members to participate in the planning effort. For pre-project planning to be successful, team continuity is needed and the team must be cultured through team building and open communication (Gibson, 1994).

The construction industry is crossing the threshold of a new era communications revolution. The Internet is revolutionizing the way the industry does business. Bill Gates, the founder of Microsoft said, "The Internet has a huge potential as it relates to construction. This is an industry that continually moves detailed information back and forth between offices and remote job sites. Pulling together even a simple straight forward project now requires the interaction of hundreds of people and thousands of documents" (Murray 1997). The technology will allow electronic documents to be indexed and retrieved using interactive exploration. Video-conferencing has already started and will become common in most businesses. This will make collaboration and co-ordination easy among the project team. Team members can talk to each other across the globe as if they were in the same building. The time is now to develop a parametric model that capitalizes on this unfolding technology to develop a systematic planning approach to guide the project team in preparing fast and reliable conceptual plans using historical project data.

CHAPTER 3: METHODOLOGY

The information extracted from the literature search, as discussed in Chapter 2, laid the foundation for the current research methodology. Several standard, and specific parameters and milestones were listed. These lists formed the basis to conduct further research using actual case studies. Several contractors were approached to solicit and sponsor the research. Selection criteria included their progressive planning culture, procedures, and tools.

Participants

This research was sponsored and funded by two prominent construction companies, the Weitz Company of Des Moines, Iowa and HCB Contractors of Dallas Texas. These companies provided the necessary historical data, input, and the important feedback that was needed for this research. Upon meetings with senior management of both companies, it was decided to choose between four to six projects with similar in their scope of work from each company. A total of seven retirement communities from the Weitz Company and four hospital additions and renovations from the HCB Contractors formed the case studies used in this research. The rationale for choosing these projects was as follows: The case studies were selected to take into account as much context as possible. The case studies are credible as they are good representation of a variety of construction jobs and are transferable to present settings. For example, the retirement community projects were similar in type of projects and consisted of several component facilities that represented both commercial and residential type of work. Most of these projects included apartments, townhomes, villas, health centers, clubhouses, parking garages, and site improvements.

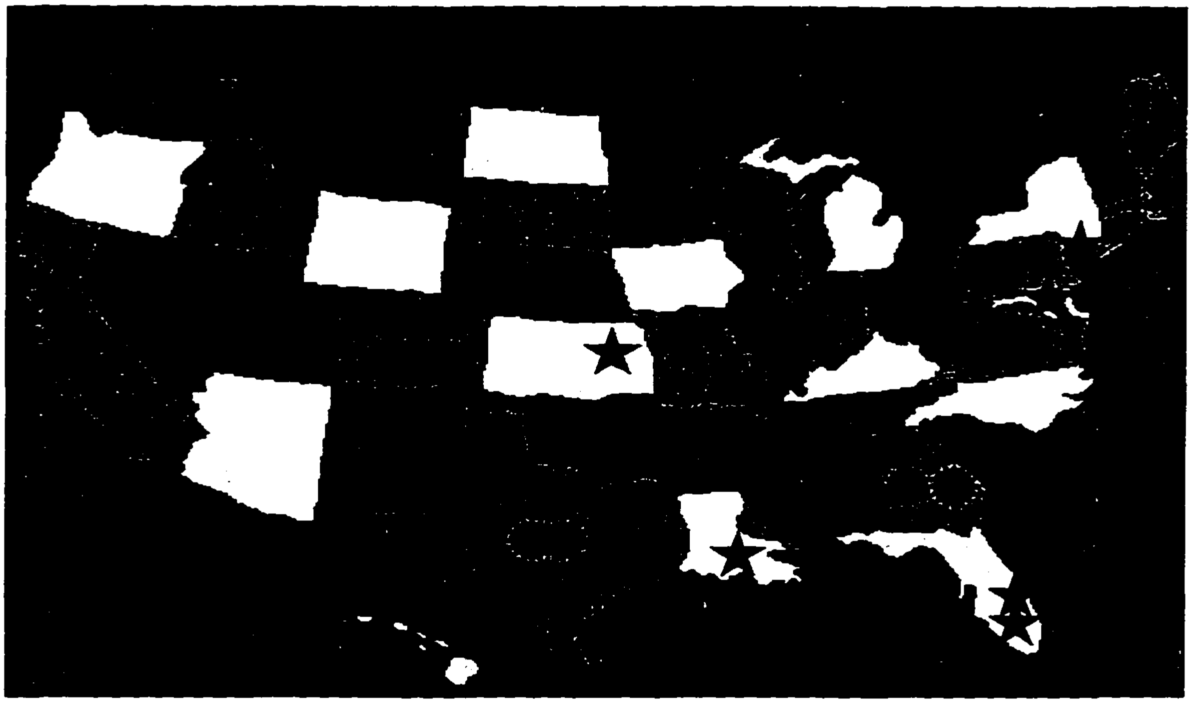


Figure 12. Selected case studies are scattered across eight States.

They were also located in various parts of the U.S. including six states with a variety of climates with a cost range of $!6 M to $ 55 M and a construction duration range of 14 months to 28 months (see Figure 12). The hospital projects were primarily located in the South (Texas and Georgia). They consisted of both new construction as well as existing renovations and remodeling work in the range of $ 1.6 M to $ 5.5 M and a construction duration range of 6 months to 19 months.

Key project personnel who worked in different aspects during the planning process and formation of plans were interviewed. These participants were selected on the basis of their recognized experience and intimate involvement in the specific projects discussed. The credibility and dependability of data was confirmed by these participants. The data from these case studies along with project management feedback was used as a basis for the research analysis.

Case Studies

Retirement Community Projects

The matrix of Table 7 provides an overview for each of the seven retirement community cases as for the location, component facilities, number of units, gross square foot (GSF), cost, duration, and start and completion dates.

Hospital Renovations and Additions Projects

The matrix of Table 8 provides an overview for each of the four hospital renovations and addition projects. The table shows such information as to the type of project, location, cost, construction duration, and start and completion dates.

Table 7. Overview of the Retirement Community Cases

CASE	LOCATION	COMPONENTS	Units	GSF	Cost	DUR	START	COMPL
A	Maryland	Site		**329,200**	**$26.8M**	**29 mo.**	Mar-91	Dec-92
		Apartments	177 units	257,691				
		Common	LS	33,448				
		Health Ctr	36 units	24,274				
		Parking	25 cars	13,787				
B	Louisiana	Site		**169,690**	**$15.9M**	**16 mo.**	May-95	Sep-96
		Apartments	92	123,000				
		ALU	22	16,800				
		Health Ctr	20	12,390				
		Common	LS	17,500				
C	Illinois	Site		**418,253**	**$35.1M**	**20 mo.**	Mar-92	Oct-93
		Apartments	215	260,564				
		Townhomes	26	57,915				
		Health Ctr	50 beds	30,179				
		Common	LS	53,462				
		Parking	39 cars	16133				
D	Massachusetts	Site		**313,531**	**$27.2M**	**22 mo.**	Oct-95	May-97
		Apartments	177	227,278				
		Health Ctr	45 beds	19,317				
		Common		30,905				
		Parking	88 cars	36,031				
E	Florida	Site		**287,568**	**$20.4M**	**14 mo.**	Aug-90	Oct-91
		Apartments	140/2 bldg	188,306				
		Health Ctr	30 Rooms	21,471				
		Common		27,718				
		Villas	26/13 bldg	50,073				
F	Kansas	Site		**262,419**	**$19.7M**	**17 mo.**	Mar-92	Jul-93
		Apartments	135	183,697				
		Health Ctr	35 beds	17,470				
		Common		29,813				
		Parking	73 cars	31,439				
G	Florida	Site		**537,000**	**$55.5M**	**28 mo.**	Jan-97	Jun-99
		Apartments	135	310,000				
		ALU		47,500				
		Health Ctr	35 beds	49,700				
		Common		64,400				
		Villas	73 cars	65,400				

Table 8. Overview of the Hospital Renovations/Addition Projects

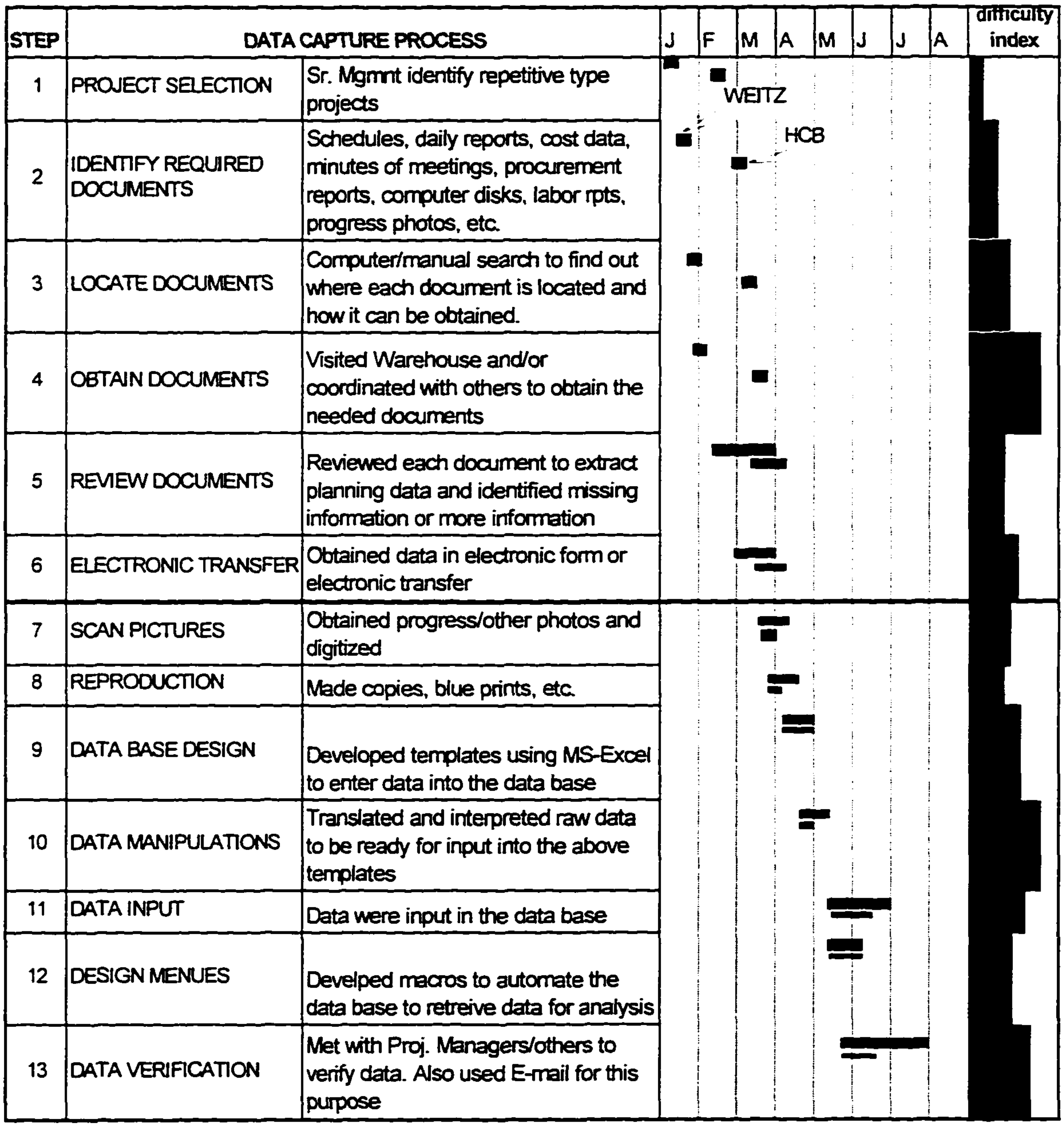
CASE	LOCATION	COMPONENT	COST	DUR (MO)	START	COMPL
A	Georgia	New/Renovation	$1.6 M	9.10 mo.	Sep-96	Jun-97
B	Georgia	New/Renovation	$3.19 M	8.07 mo.	Sep-96	May-97
C	Texas	New/Renovation	$2.95 M	6.03 mo.	Nov-94	May-95
D	Texas	New/Renovation	$5.50 M	19.27 mo.	Oct-94	May-96

Data Gathering Techniques

Since this research is more of a qualitative study in nature, a variety of data gathering techniques were employed. These included observation, document reviews, and structured and open-ended interviews. Archived project files were manually searched and pertinent information related to planning, scheduling, and cost were collected and reviewed. Planning data included project milestones, CPM schedules, quantities, cost, manpower, detail design, procurement, and construction schedules, field notes, and people's own words. Some of the data was readily available, and a few were electronically translated to an acceptable format. However, most of the data was not easily available and was collected through a manual search of the archived files.

Table 9 displays the process of the data gathering, timing, and degree of difficulties encountered in collecting the required data. Some of the source documents used to extract the planning data included: summary schedules prepared prior to construction, detailed pre-construction and design schedules, design development closure documents, detail construction schedules,

Table 9. Data Gathering Process



STEP	DATA CAPTURE PROCESS	
1	PROJECT SELECTION	Sr. Mgmnt identify repetitive type projects
2	IDENTIFY REQUIRED DOCUMENTS	Schedules, daily reports, cost data, minutes of meetings, procurement reports, computer disks, labor rpts, progress photos, etc.
3	LOCATE DOCUMENTS	Computer/manual search to find out where each document is located and how it can be obtained.
4	OBTAIN DOCUMENTS	Visited Warehouse and/or coordinated with others to obtain the needed documents
5	REVIEW DOCUMENTS	Reviewed each document to extract planning data and identified missing information or more information
6	ELECTRONIC TRANSFER	Obtained data in electronic form or electronic transfer
7	SCAN PICTURES	Obtained progress/other photos and digitized
8	REPRODUCTION	Made copies, blue prints, etc.
9	DATA BASE DESIGN	Developed templates using MS-Excel to enter data into the data base
10	DATA MANIPULATIONS	Translated and interpreted raw data to be ready for input into the above templates
11	DATA INPUT	Data were input in the data base
12	DESIGN MENUES	Develped macros to automate the data base to retreive data for analysis
13	DATA VERIFICATION	Met with Proj. Managers/others to verify data. Also used E-mail for this purpose

subcontractor and material supplier reports (SMSRs), daily reports, minutes of meetings, progress photos, questionnaire, interview, and discussion with project managers and key project personnel. The interview consisted of three parts: (1) a general questionnaire consisting of broad planning topics, (2) a project specific questionnaire addressing the milestones and related parameters, and (3) a discussion of the planning culture, philosophy, process, and product.

Research Design

Most existing planning systems have a rigid design with a fixed structure. The user prepares and inputs the information into a "Black Box" processor which performs the analysis and generates an output. The synthesis in such system is entirely left to the planner. The user prepares the input independent of the system and the system performs the analysis independent of the user with very little, if any, user interaction. CAPP has developed a different approach where the user is kept in the planning "loop" to maximize system/user interaction. This interaction allows the flexibility of adapting the system from a generic domain to a specific one.

Design Characteristics

The following characteristics have been built into the CAPP research design:

1. The design architecture is kept generic so that it can be modified and used on different domains using a uniform domain-independent format.
2. CAPP classifies existing plans according to project components and saves it in a plan library. When a new, similar component is defined, the plan which is the closest match is retrieved from the library.
3. CAPP processor and analysis is transparent facilitating the users understanding and interaction with the system. The user is permitted to dialogue with the system in order to modify system components, invoke system operations, and override planning decisions.
4. CAPP structures the knowledge into hierarchies on the basis of types of projects, project components, and level of detail. This allows postponing unavailable detail to later and yet, maintaining system integrity.

Figure 13 provides an overview of the design methodology. Historical data is collected, classified, and entered into a generic data base library. The data is analyzed, normalized, and processed allowing the user to retrieve and extract pertinent data similar to project on hand. An inference engine is derived from the analysis and used in the form of dialogues between the user and the system. The user is placed in the driver seat to exercise judgment and creative planning involving common-sense knowledge that is difficult to incorporate into an automated system. The user has the ultimate ability to adapt the system to different application domains. These design components are discussed in more details later. CAPP's data base architecture is discussed in this chapter while the data analysis and the inference engine specification and flow charts are discussed in Chapter 4.

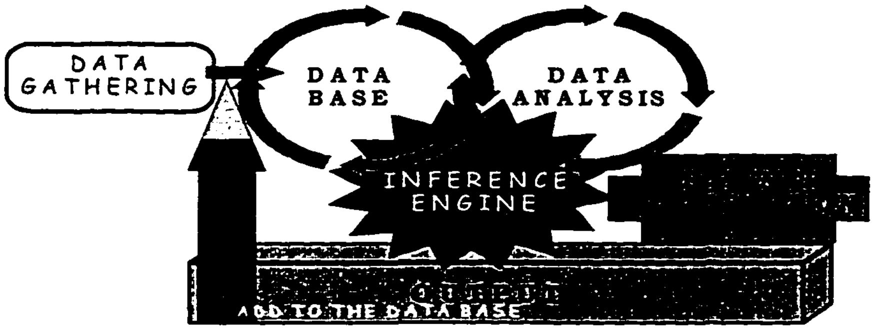


Figure 13. Overview of the Design Methodology

Data Base Architecture

Plans are hierarchical by nature and most decisions, with even small degree of complexity, involve a hierarchy of detail. Top management needs only broadest details while a foreman needs all the fine details, both using the same plan. Figure 14 shows a four level hierarchy. Data gathered from various case studies were classified based on this hierarchy. The user starts at the top level and as more information becomes available, moves down one level until the control level is reached. The level of detail that relate to milestones and user-defined parameters are kept at the control level. Any further detail is left out of the system as it becomes more project specific than generic. One of the main advantage of having a hierarchical structure is that it is easy to isolate the elements that vary from the normal domains.

Furthermore, there are cross-links between the different levels. For example, the cross-links between milestones and components for a typical retirement community project can be represented in a matrix form as shown in Table 10.

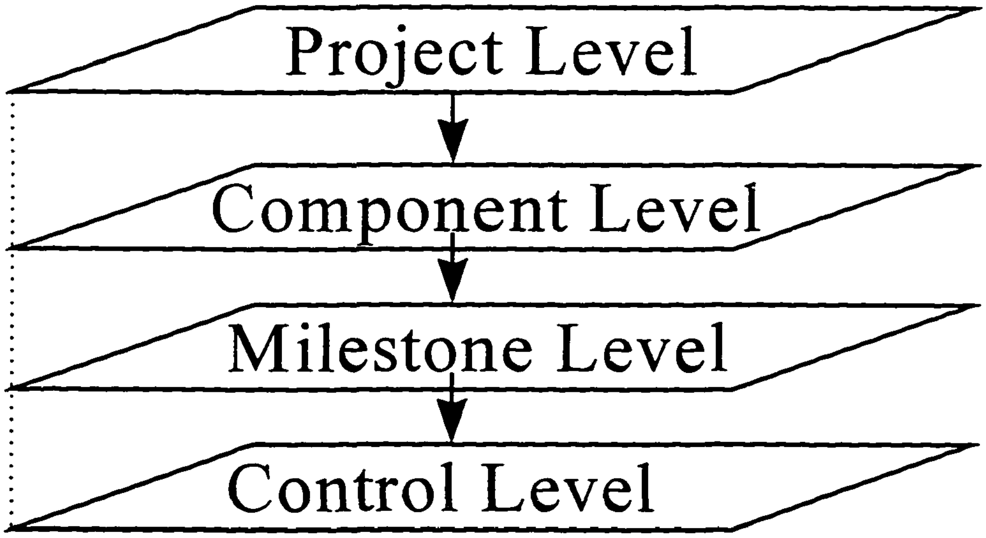


Figure 14. A four level hierarchy as a basis for data base structure

Table 10. Matrix showing Cross-Links between Milestones and Project Components for a typical retirement community project.

	A	B	C	D	E	F	G	H
1. Site Development								
2. Foundations and S.O.G.								
3. Structure								
4. Exterior Enclosure								
5. Interior Finishes								
6. Equipment								
7. Conveying								
8. Mechanical								
9. Fire Protection								
10. Electrical								

A= Apartments
B= Townhomes
C= Villas
D= Assist. Living
E= Health Center
F= Commons
G= Clubhouse
H= Parking

Milestone Definitions

1. Site Development: All activities associated with sitework, grading, paving, roadways, drainage, waterlines, site utilities, and carports.
2. Foundations and SOG: Activities related to foundation excavation, earthwork, backfill, footings, piers, elevator pits, and slab on grade.
3. Structure: Includes structural framing (steel, wood, precast, masonry), metal decking, miscellaneous steel, Structural slabs, concrete topping, structural precast, rough carpentry, stairs, load bearing masonry, and exterior metal wall framing.

4. Exterior Enclosure: Includes precast columns, skin-stucco, exterior insulation, windows/storefronts, caulking, sealants, roofing, sheetmetal, overhead doors, entry doors, and soffits.
5. Interior Finishes: Includes finish carpentry, millwork, doors, hardware, interior glass, interior framing, drywall, plaster, acoustical treatment, floor coverings, painting, wall covering, specialties, toilet partitions, lockers, cabinets, casework, and specialties.
6. Equipment and Special Construction: Includes medical, pool, dock, kitchen, laundry, and any other equipment.
7. Conveying Systems: Includes all sorts of lift equipment including elevators and escalators.
8. Mechanical: Includes all activities related to plumbing, HVAC and other mechanical piping and equipment excluding sprinklers and fire protection.
9. Fire Protection: Includes all activities related to sprinklers and fire protection.
10. Electrical: Includes all activities related to electrical work.

Data Capture Framework

Using the above framework, a data base structure was developed to collect the data. Standard frames were developed using MS-Excel templates to capture the data. MS-Excel was selected due to its flexibility, ease of use, and powerful links to other Microsoft products and data bases. A Menu-Driven data base was constructed to allow the user to easily access various case studies for the purpose of input as well as review and analysis of data. The data from each case study was input into this data base. Figure 15 shows the architecture of the data base for all the case studies used in this research. The format is quite generic yet flexible to capture the data from all case studies and present it in a uniform and consistent style. It is based on the hierarchical structure discussed above starting with the type of project and breaking it into various project components.

