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Quality Project Management

by

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Course 183
4 PDH (4 Hours)

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ABOUT THE COURSE

This course is about improving the quality for managing project work in an organization whether you are an engineer, senior manager or professional project manager. In the ideal project world, project managers are well-trained professionals and assigned to a project at the beginning of the project. In the real project world, many projects are small and assigned to engineers and managers with less than professional project management training at any time in the life of the project.

For the engineer, senior manager or professional project manager the quality for managing project work should improve significantly by combining seven key tools with a basic feature from statistical process control, the control chart. The seven key tools, called The Seven Icons ©, are presented in this course and will demonstrate how they can be used to improve planning and controlling project work.

The Seven Icons © are organized and connected in a structure that is easy to remember. The icon terms serve as a common language between managers, team members, and their bosses. This feature becomes most important when considering that practically everyone in an organization is involved in some kind of project work. Having an effective way of remembering and applying key tools to project work will improve communications throughout the organization and ultimately improve the quality for managing project work

At the end of the course is a set of questions that highlights the take-aways for the reader to remember and use for improving the quality for managing projects in their organization.

INTRODUCTION

Managing Project Work
Managing project work in the ideal project world, project managers are well-trained professionals and assigned to a project at the beginning of the project. In the real project world, many projects are small and assigned to managers with less than professional project management training and at any time during the life of the project.

The profession of project management is accepted globally and project managers are certified by examination as Project Management Professionals by The Project Management Institute (PMI®) . There is a published global standard titled, <u>The Guide to the Project Management Body of Knowledge (PMBOK® GUIDE)</u> . It is sanctioned by the American National Standards Institute (ANSI) and printed in seven languages.

Using this standard, engineers and managers in business, industry and government have been able to create many different approaches for managing projects. Each approach whether developed by a project management professional, engineer or manager may be effective for similar projects, departments or disciplines.

The Challenge to Quality
Problems arise, however, when projects span various departments or involve different disciplines. Most problems involve gaps in communications and missed critical steps when managing a project.   Computer technologists create voluminous detailed procedures seldom understood by other departments in the company. Individuals develop their own version of a project management system, using some PMI® terms and inventing others. The end result is a hodgepodge of different project management systems.

The challenge, therefore, faced by business, industry and government is how to manage the myriad of projects that are both big and small and involve a diversity of disciplines without having so many different project management systems. A solution to this challenge is to find a universal system, namely one that uses symbols and terms that provides a structure for managing projects. The universal system must be easy to visualize and remember.

The Seven Icons ©
The Seven Icons © is a universal system that consists of icon symbols and terms that can be used to plan and control project work. They are seven key tools connected together and when applied in a specific sequence provide an easy to use project control structure. Skipping or eliminating any icon in the prescribed sequence will decrease the quality for managing project work. Each icon may readily be found in the PMBOK® GUIDE and in much of the project management literature. This structure is easy to follow and remember for both novice project managers and managers supervising project work. Below are the Seven Icons © and easy to remember functions:

Icon Functions

Number Sequence	Icon	Function
1	WBS (Work Breakdown Structure)	**What** the work is
2	CPM (Critical Path Method)	**How** the work will be done
3	Bar Chart	**When** the work will be done
4	T Chart	**Who** will do the work
5	Budget the Bars	**Cost** of the work
6	Baseline	**Spending rate** of the work (cost over time)
7	Earned Value	**Measure of quality** of the work (budget versus actual)

Chart 0.1

The functions serve as an easy guide for managing a project. If an engineer or manager follows the icon sequence, the project has greater chance of meeting schedule and budget targets. The Seven Icons © serve as an analytical tool to determine the condition of an ongoing project at any time in the life of the project, whether it is assigned to a professional project manager or someone new to project work. Using the icons as a checklist, the status of the project and management action will soon become evident.

The Seven Icons © serve as a common language between the managers, the team members, and their bosses. This feature becomes important when considering that practically everyone in an organization is involved in some kind of project work. Having an effective way of remembering and applying key tools to project work will improve communications throughout the organization and ultimately improve the quality for managing project work.

Quality Project Management

The following project was selected to demonstrate the application of the seven key tools for planning and controlling project work. Each tool will be described in its sequence with an explanation of how it is connected to its predecessor.   Emphasis will be placed on the Work Breakdown Structure and Critical Path Method. These two key tools are significant for project control. Perfecting a skill in creating WBS's and developing realistic CPM's is critical to measuring project quality. In the end, improving the quality for managing project work occurs by combining the seven key tools with a basic feature from statistical process control, the control chart.

Project Title:
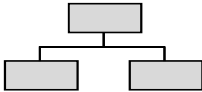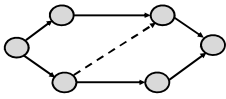
   Towerbuild Communications, Inc. (TCI)
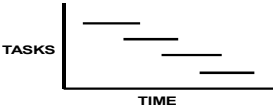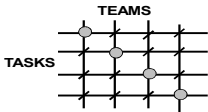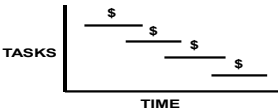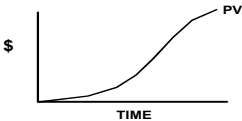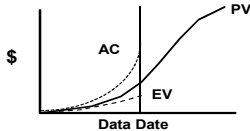
Project Description:

   The increased demand in wireless service has provided TCI with a successful business to design and build relay control centers and lease them to communications companies nation-wide. Because of TCI's success and their expertise in project management, the largest of these communications companies, Global Technologies Corporation (GTC), has contracted with TCI to deliver a client management system for their 250 million customers. This project involves new technology to design and implement a 'Client Management System' that could become a model for another new business initiative for TCI.

   A successful implementation of the client management system depends on a user-friendly design of the system, meeting budget tolerances and a very rigid GTC schedule. The contract was awarded to TCI in July at the beginning GTC's fiscal year. The contract stipulates that the project must be completed before the first of the following year.

Quality Project Management

Icon	Definition	Symbol
1	**Work Breakdown Structure:** Shows project deliverables in hierarchical graphic form. The elements describe products or services in noun form.	
2	**Critical Path Method:** is a network diagram showing task dependencies and their duration needed to produce the deliverables. The longest path of dependent tasks in the network are considered critical and used to determine the project schedule.	
3	**Bar Chart:** shows the project tasks positioned in time over the life of the project. It is typically called the project schedule and is constructed by drawing time scaled bars for each project task.	
4	**T Chart:** is a matrix showing which individual project team member or discipline group is active in which specific project task. The circle symbol represents accountability and the back slash indicates contribution.	
5	**Budget the Bars:** shows the allocation of resources to each task bar on the project bar chart. Resources are, people, material, equipment, and dollars.	
6	**Baseline:** is a curve showing project budget spending rate. It is calculated by accumulating the dollars budgeted for each bar on the schedule.	
7	**Earned Value:** is a measure of completed work compared to the work and cost planned in the original budget. At any point on the project baseline the earned value of work can be calculated and be compared to the actual cost of the work in the original plan.	

ICON ONE
WBS (Work Breakdown Structure)
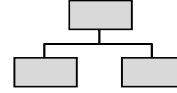
Icon One is the WBS (Work Breakdown Structure). It describes **what** the work is. The purpose of the Work Breakdown Structure is to determine **what** is to be delivered to the customer. The WBS uses nouns to show project deliverables in hierarchical graphic form with the rectangular boxes representing products or services. In the diagram below, the top box, called Level 1, is the name of the project. Below, at Level 2, the boxes identify the major deliverables. The next level, not shown on the diagram, Level 3 defines subdeliverable. A WBS for project may have many levels with each level having more detail.

```
          ┌─────────────────┐
          │  Project Name   │
          │    Level  1     │
          └────────┬────────┘
          ┌────────┴────────┐
┌─────────────────┐  ┌─────────────────┐
│ Major Deliverable│  │ Major Deliverable│
│     Level  2     │  │     Level  2     │
└─────────────────┘  └─────────────────┘
```
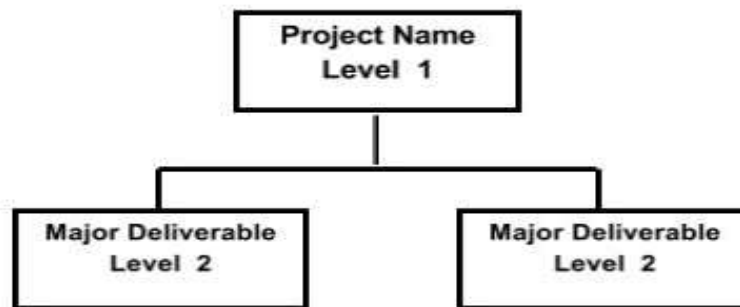
Figure 1.0

The Project Management Institute, in its practice standard for work break down structures[1] says, " ... [the WBS] provides the foundation for defining work as it relates to project objectives and establishes the structure for managing work to its completion…. [The WBS] defines the total scope of the project. Each descending level represents an increasingly detailed definition of the project work."

Creating a WBS (Work Breakdown Structure)

Creating a first-time work breakdown structure for a project is challenging. It is important for the project manager to lead the team in creating the work breakdown structure. The benefit for a team when it creates a work breakdown structure is that the team forms an indelible outcome called **team memory.** Team memory is an unforgettable collaborative experience of a team meeting with all members brainstorming, developing and agreeing

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[1] Project Management Institute, *Practice Standard for Work Breakdown Structures* 2008,

on terms, definitions, and a deliverables structure. That structure for managing project work becomes internalized and stays with each member throughout the life of the project.

Creating a work breakdown structure for a project is more of an art than a science. Most people, when assigned work, start by thinking about **how** to do the work rather than **what** the work product is. The notion of first creating a WBS before starting a project is not a normal human response. It requires training and discipline to change that response. The WBS represents the end of the project. Franklin Covey in his popular book about the habits of effective people[2] states, "begin with the end in mind." Project managers and project teams need to adopt this habit to achieve successful projects.

Product WBS (Work Breakdown Structure)

Thinking about **what** rather than **how** means using nouns to define the deliverables instead of verbs. Creating work breakdown structures for tangible or manufactured products such as automobiles, machines, buildings, and consumer items are less difficult than creating work breakdown structures for intangible products called services. For example, for an Automobile product, the major deliverables are Design, Engine, Body, and Power. These are **what** descriptions in noun format. Engine appears in two boxes on the WBS. Body listed under Automobile is the deliverable where the product is the body and all its components. Body listed under Design is the subdeliverable where the product is the body design. In each case nouns identify the products.
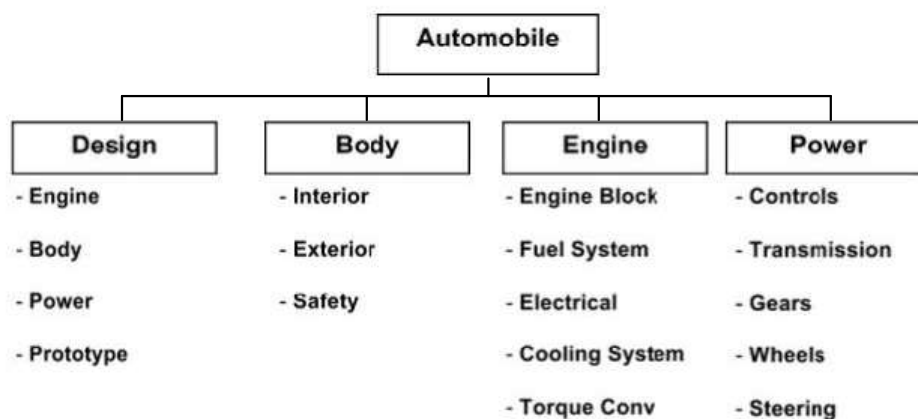
Figure 1.1- Automobile WBS

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[2] Franklin Covey, *The Seven Habits of Highly Effective People,* Fireside Press -Simon & Schuster,1999

Service WBS (Work Breakdown Structure)

Providing a project management service is an example of creating a work breakdown structure for an intangible product, turning the *how* into *what*. An illustration of this example would be to show how to prepare a response to a request for proposal (RFP) for project management services. The client, in the RFP, has requested that the proposal include a work breakdown structure for project management services for a twelve-month project. The client wants to know and understand *how* the project will be managed. Identifying the tangible products to be delivered to the client means turning the *how* into *what.*

The following are major deliverables for managing projects:

- Project Planning
- Project Control
- Project Meetings
- Project Administration

Figure 1.2 – Project Management Services WBS

Note that all sub deliverables in Figure 1.2- Project Management Services are tangible products. The tangible products of Project Planning are the draft plan, the final plan, period updates and the closeout plan. Project Control Procedures i.e. estimating, scheduling, budgeting, change control, and reporting, come in draft stage for client approval and final form for project use. Project Control includes period reports to the client with a final closeout report and lessons learned.

Some client executives require frequent face to face updates on project performance. The tangible outputs of the client meetings are client letters. The project manager spends a great deal of time in team meetings, whether for problem solving or scheduled performance reviews. The outputs of these Meetings are minutes and action item lists. Finally, the tangible outputs of Project Administration are the contract and periodic invoices.

WBS (Work Breakdown Structure) G uidelines
There are several ways to create a WBS to meet project scope. The structure of the WBS depends on team experience and control requirements. Given similar scope, different teams could create different work breakdown structures, any one of which would be acceptable to meet the project objectives. There are, however, some important guidelines that a team should use as a checklist to test the validity of the WBS.

WBS Guidelines[3] for creating deliverable elements:
- Specific and logical to satisfy the requirements of the project scope
- Represent physical accomplishment with defined start and end dates
- In measurable units- dollars, hours
- Possible milestone
- A template for customer billing and reporting performance

For example, in Project management Services, the level two deliverable, Project Control, contains the following sub deliverables:
- Specific and logical: Procedures, period reports, closeout, lessons learned.
- Physical accomplishment: Procedures, period reports, closeout, and lessons learned. Defined dates are the beginning of the project and end of project.

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[3] Project Management - The Nine Elements to Success, DeVry University 2003

- Measurable units: Five procedures, 11 monthly reports, 1 closeout report, and 1 lessons learned report.
- Possible milestone: Final procedures complete, Closeout report complete
- A template for customer billing & performance reporting: i.e. Completion of final procedures, a monthly report.

Another challenge facing the team creating the work breakdown structure is setting a reasonable level of detail and maintaining consistency across each level. The project is identified by Level 1. Level 2 represents the major deliverables. Level 3 defines the subdeliverable. Note, for example, in the Automobile WBS, the Level 2 deliverables, Design, Engine, Body, and Power, are the major components that make up the vehicle. They are distinct but equivalent in detail.

In the example of Project Management Services, the Level 2 deliverables, Project Planning, Project Control, Project Meetings, and Project Administration, are the features that make up the service. They are distinct but equivalent in detail. It follows, therefore, that each succeeding lower level should maintain an equivalent detail format. It is important to remember that there is more than one way to create a WBS to meet project scope. As discussed previously, the structure of the WBS depends on team experience and control requirements. Distinct features and equivalent detail format may even vary within a single structure.

WBS (Work Breakdown Structure) Foundation for Defining Work
The WBS is the foundation for the project and it is the source of information for planning and producing the following:
- Network Diagrams & Schedules
- Budget & Cost Estimates
- Risk Analysis for Schedule and Cost
- Staffing & Responsibility Assignments
- Project Organization Structure
- Coordination of Objectives
- Project Performance Measures

Project management convention suggests that the project manager is responsible for managing the top three levels of the work breakdown structure, regardless of project size. The team members are responsible for managing the sub deliverables at level four and below. The project manager's key role is master integrator. To do this effectively, the project manager must have a top down approach to the project objectives. The

project manager must hold the team members accountable for their individual contributions to the project objectives. This does not mean that the project manager shouldn't be familiar with the details of the project work. However, the details are the responsibility of the team member or members who are the subject matter experts. When alternatives for project decisions are presented, it is the project manager's primary job to select the person who has the knowledge and credentials to make the decision.[4]

TCI's Client Management System WBS
The project selected to demonstrate the application of the seven key tools for planning and controlling project work is TCI's Client Management System. Figure 3 below represents the Work Breakdown Structure for the project. Note that Level 1 states the project title, Client Management System. Level 2 represents the major deliverables; Design, Implement, and Turnover. Level 3 identifies the sub deliverables. Under Design are Preliminary and Final Design. Under Implement are Equipment, Software and Integration. Under Turnover are Training and Roll Out. This WBS with its corresponding deliverables will be used to supply Icon Two, CPM (Critical Path Method, with the information to determine **how** the deliverables will be produced.
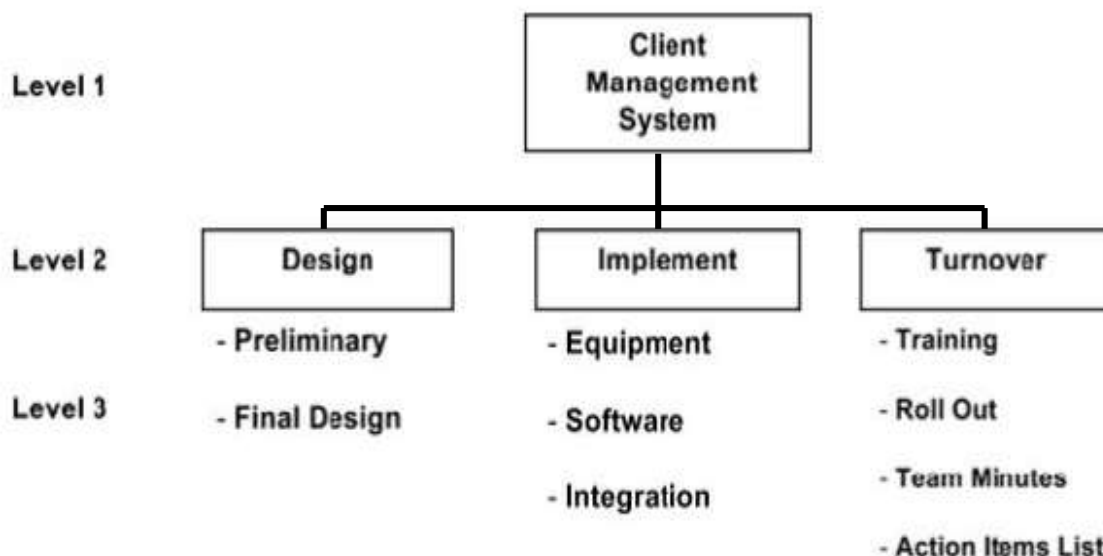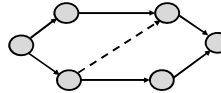