The main menu structure consists of 8 data elements for each of the historical projects. These include a project data sheet, parameters, project breakdown structure, milestones, design, procurement, and construction activities, and job photos. Figure 16 shows a project specific menu for one of the selected case studies. The 8 elements are clearly shown each using a separate icon. The first element in this menu is a project data sheet (PDS) showing basic information about the project as shown in Figure 17. PDS is on the project level (level I) in the hierarchy. Such information as the name and title of the project, the owner, the contractor, the developer, the architect, project cost, duration, and timing are shown on the data sheet. The purpose of the data sheet is to briefly define the project and scope of work by addressing the five "W"s and one "H". Project standard and specific parameters are also on the project level.

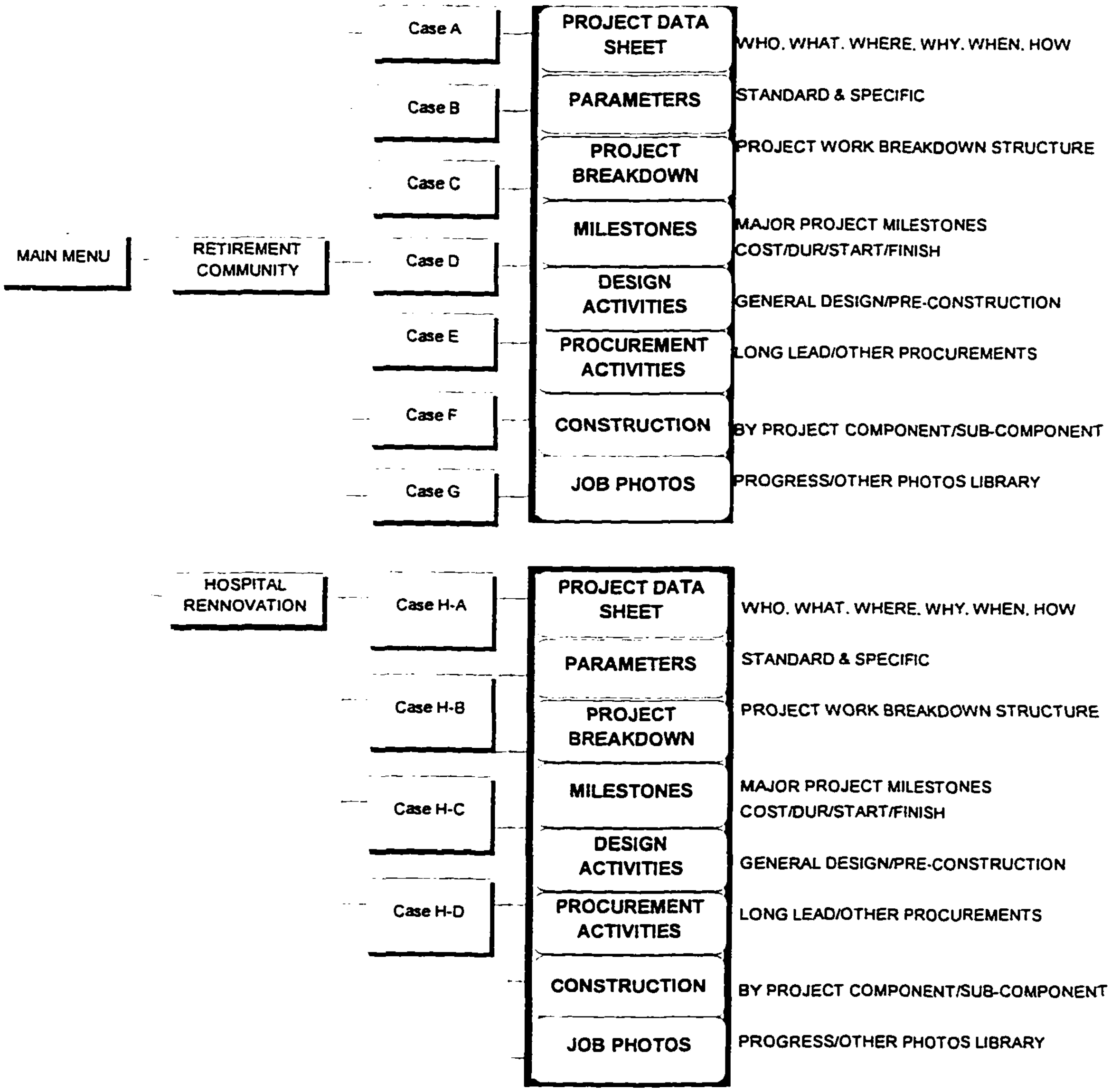
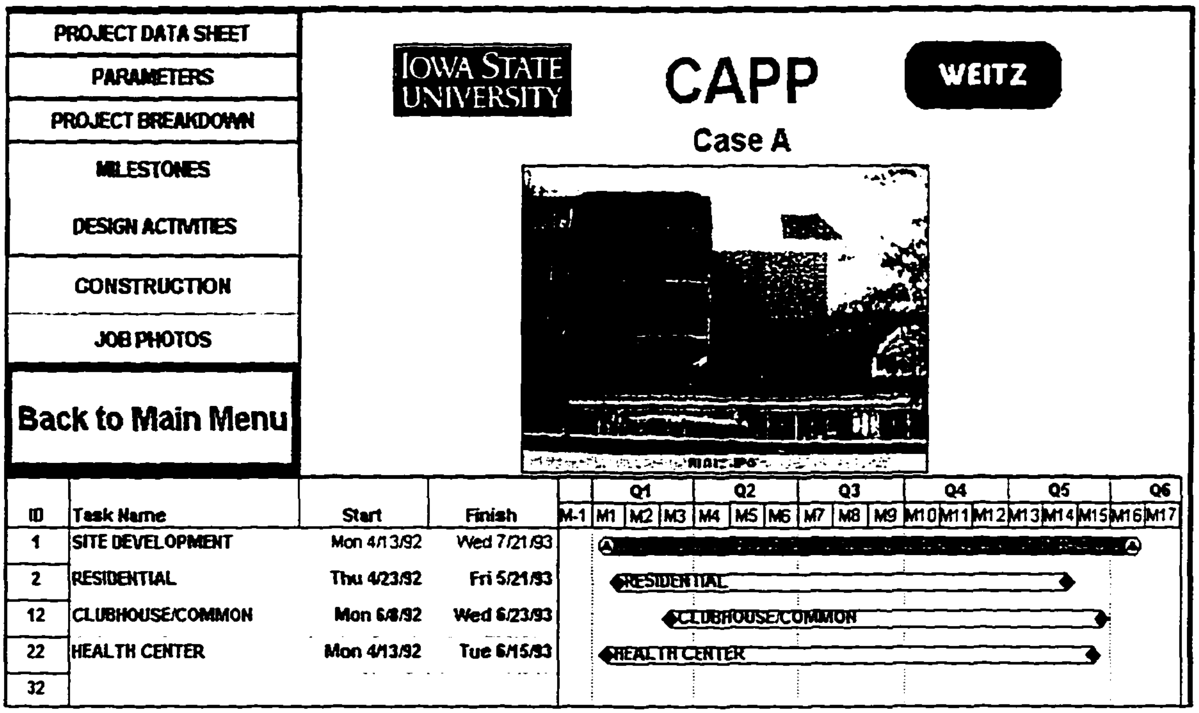


Figure 15. Data Base Architecture



ID	Task Name	Start	Finish
1	SITE DEVELOPMENT	Mon 4/13/92	Wed 7/21/93
2	RESIDENTIAL	Thu 4/23/92	Fri 5/21/93
12	CLUBHOUSE/COMMON	Mon 6/8/92	Wed 6/23/93
22	HEALTH CENTER	Mon 4/13/92	Tue 6/15/93
32			

Figure 16. An example of the CAPP Data Base Project Menu

Figure 18 is a display of project standard parameters. The standard parameters include project location, weather factors, building use, type of foundations, type of roofing, type of cladding, type of ceiling finishes, month construction begins, and other pertinent information.

Table 11 is an example of a project specific parameters. Such information as to the type of foundations, structural, mechanical, electrical, Gross Square Foot (GSF), number of units, square footage of slab-on-grade, foundation walls, structural frame, skin enclosure, interior finish, etc., are shown for each of the projects.

Project Data Sheet (PDS)

WHAT	PROJECT: CASE A Phase I
WHO	OWNER: ABC Limited Properties DEVELOPER: Life Care Services CONTRACTORThe Weitz Company A/E: Meyers & D'Aleo
WHERE	LOCATION: Towson, MD
WHY	USE: RETIREMENT COMMUNITY
WHEN	CONSTR. START DATE March 1991, Dur= 20 months
HOW	TOTAL PROJECT COST: $27m

Figure 17. An example of a Project Data Sheet

	STANDARD PARAMETERS
LOCATION	Maryland
WEATHER/CLIMATE	Cold Winter(December to March)/Humid Summer
BUILDING USE	Residential
TOTAL GROSS AREA (GSF)	329,200
TYPE OF STR. FRAME	Reinf. Concr (CIP)
TYPE OF EXT. CLADDING	Cast Stone/Masonry
LABOR AVAILABILITY	
SUBSURFACE CONDITION	Machine Excavation
SUBCONTRACTOR AVAILABILITY	
MONTH WHICH CONSTR. BEGINS	March
TYPE OF FOUNDATION	Caissons/Spread Footings Foundations
QUALITY OF LABOR-OVERALL	
TYPE OF ROOFING	EPDM & Shingle
SPRINKLERS REQMNTS	Wet System
TYPE OF CEILING FINISH	Acoustics

Figure 18. An example of a project's Standard Parameters

Table 11. An example of a project Specific Parameters

SPECIFIC PARAMETERS

PARAMETER	UNIT	SITE	RESIDENTIAL	CLUBHOUSE/C OMMON	HEALTH CENTER	PARKING STR.
GSF	GSF		257691	33448	24274	13787
NO. OF UNITS			177		36 SKILL	25 CARS
SITEWORK						
SITE GRADING	SF SITE	975000				
DEMOLITION	SF SITE	113968				
PAVING	SF PAVE	200000				
LANDSCAPING	SF SITE	363300				
SITE ACRES	ACR					
SITE UTIL	LF					
FOUNDATIONS/S.O.G						
S.O.G	SF SOG		34143	18104	24274	13882
FNDN WALLS	SF WALL		5182	3172	0	6845
STRUCTURE						
STR. STEEL FRAME	SF FRAME		0	17357	4500	0
REINF. CONCR FRAME	SF FRAME		280587	15402		13787
RAME-WOOD ROOF ON STEEL	SF FRAME		0	0	24274	0
ROOF FRAMING/DECK	SF ROOF		0	20820	0	0
STAIRS	EA		62	8	0	4
LOAD BEARING MAS. WALLS	SF WALL		13332	1920	0	1370
ENCLOSURE						
SKIN MASONRY/STONE	SF WALL		22155	4775	3698	1629
SKIN PLASTER/STUCCO	SF STUCCO		92913	7294	5722	0
WINDOWS/GLASS/STOREFRONT	SF WINDOWS		15561	3784	2504	0
OH DOORS	SF OPNG		0	160	0	176
ROOFING	SQ ROOF		499	202	264	8
INTERIOR FINISHES						
DOORS/HDWE	EA LEAF		1315	114	138	7
INT. GLAZING	SF GLASS		272	943	186	0
ACOUSTICAL TREATMENT	SF CLG		33877	21529	8186	11616
FLOOR COVERINGS	SF FL CVG		236176	27651	23254	13731
TOILET ACCESS.	EA WC		314	13	43	0
INT. MASONRY	SF WALL		0	11932	0	0
ELEVATORS	EA STOP		0	4	0	0
MEDICAL EQUIPMENT	EA BED		0	0	50	0

Table 12. An example of project milestones and cost

PARAMETER-MILESTONE		RESIDENTIAL			CLUBHOUSE/COMMON			HEALTH CENTER			
		COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST
1.00	SITE DEVELOPMENT										$2,849
2.00	FOUNDATIONS & S.O.G.	$917	04/23/92	08/13/92	$206	06/08/92	09/18/92	$133	05/21/92	08/07/92	$1,655
3.00	STRUCTURE	$3,792	06/22/92	11/06/92	$441	08/17/92	10/16/92	$172	07/24/92	09/28/92	$4,540
4.00	EXTERIOR ENCLOSURE	$2,765	08/21/92	12/22/92	$599	09/10/92	12/25/92	$407	08/25/92	11/09/92	$3,864
5.00	INTERIOR FINISHES	$4,117	08/31/92	05/21/93	$796	08/24/92	06/23/93	$493	09/23/92	06/15/93	$5,454
6.00	EQUIPMENT&SPEC CONS	$19	11/02/92	04/09/93	$409	03/04/93	05/11/93	$59	02/23/93	04/14/93	$495
7.00	CONVEYING SYS	$216	11/09/92	01/08/93	$44	09/21/92	11/04/92				$274
8.00	MECHANICAL	$2,614	06/04/92	04/02/93	$474	07/27/92	03/31/93	$344	09/23/92	04/13/93	$3,492
9.00	FIRE PROTECTION	$386	08/24/92	04/16/93	$116	09/17/92	03/22/93	$80	10/14/92	04/02/93	$608
10.00	ELECTRICAL	$1,851	09/21/92	04/16/93	$303	09/24/92	03/25/93	$181	11/09/92	04/19/93	$2,370
11.00	JOB SERVICES										
12.00	MAJOR EQUIPMENT										
13.00	GC FEE										
14.00	BOND/CONTINGENCY/MISC.										
	TOTAL	**$16,677**	04/23/92	05/21/93	**$3,388**	06/08/92	06/23/93	**$1,869**	05/21/92	06/15/93	**$25,601**
	COST/GSF										
	DURATION (MONTHS)		13.1			12.7			13.0		

Table 12 is an example of project milestones and cost for each of the project components. This is a useful report representing the total project cost and schedule information in one picture. However, the dates and cost figures must be converted to a percentage of cost and duration (i.e. normalized) to be used as a reference for future. More detail on how this is done is discussed in Chapter 4.

Analytical Approach/Limitations

Several problems encountered during the data gathering phase included:

1. Information not available or in wrong format: Although there was plenty of information in the archived files, some of this data were in the wrong format or was not complete. For example, procurement data was available only for a few projects.

2. Not all available data were directly examined due to logistic problems. For example, for one project located in a remote location we were relying on others to examine the files and extract the required data.
3. Information was subject to interpretation. For example, there were no formal work breakdown structures ever developed or published for most of the case studies, yet project breakdown structure was prepared interpreting and manipulating the available data.
4. Some of the data from the various case studies were not comparable. Each project had unique features. Therefore, sample projects contained some data abnormalities. These abnormalities had to be identified and necessary adjustment be made before used for future referencing.
5. There were some data integrity problems associated with some of the projects. For example, although the start and finish of each task may have been recorded, the physical work on the task may have been in fact interrupted with several gaps in the schedule which may give the wrong information as for the true duration of the task.

CHAPTER 4: DISCUSSION OF RESULTS

Interviews

Key project personnel who had direct involvement in the planning of the case studies were interviewed in order to get their feedback and answer a questionnaire which was developed for this research. A copy of the questionnaire is included in the Appendix A. The questionnaire consisted of two parts. The first part was general covering such issues as the planning culture, management commitment, degree of involvement, and important factors affecting the initial planning. The second part was more specific to the selected case studies and addressed the identification and ranking of parameters that affect important project milestones. The results of the first part of the questionnaire are summarized in Table 13. Several interesting conclusions drawn from the results of this survey are discussed under the "Interview Analysis" section. The survey participants worked as senior management, project managers and project engineers on most of the selected projects with a high degree of involvement in the planning of these projects.

The questionnaire also included several questions which required discrete answers. The results of the discrete questions are tabulated in Table 14.

Table 13. Result of Planning Questionnaire - Part I

n=8	MEAN
Management Commitment	
Importance of planning to the project managers	4.33
Top management commitment to planning	3.75
Understanding of goals/strategies by those involved in planning	3.50
Availability of Data	
Availability of total project duration prior to start of planning	4.28
Initial project staffing prior to start of planning	4.17
Availability of Contractual milestones dates	3.67
Availability of Budget/Scope of Work	2.33
Availability of planning data during conceptual planning	2.06
Factors Affecting Initial Planning	
Past Project experience	4.78
Weather	3.67
Budget estimate	3.50
Crew Sizes	3.11
Contingency	3.00
Labor productivity	2.67
Resource loading	0.67
Degree of Involvement in Planning	
Project Manager	4.95
Project Superintendent	4.28
Sr. Management	4.06
Project Engineer	3.83
Major Subcontractors	2.67
Client Representative	2.20
Other Subcontractors	2.28
Project Estimator	2.78
Vendors	1.78
Foreman	1.34
Design Engineer	1.00
Project Scheduler	n/a
Other Planning Issues	
Use of project summary schedule	4.39
Evaluation of actuals vs plan	3.56
Recording of actual dates	3.33
Use of Planning guides and procedures	3.00
Use of resource levelling	0.67

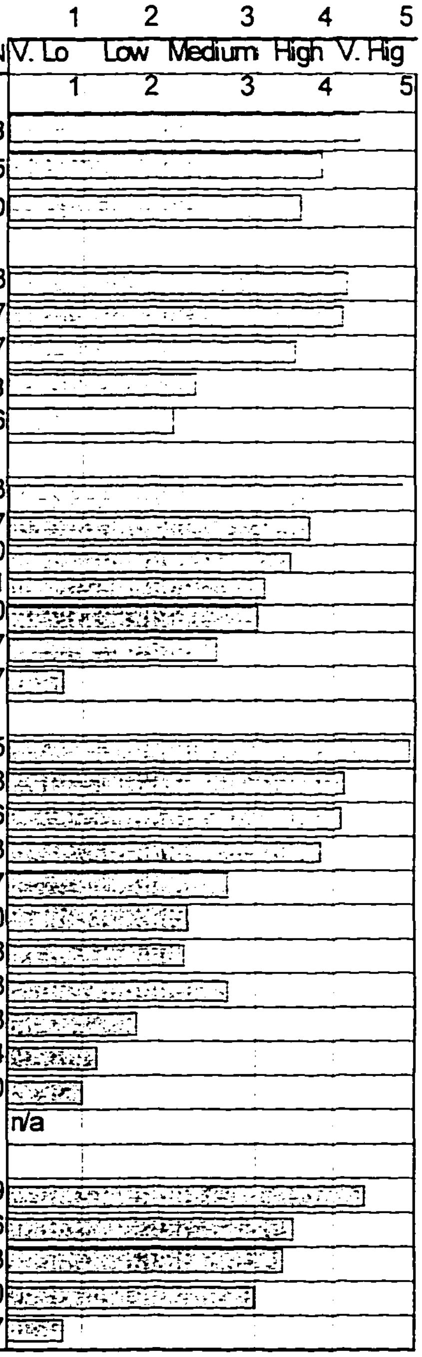


Table 14. Results of Discrete Type of Questions

QUESTION	ANSWER
Do you distinguish between planning and scheduling?	100% YES
Do you believe that planning should be performed by those who are ultimately responsible for its execution?	100% YES
Do you develop a Work Breakdown Structure (WBS) before you plan?	66% NO, 34% YES but not formally
Do you consider the planning process as a top-down or bottom-up approach?	88% Bottom-Up 12% Top-Down
How much time do you devote to the initial planning?	62% One Week 25% Two Weeks 13% Not Enough
Is there enough time is allocated to the initial planning?	63% No 38% Yes
Should detail planning be left for the field?	66% Yes 34% No
Do you believe in cost-schedule integration?	50% Yes 50% No
Do you cost load the plan?	88% No 12% Yes
Do you prepare activities, durations, and sequences manually before entering into the computer program?	34% Yes 66% No
How often do you update the plan?	66% Monthly or Quarterly 34% Other including at major design milestones

The second part of the questionnaire identified and ranked the parameters affecting the project milestones. The result is tabulated in Table 15.

Interview Analysis

Several interesting conclusions can be drawn from the results of the questionnaire and personal interviews with key planning personnel. Part I of the questionnaire shows a strong management commitment to planning although not all those who are involved in planning understand the goals and objectives.

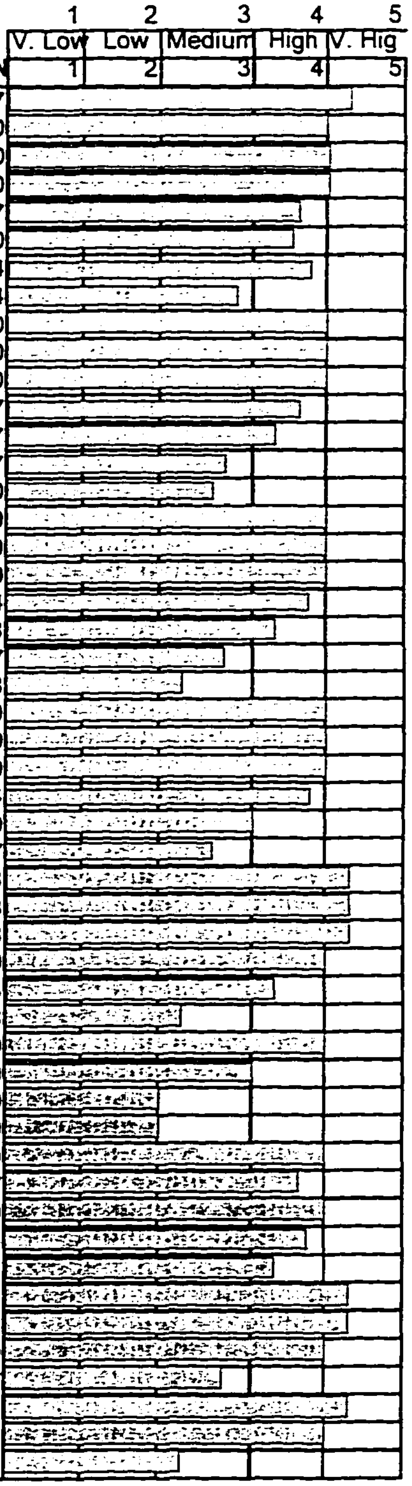
Budget and scope of work are well established prior to start of planning. The overall project duration is already determined prior to the start of planning. This confirms the earlier assumption that, in contrast to estimating where the management looks for a bottom line number, the bottom line project duration is already known. However, not all the contractual milestones are known at this time. The participants also indicated that very little planning data is available during conceptual planning and users rely heavily on past project experience.