Figure 1.3

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[4] The Implementation of Project Management: The Professional's Handbook, Addison Wesley, PMI® 1981

ICON TWO
CPM (CRITICAL PATH METHOD)

Icon Two, is CPM (Critical Path Method). The purpose of Icon Two is to determine **how** the deliverables will be produced. Before continuing with TCI's Client Management System project, it is important to review the concept of network diagrams and discuss the process for determining critical path. Below is a graphic representation of the tasks (activities)[5] necessary to produce the deliverables or products of a project. It is called a network diagram. The information for drawing the network diagram is supplied by the deliverables for Icon One, WBS. Icon Two determines how the deliverables will be produced using verbs; i.e. design, write, buy, test, train. Icon Two identifies the critical activities that are used to calculate the project duration.
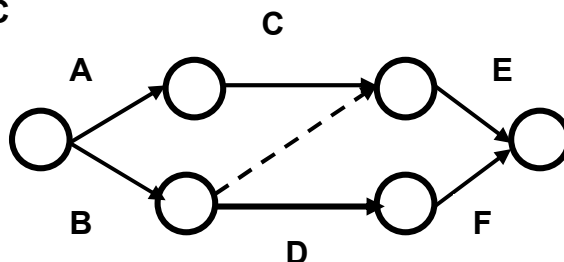
Drawing a Network Diagram

Icon Two is one of two types of network diagrams used to schedule a project. It displays logical relationships between project activities. Two requirements are necessary to produce a network diagram. They are:

- Activity **logic,** determining predecessors and successors, and
- Activity **duration,** that is elapsed time, not effort

The activities, represented by an arrow, are drawn from left to right and are connected based on their dependencies. The diagram shows what the project activities are, in what sequence they will be performed, and how much time it will take. The name of Icon Two is CPM (Critical Path Method). The critical path is the path that contains the connected activities that add up to the longest duration in the network diagram. A project will be delayed if any activity on the critical path takes more time to complete.

LOGIC

DURATION
A: *Design* the system - 5 days
B: *Write* the system Specs - 3 Days
C: *Buy* the equipment - 5 Days
D: *Write* the program - 7 Days
E: *Test* the system - 4 Days
F: *Train* the operators - 2 Days

Figure 2.1 Activity on Arrow (AOA) Network Diagram

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[5] **The terms Activities and Tasks are used interchangeably thru out the discussion**

PATH: A, C, E = 14 Days ←—————— Critical Path = Longest Path

PATH: B, D, F = 12Days

PATH: B, E = 7 Days

The longest path is also the shortest project schedule time.

Network diagrams, where activities are represented by arrows as displayed by Icon Two, are called activity on arrow diagrams (AOA). Another type of network diagram is called activity on node (AON). AON type diagram displays the activities as squares. See example below.
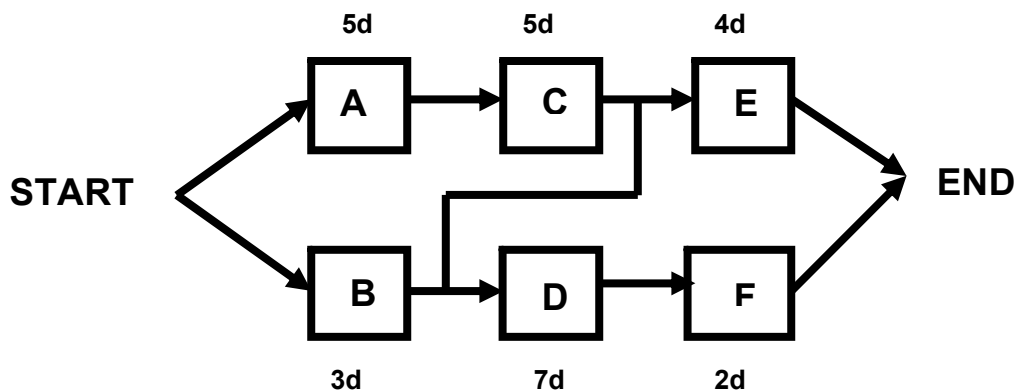
Figure 2.2

 Similar to the AOA diagram, the AON network diagram also has the activities drawn from left to right and connected based on their dependencies. Similarly, the AON diagram also shows what the project activities are, in what sequence they will be performed, and how much time it will take. The critical path is the path that contains the connected activities that add up to the longest duration in the network diagram.

Before computers were invented, AOA network diagrams were used for scheduling projects. With the advent of computers and scheduling software, the AOA network diagram has become obsolete. Today, there are many software packages that help project managers and team members create AON network diagrams and automatically calculate the critical path and project duration. In fact, creating an AON computer generated network diagram starts most projects. This may be a mistake.

Unfortunately there is no software today that can duplicate the human mind for creating a work breakdown structure. Creating a work breakdown structure for a project is more of an art than a science. Most people, when assigned work, start by thinking about **how** to do the work rather than **what** the work product is. The notion of first creating a WBS before starting a project is not a normal human response. It requires training and discipline to change that response. A computer generated WBS from a network diagram will bias the work breakdown. That means that some deliverables will be missed and others undefined. It's backward to the concept of begin with the end in mind.

Large scale projects demand computer generated schedules. The vast majority of projects fall into the small to medium range. In many cases, medium size projects need to have the computer-generated schedule checked and rechecked to see if anything is missing. It is important to understand the process used to calculate the critical path in order to know if the software results are reasonable. The computer is only a tool. It's like a calculator. Grammar schools still teach math basics, adding, subtracting and the multiplication tables, even though they allow students to use calculators. Knowing how to manually determine critical activities and calculate the project duration will enhance project management skills and improve confidence when using the computer to monitor and control project work.

How to Use Icon Two
Five steps are used to draw a network diagram, identify the critical activities and calculate project duration:
1. Determine what activities will produce the deliverables from the WBS
2. Draw the diagram using activity logic to connect all the activities
3. Estimate the activity duration time i.e. months, weeks, days, hours
4. Add the activity duration times of all the different paths
5. Identifying the longest path

TCI's Client Management System CPM
TCI's Client Management System, WBS, will be used to construct a network diagram, find the critical path and calculate the project duration. The network diagram consists of the activities that produce the products. Activities are defined using verbs. The network diagram is sometimes referred to as a network **schedule** because it incorporates duration.

Quality Project Management

STEP 1

The Chart 2.1 below shows an example of how deliverables (WBS products) are transformed into activities. Step 1 involves describing the activity using a verb and giving it identification. Note that a deliverable may have more than a single activity. For example, the Level 2 Implement deliverable includes three Level 3 activities; Purchase Equipment (B), Code Software (C) Integrate and Test (D).

WBS CLIENT MANAGEMENT SYSTEM   Level 1

WBS Level 2	WBS Level 3	Step 1	Step 1	Step 2	Step 3
Major Deliverables (nouns)	Sub Deliverables (nouns)	Activity (verbs)	Identification	Precedence	Estimated Duration in Weeks
Design	Preliminary Final Design	Design System	A	None	5
Implement	Equipment	Purchase Equip	B	A	5
	Software	Code Software	C	A	8
	Integration	Integrate &Test	D	A	10
Turnover	Training	Train operators	E	B,C,D	3
	Roll Out	Release to Client	F	E	2

Chart 2.1

STEP 2
Connecting the activities into a network diagram is the next step. Drawing the network diagram involves a process using three (3) questions. Starting with any activity from step 2, draw the single activity and ask the following questions:

1. What activity(s) must happen before this activity?
2. What activity(s) must happen after this activity?
3. What activity(s) can happen at the same time?

The answer to each question may or may not produce another connecting activity to the diagram. Add the new activities to the diagram. Continue asking the three questions of each activity placed on the network diagram until the answer to the three questions

produces no more connecting activities. Once this happens the network may be considered complete. The example below shows the application of this process using the three questions beginning with the activity Purchase Equipment (B)

Question: What activity(s) m ust happen before Purchase Equipment (B) ?
Answer: Design the System (A)

Question: What activity(s) m ust happen after Purchase Equipment (B) ?
Answer: Train Operators (E)

Question: What activity(s) ca n happen at the same time as Purchase Equipment (B) ?
Answer: Code Software (C) , Integrate & Test (D)

The Figure 2.3 shows the answer to the questions and a partially completed network diagram. By continuing to ask the three questions of each activity placed on the network diagram, the network may be considered complete. Figure 2.4 shows when the answer to the three questions produces no more connecting activities.
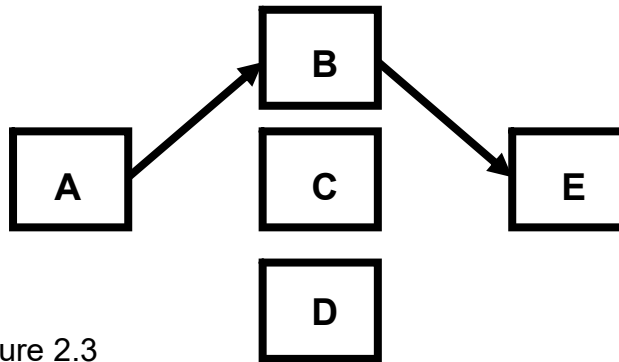
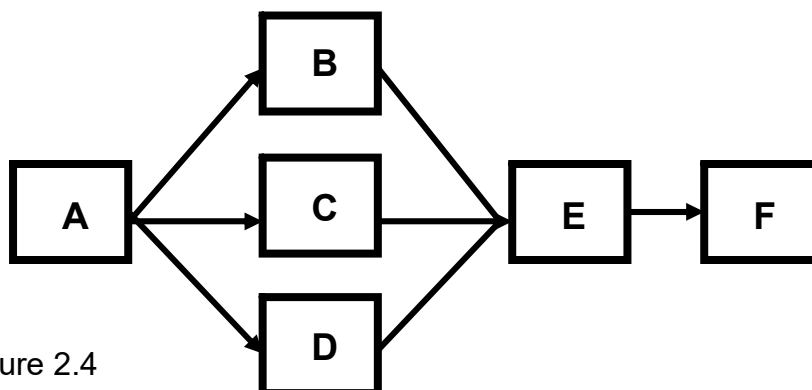Figure 2.3

AON Network Schedule - Client Management System

Figure 2.4

STEP 3

Duration estimating, step 3, is a critical part of project cost and budgeting control. Most organizations record actual effort and duration of project work, creating a data bank of estimating information to use for monitoring and measuring project progress and profitability. And, while this data is used for most projects, for a particular project it may be modified based on the experience of the project manager or the expertise of a team member.