The survey identified weather, budget estimate, and crew size to have a high impact on planning. In addition, several participants indicated use of contingency in the initial planning as a medium to high factor. As for involvement in planning, project managers and superintendents have a high involvement in planning while design engineers and project estimators have a very low involvement. Major subcontractors play a moderate role in planning. On other related issues, project summary schedules are highly recommended while resource scheduling and resource leveling is rarely used.

In the second part of the questionnaire, important parameters and their degree of influence on each of the milestones were identified. These parameters are of quantitative as well as qualitative nature. For example, site grading, square foot of slab on grade, number of elevators, tons of structural steel, etc., are quantitative while weather factors, type of foundation system,

Table 15. Result of Planning Questionnaire - Part II

MILESTONE	PARAMETER n=8	MEAN
1. SITE DEVELOPMENT	SITE GRADING	4.17
	SITE ACCESS	4.00
	SOILS	4.00
	UTILITY	4.00
	GSF	3.67
	WEATHER	3.50
	SITE PAVING	3.84
	MONTHS CONST. STARTS	2.84
2. FOUNDATION/S.O.G.	FOUNDATION SYS	4.00
	MANPOWER/SUB AVAIL.	4.00
	S.O.G. SF	4.00
	WALL S.F.	3.67
	WEATHER	3.17
	GSF	2.67
	MONTHS CONST. STARTS	2.50
3. STRUCTURE	NO. OF STORIES	4.00
	TYPE OF STR.	4.00
	WOOD FRAMING	4.00
	LOAD BEARING WALLS	3.84
	WEATHER	3.33
	GSF	2.67
	STR. STEEL (TON)	2.33
4. EXTERIOR ENCLOSURE	ROOF SQ	4.00
	ROOF TYPE	4.00
	SKIN WALLS SF	4.00
	SF GLASS/GLAZING	3.84
	WEATHER	3.00
	GSF	2.67
5. INTERIOR FINISHES	CEILING SF	4.33
	FLOORING SF	4.33
	INT. FRAMING	4.33
	LEVEL OF FINISH	4.00
	GSF	3.33
	NO. OF DOORS	2.33
6. EQUIPMENT/SPEC CONS	LEAD TIME	4.00
	SF KITCHEN	3.00
	FLOORING SF	2.00
	GSF	2.00
7. CONVEYING SYS	TYPE OF ELEV.	4.00
	NO. OF STOPS (ELEV)	3.67
8. MECHANICAL	TYPE OF SYS	4.00
	GSF	3.84
	FIXTRS	3.33
9. FIRE PROTECTION	GSF	4.33
	SPRKLR AREA	4.33
	TYPE OF SYS	4.00
	SPRKLRS EA	2.67
10. ELECTRICAL	GSF	4.33
	TYPE	4.00
	FIXTRS EA	2.33



soils conditions, labor productivity, availability of subcontractors, etc., are qualitative and subjective. In the section that follows, the quantitative variables are put to test using both linear and multiple regression models. However, before proceeding with regression analysis, the process of data normalization must be discussed.

Data Normalization

Captured data from all the case studies were normalized in order to establish consistency of data using a standard format that brings the data from all cases or domains to the same basis. This is accomplished by first converting start and finish dates for each component to the number of weeks from start of construction and cost of the components to percentage of total cost. Several data normalization factors are then applied to the durations and cost to adjust any abnormalities. An example of normalization factors are shown in Table 16. The factors vary from 0.7 to 1.4 with 1.0 being normal and anything above it is considered above normal, and below it as below normal.

Table 16. Example of data normalization factors

FACTORS	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4
WEATHER			x					
MANPOWER AVAILABILITY					x			
MANPOWER QUALIFICATIONS				x				
PRODUCTIVITY			x					
LOCATION					x			
COMPLEXITY		x						

The process of data normalization is shown in Figure 19. The process is accomplished in six steps:

1. User defines Project Data Sheet
2. User enters Standard Parameters
3. User enters project Specific Parameters
4. Milestone dates are converted to number of weeks from start of construction, and cost is converted to percentage of total cost.
5. Normalization factors are applied to the milestone durations and cost
6. User reviews and validates the data

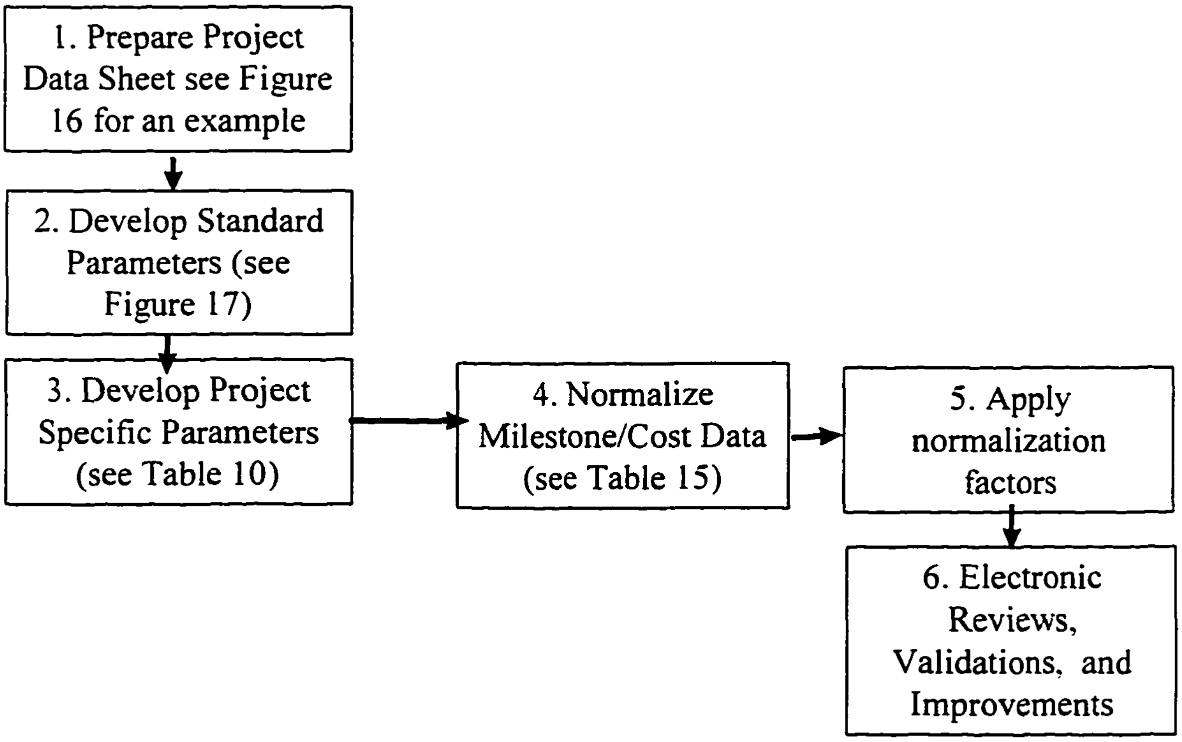


Figure 19. The process of data normalization

An example of a normalized data extracted from one case study is shown in Table 17. Appendix B includes normalized parameters/milestones for each of the case studies.

Regression and Correlation Analysis

Regression and correlation analysis are two techniques which are aimed at measuring relationships between two or more variables and testing their significance (Fleming 1991). Regression analysis is one of the most common statistical procedures readily available in almost every computer statistical program. Ordinarily, the cause is regarded as the independent variable and the effect is regarded as the dependent variable. In the case of CAPP, the dependent variables are the milestones while independent variables are the parameters that are related to these milestones. For example, regression analysis is a good indication of how closely are these variables related and allows us to test the strength of this closeness. However, before we proceed with the actual analysis, a few related terms must be explained.

Simple Regression

Simple regression analysis is concerned with the relationship between a dependent variable and one independent variable. In general, the equation for linear regression model is that of any straight line: $Y=b_0+b_1X$ where Y is the

Table 17. Data Normalization Process Example

PARAMETER-MILESTONE	RESIDENTIAL			COMMONS			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1.00 SITE DEVELOPMENT									
2.00 FOUNDATIONS & S.O.G.	$238	05/04/92	09/28/92	$702	06/09/92	08/31/92	$416	07/01/92	09/16/92
3.00 STRUCTURE	$1,835	07/28/92	11/23/92	$447	08/01/92	12/18/92	$329	09/04/92	11/09/92
4.00 EXTERIOR ENCLOSURE	$2,832	09/08/92	03/01/93	$614	12/18/92	03/22/93	$588	10/06/92	12/21/92
5.00 INTERIOR FINISHES	$5,545	09/15/92	09/20/93	$771	12/30/92	10/20/93	$525	11/04/92	07/13/93
6.00 EQUIPMENT&SPEC CONS	$18	01/25/93	04/15/93	$439	05/03/93	06/01/93	$40	04/06/93	05/26/93
7.00 CONVEYING SYS	$81	12/01/92	03/01/93	$81	01/25/93	02/15/93	$30	12/22/92	12/22/92
8.00 MECHANICAL	$2,544	09/15/92	07/19/93	$839	12/30/92	08/12/93	$475	11/04/92	05/25/93
9.00 FIRE PROTECTION	$365	09/15/92	07/19/93	$107	12/30/92	08/12/93	$61	11/04/92	04/23/93
10.00 ELECTRICAL	$1,628	09/15/92	07/19/93	$535	12/30/92	08/12/93	$294	11/04/92	04/14/93
TOTAL	$15,086	05/04/92	09/20/93	$4,535	06/09/92	10/20/93	$2,758	07/01/92	07/13/93
COST/GSF									
DURATION (MONTHS)	16.8			16.6			12.6		

NORMALIZED

PARAMETER-MILESTONE	RESIDENTIAL			COMMONS			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1.00 SITE DEVELOPMENT									
2.00 FOUNDATIONS & S.O.G.	0.01	9.00	30.05	0.02	14.14	26.05	0.01	17.29	28.34
3.00 STRUCTURE	0.05	21.14	38.05	0.01	21.71	41.62	0.01	26.57	36.05
4.00 EXTERIOR ENCLOSURE	0.08	27.14	52.05	0.02	41.57	55.05	0.02	31.14	42.05
5.00 INTERIOR FINISHES	0.16	28.14	81.05	0.02	43.29	85.34	0.01	35.29	71.20
6.00 EQUIPMENT&SPEC CONS	0.00	47.00	58.48	0.01	61.00	65.20	0.00	57.14	64.34
7.00 CONVEYING SYS	0.00	39.14	52.05	0.00	47.00	50.05	0.00	42.14	42.20
8.00 MECHANICAL	0.07	28.14	72.05	0.02	43.29	75.48	0.01	35.29	64.20
9.00 FIRE PROTECTION	0.01	28.14	72.05	0.00	43.29	75.48	0.00	35.29	59.63
10.00 ELECTRICAL	0.05	28.14	72.05	0.02	43.29	75.48	0.01	35.29	58.34
TOTAL	0.43	9.00	81.05	0.13	14.14	85.34	0.08	17.29	71.20
COST/GSF									
DURATION (WEEKS)	72.80			71.93			54.47		

dependent variable and X is the independent variable and b_0 is the first parameter of the equation which indicates value of Y when X=0 and b_1 represents the second parameter of the equation which measures the slope of the regression line.

Multiple Regression

Multiple regression analysis is concerned with the relationship between a dependent variable and two or more independent variables. The mathematical model is: $Y= b_0+b_1X_1+b_2X_2+.....b_iX_i$ where the independent variables are denoted by X_1, X_2, etc. The assumptions of multiple regression models are similar to those of simple regression involving only one independent variable.

Method of Least Square

By the least-square method the best-fitting regression line is that for which the sum of the squared deviations between the estimated and actual values of the dependent variable for the sample data is minimized. This minimization of estimating parameters is called the method of least square and denoted by SSE.

ANOVA

The analysis of variance (ANOVA) is a technique used to analyze total variation and test the differences among several means. ANOVA is used to perform simple analysis of variance and test the hypothesis that means from two or more samples are equal (drawn from populations with the same mean). The symbolic ANOVA layout using a demonstrated example is shown in Table 18.

Table 18. Analysis of Variance (ANOVA), an example.

Source of variation	**Degree of freedom**	**Sum of squares**	**Mean square**	**Computed "F" value**
Treatments (among group)	k-1 = **4**	SSA = **85,356**	SSA/k-1 = **21,339**	**21,339/4,961 = 4.30**
Error or residual (within group)	k(n-1) = **25**	SSE = **124,021**	SSE/k(n-1) = **4,961**	
Total	nk-1 = **29**	SST = **209,377**		

The degree of freedom is the number of sample data less the number of restrictions placed on them. In the above example, the degree of freedom for the treatments is the number of treatments less one. The degree of freedom of error is the number of treatments times total sample population less one. The F value is a ratio of variance. The F value is calculated by dividing the means square among treatment group (MSA) over the means square error (MSE) and indicates whether there is a linear relationship between the dependent variable, Y, and the set of independent variables, X_i . It is mostly used to test whether the observed relationship between the dependent and independent variables occurs by chance. In the above example, F value is 4.30. The "Critical F" distribution can be found from any statistics tables by looking up degrees of freedoms and the confidence level. A confidence level of 95% indicates that we are 95%

confident in the desired result. The confidence level equals 100(1 - alpha)%, or in other words, an alpha of 0.05 indicates a 95% confidence level. The Critical F in the above example = Critical F(4,25,0.05)=2.76 (from tables) which is less than the F value of 4.30. This means that the assumptions fall in the critical region and the null hypothesis H_0 that there is no relationship effect is rejected.

Coefficient of Correlation

The coefficient of correlation, R^2 is the proportion of the variation in a dependent variable, Y, that is explained by the regression model. It is particularly useful in describing the closeness of the relationship between X and Y. R^2 ranges in value from 0 to 1. If it is 1, there is a perfect correlation in the sample—there is no difference between the estimated y-value and the actual Y-value. At the other extreme, if the coefficient of determination is 0, the regression equation is not helpful in predicting a Y-value. The higher the R^2 value, the closer is the relationship. For example if the value is 0.44, this means that 44 per cent of the variation is explained by the independent variable, while 56 per cent is "unexplained" due to other factors.

Limitations of Regression and Correlation Analysis

Following are some pitfalls and limitations associated with regression and correlation analysis (Kazmier, 1988):

1. A significant correlation coefficient does not necessary indicate causation, but rather may indicate common linkage to other events.

2. The use of confidence interval is based on the assumption that the conditional distribution of Y are normal and have equal variance.
3. A significant correlation is not necessary an important correlation. For example, a correlation of R=+0.10 can be significantly different from 0 when a=0.05. Yet, the coefficient of determination of R^2=0.01 for this example indicates that only one percent of the variance in Y is explained by X.
4. If the Y estimate involves prediction of a result which has not yet occurred, the historical data which was used as the basis for regression may not be relevant for future events.

Regression Models used in this Study

The regression model used in this research was generated by MS-Excel program. Microsoft Excel calculates for each point the squared difference between the y-value estimated for that point and its actual y-value. The sum of these squared differences is called the residual sum of squares. Microsoft Excel then calculates the sum of the squared differences between the actual y-values and the average of the y-values, which is called the total sum of squares (regression sum of squares + residual sum of squares). The smaller the residual sum of squares is compared with the total sum of squares, the larger the value of the coefficient of determination, R^2, which is an indicator of how well the equation resulting from the regression analysis explains the relationship among the variables. A classical example using MINITAB statistical package was used to test the validity of the MS-Excel output. The results using R^2, F Test, and the t statistics were exactly the same leading to the conclusion that Ms-Excel be used due to its extreme flexibility and user friendliness. Furthermore, all of the raw data were already on MS-Excel.

The regression analysis in this research was performed separately for each of the milestones first by system and then by system/component. A number of trial and error were used to calculate R^2 values using one or several independent variables to see which one best fit. Certain cases were excluded at times due to the abnormality of data. When dealing with regression analysis one must be aware of the limitations of such analysis. Even if Y is statistically related to Xi, there is no evidence of a cause-and-effect relationship (Orczyk, 1989). Therefore, one must be cautious when applying a regression model even if the cause and effect have been established. The regression model should be used only when future conditions are the same as they were for the observed data (Neter, 1985).

Regression Analysis for Site Development

Site development milestone was presumed to be driven by site grading, site access, soils conditions, site utility, weather, gross square foot, months construction starts, and site paving parameters. Of these, site paving, site grading, and gross square foot values were easily available and are of quantitative nature. Several regression trials using each of these independent variables and a combination of them with both simple and multiple regression was performed. The combination leading to the highest coefficient of correlation was achieved using two independent variables of paving and site grading. The results are tabulated in Table 19.

The regression analysis points out that a very strong relationship exist (R^2=0.927) between site grading and paving independent variables and the dependent variable, site development. In addition, the F test value of 6.34 is > critical F(2,1,0.05)=4.99, therefore, the null hypothesis that there is no regression effect is rejected.

Data from one case study was excluded from the analysis due to the very abnormal site as well as lack of availability of some of the data. It should be pointed out that linear regression using each of the independent variables separately only produced a R^2 value of only 0.3 indicating that both parameters together have a much higher influence on the milestone than individually. Therefore, it is important to take these parameters into account when planning sitework activities and milestones.

Regression Analysis for Foundations and Slab On Grade (S.O.G)

Foundation and S.O.G. milestones were presumed to be influenced by foundation system, manpower and subcontractor availability, slab on grade square footage, GSF, square foot of foundation walls, weather, and months

Table 19. Regression Statistics for Site Development Milestone

SITE DEVELOPMENT

CASE	COMPONEN	DURATION	PARAMETERS		
			PAVING	GRADIN	GSF
		Y	X_1	X_2	
A	SITEWORK	66.29	200000	975000	329200
C	SITEWORK	85.34	217620	204400	418253
D	SITEWORK	80.48	260695	774563	313531
F	SITEWORK	73.86	47600	208951	262419
G	SITEWORK	127.43			537327
B	SITEWORK	77.86	183000		169690
	AVERAGE	**85**	**181783**	**540729**	**338403**

SUMMARY OUTPUT
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.962762781
R Square	0.926912172
Adjusted R Square	0.780736516
Standard Error	3.873656631
Observations	4

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	190.2986782	95.1493391	6.341084	0.270347606
Residual	1	15.00521569	15.0052157		
Total	3	205.3038939			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*pper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	73.72642373	4.858603442	15.1744065	0.041893	11.99227815	135.4606	11.9922782	135.4605693
X Variable 1	8.17E-05	2.85E-05	2.86E+00	2.14E-01	-2.81E-04	4.44E-04	-2.81E-04	4.44E-04
X Variable 2	-2.23E-05	6.72E-06	-3.32E+00	1.86E-01	-1.08E-04	6.30E-05	-1.08E-04	6.30E-05

construction starts. Data was readily available for S.O.G, and GSF. Some data was also available for square foot of foundation walls. However, several areas did not have foundation walls or data was not available. Therefore, regression model took into account 2 variables, of square foot of SOG and GSF. Results are tabulated in Table 20. The regression analysis points out that a good relationship exist (R^2=0.753) between square foot of SOG and GSF independent variables and the dependent variable, foundation/SOG milestone. Data from one case study was excluded from the analysis due to the abnormal site conditions.

Table 20. Regression Statistics for Foundation and SOG Milestone

FOUNDATION/S.O.G.

CASE	COMPONENT	DURATION	SOG SF	GSF	WALL SF
		Y	X1	x2	x3
A	RESIDENTIAL	16.00	34143	257691	5182.0
A	CLUBHOUSE	11.14	18104	33448	3172.0
A	HEALTH CENTER	11.14	24274	24274	0.0
A	PARKING	2.86	13882	13787	6845.0
B	RESIDENTIAL	19.00	63624	123000	0.0
B	COMMONS	8.14	16552	17500	0.0
B	NURSING	5.86	13000	12390	0.0
B	ALU	8.14	18088	16800	0.0
C	RESIDENTIAL	21.05	47691	260564	0.0
C	COMMONS	11.91	38498	53462	20490.0
C	HEALTH CENTER	11.05	28178	30179	14600.0
C	TOWNHOMES	13.91	54847	57915	0.0
D	RESIDENTIAL	35.29	74517	227278	3000.0
D	COMMONS	14.00	14580	30905	2288.0
D	HEALTH CENTER	11.00	16957	19317	5130.0
F	RESIDENTIAL	9.43	20530	183697	0.0
F	COMMONS	2.14	17700	29813	8176
F	HEALTH CENTER	2.14	17700	17470	0
G	RESIDENTIAL	11.86	83712	310239	0
G	ASSIST. LIVING	39.00	25013	47524	0
G	HEALTH CENTER	9.00	25384	49734	0
G	VILLAS	23.57	65586	65404	0
	AVERAGE	**14**	**33298**	**85563**	**3131**

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.868
R Square	**0.754**
Adjusted R Square	0.709
Standard Error	4.573
Observations	14.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2.000	703.859	351.930	**16.828**	0.000
Residual	11.000	230.048	20.913		
Total	13.000	933.907			

	Coefficients	*tandard Erro*	*t Stat*	*P-value*	*Lower 95%*	*pper 95%*	*ower 95.0*	*Upper 95.0%*
Intercept	0.685	2.447	0.280	0.785	-4.701	6.071	-4.701	6.071
X Variable 1	3.18E-04	8.81E-05	3.61E+00	4.10E-03	1.24E-04	5.12E-04	1.24E-04	5.12E-04
X Variable 2	2.38E-05	1.65E-05	1.45E+00	1.76E-01	-1.24E-05	6.00E-05	-1.24E-05	6.00E-05

This implies that 75% of the variation is explained by the two independent variables above while 25% is "unexplained" due to other factors not considered here. The F test value of 16.83 is > critical F(2,11,0.05)=3.98, therefore, the null hypothesis that there is no regression effect is rejected.

Regression Analysis for the Structure Milestone

The structure milestone was presumed to be influenced by number of stories, type of structure, framing, load bearing walls, GSF, weather, and structural steel. Two independent variables of square foot of framing, and GSF were available and used in the analysis. The model is shown in Table 21.

The regression analysis points out that a good relationship exist (R^2=0.568) between square foot of framing and GSF independent variables and the dependent variable, structure milestone. This implies that 57% of the variation is explained by the two independent variables above while 43% is "unexplained" due to other factors. The F test value of 9.87 is > critical F(2,15,0.05)=3.68, therefore, the null hypothesis that there is no regression effect is rejected.

Regression Analysis for Enclosure Milestone

The enclosure milestone was presumed to be influenced by roof square, type of roofing, square foot of skin walls, weather, square foot of glass and glazing, and GSF. Fortunately most of these variables were available and used in the multi-regression model as shown in Table 22. The regression analysis points out that a positive relationship exist (R^2=0.516) between the independent variables and the dependent variable, enclosure milestone. This implies that 52% of the variation is explained by the two independent variables above while 48% is "unexplained" due to other factors not considered. The F test value of 3.466 is still greater than the critical F(4,13,0.05)=3.18, therefore, the null hypothesis that there is no regression effect is rejected.

Regression Analysis for Interior Finishes Milestone

The interior finishes milestone was presumed to be influenced by square foot of ceiling area, flooring area, interior framing, level of finish, GSF, and number of doors/hardware. From these variables, square foot of ceiling and flooring, GSF, and number of doors were easily available for all the cases and used in the model. However, the hypothesis was rejected based on the F test in the initial run. Therefore, the least significant variable (Ceiling area) was dropped from the analysis. The interior finishes model is shown in Table 23. The regression analysis points out a positive relationship exist (R^2=0.441) between the independent variables and the dependent variable, enclosure milestone. This implies that 44% of the variation is explained by the two independent variables above while56% is "unexplained" due to other factors not considered. The F test value of 3.686 is still greater than the critical F(3,14,0.05)=3.34, therefore, the null hypothesis that there is no regression effect is rejected.

Table 21. Regression Statistics for Structure Milestone

STRUCTURE

CASE	COMPONENT	DURATION		
			F FRAM	GSF
		Y	X_1	X_2
A	RESIDENTIAL	19.57	280587	257691
A	CLUBHOUSE	8.57	17357	33448
A	HEALTH CENTER	9.43	24274	24274
A	PARKING	2.86	13787	13787
B	RESIDENTIAL	17.86	137440	123000
B	COMMONS	10.00	21140	17500
B	NURSING	10.14	14000	12390
B	ALU	7.57	20500	16800
C	RESIDENTIAL	16.91	214000	260564
C	COMMONS	19.91	29600	53462
C	HEALTH CENTER	9.48	28178	30179
C	TOWNHOMES	13.20	54847	57915
D	RESIDENTIAL	30.29	227278	227278
D	COMMONS	9.00	30905	30905
D	HEALTH CENTER	10.00	16957	19317
F	RESIDENTIAL	18.57	199031	183697
F	COMMONS	3.86	12730	29813
F	HEALTH CENTER	3.86	56300	17470
G	RESIDENTIAL	20.86	260866	310239
G	ASSIST. LIVING	5.57	31891	47524
G	HEALTH CENTER	5.57	41152	49734
G	VILLAS	19.57	81034	65404
	AVERAGE	**12**	**82448**	**85563**

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.753833478
R Square	**0.568264913**
Adjusted R Square	0.510700235
Standard Error	5.334063614
Observations	18

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	561.7474855	280.874	9.8717639	0.00183709
Residual	15	426.7835196	28.4522		
Total	17	988.5310052			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*pper 95%*	*ower 95.0*	*Upper 95.0%*
Intercept	7.20176157	1.753268558	4.10762	0.0009318	3.4647558	10.93877	3.464756	10.9387673
X Variable 1	4.30E-05	6.26E-05	6.87E-01	5.03E-01	-9.04E-05	1.76E-04	-9.04E-05	1.76E-04
X Variable 2	1.62E-05	5.96E-05	2.72E-01	7.89E-01	-1.11E-04	1.43E-04	-1.11E-04	1.43E-04

Table 22. Regression Statistics for Enclosure Milestone

ENCLOSURE

CASE	COMPONENT	DURATION	ROOF SQ	GSF	EXT. SKIN	SF GLASS
		Y	X1	X2	X3	X4
A	RESIDENTIAL	17.57	499	257691	92913	15561
A	CLUBHOUSE	15.14	202	33448	7294	3784
A	HEALTH CENTER	10.86	264	24274	5722	2504
A	PARKING	3.86	8	13787	1629	0
B	RESIDENTIAL	25.28	827	123000	20800	7014
B	COMMONS	12.57	222	17500	1870	1475
B	NURSING	10.14	157	12390	1377	1165
B	ALU	12.00	228	17500	1400	1450
C	RESIDENTIAL	24.91	1122	260564	84072	49000
C	COMMONS	13.48	719	53462	15237	8671
C	HEALTH CENTER	10.91	154	30179	11605	3800
C	TOWNHOMES	14.63	370	57915	36081	2588
D	RESIDENTIAL	28.29	870	227278	95448	17182
D	COMMONS	13.14	270	30905	16013	3313
D	HEALTH CENTER	20.71	195	19317	7305	1391
F	RESIDENTIAL	34.43	639	183697	50596	12500
F	COMMONS	9.86	15	29813	13294	2363
F	HEALTH CENTER	9.86	233	17470	5908	992
G	RESIDENTIAL	15.57	1040	310239	107113	38597
G	ASSIST. LIVING	17.57	306	47524	53335	8874
G	HEALTH CENTER	17.57	328	49734	36929	5852
G	VILLAS	27.57	871	65404	52959	14324
	AVERAGE	**17**	**434**	**85595**	**32677**	**9200**

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.718
R Square	0.516
Adjusted R Square	0.367
Standard Error	6.126
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	4.000	520.299	130.075	3.466	0.039
Residual	13.000	487.905	37.531		
Total	17.000	1008.204			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0*	*Upper 95.0%*
Intercept	8.768	2.662	3.294	0.006	3.017	14.519	3.017	14.519
X Variable 1	2.04E-02	9.23E-03	2.21E+00	4.59E-02	4.30E-04	4.03E-02	4.30E-04	4.03E-02
X Variable 2	6.29E-06	4.62E-05	1.36E-01	8.94E-01	-9.35E-05	1.06E-04	-9.35E-05	1.06E-04
X Variable 3	5.87E-05	1.20E-04	4.90E-01	6.32E-01	-2.00E-04	3.17E-04	-2.00E-04	3.17E-04
X Variable 4	-3.58E-04	2.70E-04	-1.32E+00	2.09E-01	-9.42E-04	2.26E-04	-9.42E-04	2.26E-04

Regression Analysis by System and Component

The above analyses were performed by system regardless of what the project components were. Another type of analysis was then performed by grouping all the components within each system. For example, foundation systems milestones/parameters for health center component were grouped together and analyzed separately. The result of this analysis is shown in Appendix C. This analysis shows an interesting result. In almost all cases, the R^2 is much higher than previous analysis. In fact, the R^2 for most of the similar components were close to 97% to 99% value indicating a very strong relationship exists between the selected parameters and milestones at the project component level.

Inference Engine Module

The design of an expert system that simulates planners knowledge as a basis for developing the inference engine module program heavily depends on which planning philosophy one adapts (see Figure 20). Two contrasting philosophies of bottom-up or top-down were discussed earlier in this study. Most planners seem to favor the bottom-up approach. All of the participants interviewed in this study indicated that they plan using the bottom-up approach. The bottom-up approach is preceptive, intuitive, informal, and unstructured with

Table 23. Regression Statistics for Interior Finishes

FINISHES

CASE	COMPONENT	DURATION	PARAMETERS			
			F CEILIN	GSF	FLOORING	# of DOORS
		Y	X1	X2	X3	X4
A	RESIDENTIAL	37.57	33877	257691	236176	1315
A	CLUBHOUSE	43.29	21529	33448	27651	114
A	HEALTH CENTER	37.86	8186	24274	23254	138
A	PARKING	2.86	11616	13787	13731	7
B	RESIDENTIAL	40.14	2400	123000	90127	975
B	COMMONS	11.14	7798	17500	5337	66
B	NURSING	22.00	5160	12390	1487	79
B	ALU	19.71	3564	17500	4430	82
C	RESIDENTIAL	52.91	244577	260564	260564	1310
C	COMMONS	42.05	38031	53462	39383	200
C	HEALTH CENTER	35.91	9200	30179	30179	177
C	TOWNHOMES	40.63	416	57915	54847	195
D	RESIDENTIAL	45.86	26388	227278	227278	1493
D	COMMONS	27.00	21375	30905	26226	121
D	HEALTH CENTER	27.14	14930	19317	40000	120
F	RESIDENTIAL	44.00	28684	183697	183697	1179
F	COMMONS	48.00	22878	29813	28756	105
F	HEALTH CENTER	48.00	0	17470	17872	90
G	RESIDENTIAL	73.43	43919	310239	310000	3150
G	ASSIST. LIVING	23.43	21079	47524	47500	232
G	HEALTH CENTER	43.57	50355	49734	133240	235
G	VILLAS	36.57	53672	65404	61386	1014
	AVERAGE	**37**	**30438**	**85595**	**84687**	**564**

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.664
R Square	0.441
Adjusted R Square	0.322
Standard Error	11.839
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	3.000	1550.190	516.730	3.686	0.038
Residual	14.000	1962.429	140.173		
Total	17.000	3512.619			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0*	*Upper 95%*
Intercept	31.829	4.063	7.834	0.000	23.115	40.544	23.115	40.544
X Variable 1	-8.33E-05	1.44E-04	-5.80E-01	5.71E-01	-3.91E-04	2.25E-04	-3.91E-04	2.25E-04
X Variable 2	8.47E-05	1.35E-04	6.27E-01	5.41E-01	-2.05E-04	3.75E-04	-2.05E-04	3.75E-04
X Variable 3	1.17E-02	8.67E-03	1.34E+00	2.00E-01	-6.94E-03	3.03E-02	-6.94E-03	3.03E-02

focus on the planning process than the product. This type of planning is performed by those who are ultimately responsible for performing the work. The planners start with detail activities and try to summarize the outcome for management use. There are two problems associated with this approach. First, when one starts at the detail, it is hard to focus on the planning hierarchy and keeping the "big picture" in view. Planners may focus on getting the activities right without the right activity. There is also a good chance of missing some important activities. The second problem is due to the fact that since little data is available at the conceptual stage, planners are forced to make assumptions or wait until more information becomes available. In either case, the plan's integrity

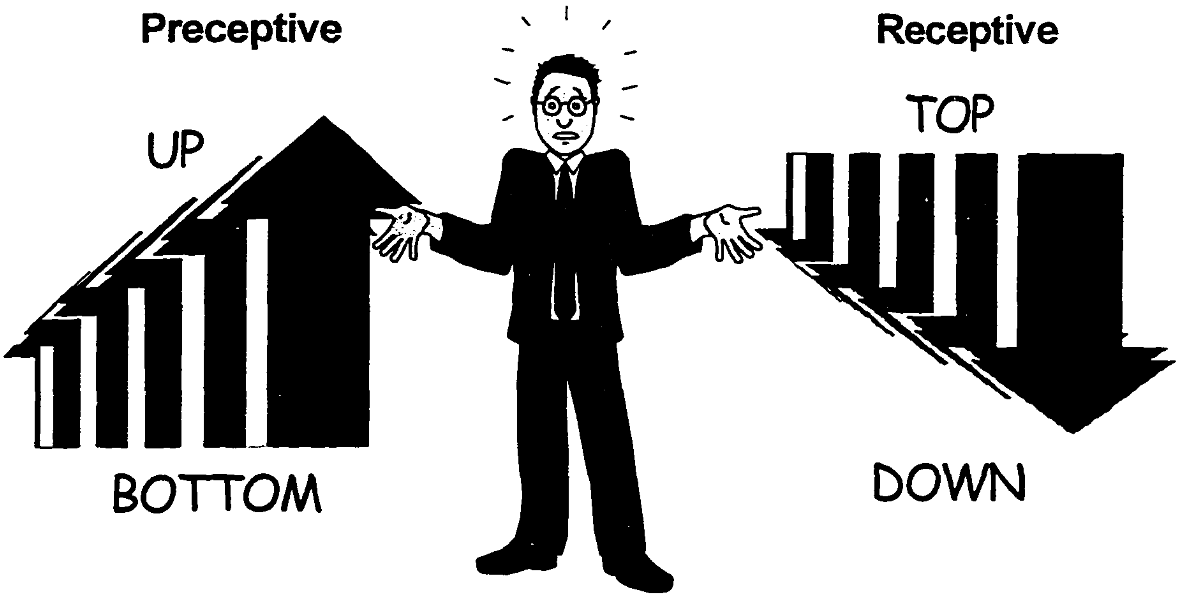


Figure 20. Which planning approach to use?

and timing will be affected. It is also quite possible to make the wrong assumptions.

The top-down approach, on the other hand, is receptive systematic, formal, and logical that focuses on the plan itself. The plan is usually prepared by planning experts who normally will not be performing the work. They set it up and turn it over to those responsible for plan implementation. This type of planning is hierarchical by nature keeping the big picture and project objectives in view. However, the biggest problem associated with this approach is that of alienation of planner from the doer. The person who is responsible for implementing the plan is not in the planning loop. In fact, the entire planning process is underestimated at the cost of producing an output (product). This usually results in hostility on the part of the line managers and they are usually reluctant to use the plan. Furthermore, there is the danger of producing an oversimplified plan while neglecting some important detail.

This research provided a change of paradigm by introducing a new methodology that combines the merits of both methods while avoiding their pitfalls. The proposed methodology is based on a "Top-Down" and "Back-To-Front" approach. CAPP's new planning paradigm puts the planner at the top of the project in a pro-active mode to start with project objectives and breakdown the project milestones to meet the contractual dates and deadlines (see Figure 21).

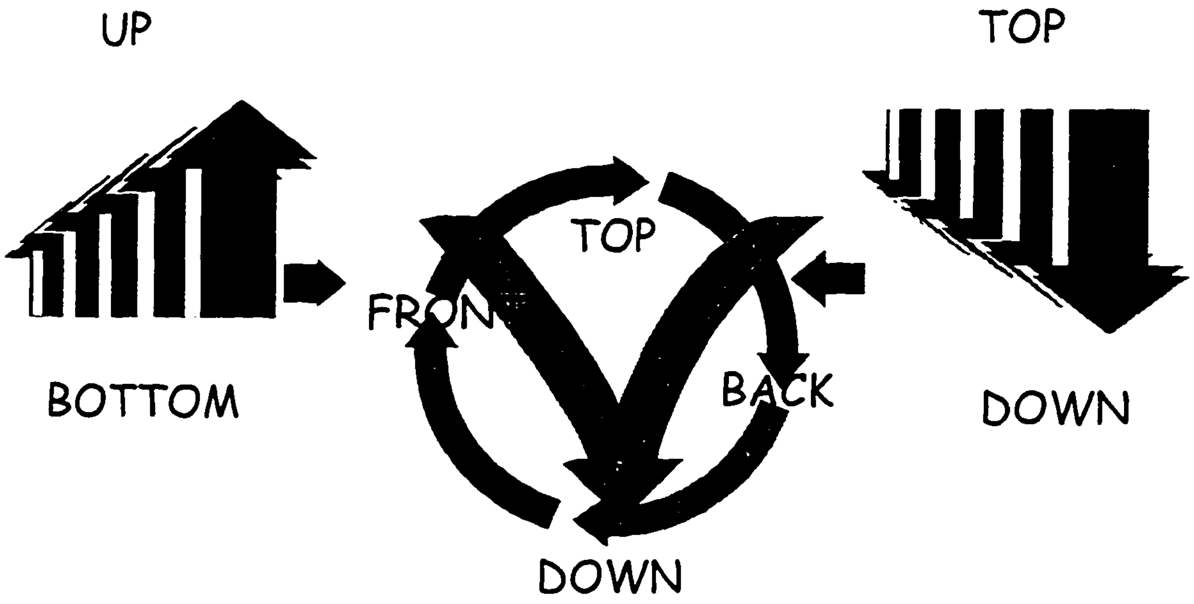


Figure 21. CAPP has introduced a new paradigm based on top-down and back to front.

Level of Detail

One of the problems inherent in existing planning methodologies is how to manage planning details. The level of detail used by CAPP for the initial planning is what can be referred to as the "control " level. This is a step further than milestone and summary levels but not as detailed as plans used in the field. Just as a ship navigator needs details of the next mile or so, not the entire journey, CAPP pays attention to short term details of what lies immediately ahead, while keeping in view the strategy of future. It moves from top down the hierarchy with a back to front cycle as shown in Figure 22.

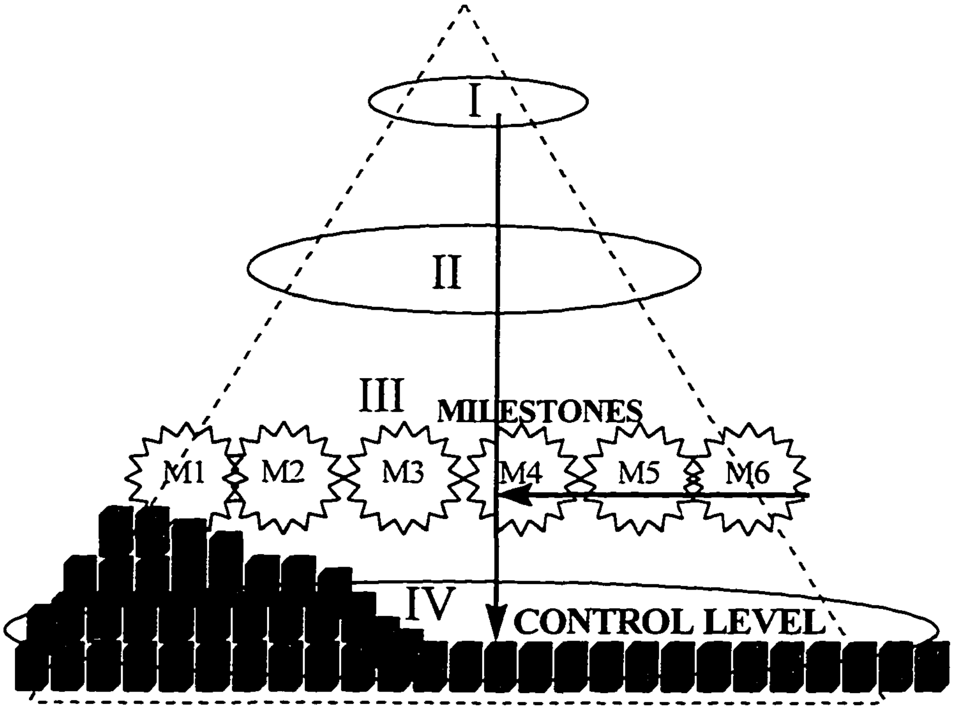


Figure 22. CAPP level of detail moves down the hierarchy in a back to front cycle with emphasis on short term details and a strategy for the future..

The generation of enormous volumes of information at the conceptual phase of a project will not be cost effective. In fact, there are many uncertainties regarding the details. When detailed information is not available activities are kept at a summary level with a strategic plan to find out the causes for lack of information and how and when more details will be available. Another unique feature of CAPP is to plan for uncertainty. CAPP makes allowance for multiple decision planning by allowing the user to interject decision points into the milestone plan that may lead to multiple courses of action. Rather than merely assuming a path, CAPP encourages the user to plan for multiple paths.

Flow Charts and Outline Specifications

The flow chart of Figure 23 is to be used as a guide in developing the inference engine program that can help the user to interface and dialogue with the system in producing a plan based on past projects. The actual programming of the Inference Engine is outside the scope of this research.

The following are step by step explanations to be used as a guide in developing the inference engine module:

Step 1. User initiates the type of project at hand and identifies the project components. This is done through an icon-based menu-driven screen similar to the prototype of Figure 24. The pictorial format facilitates user interaction with minimum amount of input on the part of the user. A library of various icons for different types of facilities and components are kept in a data base and are retrieved based on what previous icon is "clicked" by the user. The user has also the option of examining an existing project from the library of projects, make inquiries from others through Internet or E-mail, or review a multimedia library of past project pictures and films. retrieved based on what previous icon is "clicked" by the user. The user has also the option of examining an existing project from the library of projects, make inquiries from others through Internet or E-mail, or review a multimedia library of past project pictures and films.