This activity data used is typically the average duration of an activity and called 'normal.' The data bank also contains the average minimum time and the average maximum time durations. Project management terms call the average minimum time 'optimistic' and the average maximum time, 'pessimistic.' Most project network diagrams are constructed with normal durations. Projects with tight schedule constraints may use all three durations, optimistic, normal, and pessimistic in a statistical formula to determine the probability of schedule completion.

Activity Data Bank - CMS

Activity	Optimistic weeks	Normal weeks	Pessimistic weeks
Design System	4	5	8
Purchase Equip	3	5	7
Code Software	6	8	9
Integrate &Test	8	10	12
Train operators	2	3	5
Release to Client	1	2	3

Chart 2.2

STEP 4

The completed network diagram, Figure 2.4, is used to determine the critical path. The critical path is the path that contains activities that add up to the longest duration in the network diagram. The network diagram has three activity paths. Adding the activities for each path that go forward from left to right the results are:

- Path 1 is A,B,E,F
  - 5+5+3+2 = 15 Weeks
- Path 2 is A,C,E,F
  - 5+8+3+2 = 18 Weeks
- Path 3 is A,D,E,F
  - 5+10+3+2 = 20 Weeks

STEP 5
Path 3, 20 weeks is the longest path. Thus the project duration is 20 weeks. The critical activities are A, D, E, F. Given the project duration of 20 weeks, there appears to be more than a five week cushion from July to January for TCI to meet the project schedule.

What if GTC requested that they needed the project before December? That would mean that there is new schedule requirement of 21 weeks. The probability of meeting a 21 week schedule still looks attainable since the project schedule is 20 weeks. However, because the project involves new technology and has some risk, it becomes important to advise the client with a measurable schedule value rather than just saying, "We think we can make the schedule." That means measuring the risk by calculating the probability of meeting the schedule. This requires the application of a statistical process using the optimistic and pessimistic time values from the Activity Data Bank. [6]

Step 5 A
Using the time values for each critical activity from the activity Data Bank calculate the expected time for the project.

Expected time for an activity = $\dfrac{\text{Optimistic time} + 4 \times \text{Normal time} + \text{Pessimistic time}}{6}$

Step 5 B
Using the expected time values for each critical activity summarize the variances and calculate the standard deviation by taking the square root of the sum.

Activity Data Bank CMS/Risk Analysis

Activity	Optimistic weeks	Normal weeks	Pessimistic weeks	(5A) Expected weeks	Standard Deviation	(5B) Variance
Design System	4	5	8	5.333	0.667	0.444
Integrate &Test	8	10	12	10.003	0.667	0.444
Train operators	2	3	5	3.500	0.833	0.694
Release to Client	1	2	3	2.000	0.333	0.111
Total		20		20.836		1.693
Figure 2.3				Square Root		1.302

---

[6] Tom Kendrick, *Identifying and Managing Project Risk,* 2 edition, AMACOM, 2009

Step 5 C

Using the formula below calculate **Z** to use on the Standard Normal Distribution Table.

$$\frac{\text{Project Schedule} - \text{Expected Schedule}}{\text{Standard Deviation}} = \mathbf{Z}$$

$$\frac{21 \text{ weeks} - 20.83 \text{ weeks}}{1.302} = 0.128$$

Step 5 D

Locating the Z of [0.128] on the Standard Normal Distribution Table shows a value of [0.89973]. Thus the probability of meeting a 21 week schedule is of 90%. There is a 10% risk of not meeting the schedule using the original schedule of 25 weeks in the formula results in a Z of [3.201]. On the Standard Normal Distribution Table this shows a value of [.99934]. Meeting a 25 week schedule is almost 100%.

Icon Two, CPM (Critical Path Method) is the manual process for producing network diagrams and calculating a critical path. The project management world has many scheduling software programs that can produce network diagrams, calculate a critical path and determine the statistical probability of completing the schedule. However, even the most sophisticated software requires the knowledge and experience of the project manager and team to create a definitive WBS, translate deliverables into logical dependent activities, and use realistic durations for estimating the project schedule.
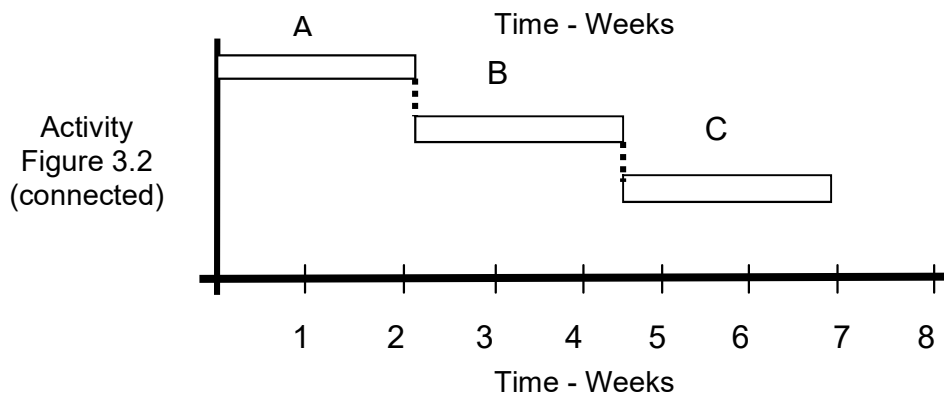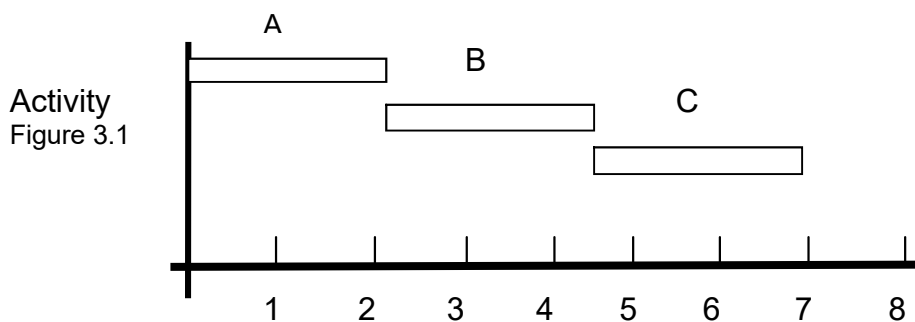
**ICON THREE
BAR CHART**
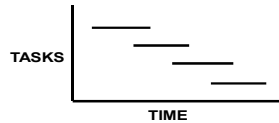
TASKS

TIME

Bar Chart, Icon Three, shows the project tasks positioned in time over the life of the project. It is typically called the project schedule and is constructed by drawing time scaled bars for each project task. A project schedule shows when the work will start and when the work will be done. Typically, project schedules include start and finish dates of each activity. Project schedules are easy to read.

The diagram below, Activity Figure 3.1, is constructed with the horizontal line showing time in weeks and the vertical line listing the tasks A, B, C. The activities are represented by bars. Activity A has a duration of 2 weeks and starts at the beginning of the project. Activity B has a duration of 2 ½ weeks and starts at week 2. Activity C has a duration of 2 ½ weeks and starts at week 4 ½. It is assumed that activities A, B, C are dependent on each other. Activity B cannot start until Activity A is finished and Activity C cannot start until Activity B is finished. Most software scheduling programs automatically connect the activities as shown on the Activity Figure 3.2 by the dotted lines.

Activity
Figure 3.1

A   B   C

1   2   3   4   5   6   7   8

Time - Weeks

Activity
Figure 3.2
(connected)

A   B   C

1   2   3   4   5   6   7   8

Time - Weeks

Before computers were invented Bar Charts were drawn manually and used for scheduling projects. Activities on bar chart schedules were drawn manually from experience, not necessarily connected and not always reliable. When network diagrams were introduced to the scheduling process to support bar charts, project schedules became more reliable and realistic. The advantage of using a computer to draw a schedule is that logic and duration are required before the computer can create a schedule.