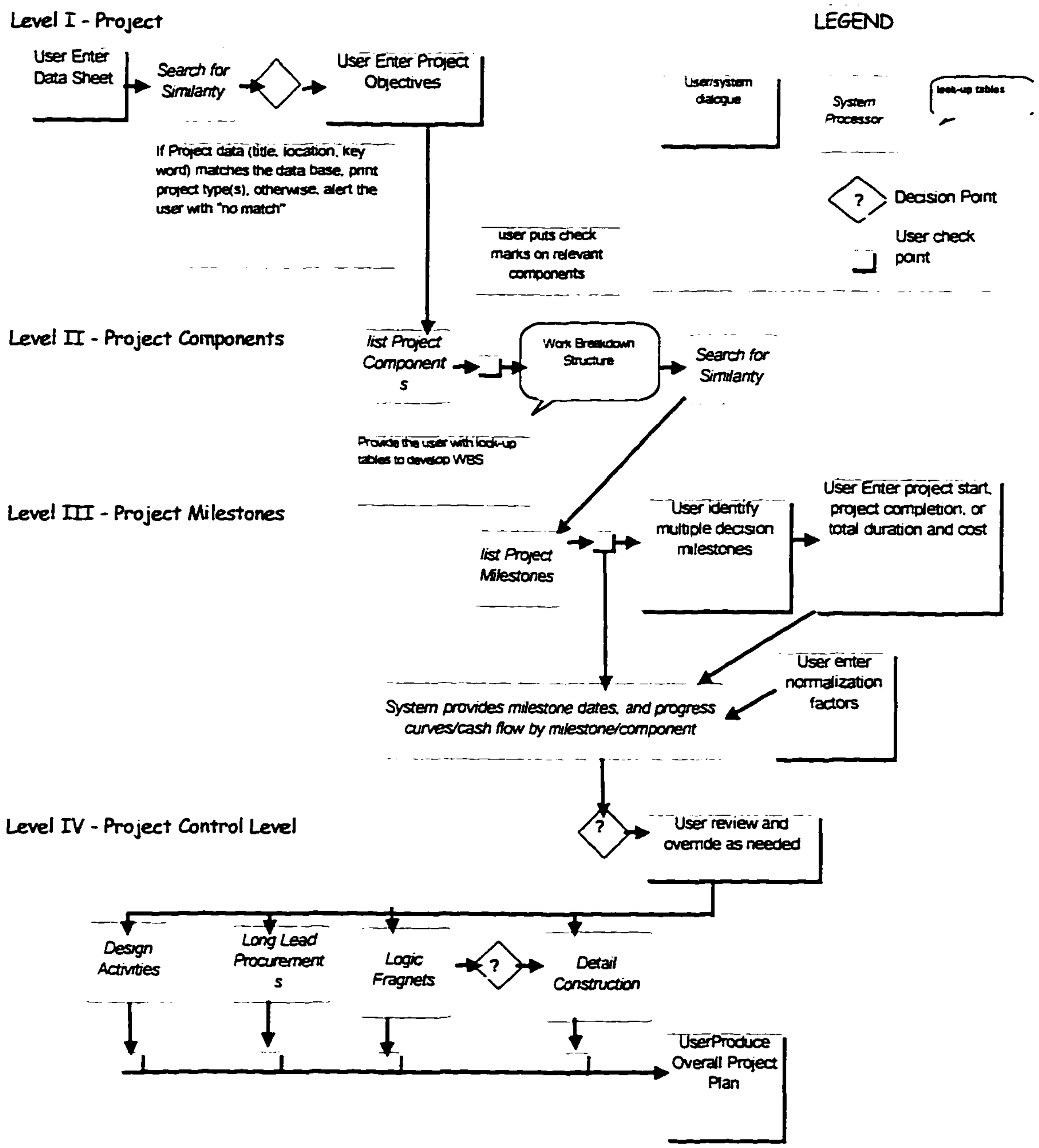


Figure 23. Inference Engine Flowchart

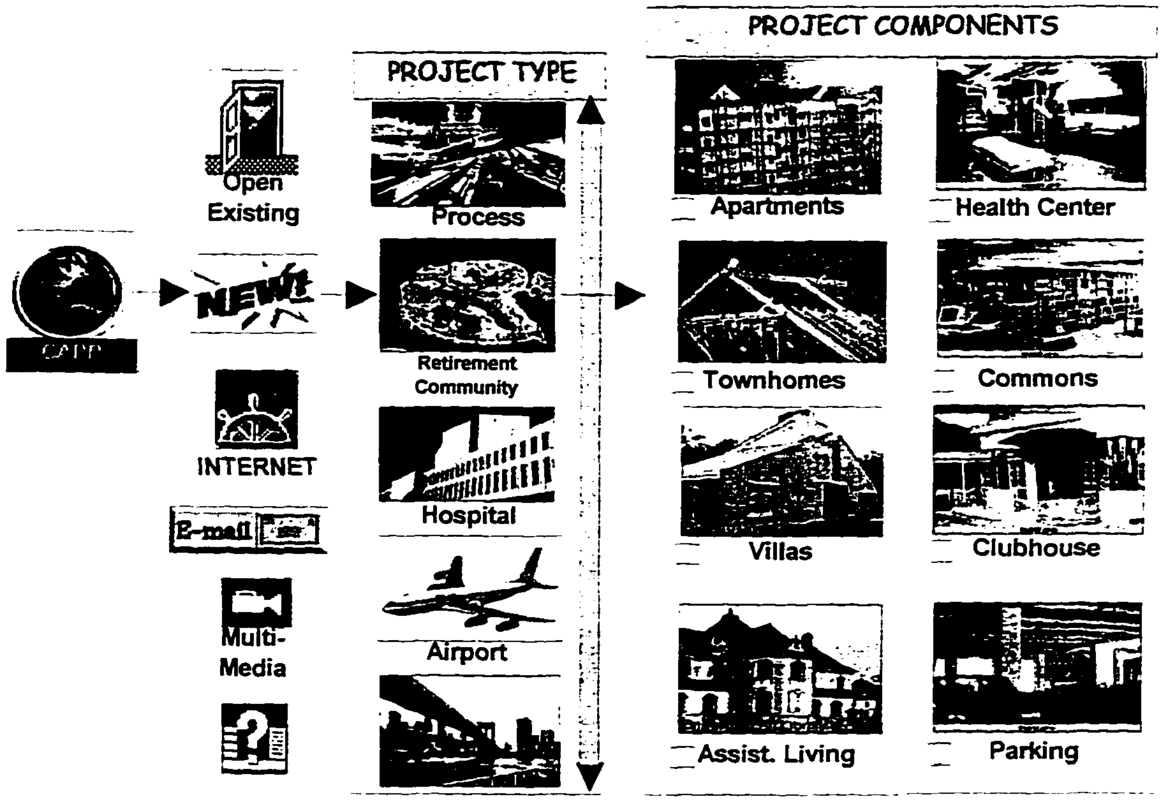
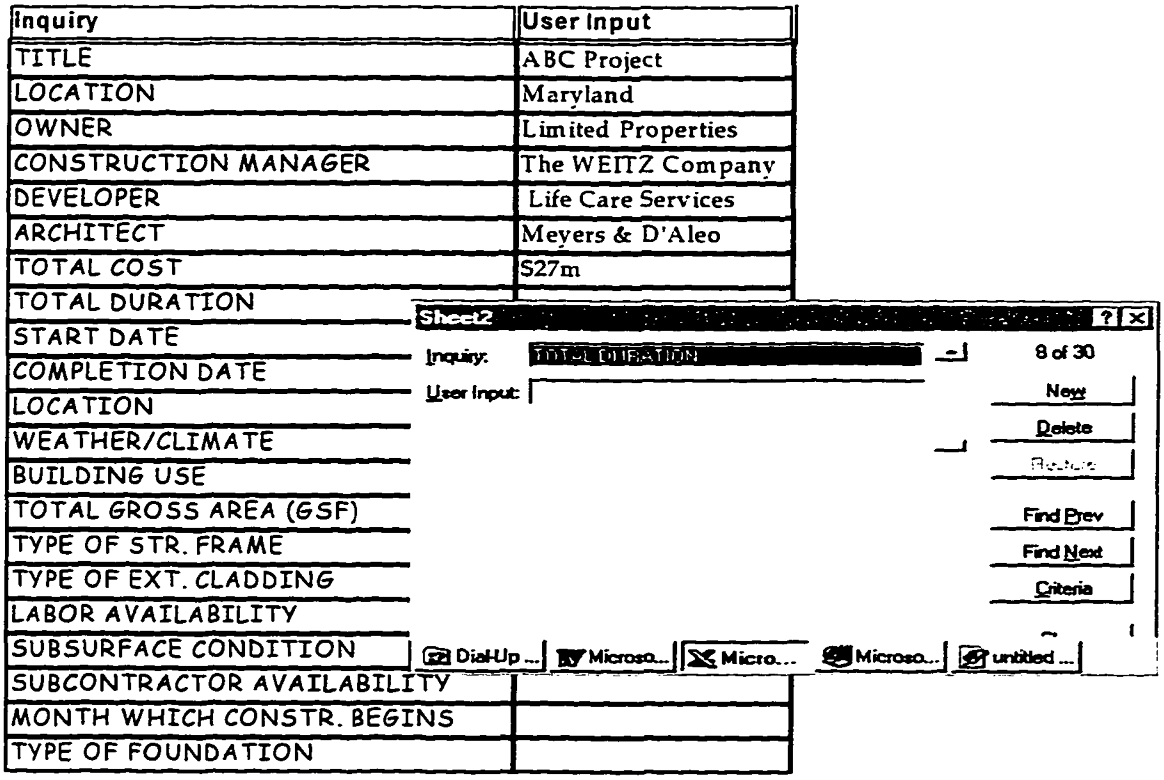


Figure 24. User identifies project type and components

Step 2. User enters basic project data through an interactive project data sheet screen similar to the Figure 25. A user dialogue box facilitates user input to capture as much information as possible regarding the new project. This includes such information as project title, location, owner, construction manager, developer, architect, total cost, total duration, start date, completion date, and other data as shown in the example of Figure 20.

Step 3. A list of project components, milestones, and relevant parameters is already defined and entered as a table in MS-Access as shown in Figure 26.



Inquiry	User Input
TITLE	ABC Project
LOCATION	Maryland
OWNER	Limited Properties
CONSTRUCTION MANAGER	The WEITZ Company
DEVELOPER	Life Care Services
ARCHITECT	Meyers & D'Aleo
TOTAL COST	S27m
TOTAL DURATION	
START DATE	
COMPLETION DATE	
LOCATION	
WEATHER/CLIMATE	
BUILDING USE	
TOTAL GROSS AREA (GSF)	
TYPE OF STR. FRAME	
TYPE OF EXT. CLADDING	
LABOR AVAILABILITY	
SUBSURFACE CONDITION	
SUBCONTRACTOR AVAILABILITY	
MONTH WHICH CONSTR. BEGINS	
TYPE OF FOUNDATION	

Inquiry: TOTAL DURATION

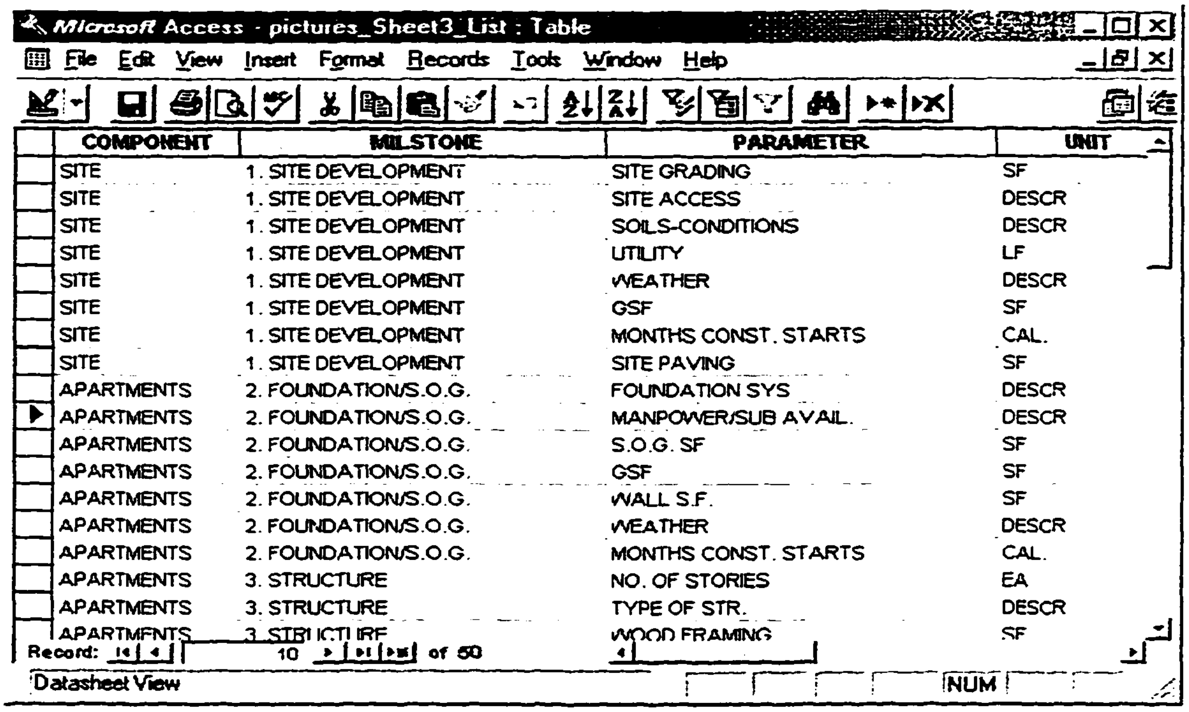
User Input:

8 of 30

Figure 25. User enters basic project data via an interactive dialogue box

This list has been prepared based on the list of parameters and milestones defined by the participants of this research and confirmed through the analysis section. The users are free to examine this table and add or subtract from it or make any modifications before using it on the new project. By having this table pre-defined and entered beforehand, the user will only need to scroll through this list through an interactive dialogue box discussed in the next section.

Step 4. User enters project parameter values through another interactive dialogue box. An example of a user dialogue box using MS-Access is shown in

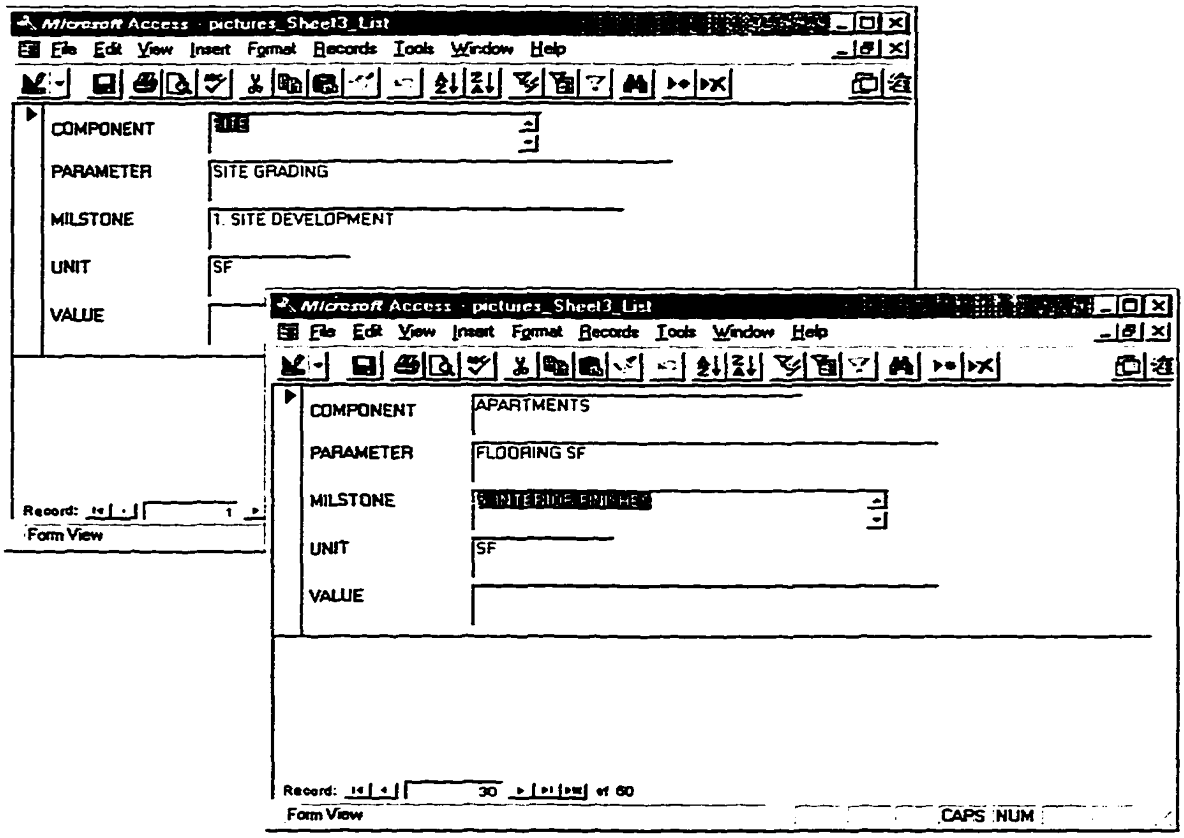


COMPONENT	MILSTONE	PARAMETER	UNIT
SITE	1. SITE DEVELOPMENT	SITE GRADING	SF
SITE	1. SITE DEVELOPMENT	SITE ACCESS	DESCR
SITE	1. SITE DEVELOPMENT	SOILS-CONDITIONS	DESCR
SITE	1. SITE DEVELOPMENT	UTILITY	LF
SITE	1. SITE DEVELOPMENT	WEATHER	DESCR
SITE	1. SITE DEVELOPMENT	GSF	SF
SITE	1. SITE DEVELOPMENT	MONTHS CONST. STARTS	CAL.
SITE	1. SITE DEVELOPMENT	SITE PAVING	SF
APARTMENTS	2. FOUNDATION/S.O.G.	FOUNDATION SYS	DESCR
APARTMENTS	2. FOUNDATION/S.O.G.	MANPOWER/SUB AVAIL.	DESCR
APARTMENTS	2. FOUNDATION/S.O.G.	S.O.G. SF	SF
APARTMENTS	2. FOUNDATION/S.O.G.	GSF	SF
APARTMENTS	2. FOUNDATION/S.O.G.	WALL S.F.	SF
APARTMENTS	2. FOUNDATION/S.O.G.	WEATHER	DESCR
APARTMENTS	2. FOUNDATION/S.O.G.	MONTHS CONST. STARTS	CAL.
APARTMENTS	3. STRUCTURE	NO. OF STORIES	EA
APARTMENTS	3. STRUCTURE	TYPE OF STR.	DESCR
APARTMENTS	3. STRUCTURE	WOOD FRAMING	SF

Figure 26. Predefined data table showing component, milestone, and parameters

Figure 27. All the relevant parameters, milestones, and project components were predefined as discussed before. Therefore, the user can scroll and select from the list of project components and the system will automatically ask the user to enter parameter values. At any point during this process the user has the option to override the milestones, or the parameters and add any new milestones and parameters.

Step 5. Once all the parameter values are defined by the user, the system searches the data base for other project components that are closely related to the user entered value. A list of average cost/milestone durations, start, and finish times are used as a benchmark to compare and adjust the values based



COMPONENT [illegible]
PARAMETER SITE GRADING
MILSTONE 1. SITE DEVELOPMENT
UNIT SF
VALUE
Record: 1

COMPONENT APARTMENTS
PARAMETER FLOORING SF
MILSTONE [illegible] INTERIOR FINISHES
UNIT SF
VALUE
Record: 30 of 60

Figure 27. User enters parameter values via an interactive dialogue box

on the data entered. The benchmark milestone and parameters is shown in Table 25. Based on this similarity analysis, a list of cost and milestones is generated as output. Table 25 is a sample milestone schedule output based on averaging the values from each case study. Other sample reports are included in Appendix D.

Using Averages versus Median or Mode

The benchmark milestones and parameters is used as a frame of reference with which to compare previous projects to the proposed project on hand. There are three options available for measuring where the bulk of data lies. These are

Mean (average), median, or mode. Mean is calculated by averaging the data, median is the middle number, and mode is the number that occurs most frequently. Both mean and median are valid for interval or ratio data while mode is valid for all scales but not very useful for interval or ratio due to the values which are typically spread too thin for duplicates to occur. The mean and median values from the case studies were calculated using MS-Excel. These are shown in Tables 24 and 25. The calculated mode values were incomplete due to the small population size that contained very little data with duplicate values.

Figure 28 is a plot comparing the mean and median values for the case studies used in this study. An analysis of mean and median calculations indicates a very close relationship between the two and therefore, one can conclude that it probably will not make a significant difference which one to choose. However, it should be noted that the mean is sensitive to perturbations in the data while the median is not. Also, due to the small population sample used in this study, no definite conclusion can be made and this subject should be studied further when more data is added to the CAPP data base. Figure 29 is a sample milestone schedule output.

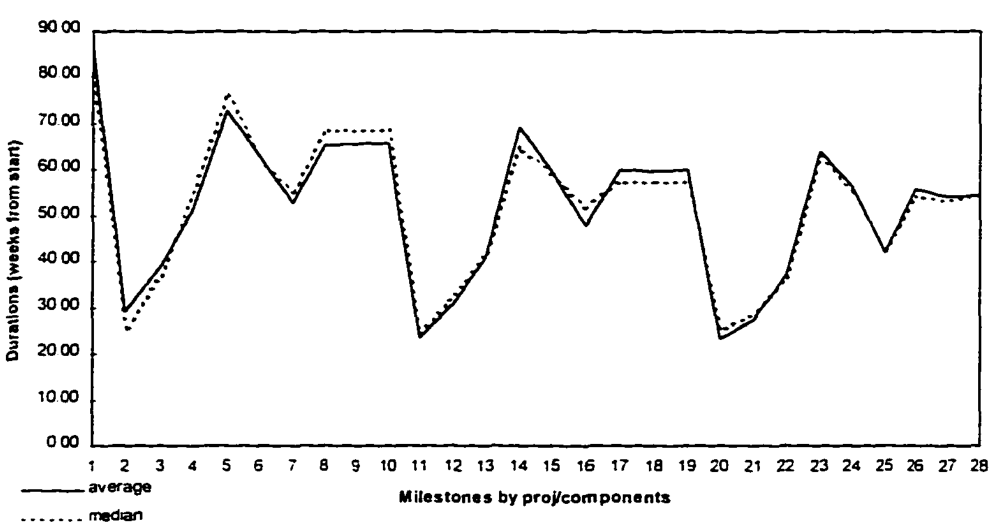


Figure 28. Calculated means v.s. medians shows no significant differences.

Internet Technology

The Internet is one of the most cost-effective information tool now available to the construction industry. The evolving Internet technology can help planners manage information much more efficiently. Bill Gates, founder of Microsoft, has said, "The Internet has a huge potential as it relates to construction industry. This is an industry that continually moves detailed information back and forth between offices and remote job sites. Pulling together even a simple straightforward project now requires the interaction of hundreds of people and thousands of documents. Today's challenges are incredible" (Murray 1997).

Table 24. Benchmark milestone cost, start, finish times by components based on means.

PARAMETER-MILESTONE	SITEWORK		
	COST	START	FINISH
1.00 SITE DEVELOPMENT	0.09	0.00	86.68

PARAMETER-MILESTONE	RESIDENTIAL		
	COST	START	FINISH
2.00 FOUNDATIONS & S.O.G.	0.02	8.95	29.39
3.00 STRUCTURE	0.09	17.74	39.07
4.00 EXTERIOR ENCLOSURE	0.08	25.38	51.68
5.00 INTERIOR FINISHES	0.16	27.92	73.00
6.00 EQUIPMENT&SPEC CONS	0.00	43.27	63.04
7.00 CONVEYING SYS	0.01	34.27	53.04
8.00 MECHANICAL	0.09	23.60	65.22
9.00 FIRE PROTECTION	0.02	26.49	65.72
10.00 ELECTRICAL	0.05	27.49	65.72

PARAMETER-MILESTONE	COMMONS		
	COST	START	FINISH
2.00 FOUNDATIONS & S.O.G.	0.01	13.06	23.72
3.00 STRUCTURE	0.01	20.45	30.79
4.00 EXTERIOR ENCLOSURE	0.02	28.24	41.14
5.00 INTERIOR FINISHES	0.03	29.35	69.43
6.00 EQUIPMENT&SPEC CONS	0.01	52.67	59.86
7.00 CONVEYING SYS	0.00	34.38	47.97
8.00 MECHANICAL	0.02	35.49	60.18
9.00 FIRE PROTECTION	0.00	37.35	59.86
10.00 ELECTRICAL	0.01	37.60	59.97

PARAMETER-MILESTONE	HEALTH CENTER		
	COST	START	FINISH
2.00 FOUNDATIONS & S.O.G.	0.01	12.32	23.38
3.00 STRUCTURE	0.01	19.49	27.68
4.00 EXTERIOR ENCLOSURE	0.01	23.99	37.07
5.00 INTERIOR FINISHES	0.02	26.88	64.11
6.00 EQUIPMENT&SPEC CONS	0.00	51.10	56.43
7.00 CONVEYING SYS	0.00	42.14	42.20
8.00 MECHANICAL	0.01	34.24	55.82
9.00 FIRE PROTECTION	0.00	34.99	54.29
10.00 ELECTRICAL	0.01	35.92	54.57

Note: Cost is in percentage of total cost, start and finish times are weeks from start of construction.

Table 25. Benchmark milestone cost, start, finish times by components based on medians

PARAMETER-MILESTONE	SITEWORK		
	COST	START	FINISH
1.00 SITE DEVELOPMENT	0.08	0.00	80.48

PARAMETER-MILESTONE	RESIDENTIAL		
	COST	START	FINISH
1.00 SITE DEVELOPMENT			
2.00 FOUNDATIONS & S.O.G.	0.02	9.86	25.10
3.00 STRUCTURE	0.07	18.64	36.38
4.00 EXTERIOR ENCLOSURE	0.07	25.64	55.31
5.00 INTERIOR FINISHES	0.16	29.00	76.69
6.00 EQUIPMENT&SPEC CONS	0.00	39.79	62.31
7.00 CONVEYING SYS	0.01	34.57	55.31
8.00 MECHANICAL	0.08	25.00	68.67
9.00 FIRE PROTECTION	0.02	25.00	68.67
10.00 ELECTRICAL	0.05	25.57	68.67

PARAMETER-MILESTONE	COMMONS		
	COST	START	FINISH
1.00 SITE DEVELOPMENT			
2.00 FOUNDATIONS & S.O.G.	0.01	12.79	24.31
3.00 STRUCTURE	0.01	19.86	32.05
4.00 EXTERIOR ENCLOSURE	0.02	26.98	41.12
5.00 INTERIOR FINISHES	0.03	28.98	65.05
6.00 EQUIPMENT&SPEC CONS	0.01	51.62	59.05
7.00 CONVEYING SYS	0.00	35.00	52.00
8.00 MECHANICAL	0.02	41.62	57.48
9.00 FIRE PROTECTION	0.00	41.62	57.48
10.00 ELECTRICAL	0.01	41.62	57.48

PARAMETER-MILESTONE	HEALTH CENTER		
	COST	START	FINISH
1.00 SITE DEVELOPMENT			
2.00 FOUNDATIONS & S.O.G.	0.01	14.24	25.24
3.00 STRUCTURE	0.01	18.90	28.62
4.00 EXTERIOR ENCLOSURE	0.01	23.69	36.03
5.00 INTERIOR FINISHES	0.02	28.05	62.64
6.00 EQUIPMENT&SPEC CONS	0.00	51.05	55.21
7.00 CONVEYING SYS	0.00	42.14	42.20
8.00 MECHANICAL	0.01	34.98	54.07
9.00 FIRE PROTECTION	0.00	34.98	53.48
10.00 ELECTRICAL	0.01	34.98	54.50

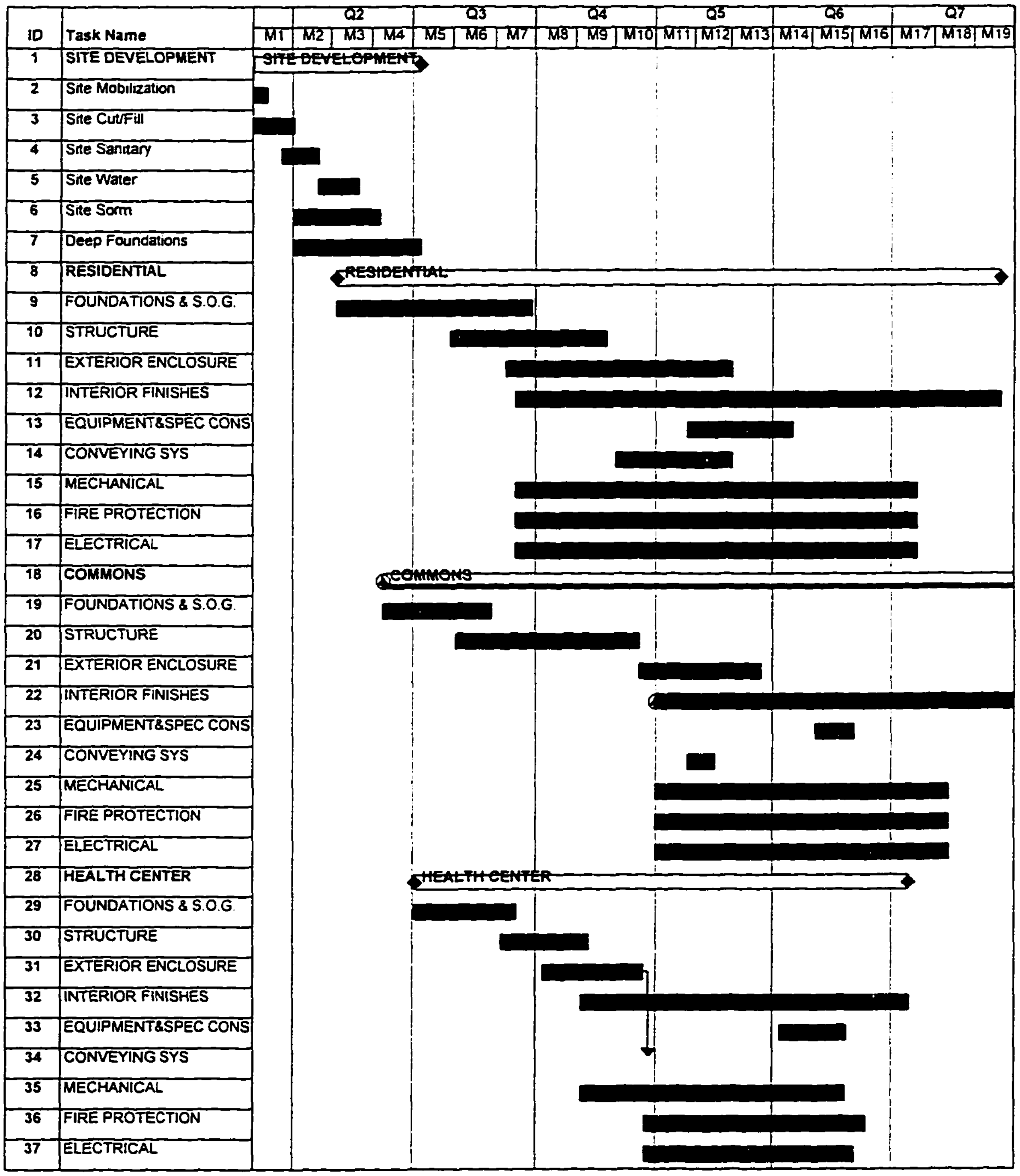
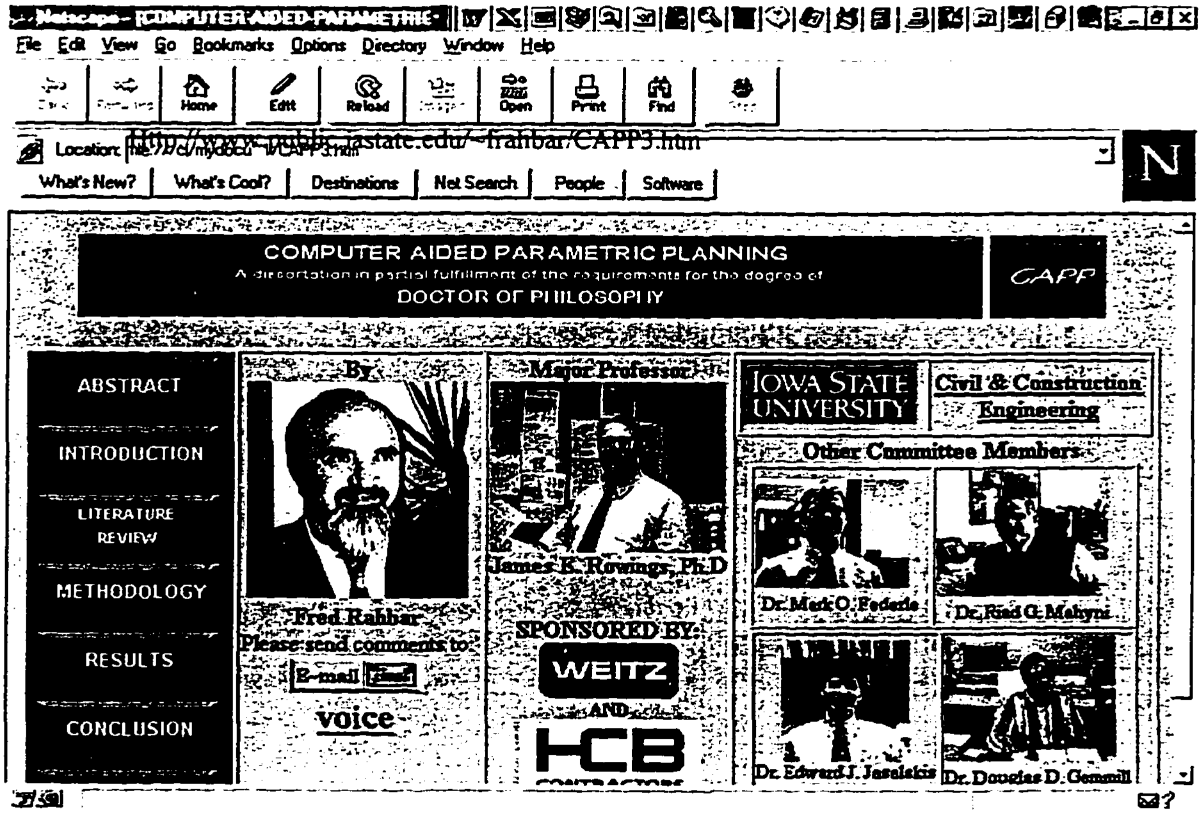


Figure 29. Sample Milestone Schedule Output

Using state-of-the-art web technology, CAPP data base can be accessed through the Internet or Intranet, an internal version of Internet. All archived information contained in the data base including work breakdown structure, milestones, design, procurement, and construction activities, sequences, manpower, cost, cash flow, and progress photos can be accessed in an instant by any authorized from almost any location in the world. A separate web page can be set-up for each project that can be viewed by the client and project team who have access to a web browser. This technology is evolving at an incredible rate. More and more of the state-of-the-art project control software are introduced to convert the project data to hyper-text in order to be accessed through the Internet.

This study explored the possibility of using the Internet technology to facilitate the planning process. Due to limited server space, it was not feasible to set up the entire CAPP data base on the Internet. Nevertheless, a small segment of the database was set-up on the Internet to demonstrate the concept. the question of data security and confidentiality is an issue that must be addressed in the future. It should be noted that the entire body of this dissertation was set-up on a web page to be accessed and reviewed by the sponsoring companies and the program of study committee. The site (see Figure 31) was frequently updated throughout the progress of this research.



COMPUTER AIDED PARAMETRIC PLANNING

A dissertation in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

By

Fred Rahbar

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Figure 31. CAPP Web Page

CHAPTER 5: SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to develop a planning framework, with the aid of a computer-aided model, to guide the end user in preparing quick conceptual project plans using identified parameters and past project data. Several standard parameters and milestones identified in the literature search formed the basis for the research methodology. Two prominent construction companies provided the case studies by sponsorship and funding this research. The case studies were made up of seven retirement communities and four hospital renovations and additions. A variety of data gathering techniques including observation, document reviews, as well as formal and informal interviews were employed. Information from each case study was collected, reviewed, sanitized, and input into a menu-driven data base module which was designed for this research. The data was then normalized and analyzed through a data analysis module.

The analysis included examination of a questionnaire which identified and ranked parameters, and milestones that affected the timing, sequencing, and overall duration of a project and its components. The results of this examination was then verified using regression analysis models performed for each project milestone as well as by project components. Based on this analysis, an outline specification consisting of prototype example menus, data tables, lists, and interactive user dialogue boxes was developed to form the basis for developing an inference engine module program.

The specific objectives and outcome of this research are summarized in Table 26.

Table 26. Objectives and Outcomes

	OBJECTIVES	OUTCOME
1	Capture planning data from past projects in a consistent and uniform format.	A menu-driven spreadsheet database containing planning data from 6 retirement communities and 4 hospital expansion and renovation projects that allows the user to quickly retrieve and extract data at several levels and project components.
2	Identify the parameters, milestones, and activities that affect the timing, sequencing, and overall duration of a typical project and normalize the data.	For each case study above, a project data sheet, standard and project specific parameters, milestones, relative duration and cost, CPM activities and logic at various project components, and a pictorial library of job photos is developed and can be quickly retrieved.
3	Analyse historical data and develop a set of rules, directions, and decision points to simulate the manual process to be used as a basis for developing the Inference Engine Module.	An Outline Specification including knowledge-based flow diagrams with an simulated demo for developing the Inference Engine Module as a guides to search the Data Base and produce a customized project plan for the specific project on hand.
4	Explore use of Internet technology to help facilitate the planning process.	An introduction of the latest in Internet technology as applied to the process of planning.

Conclusion

The research questions were validated through interviews with key project personnel, case indexing, regression analysis, and using the author's extensive planning experience. The objective of validation was to test the research questions and the practical application of this research. The research methodology was more qualitative than quantitative involving empirical material through case studies, personal experiences, introspective, and observations. The following conclusion can be said in regards to each of the research questions.

Q1. How can archived planning data from various projects in the past can be captured in a consistent format and quickly retrieved, extracted, and re-used as a reference in generating conceptual plans for a similar project at hand?

This question was validated through the development of a menu-driven database confirmed by positive feedback received from the project managers and others who examined it. A total of 11 case studies were collected, organized, and input using the data base which is referred to as the CAPP Input Module. This module was demonstrated to several project managers as well as top executives of the sponsored companies. It was established that data from different projects can be captured and quickly retrieved using a consistent format. The only limitations in this data base was the limitations on technology as far as quality of captured images from projects' progress photos. These images consumed a vast amount of space and had to be compressed at the cost of loss of quality.

Q2. How can a planner's creativity, intuition, and judgment be maintained while automating the planning process through the use of historical data?

A new planning paradigm was introduced with the planner at the heart of the system allowing great flexibility to exercise judgment and intuition. The new paradigm is a top-down and back-to-front planning approach. This will allow the planner to be on top of the project in a pro-active mode to start with project objectives and breakdown the project milestones to meet the contractual dates and deadlines. The level of detail recommended for the initial planning is at the planner's control. User interaction is one of the prominent feature of the system. Redundant and routine data collection, input, calculations, etc., are carried out automatically, while several decision points were built-in the system that requires user participation enforcing more creative input on the part of the user. The response to this question cannot be said any better than what one of the evaluators mentioned and we quote "this system will not only safeguard planners' creativity, intuition, and judgment, but it will enhance it:.

Q3. What parameters, milestones, and activities affect the timing, sequencing, and overall duration of a project?

The research case studies identified a set of standard and specific parameters that influenced plan generation by project and project components. Major milestones, cost, work breakdown, and project activities and sequences were also identified. An initial investigation produced a potential list of parameters and the related milestones affected by it. Then through an interview, questionnaire, and regression analysis, this was confirmed and a typical list of parameters and milestones and their degree of influential relationships were determined. The analysis affirmed strong relationships existed between the project parameters and milestone durations and timing. However, most of the regression analysis performed used quantitative type of parameters. Future research analysis can be performed taking qualitative parameters into account as well.

Q4. Can the use of advanced information technology facilitate the planning process?

This study introduced the use of the latest Internet technology to facilitate the planning process. CAPP's data base module can be easily translated into hypertext language (HTML) and accessed by almost anyone in the world who has access to the Internet. However, the question of data security and confidentiality is an issue that must be addressed in the future implementation of the system. In fact, the entire body of this dissertation was reproduced on a web page and was accessed and reviewed by the sponsoring companies. The program of study committee also had access to this site. The site was frequently updated throughout the progress of this research. There is no doubt that the latest technology and the Internet can positively contribute to facilitating the gathering of information and planning input that is required from a numerous parties who are normally situated distances apart.

Recommendations for Future Research

During the course of this research several areas that needed further study were identified. These areas include the following:

Developing the Inference Engine Program

This study produced a historical data base, and identified the important parameters and milestones that affect timing and sequencing of activities and durations. However, in its current phase, the user makes the comparisons between the new project and historical data on a semi-manual basis. In order to automate this process, an Inference Engine Module needs to be developed using a computer software. Nevertheless, CAPP provided an outline specification, summary flowcharts, and input/output menus and sample reports as requirements to develop such software program. The inference engine can be developed as a stand-alone or as add-on to the existing state-of-the-art CPM processors. The purpose of this program is to facilitate the front-end planning requirements.

Increase the Number of Similar Projects in the Data Base

The analysis performed in this study were based only a handful of similar projects. Therefore, the total number of cases used for regression study were far below the normal population sample with a large variation in activity and milestone durations. Having more projects of similar nature would provide the required quantitative data and allow a more sound statistical analysis.

Developing Similar Approach for Other Types of Construction Projects

This study was based on two types of projects, retirement community, and hospital expansion and renovation. Similar study can be done using other types of projects.

APPENDIX A: QUESTIONNAIRE

Planning Questionnaire

Name: ____________________ Date: ________ Title: __________________

Part I: General

(N) None or not applicable
(VL) Very Low
(L) Low
(M) Medium
(H) High
(VH) Very High

1. To what degree are the corporate goals and business strategies understood by those involved in project planning? ( )
2. How important is planning to you as compared with other management functions? ( )
3. To what extend is the top management committed to planning? ( )
4. To what degree is the planning data available when you prepare the initial conceptual plan? ( )
5. To what extend is the budget and scope of work established at the time of the initial conceptual planning? ( )
6. To what degree do you resource load the schedules? ( )
7. To what degree do you perform resource leveling? ( )
8. To what degree do you keep crew sizes and resources into account when you assign activity durations? ( )
9. To what degree is the project's initial staffing level established when you prepare initial plans? ( )
10. How much do you depend on past project experiences in establishing durations and sequences of work? ( )
11. How much do you depend on the budget estimate when establishing activity durations? ( )
12. To what degree is each of the following parties involved in plan preparations at the conceptual phase of a project?
    - Senior Management ( )
    - Project Manager ( )
    - Proj. Superintendent ( )
    - Project Scheduler ( )
    - Design Engineer ( )
    - other Subcontractors ( )

    Client Representative ( )
    Project Engineer ( )
    Foreman ( )
    Project Estimator ( )
    Major Subcontractor ( )
    Vendors ( )

13. To what extend are contractual milestone dates already established at the time of the initial planning? ( )

(N) None or not applicable (VL) Very Low (L) Low
(M) Medium (H) High (VH) Very High

14. To what extend is the total project duration already established at the time of the initial planning? ( )
15. To what extend do you use project summary schedules? ( )
16. Do you distinguish between planning and scheduling? ( ) Yes ( ) No
17. Do you believe that planning should be performed by those who are ultimately responsible for its execution? ( ) Yes ( ) No
18. Do you develop a Work Breakdown Structure (WBS) before you plan? ( ) Yes ( ) No
19. Do you consider the planning process as a top-down or bottom-up approach? ______________________
20. How much time do you devote to the initial planning? ____________
21. Is there enough time is allocated to the initial planning? ( ) Yes ( ) No
22. Should detail planning be left for the field? ( ) Yes ( ) No
23. Do you have a set of planning guides and procedures in your office? ( ) Yes ( ) No and to what extend do you use them? ( )
24. What degree of contingency do you allow in the initial plan? ( )
25. To what degree do you evaluate actuals against the plan? ( )
26. Do you believe in cost-schedule integration? ( ) Yes ( ) No
27. Do you cost load the plan? ( ) Yes ( ) No
28. Do you prepare activities, durations, and sequences manually before entering into the computer program? ( ) Yes ( ) No
29. Do you issue copies of the initial plan to the:
    a) Owner ( ) Yes ( ) No ( ) Sometimes
    b) Architect ( ) Yes ( ) No ( ) Sometimes
    c) Subcontractors ( ) Yes ( ) No ( ) Sometimes
30. How often do you update the plan? ( ) weekly ( ) Monthly ( ) Qrtrly ( ) Other
31. To what extend do you record actual start, and actual finish dates every time you update the plan? ( )
32. To what extend do you consider weather impact when preparing the initial plan? ( )
33. To what extend do you consider labor productivity when planning? ( )

Part II: Project Specific

(N) None or not applicable	(VL) Very Low	(L) Low
(M) Medium	(H) High	(VH) Very High

1. Please check if you were involved in any of the following projects:

	Project	Your Involvement
1	A	
2	B	
3	C	
4	D	
5	E	
6	F	
7	G	

2. To what degree did the following parameters influence the associated milestones. Feel free to add other relevant parameters if not listed.