There are many software scheduling packages that help project managers and team members automatically calculate the critical path and project duration. The computer, in essence combines Icon Two, CPM, and Icon Three, Bar Chart. Experienced schedule and cost engineers typically start with scheduling software to create project schedules. However, for the novice project manager or engineer new to projects, the benefit of working through CPM and Bar Chart icons will build confidence in the scheduling process and improve the quality for managing project work.

TCI's Client Management System Bar Chart
Constructing a bar chart for the Client Management System starts with drawing a horizontal line to represent time in week increments and vertical line to position the activities.
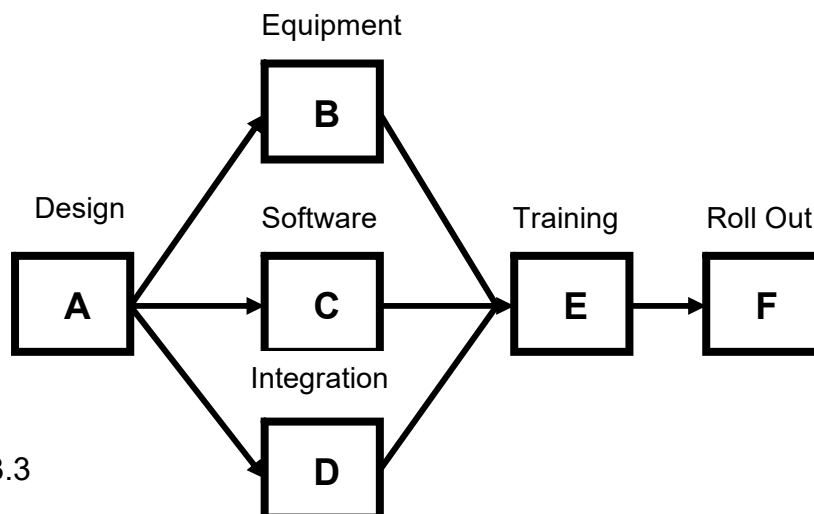
AON Network Schedule – Client Management System

Figure 3.3

Bar Chart Data CMS

Identification	Activity	Precedence	Duration in Weeks
A	Design	None	5
B	Equipment	A	5
C	Software	A	8
D	Integration	A	10
E	Training	B,C,D	3
F	Roll Out	E	2

Chart 3.1

The CPM diagram, Figure 3.3, and the information from Chart 3.1 show the following activity sequence. The Design activity has a duration of 5 weeks and can start at the beginning of the project. The Equipment activity has a duration of 5 weeks and can start after the Design activity is complete. The Software activity has a duration of 8 weeks and can start after the Design activity is complete. The Integration activity has a duration of 10 weeks and can start after the Design activity is complete. The Training activity cannot start until the activities Equipment, Software, and Integration are complete. The Roll Out activity can start only after the Integration activity is complete. The longest path, called the Critical Path is shown by the shaded bars. The Critical Path is shown in the shaded blocks and represents the project schedule that was calculated at 20 weeks
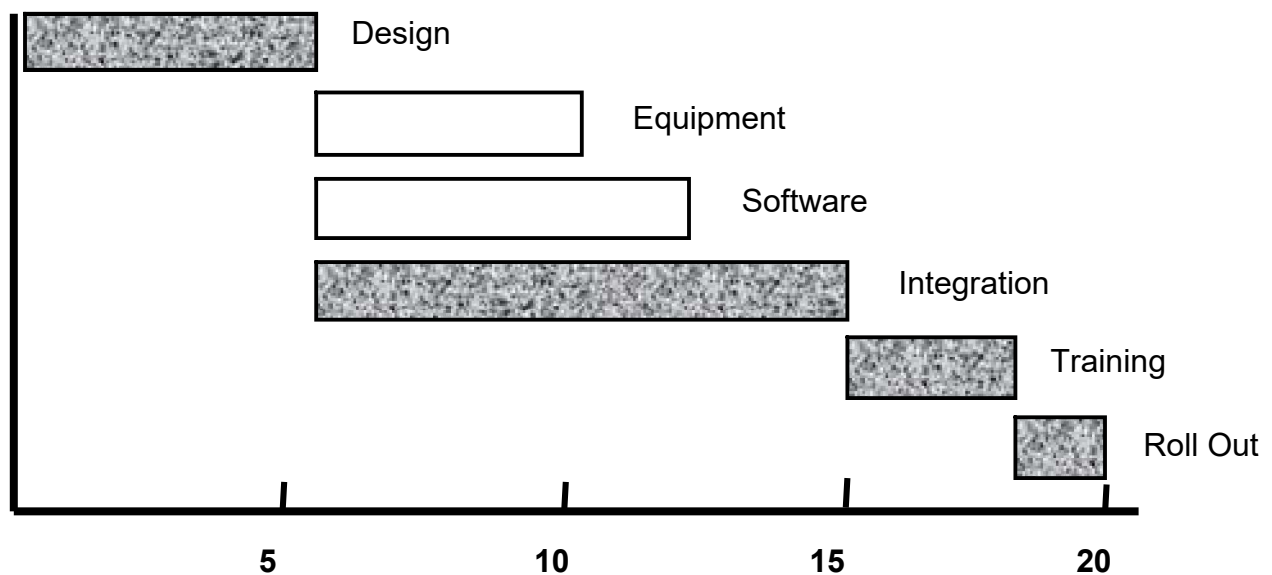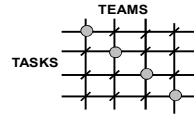
Bar Chart CMS

Figure 3.4

ICON FOUR
T CHART

Icon Four describes **who** will do the work. The **'T'** stands for **Tasks** and **Teams.** The diagram below is a matrix that uses a horizontal line to identify the activities **(Tasks)** and a vertical line to identify the personnel **(Team)** with the skills to perform the work. The symbol at the intersection of the horizontal **Task** line and the vertical **Team** line describes the role to be taken by the personnel. A circle symbol indicates an accountability role and a backward slash mark (/) identifies a contribution role. Contribution means providing technical input to the task.
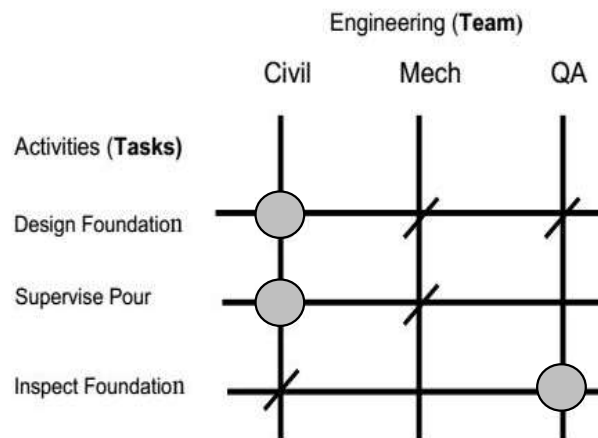
Figure 4.1

The example above, Figure 4.1, contains activities (Tasks) for designing, pouring, and inspecting a concrete building foundation. The engineering (Team) assigned to perform the work includes a civil engineer, a mechanical engineer, and a quality control inspector. The civil engineer is accountable for the Design Foundations task as shown by the dot at the intersection of the vertical Civil line and the horizontal Design Foundations line. The mechanical engineer (backward slash) shows contribution to Design Foundations that might include specifications for rebar and ties for foundation strength. The quality control inspector (backward slash) shows contribution that might include specifications and requirement for slump test and final inspection. Note that the civil engineer is accountable for supervising the pour and the mechanical engineer'

contribution is to be present to see that the rebar material and the ties are in place. The quality control inspector is accountable for the final foundation inspection.

Other symbols may be used as needed, for example; approval required preceding (A) , review required to proceed (R) , quality inspection of results (Q) . The project management process for assigning members of a team to perform work and be held accountable is not a new concept, and there are many ways of performing that function. The Project Management Institute, in The Guide to Project Management Body of Knowledge (PMBOK®) [7], uses the term 'Responsibility Assignment Matrix (RAM) to describe who will do the work.

Constructing a T chart for the Client Management System starts with drawing the horizontal lines that represent the Tasks (activities) from the CPM diagram, drawing the vertical lines that identify the team members who will be assigned to do the work.

The T Chart, Figure 4.2, for the Client Management System shows that the Sales team member is accountable for the Design task. Sales leads the proposal effort and deals directly with the client. Engineering, Systems, Training, and QA contributes to Sales. Engineering provides technical input. Systems provides computer and software knowledge. Training provides training tools to be designed into the system and QA specifies the check points to meet the quality requirements. Sales creates the design, signs the contract with the client and is also accountable for the Roll Out task.   The Engineering team member with contributions from Systems and Training is accountable for the selection and purchase of the equipment. Systems is accountable for Software and software testing with contributions from Engineering and Training. QA is accountable for Integrate and Systems Test with contributions from the entire team. Training is accountable for developing the training program and publishing the training materials with contributions from the engineering and systems team members.