MILESTONE	PARAMETERS	OTHER PARAMETERS (SPECIFY)
SITE DEVELOPMENT	SF Site Grading ( ) SF Site Paving ( ) GSF ( ) Weather ( ) Month Const. Starts ( )	
FOUNDATION/S.O.G	SF S.O.G ( ) SF Wall ( ) GSF ( ) Weather ( ) Month Const. Starts ( )	
STRUCTURE	Ton Str. Steel ( ) SF Load Bearing Walls ( ) SF Wood Framing ( ) GSF ( ) Weather ( )	
EXTERIOR ENCLOSURE	Roof SQ ( ) SF Skin Walls ( ) SF Glass/Glazing ( ) GSF ( ) Weather ( )	
INTERIOR FINISHES	SF Int. Framing ( ) No. of Doors ( ) SF Flooring ( ) SF Ceiling ( ) GSF ( )	

MILESTONE	PARAMETERS	OTHER PARAMETERS (SPECIFY)
EQUIPMENTandSPEC CONS	GSF ( ) SF Kitchen ( ) SF Flooring ( )	
CONVEYING SYS	EA Elevators ( )	
MECHANICAL	EA Fixtrs ( ) GSF ( )	
FIRE PROTECTION	EA Sprklrs ( ) GSF ( )	
ELECTRICAL	EA Fixtrs ( ) GSF ( )	

Please answer the following as related to the above projects. Feel free to comment below each line.

3. To what degree was the weather a factor in planning? ( )

4. To what degree availability of labor was a factor? ( )

5. To what degree quality of labor was a factor? ( )

6. To what degree availability of subcontractors was a factor? ( )

7. To what degree subsurface condition was a factor? ( )

8. To what degree site accessibility was a factor? ( )

To what degree amount of site improvement was a factor? ( )

APPENDIX B: NORMALIZED PARAMETERS/MILESTONES

CASE A

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			CLUBHOUSE/COMMON			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1 00 SITE DEVELOPMENT	$2.849	04/13/92	07/21/93									
2 00 FOUNDATIONS & S O G				$917	04/23/92	08/13/92	$206	06/08/92	09/18/92	$133	05/21/92	08/07/92
3 00 STRUCTURE				$3.792	06/22/92	11/06/92	$441	08/17/92	10/16/92	$172	07/24/92	09/28/92
4 00 EXTERIOR ENCLOSURE				$2.765	08/21/92	12/22/92	$599	09/10/92	12/25/92	$407	08/25/92	11/09/92
5 00 INTERIOR FINISHES				$4.117	08/31/92	05/21/93	$796	08/24/92	06/23/93	$493	09/23/92	06/15/93
6 00 EQUIPMENT&SPEC CONS				$19	11/02/92	04/09/93	$409	03/04/93	05/11/93	$59	02/23/93	04/14/93
7 00 CONVEYING SYS				$216	11/09/92	01/08/93	$44	09/21/92	11/04/92			
8 00 MECHANICAL				$2.614	06/04/92	04/02/93	$474	07/27/92	03/31/93	$344	09/23/92	04/13/93
9 00 FIRE PROTECTION				$386	08/24/92	04/16/93	$116	09/17/92	03/22/93	$80	10/14/92	04/02/93
10 00 ELECTRICAL				$1.851	09/21/92	04/16/93	$303	09/24/92	03/25/93	$181	11/09/92	04/19/93
11 00 JOB SERVICES												
12 00 MAJOR EQUIPMENT												
13 00 GC FEE												
14 00 BOND/CONTINGENCY/MISC												
TOTAL	$2.849			$16.677	04/23/92	05/21/93	$3.388	06/08/92	06/23/93	$1.869	05/21/92	06/15/93
COST/GSF												
DURATION (MONTHS)	15 5			13.1			12.7			13 0		

note Cost in thousands of dollars

NORMALIZED

% NOTE. ALL START AND FINISH TIMES ARE NO. OF WEEKS FROM START

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			CLUBHOUSE/COMMON			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1 00 SITE DEVELOPMENT	0 11	0 00	66.29									
2 00 FOUNDATIONS & S O G				0.04	1 43	17 43	0 01	8.00	22 57	0 01	5 43	16 57
3 00 STRUCTURE				0 15	10.00	29 57	0.02	18.00	26 57	0.01	14 57	24 00
4 00 EXTERIOR ENCLOSURE				0 11	18 57	36 14	0.02	21 43	36.57	0 02	19 14	30 00
5 00 INTERIOR FINISHES				0.16	20 00	57 57	0.03	19 00	62 29	0 02	23.29	61 14
6 00 EQUIPMENT&SPEC CONS				0.00	29.00	51 57	0 02	46 43	56 14	0 00	45 14	52.29
7 00 CONVEYING SYS				0.01	30.00	38 57	0.00	23 00	29 29			
8 00 MECHANICAL				0 10	7 43	50 57	0 02	15 00	50.29	0 01	23.29	52 14
9 00 FIRE PROTECTION				0.02	19 00	52.57	0.00	22 43	49 00	0 00	26 29	50 57
10 00 ELECTRICAL				0.07	23.00	52.57	0.01	23 43	49 43	0.01	30 00	53.00
11 00 JOB SERVICES												
12 00 MAJOR EQUIPMENT												
13 00 GC FEE												
14 00 BOND/CONTINGENCY/MISC												
TOTAL	0.11			0.65	1 43	57 57	0.13	8 00	62.29	0.07	5.43	61 14
COST/GSF												
DURATION (WEEKS)	66 97			56.72			54 85			56 29		

CASE B

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			COMMONS			NURSING		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1.00 SITE DEVELOPMENT	$1.829	03/01/95	10/01/96		03/01/95	7/6/95		03/01/95	05/01/95		03/01/95	07/06/95*
2.00 FOUNDATIONS & S.O.G.				$311	06/15/95	10/26/95	$75	06/26/95	8/22/95	$61	07/05/95	08/15/95
3.00 STRUCTURE				$1.360	08/16/95	12/19/95	$214	10/19/95	12/28/95	$100	09/26/95	12/06/95
4.00 EXTERIOR ENCLOSURE				$738	10/26/95	04/20/96	$173	12/28/95	03/25/96	$109	12/06/95	02/15/96
5.00 INTERIOR FINISHES				$2.542	11/20/95	10/01/96	$341	02/27/96	05/15/96	$290	01/22/96	06/24/96
6.00 EQUIPMENT&SPEC CONS				$33			$254			$12		
7.00 CONVEYING SYS				$60	01/30/96	10/01/96	$30	N/A	N/A		N/A	N/A
8.00 MECHANICAL				$1.126	06/30/95	10/01/96	$205	07/10/95	05/15/96	$149	07/13/95	06/24/96
9.00 FIRE PROTECTION				$220	11/20/95	10/01/96	$26	01/16/96	05/15/96	$29	02/06/96	06/24/96
10.00 ELECTRICAL				$803	06/28/95	10/01/96	$172	06/26/95	05/15/96	$131	07/07/95	06/24/96
11.00 JOB SERVICES					06/14/95	10/01/96		06/14/95	05/15/96		06/14/95	06/24/96
12.00 MAJOR EQUIPMENT					06/14/95	10/01/96		06/14/95	05/15/96		06/14/95	06/24/96
13.00 GC FEE					06/14/95	10/01/96		06/14/95	05/15/96		06/14/95	06/24/96
14.00 BOND/CONTINGENCY/MISC					06/14/95	10/01/96		06/14/95	05/15/96		06/14/95	06/24/96
TOTAL	$1.829			$7.193	06/15/95	10/01/96	$1.480	06/26/95	05/15/96	$881	07/05/95	06/24/96
COST/GSF												
DURATION (MONTHS)	19.3			15.8			10.8			11.8		

note. Cost in thousands of dollars

NORMALIZED

% NOTE. ALL START AND FINISH TIMES ARE NO. OF WEEKS FROM START

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			COMMONS			NURSING		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1.00 SITE DEVELOPMENT	0.11	0.00	77.86									
2.00 FOUNDATIONS & S.O.G				0.04	15.14	34.14	0.01	16.71	24.86	0.01	18.00	23.86
3.00 STRUCTURE				0.15	24.00	41.86	0.02	33.14	43.14	0.01	29.86	40.00
4.00 EXTERIOR ENCLOSURE				0.11	34.14	59.43	0.02	43.14	55.71	0.02	40.00	50.14
5.00 INTERIOR FINISHES				0.16	37.71	77.86	0.03	51.86	63.00	0.02	46.71	68.71
6.00 EQUIPMENT&SPEC CONS				0.00			0.02			0.00		
7.00 CONVEYING SYS				0.01	47.86	77.86	0.00					
8.00 MECHANICAL				0.10	17.29	77.86	0.02	18.71	63.00	0.01	19.14	68.71
9.00 FIRE PROTECTION				0.02	37.71	77.86	0.00	45.86	63.00	0.00	48.86	68.71
10.00 ELECTRICAL				0.07	17.00	77.86	0.01	16.71	63.00	0.01	18.29	68.71
11.00 JOB SERVICES												
12.00 MAJOR EQUIPMENT												
13.00 GC FEE												
14.00 BOND/CONTINGENCY/MISC.												
TOTAL	0.11	0.00	77.86	0.65	15.14	77.86	0.13	16.71	63.00	0.07	18.00	68.71
COST/GSF												
DURATION (WEEKS)	77.86			62.71			46.29			50.71		

CASE C

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			COMMONS			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1 00 SITE DEVELOPMENT	$1.934	03/02/92	10/20/93									
2 00 FOUNDATIONS & S O G				$238	05/04/92	09/28/92	$702	06/09/92	08/31/92	$416	07/01/92	09/16/92
3 00 STRUCTURE				$1.835	07/28/92	11/23/92	$447	08/01/92	12/18/92	$329	09/04/92	11/09/92
4 00 EXTERIOR ENCLOSURE				$2.832	09/08/92	03/01/93	$614	12/18/92	03/22/93	$588	10/06/92	12/21/92
5 00 INTERIOR FINISHES				$5.545	09/15/92	09/20/93	$771	12/30/92	10/20/93	$525	11/04/92	07/13/93
6 00 EQUIPMENT&SPEC CONS				$18	01/25/93	04/15/93	$439	05/03/93	06/01/93	$40	04/06/93	05/26/93
7 00 CONVEYING SYS				$81	12/01/92	03/01/93	$81	01/25/93	02/15/93	$30	12/22/92	12/22/92
8 00 MECHANICAL				$2.544	09/15/92	07/19/93	$839	12/30/92	08/12/93	$475	11/04/92	05/25/93
9 00 FIRE PROTECTION				$365	09/15/92	07/19/93	$107	12/30/92	08/12/93	$61	11/04/92	04/23/93
10 00 ELECTRICAL	207			$1.628	09/15/92	07/19/93	$535	12/30/92	08/12/93	$294	11/04/92	04/14/93
11 00 JOB SERVICES	$3.162											
12 00 MAJOR EQUIPMENT												
13 00 GC FEE	$1.186											
14 00 BOND/CONTINGENCY/MISC	$1.466											
TOTAL	$7.955			$15.086	05/04/92	09/20/93	$4.535	06/09/92	10/20/93	$2.758	07/01/92	07/13/93
COST/GSF												
DURATION (MONTHS)	4 2			16 8			16 6			12.6		

note. Cost in thousands of dollars

NORMALIZED

% NOTE. ALL START AND FINISH TIMES ARE NO OF WEEKS FROM START

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			COMMONS			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1 00 SITE DEVELOPMENT	0 06	0 00	85 34									
2 00 FOUNDATIONS & S O G				0.01	9 00	30.05	0.02	14 14	26 05	0 01	17 29	28 34
3 00 STRUCTURE				0.05	21 14	38.05	0 01	21 71	41 62	0 01	26 57	36 05
4 00 EXTERIOR ENCLOSURE				0.08	27 14	52.05	0.02	41 57	55.05	0.02	31 14	42 05
5 00 INTERIOR FINISHES				0.16	28.14	81 05	0.02	43.29	85.34	0.01	35.29	71 20
6 00 EQUIPMENT&SPEC CONS				0 00	47 00	58 48	0.01	61.00	65 20	0 00	57 14	64 34
7 00 CONVEYING SYS				0.00	39 14	52 05	0.00	47 00	50.05	0.00	42.14	42 20
8 00 MECHANICAL				0.07	28.14	72.05	0.02	43.29	75 48	0 01	35.29	64 20
9 00 FIRE PROTECTION				0.01	28.14	72.05	0 00	43.29	75.48	0 00	35 29	59 63
10 00 ELECTRICAL	0 01			0 05	28.14	72.05	0.02	43.29	75.48	0.01	35.29	58 34
11 00 JOB SERVICES	0 09											
12 00 MAJOR EQUIPMENT												
13 00 GC FEE	0 03											
14 00 BOND/CONTINGENCY/MISC.	0 04											
TOTAL	0.23			0.43	9.00	81 05	0.13	14.14	85.34	0.08	17 29	71 20
COST/GSF												
DURATION (WEEKS)	85.34			72 80			71 93			54 47		

CASE D

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			COMMONS			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1 00 SITE DEVELOPMENT	$2,299	10/16/95	05/01/97									
2 00 FOUNDATIONS & S.O G				$705	01/27/96	09/30/96	$185	02/24/96	06/01/96	$189	01/24/96	04/10/96
3 00 STRUCTURE				$1.986	03/30/96	10/28/96	$434	05/03/96	07/05/96	$288	03/27/96	06/05/96
4 00 EXTERIOR ENCLOSURE				$1.631	05/25/96	12/09/96	$393	05/31/96	08/31/96	$182	05/01/96	09/23/96
5 00 INTERIOR FINISHES				$3,983	06/08/96	04/25/97	$757	07/15/96	01/20/97	$716	06/02/96	12/09/96
6 00 EQUIPMENT&SPEC CONS				$29	01/10/97	03/31/97	$376	10/01/96	12/09/96	$97	09/23/96	10/07/96
7 00 CONVEYING SYS				$162	09/23/96	12/30/96	$44	09/20/96	10/28/96	$30	08/15/96	09/23/96
8 00 MECHANICAL				$2,246	07/01/96	03/10/97	$452	07/22/96	12/02/96	$203	06/15/96	10/07/96
9 00 FIRE PROTECTION				$493	07/01/96	03/10/97	$70	07/22/96	12/02/96	$55	06/15/96	10/07/96
10 00 ELECTRICAL	162			$1.342	07/01/96	03/10/97	$317	07/22/96	12/02/96	$198	06/15/96	10/07/96
11 00 JOB SERVICES	$3,015											
12 00 MAJOR EQUIPMENT												
13 00 GC FEE	$1.297											
14 00 BOND/CONTINGENCY/MISC	$1.161											
TOTAL	$7,934			$12,577	01/27/96	04/25/97	$3,028	02/24/96	01/20/97	$1,958	01/24/96	12/09/96
COST/GSF												
DURATION (MONTHS)		18 8			15 1			11 0			10 7	

note Cost in thousands of dollars

NORMALIZED

% NOTE ALL START AND FINISH TIMES ARE NO OF WEEKS FROM START

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			COMMONS			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1 00 SITE DEVELOPMENT	0 08	0 00	80 48									
2 00 FOUNDATIONS & S O G				0 03	14 67	49 95	0.01	18.67	32.67	0 01	14 24	25 24
3 00 STRUCTURE				0.07	23.67	53.95	0.02	28.52	37 52	0 01	23.24	33 24
4 00 EXTERIOR ENCLOSURE				0.06	31 67	59.95	0 01	32.52	45 67	0.01	28.24	48 95
5 00 INTERIOR FINISHES				0.15	33.67	79 52	0.03	38.95	65.95	0 03	32 81	59 95
6 00 EQUIPMENT&SPEC CONS				0 00	64.52	75.95	0.01	50 10	59 95	0.00	48 95	50 95
7 00 CONVEYING SYS				0.01	48.95	62.95	0.00	48.52	53.95			
8 00 MECHANICAL				0 08	36.95	72 95	0.02	39.95	58.95	0 01	34 67	50 95
9.00 FIRE PROTECTION				0 02	36.95	72 95	0.00	39 95	58.95	0 00	34 67	50 95
10.00 ELECTRICAL				0.05	36.95	72.95	0.01	39 95	58 95	0.01	34 67	50 95
11.00 JOB SERVICES												
12.00 MAJOR EQUIPMENT												
13 00 GC FEE												
14 00 BOND/CONTINGENCY/MISC.												
TOTAL	0.08			0.48	14 67	79 52	0.11	18 67	65 95	0.07	14 24	59.95
COST/GSF												
DURATION (WEEKS)		81 31			65.53			47 77			46 19	

CASE F

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			COMMONS			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1.00 SITE DEVELOPMENT	$1.122	03/01/92	07/31/93									
2.00 FOUNDATIONS & S O G				$254	05/15/92	07/20/92	$404	05/20/92	06/04/92	$0		
3.00 STRUCTURE				$1.506	06/22/92	10/30/92	$217	06/04/92	07/01/92	$528	06/04/92	07/01/92
4.00 EXTERIOR ENCLOSURE				$1.184	08/17/92	04/15/93	$231	07/01/92	09/08/92	$188	07/01/92	09/08/92
5.00 INTERIOR FINISHES				$3.115	09/26/92	07/31/93	$839	06/22/92	05/24/93	$439	06/22/92	05/24/93
6.00 EQUIPMENT&SPEC CONS				$12	10/15/92	06/07/93	$272	03/08/93	04/12/93	$37	03/08/93	04/12/93
7.00 CONVEYING SYS				$166	07/12/92	04/15/93	$66	07/12/92	04/15/93	$33	07/12/92	04/15/93
8.00 MECHANICAL				$1.702	08/01/92	06/01/93	$400	01/01/93	03/28/93	$188	01/01/93	03/28/93
9.00 FIRE PROTECTION				$514	08/01/92	06/01/93	$39	01/01/93	03/28/93	$27	01/01/93	03/28/93
10.00 ELECTRICAL	73			$997	08/01/92	06/01/93	$230	01/01/93	03/28/93	$96	01/01/93	03/28/93
11.00 JOB SERVICES	$1.900											
12.00 MAJOR EQUIPMENT												
13.00 GC FEE	$941											
14.00 BOND/CONTINGENCY/MISC	$609											
TOTAL	$4.645			$9.450	05/15/92	07/31/93	$2.698	05/20/92	05/24/93	$1.536	06/04/92	05/24/93
COST/GSF												
DURATION (MONTHS)	17.2			14.7			12.3			11.8		

note: Cost in thousands of dollars

NORMALIZED

% NOTE. ALL START AND FINISH TIMES ARE NO. OF WEEKS FROM START

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			COMMONS			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1.00 SITE DEVELOPMENT	0.06	0.00	73.86									
2.00 FOUNDATIONS & S O G				0.01	10.71	20.14	0.02	11.43	13.57	0.00	-4809.14	-4809.14
3.00 STRUCTURE				0.08	16.14	34.71	0.01	13.57	17.43	0.03	13.57	17.43
4.00 EXTERIOR ENCLOSURE				0.06	24.14	58.57	0.01	17.43	27.29	0.01	17.43	27.29
5.00 INTERIOR FINISHES				0.16	29.86	73.86	0.04	16.14	64.14	0.02	16.14	64.14
6.00 EQUIPMENT&SPEC CONS				0.00	32.57	66.14	0.01	53.14	58.14	0.00	53.14	58.14
7.00 CONVEYING SYS				0.01	19.00	58.57	0.00	19.00	58.57			
8.00 MECHANICAL				0.09	21.86	65.29	0.02	43.71	56.00	0.01	43.71	56.00
9.00 FIRE PROTECTION				0.03	21.86	65.29	0.00	43.71	56.00	0.00	43.71	56.00
10.00 ELECTRICAL				0.05	21.86	65.29	0.01	43.71	56.00	0.00	43.71	56.00
11.00 JOB SERVICES												
12.00 MAJOR EQUIPMENT												
13.00 GC FEE												
14.00 BOND/CONTINGENCY/MISC												
TOTAL	0.06			0.48	10.71	73.86	0.14	11.43	64.14	0.08	-4809.14	64.14
COST/GSF												
DURATION (WEEKS)	74.62			63.80			53.26			51.09		

CASE G

PARAMETER-MILESTONE	SITEWORK/Commons			RESIDENTIAL-apts			ASSIST LIVING			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1 00 SITE DEVELOPMENT	$7.494	01/07/97	06/18/99									
2 00 FOUNDATIONS & S.O G	$369	09/29/97	12/05/97	$481	09/30/97	12/22/97	$147	01/17/97	01/09/98	$152	11/07/97	01/09/98
3 00 STRUCTURE	$1.141	12/08/97	02/27/98	$3.770	12/09/97	05/04/98	$551	05/04/98	06/12/98	$723	04/27/98	06/05/98
4 00 EXTERIOR ENCLOSURE	$881	04/05/98	04/28/98	$1.851	04/27/98	08/14/98	$579	06/08/98	10/09/98	$459	06/01/98	10/02/98
5 00 INTERIOR FINISHES	$1.525			$7.028	01/20/98	06/18/99	$1.157	10/19/98	04/01/99	$1.255	05/18/98	03/19/99
6 00 EQUIPMENT&SPEC CONS	$591			$238	11/02/98	03/19/99	$63	12/14/98	02/05/99	$63	09/21/98	12/25/98
7 00 CONVEYING SYS	$0			$248	06/15/98	07/24/98	$31	08/10/98	09/18/98	$62	08/03/98	09/11/98
8 00 MECHANICAL	$2.057			$3.260	10/28/97	03/19/99	$750	06/22/98	12/14/98	$842	12/08/97	11/16/98
9 00 FIRE PROTECTION	$210			$415	02/17/98	03/19/99	$96	06/22/98	12/14/98	$102	06/15/98	11/16/98
10 00 ELECTRICAL	$920			$1.839	10/28/97	03/19/99	$510	06/22/98	12/14/98	$728	12/08/97	11/16/98
11 00 JOB SERVICES	$3.491	01/07/97	06/18/99									
12 00 MAJOR EQUIPMENT												
13 00 GC FEE	$1.458	01/07/97	06/18/99									
14 00 BOND/CONTINGENCY/MISC	$3.047	01/07/97	06/18/99									
TOTAL	$23.185	01/07/97	06/18/99	$19.130	09/30/97	06/18/99	$3.884	01/17/97	04/01/99	$4.385	11/07/97	03/19/99
COST/GSF												
DURATION (MONTHS)		29 7			20 9			26 8			16 6	

note Cost in thousands of dollars

NORMALIZED

% NOTE ALL START AND FINISH TIMES ARE NO OF WEEKS FROM START

PARAMETER-MILESTONE	SITEWORK			RESIDENTIAL			ASSIST LIVING			HEALTH CENTER		
	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH	COST	START	FINISH
1 00 SITE DEVELOPMENT	0 14	0 00	127 43									
2 00 FOUNDATIONS & S.O G				0.01	38 00	49 86	0.00	1 43	52 43	0.00	43 43	52 43
3 00 STRUCTURE				0 07	48 00	68.86	0.01	68 86	74 43	0 01	67 86	73 43
4 00 EXTERIOR ENCLOSURE				0.03	67 86	83.43	0.01	73.86	91 43	0.01	72 86	90 43
5 00 INTERIOR FINISHES				0 13	54 00	127 43	0.02	92 86	116.29	0 02	70 86	114 43
6.00 EQUIPMENT&SPEC CONS				0.00	94 86	114.43	0.00	100 86	108 43	0.00	88 86	102 43
7 00 CONVEYING SYS				0.00	74.86	80 43	0.00	82 86	88.43			
8.00 MECHANICAL				0.06	42 00	114.43	0.01	75 86	100 86	0.02	47 86	96 86
9 00 FIRE PROTECTION				0.01	58.00	114.43	0.00	75 86	100 86	0.00	74 86	96 86
10.00 ELECTRICAL				0.03	42 00	114.43	0.01	75 86	100.86	0 01	47 86	96 86
11 00 JOB SERVICES												
12.00 MAJOR EQUIPMENT												
13.00 GC FEE												
14 00 BOND/CONTINGENCY/MISC												
TOTAL	0.14			0.35	38 00	127 43	0.07	1 43	116.29	0.08	43.43	114.43
COST/GSF												
DURATION (WEEKS)		128.75			90 35			116.04			71 73	

APPENDIX C: REGRESSION ANALYSIS BY SYSTEM/COMPONENT

FOUNDATION/S.O.G.

CASE	COMPONENT	DURATION		
			SOG SF	GSF
		Y	X1	X3
A	CLUBHOUSE	11.14	18104	33448
C	COMMONS	11.91	38498	53462
D	COMMONS	14.00	14580	30905
F	COMMONS	2.14	17700	29813

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999621433
R Square	0.99924301
Adjusted R Square	0.99772903
Standard Error	0.249948479
Observations	4

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	82.46732044	41.2336602	660.010569	0.027513454
Residual	1	0.062474242	0.06247424		
Total	3	82.52979469			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*pper 95%*	*ower 95.0*	*Upper 95.0%*
Intercept	-33.83260676	1.209749665	-27.966618	0.02275387	-49.20386783	-18.4613	-49.2039	-18.4613457
X Variable 1	-2.77E-03	8.11E-05	-3.42E+01	1.86E-02	-3.80E-03	-1.74E-03	-3.80E-03	-1.74E-03
X Variable 2	2.85E-03	7.98E-05	3.57E+01	1.78E-02	1.84E-03	3.86E-03	1.84E-03	3.86E-03

STRUCTURE

CASE	COMPONENT	DURATION		
			SF FRAME	GSF
		Y	X4	X5
A	CLUBHOUSE	8.57	17357	33448
C	COMMONS	19.91	29600	53462
D	COMMONS	9.00	30905	30905
F	COMMONS	3.86	12730	29813

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.993104009
R Square	0.986255573
Adjusted R Square	0.95876672
Standard Error	1.379947542
Observations	4

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	136.6431911	68.321596	35.87838	0.11723663
Residual	1	1.904255219	1.9042552		
Total	3	138.5474463			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*pper 95%*	*ower 95.0*	*Upper 95.0%*
Intercept	-12.91866599	2.831735685	-4.5621016	0.137373	-48.8991252	23.06179	-48.8991	23.06179324
X Variable 1	2.16E-04	1.03E-04	2.09E+00	2.84E-01	-1.09E-03	1.53E-03	-1.09E-03	1.53E-03
X Variable 2	4.98E-04	8.33E-05	5.98E+00	1.06E-01	-5.61E-04	1.56E-03	-5.61E-04	1.56E-03

ENCLOSURE

CASE	COMPONENT	DURATION					
			ROOF SQ	GSF	SF GLASS	EXT. SKIN	
		Y	X1	X2	X4	X3	
A	CLUBHOUSE	15.14	202	33448	3784	7294	
D	COMMONS	13.14	270	30905	3313	16013	
F	COMMONS	9.86	15	29813	2363	13294	
C	COMMONS	13.48	719	53462	8671	15237	EXCLUDED

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.79940455
R Square	0.639047634
Adjusted R Square	0.278095268
Standard Error	2.267538229
Observations	3

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1	9.103168339	9.1031683	1.770449	0.4102969
Residual	1	5.14172962	5.1417296		
Total	2	14.24489796			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0*	*Upper 95.0%*
Intercept	10.09150843	2.366293189	4.2646906	0.146628	-19.9749685	40.157985	-19.975	40.15798535
X Variable 1	1.62E-02	1.21E-02	1.33E+00	4.10E-01	-1.38E-01	1.70E-01	-1.38E-01	1.70E-01

FINISHES

CASE	COMPONENT	DURATION	PARAMETERS		
			SF CEILING	GSF	FLOORING
		Y	X1	X2	X3
A	CLUBHOUSE	43.29	21529	33448	27651
C	COMMONS	42.05	38031	53462	39383
D	COMMONS	27.00	21375	30905	26226
F	COMMONS	48.00	22878	29813	28756

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.711495461
R Square	0.506225791
Adjusted R Square	-0.481322627
Standard Error	11.06562499
Observations	4

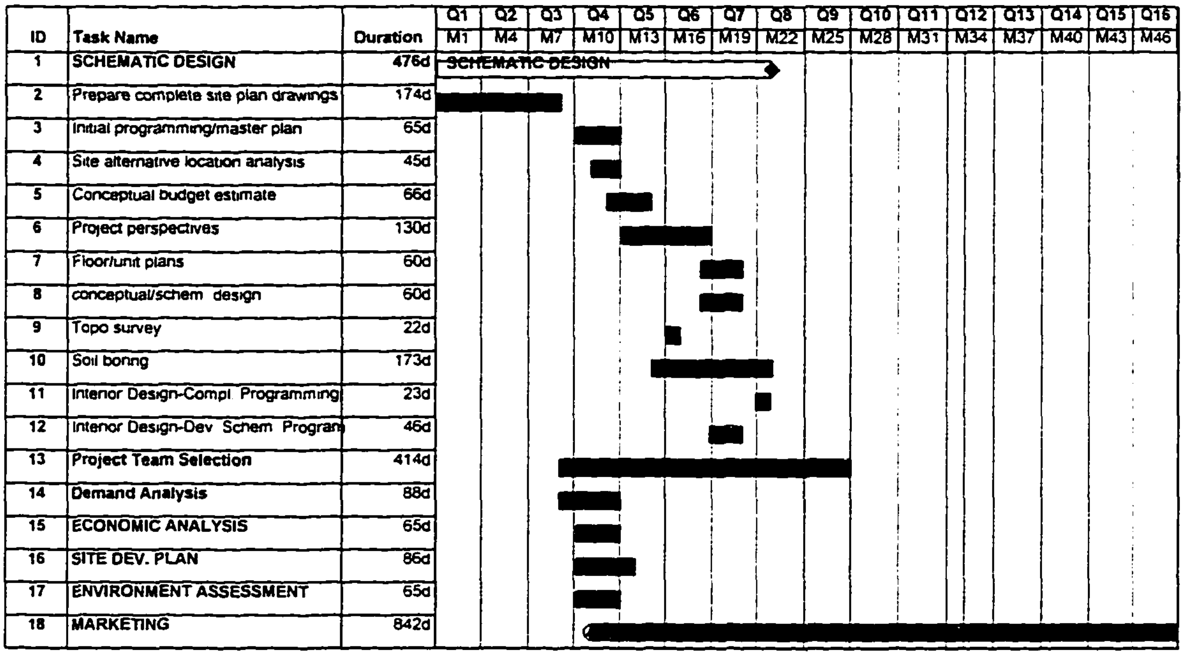
ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	125.5358483	62.767924	0.512609	0.70269069
Residual	1	122.4480564	122.44806		
Total	3	247.9839047			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0*	*Upper 95.0%*
Intercept	-13.20437719	53.99055111	-0.2445683	0.8473	-699.216434	672.80768	-699.216	672.80768
X Variable 1	-2.17E-03	2.38E-03	-9.13E-01	5.29E-01	-3.24E-02	2.81E-02	-3.24E-02	2.81E-02
X Variable 2	4.38E-03	4.41E-03	9.91E-01	5.03E-01	-5.17E-02	6.05E-02	-5.17E-02	6.05E-02

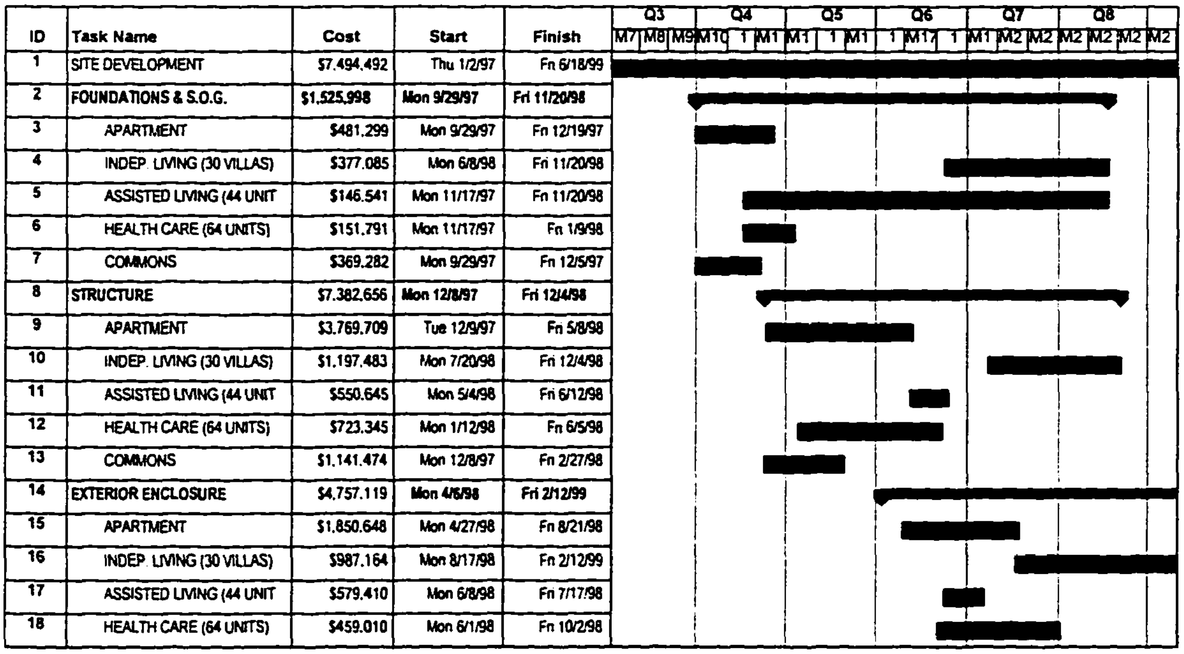
APPENDIX D: SAMPLE REPORTS

DESIGN ACTIVITIES



ID	Task Name	Duration
1	**SCHEMATIC DESIGN**	476d
2	Prepare complete site plan drawings	174d
3	Initial programming/master plan	65d
4	Site alternative location analysis	45d
5	Conceptual budget estimate	66d
6	Project perspectives	130d
7	Floor/unit plans	60d
8	conceptual/schem. design	60d
9	Topo survey	22d
10	Soil boring	173d
11	Interior Design-Compl. Programming	23d
12	Interior Design-Dev. Schem. Program	46d
13	**Project Team Selection**	414d
14	**Demand Analysis**	88d
15	**ECONOMIC ANALYSIS**	65d
16	**SITE DEV. PLAN**	86d
17	**ENVIRONMENT ASSESSMENT**	65d
18	**MARKETING**	842d

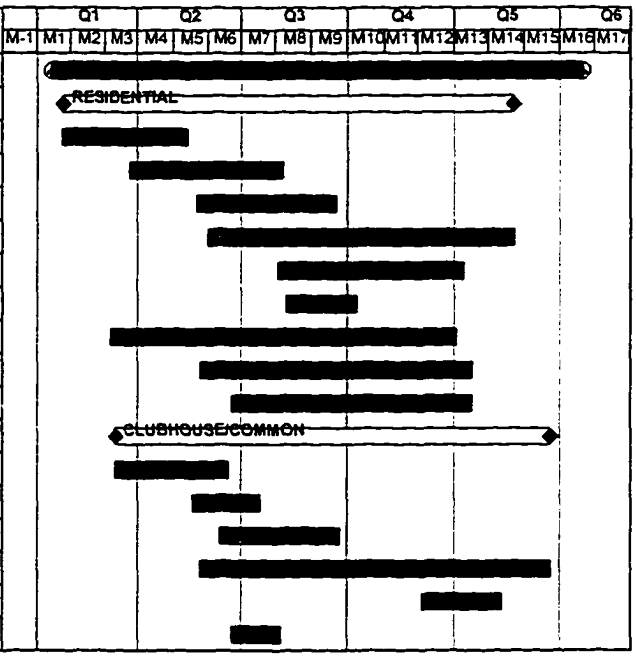
SUMMARY SCHEDULE



ID	Task Name	Cost	Start	Finish
1	SITE DEVELOPMENT	$7,494,492	Thu 1/2/97	Fri 6/18/99
2	**FOUNDATIONS & S.O.G.**	**$1,525,998**	**Mon 9/29/97**	**Fri 11/20/98**
3	APARTMENT	$481,299	Mon 9/29/97	Fri 12/19/97
4	INDEP. LIVING (30 VILLAS)	$377,085	Mon 6/8/98	Fri 11/20/98
5	ASSISTED LIVING (44 UNIT	$146,541	Mon 11/17/97	Fri 11/20/98
6	HEALTH CARE (64 UNITS)	$151,791	Mon 11/17/97	Fri 1/9/98
7	COMMONS	$369,282	Mon 9/29/97	Fri 12/5/97
8	**STRUCTURE**	**$7,382,656**	**Mon 12/8/97**	**Fri 12/4/98**
9	APARTMENT	$3,769,709	Tue 12/9/97	Fri 5/8/98
10	INDEP. LIVING (30 VILLAS)	$1,197,483	Mon 7/20/98	Fri 12/4/98
11	ASSISTED LIVING (44 UNIT	$550,645	Mon 5/4/98	Fri 6/12/98
12	HEALTH CARE (64 UNITS)	$723,345	Mon 1/12/98	Fri 6/5/98
13	COMMONS	$1,141,474	Mon 12/8/97	Fri 2/27/98
14	**EXTERIOR ENCLOSURE**	**$4,757,119**	**Mon 4/6/98**	**Fri 2/12/99**
15	APARTMENT	$1,850,648	Mon 4/27/98	Fri 8/21/98
16	INDEP. LIVING (30 VILLAS)	$987,164	Mon 8/17/98	Fri 2/12/99
17	ASSISTED LIVING (44 UNIT	$579,410	Mon 6/8/98	Fri 7/17/98
18	HEALTH CARE (64 UNITS)	$459,010	Mon 6/1/98	Fri 10/2/98

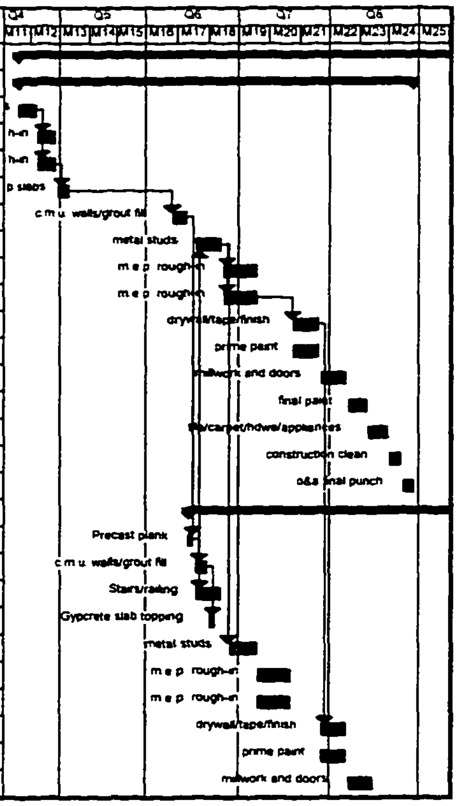
CONSTRUCTION MILESTONE SCHEDULES

ID	Task Name	Start	Finish
1	SITE DEVELOPMENT	Mon 4/13/92	Wed 7/21/93
2	**RESIDENTIAL**	**Thu 4/23/92**	**Fri 5/21/93**
3	FOUNDATIONS & S O G	Thu 4/23/92	Thu 8/13/92
4	STRUCTURE	Mon 6/22/92	Fri 11/6/92
5	EXTERIOR ENCLOSURE	Fri 8/21/92	Tue 12/22/92
6	INTERIOR FINISHES	Mon 8/31/92	Fri 5/21/93
7	EQUIPMENT&SPEC CONS	Mon 11/2/92	Fri 4/9/93
8	CONVEYING SYS	Mon 11/9/92	Fri 1/8/93
9	MECHANICAL	Thu 6/4/92	Fri 4/2/93
10	FIRE PROTECTION	Mon 8/24/92	Fri 4/16/93
11	ELECTRICAL	Mon 9/21/92	Fri 4/16/93
12	**CLUBHOUSE/COMMON**	**Mon 6/8/92**	**Wed 6/23/93**
13	FOUNDATIONS & S O G	Mon 6/8/92	Fri 9/18/92
14	STRUCTURE	Mon 8/17/92	Fri 10/16/92
15	EXTERIOR ENCLOSURE	Thu 9/10/92	Fri 12/25/92
16	INTERIOR FINISHES	Mon 8/24/92	Wed 6/23/93
17	EQUIPMENT&SPEC CONS	Thu 3/4/93	Tue 5/11/93
18	CONVEYING SYS	Mon 9/21/92	Wed 11/4/92



DETAIL CONSTRUCTION SCHEDULE

ID	Name	Duration	Early Start	Early Finish	Cost
244	HEALTH CARE (64 UNITS)	350d	11/17/97	3/19/99	$0 00
245	1ST FLOOR	290d	11/17/97	12/25/98	$0 00
246	f&p foundations	15d	11/17/97	12/5/97	$0 00
247	ug m e p rough-in	15d	12/8/97	12/26/97	$0 00
248	ug m e p rough-in	15d	12/8/97	12/26/97	$0 00
249	f&p slabs	10d	12/29/97	1/9/98	$0 00
250	c m u walls/grout fill	10d	4/27/98	5/8/98	$0 00
251	metal studs	20d	5/18/98	6/12/98	$0 00
252	m e p rough-in	25d	6/15/98	7/17/98	$0 00
253	m e p rough-in	25d	6/15/98	7/17/98	$0 00
254	drywall/tape/finish	20d	8/24/98	9/18/98	$0 00
255	prime paint	20d	8/24/98	9/18/98	$0 00
256	millwork and doors	20d	9/21/98	10/16/98	$0 00
257	final paint	15d	10/19/98	11/6/98	$0 00
258	tile/carpet/hdwe/appliances	15d	11/9/98	11/27/98	$0 00
259	construction clean	10d	11/30/98	12/11/98	$0 00
260	o&a final punch	10d	12/14/98	12/25/98	$0 00
261	2ND FLOOR	225d	5/11/98	3/19/99	$0 00
262	Precast plank	5d	5/11/98	5/15/98	$0 00
263	c m u walls/grout fill	10d	5/18/98	5/29/98	$0 00
264	Stairs/railing	20d	5/18/98	6/12/98	$0 00
265	Gypcrete slab topping	5d	6/1/98	6/5/98	$0 00
266	metal studs	20d	6/22/98	7/17/98	$0 00
267	m e p rough-in	25d	7/20/98	8/21/98	$0 00
268	m e p rough-in	25d	7/20/98	8/21/98	$0 00
269	drywall/tape/finish	20d	9/21/98	10/16/98	$0 00
270	prime paint	20d	9/21/98	10/16/98	$0 00
271	millwork and doors	20d	10/19/98	11/13/98	$0 00



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