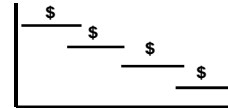[7] Project Management Institute, *The Guide to Project Management Body of Knowledge (PMBOK®),*4th Edition,1984) 2008

Client Management System - T Chart

Tasks   **Teams**

Figure 4.2
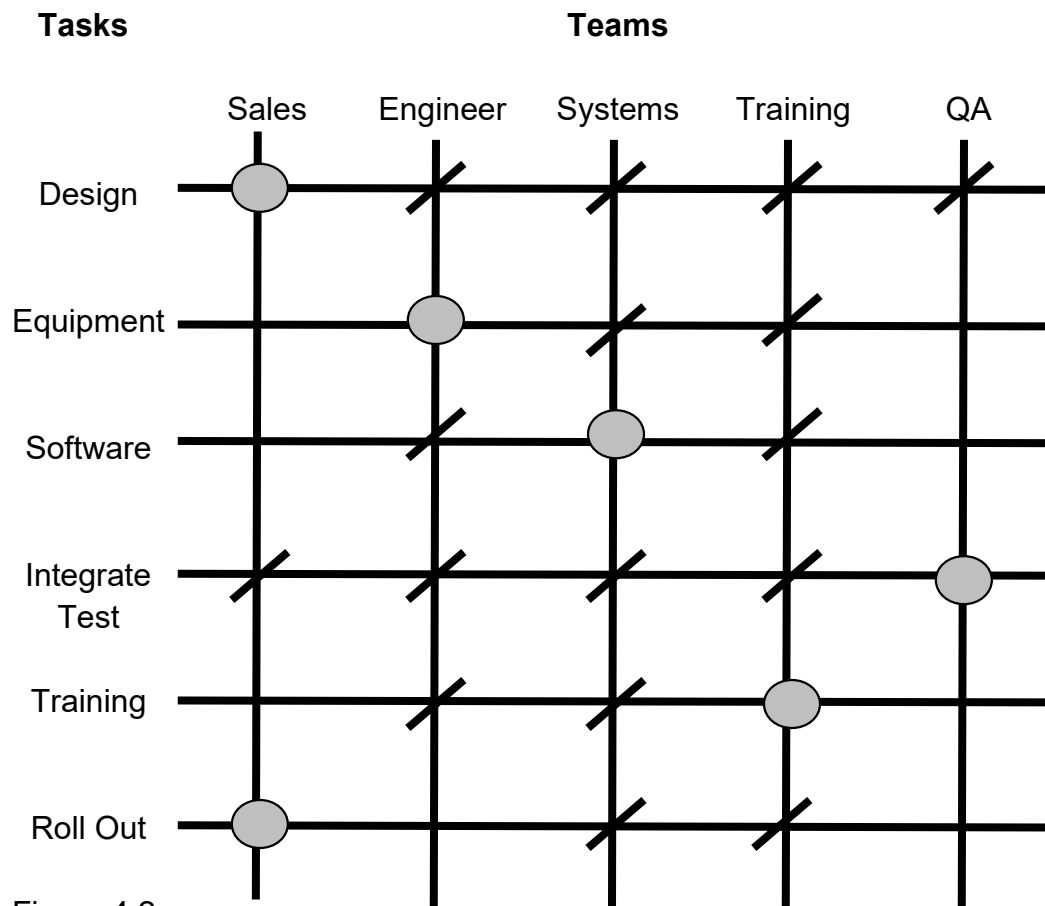
ICON FIVE
BUDGET THE BARS

Budget the Bars, Icon Five, shows the allocation of resources to each task bar on the project bar chart. Resources are, people, material, equipment, and dollars. The Bar Chart shows the cost of the work over time. It is important to note that estimated cost is different from budget. Cost is calculated by estimating and summarizing the cost of material, labor and general and administrative expenses to perform a task. Budget is determined by allocating the cost summary to the duration of the task. The Budget the Bars diagram below shows how costs ($) have been allocated to the tasks.
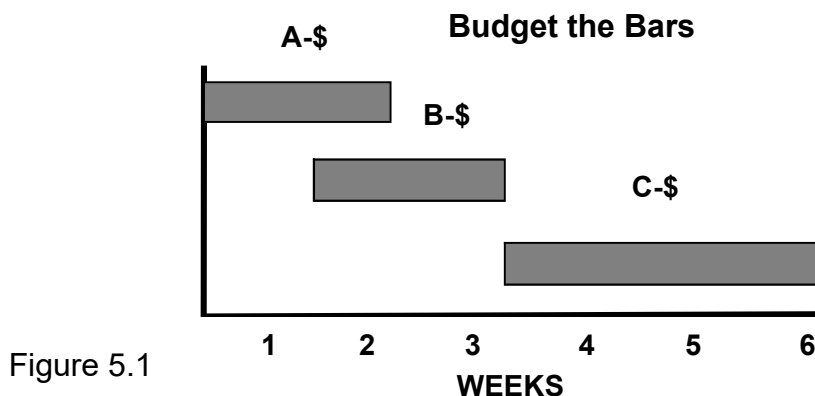
Budget the Bars

Figure 5.1

WEEKS

Estimating direct material for products, such as buildings, automobiles, or appliances, begins with determining the quantity of materials needed to build or fabricate the product. The pounds, cubic yards, board feet, square feet, castings, tools and molds, etc. are usually obtained from bills of material, parts lists, or detailed drawings or specifications documents. Estimating direct material for services might be test equipment, prototypes, computer hardware and software, and paper publication products. Once material quantities have been determined from drawings, specifications and parts lists, costs can be calculated from material handbooks, supplier catalogs or supplier quotes.

Estimating labor is determined by multiplying the amount of time in hours to complete a task by the hourly rate in dollars of the person performing the work. Construction and manufacturing industries initially used process methods and time studies to establish standards for building and fabricating work. The Engineering News-Record, McGraw Hill

Construction, is a weekly publication that contains national labor cost data. The National Society of Professional Engineers has developed position descriptions….. for nine levels of engineers.[8] The skill levels identify activities that are consistent with all types of services; i.e. design, analysis, drafting, writing, and coding. In most cases, the labor hours can be correlated to the product, whether it is an engineering drawing, a software program or an operations audit.

Most organizations collect and store actual cost data to be used in estimating their work. Cost engineers and accountants continuously analyze and update cost data. Sophisticated software programs and spread sheets exist that use learning curves and risk analysis to produce estimates in rapid fashion. Still, individual experience and human lessons learned are major factors in estimating the cost of work.

Design Activity Cost Table - CMS

Sub-task	Sales Hours	Engineer Hours	Systems Hours	Training Hours	QA Hours	Hours	Dollars
Client meetings	16	4	4			24	$3,912
Proposal	12	4	4	2	2	24	$7,824
Preliminary Design	8	10	10	4	4	36	$11,736
Design Workshop	8	6	6	4	4	28	$9,128
Final Design	6	6	4	2	2	20	$6,520
Client Review	4	4	4			12	$1,956
Material/Books/etc							$3,924
Totals	54	34	32	12	12	144	$45,000

Chart 5.1

The table above shows an example of the Design activity cost calculations for the Client Management System. The Design activity was divided into the following sub-tasks:
> Client meetings: Meeting with client to obtain requirements
> Proposal: Draft, writing, proofing, publishing, binding
> Preliminary Design: Drawings, flow charts, diagrams, tests
> Design Workshop: Team meeting to work out specification details
> Final Design: Team review and finalize the design
> Client Review: Approval, notice to proceed

---

[8] Rodney D. Stewart, *Cost Estimating, 2Edition*, Wiley Interscience, 1991) 1995

Note that the Sales team member who was accountable for Design has the majority of labor hours. The other team members' contribution is shown by their labor hours. Dollars are labor-hours multiplied by TCI's standard billing rate of $163 per hour. Material cost in dollars is bound proposal books, design documents, and final design copies. Similar cost tables would be constructed for each activity and summarized into a project cost table as shown below.

Total Project Cost Table - CMS

Identification	Activity	Precedence	Duration in Weeks	Cost
A	Design	None	5	$45,000
B	Equipment	A	5	$236,000
C	Software	A	8	$72,000
D	Integration	A	10	$90,000
E	Training	B,C,D	3	$32,000
F	Roll Out	E	2	$18,000
Chart 5.2			**Total**	$493,000

Figure 6.4 below contains the Budget the Bars for the Client Management System. It is significant because it provides a distinction between cost and budget.
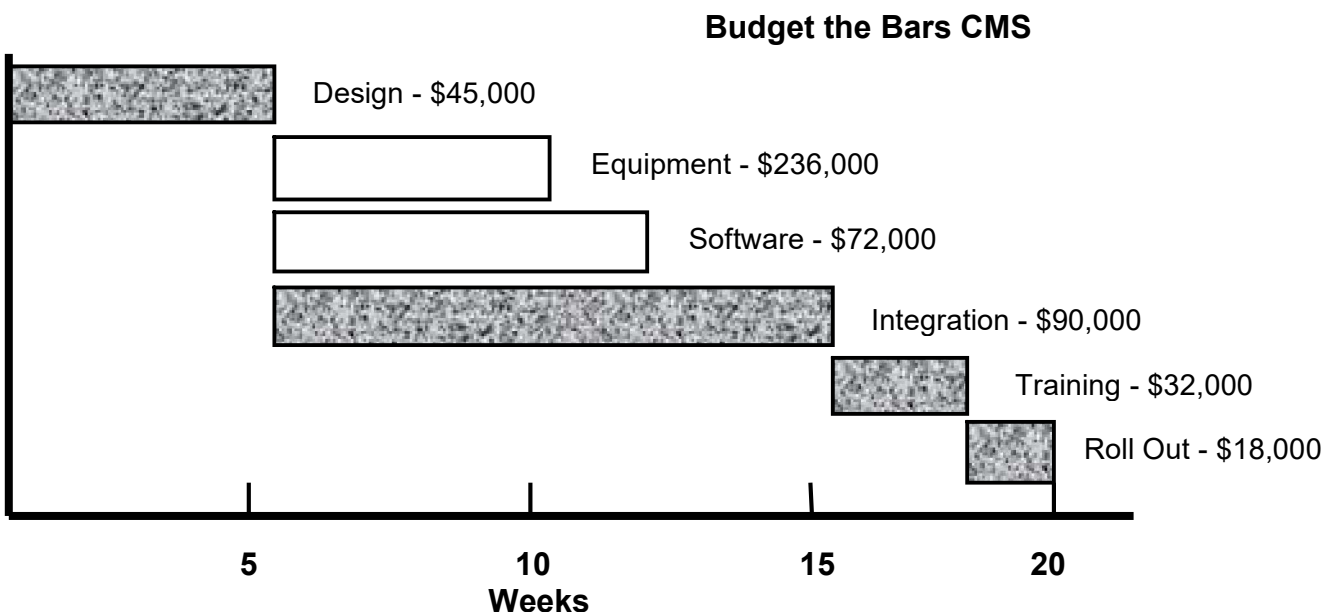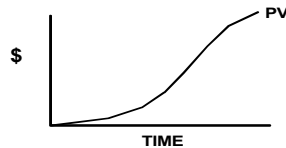
Budget the Bars CMS

Design - $45,000
Equipment - $236,000
Software - $72,000
Integration - $90,000
Training - $32,000
Roll Out - $18,000

5   10   15   20
Weeks

Figure 6.4

ICON SIX
BASELINE

$

Baseline[9], Icon Six, is a curve showing the project budget spending rate. It is calculated by accumulating the dollars budgeted for each bar on the schedule. Below is an example of Budget the Bars diagram of a home project for building a wooden deck. It takes 2 weeks to design the deck and the cost is $2,000. Ordering and purchasing the material takes 2 weeks and the cost is $12,000. Building the wooden deck takes 3 weeks and costs $15,000. The total cost of the wooden deck is $29,000.

Figure 6.1
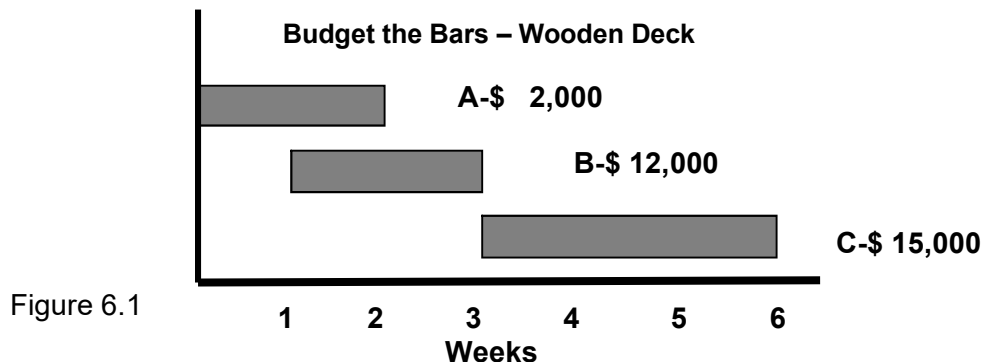
Constructing the Baseline requires that the activity bar (cost) is divided into time line intervals. For this project the time line intervals is weeks. This is shown on the diagram by the dotted lines extending the week time measure and in the in the cost table below.

Figure 6.2

---
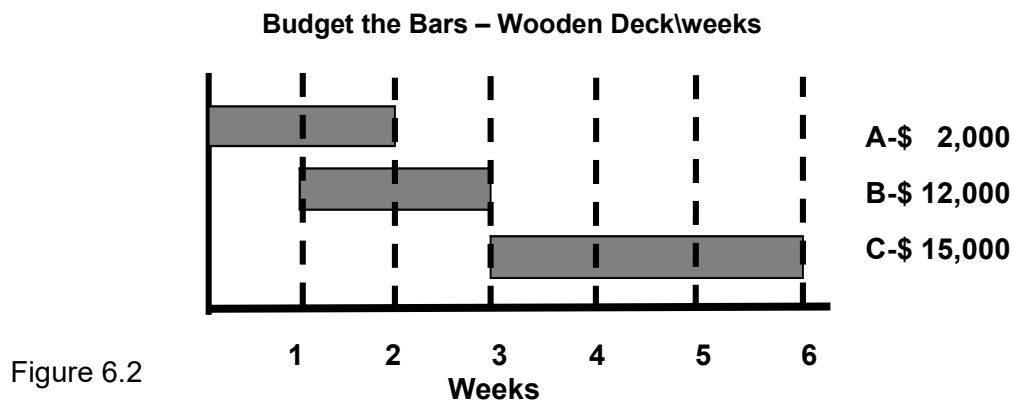
[9] Project Management Body of Knowledge (PMBOK® GUIDE), 4 Ed, Project Management Institute ,2008

Project Cost Table - Wooden Deck

Identification	Activity	Duration in Weeks	Cost	Cost per Week
A	Design	2	$ 2,000	$1,000
B	Purchase	2	$12,000	$6,000
C	Build	3	$15,000	$5,000
Chart 6.1		**Total**	$29,000	

The Baseline Curve is calculated by accumulating the cost of each bar per week with the total cost at the end of each week becoming a point on the curve. The End of Week cost is added to next week's Sub-Total. For example, the End of Week 2 = the end of week 1 ($1000) added to Week 2 Sub-Total ($7000) = $8000.

Baseline Cost Table - Wooden Deck

Week / Activity	1	2	3	4	5	6
Design	$1,000	$1,000				
Purchase		$6,000	$6,000			
Build				$5,000	$5,000	$5,000
Week Sub-Total	$1,000	$7,000	$6,000	$5,000	$5,000	$5,000
End of Week	**$1,000**	**$8,000**	**$14,000**	**$19,000**	**$24,000**	**$29,000**

Chart 6.2
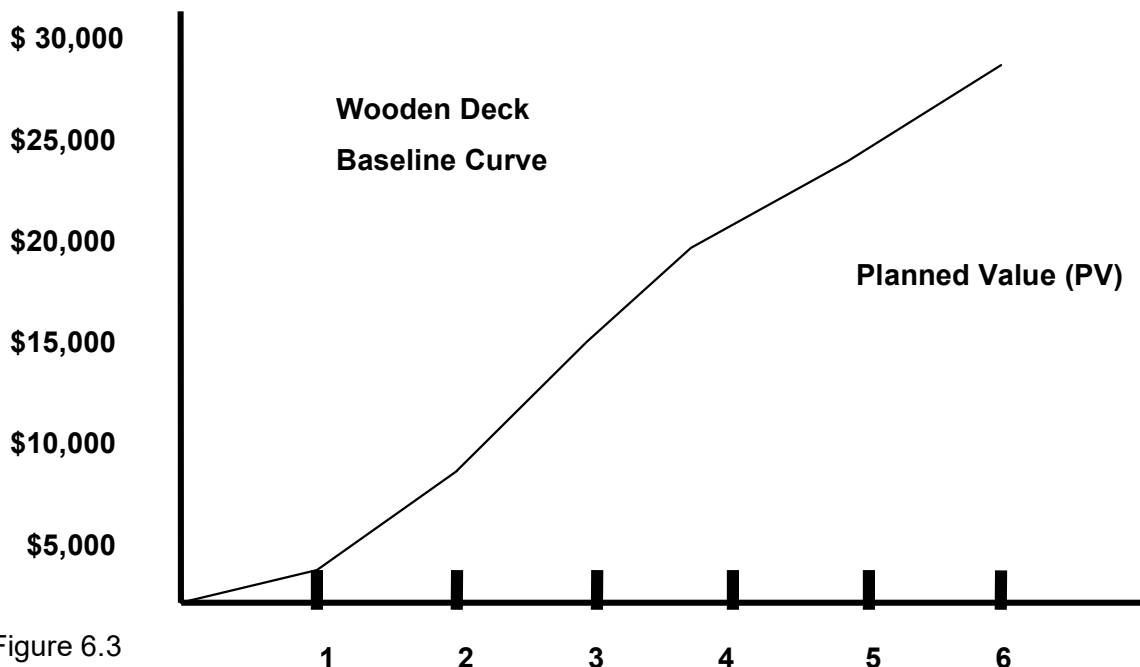

Figure 6.3

Project Cost Table - Client Management System

Identification	Activity	Duration in Weeks	Cost	Cost per Week
A	Design	5	$45,000	$9,000
B	Equipment	5	$236,000	$47,200
C	Software	8	$72,000	$9,000
D	Integration	10	$90,000	$9,000
E	Training	3	$32,000	$10,667
F	Roll Out	2	$18,000	$9,000
Chart 6.3		**Total**	**$493,000**	

After a review of the display constraints and time intervals, it was determined that a 5 week time period was a more effective way to present the Baseline diagram for the Client Management System. This is shown below on the diagram by the dotted lines extending the week time measure.

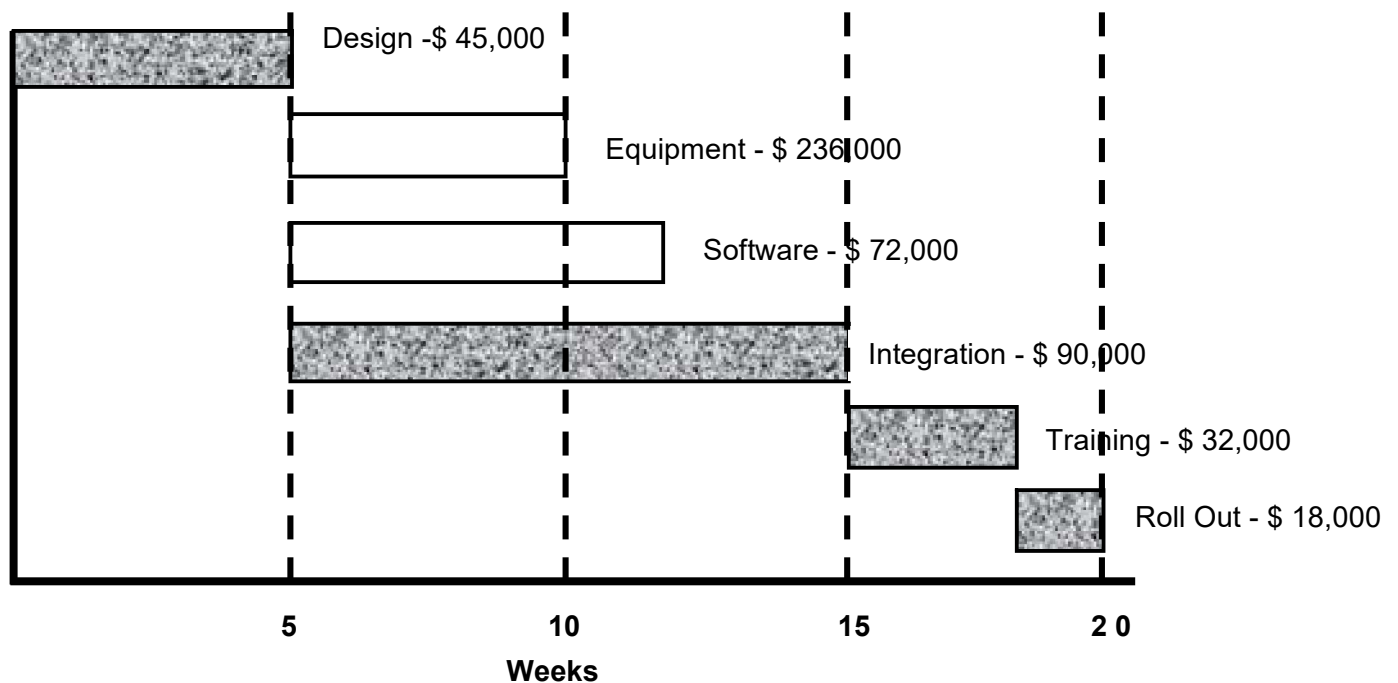**Budget the Bars - Client Management System**

Design -$ 45,000

Equipment - $ 236,000

Software - $ 72,000

Integration - $ 90,000

Training - $ 32,000

Roll Out - $ 18,000

5   10   15   2 0

Weeks

Figure 6.4

Client Management System – Baseline Cost Table

Week Activity	5	10	15	20
Design	$45,000			
Equipment		$236,000		
Software		$45,000	$27,000	
Integration		$45,000	$45,000	
Training				$32,000
Roll Out				$18,000
Week Sub-Total	$45,000	$326,000	$72,000	$50,000
End of Week	**$45,000**	**$371,000**	**$443,000**	**$493,000**

Chart 6.4

Baseline Curve
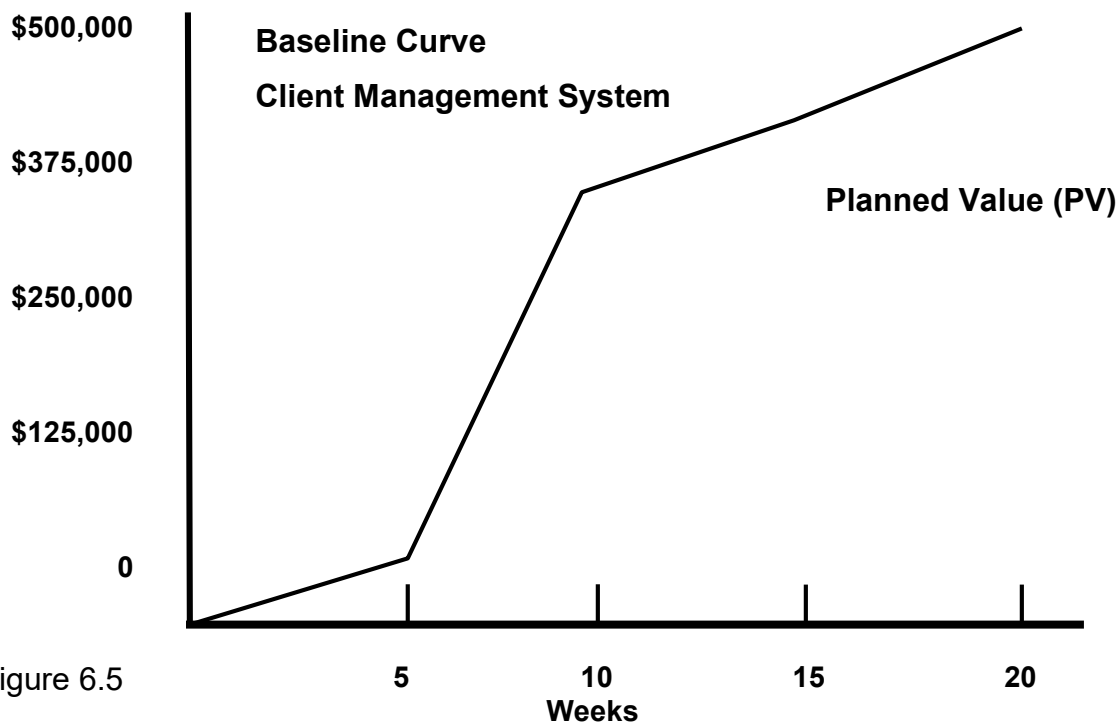**Client Management System**

Planned Value (PV)

Figure 6.5

Weeks

The word baseline is a generic term that can be found in medical, legal, financial and business glossaries. It is a line serving as the basis for measurement and comparison. As Icon Six, Baseline, also called planned value (PV), represents the spending rate of the work to be done. It is used as a measure of project status when compared to the deliverables that have been reported complete and the actual cost of those deliverables.

**ICON SEVEN
EARNED VALUE**
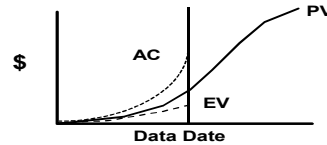
Earned Value, Icon Seven, is the monetary value of completed work. The concept of earned value is not new. Earned Value[10] is the value of completed work according to the original budget. Earned Value Management[11] (EVM) is a project management technique for measuring project performance and progress. It has the ability to combine measurement of scope, schedule, and cost. The essential features of EMV include:

1. A project plan that identifies the work to be done *[Bar Chart-Icon Three]*
2. The value of the work, planned value (PV) *[Baseline- Icon Five]*
3. Pre-defined earning rules from the original budget to quantify completed work called earned value (EV) *[Earned Value-Icon Seven]*

The industry accepted pre-defined earning rule typically uses a straight line method for quantifying completed work. For example, if the original budget for an activity spreads cost equally over the activity duration, then the percent of work completed would yield an equal percent of the cost of work.

Activity original budget = $ 2,000
Percent of work completed = 50%
Earned Value = (.50 x $ 2,000) = $1,000

For large and complex projects, the pre-defined earning rules may vary according to the company's financial requirements. This occurs mainly when large quantities of material are involved. For example, an activity may have a long duration, i.e. off site fabrication; earned value could not be calculated until the fabricated product is delivered to the site near the end of the duration. In a similar instance, sometimes the company's contract calls for making progress payments during fabrication. Then, earned value can be calculated based on the progress payments reflecting the percent complete of the work.

In the Wooden Deck project example, the Design activity baseline (PV) shows that it is planned to be one-half complete at the end of week one. PV = $1,000. If the Design

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[10] Gido & Clements, *Successful Project Management, 5Edition,* South- Western Cengage Learning 2012
[11] Earned Value Management, http://en.wikipedia.org/wiki/Earned_value_management

activity is reported to be one-half complete at the end of week one, using the straight line method as the pre-defined earning rule, the Design activity has earned the value (EV) of $1,000.   Then EV = PV. That means the design activity is on schedule. If the reported actual cost (AC) for the design activity is $ 1,000 then EV = AC. That means the design activity is on budget.

The constant elements in EMV are time and the pre-defined earning rules. Time is determined by points on the schedule called the Data Date (DD). Earned value (EV) must be determined at the Data Date (DD). The DD for the Design activity was selected at week one. The PV for Design at week one was $1,000. The variables in EMV are Earned Value (EV) and Actual Cost (AC).

Earned value (EV) is based on completed work. Actual cost (AC) is based on cost reports from accounting. When there is a difference between EV and PV and AC, the difference is called variance. Variance can be positive or negative.

- EV is greater than PV = + variance (project is ahead of schedule)

- EV is smaller than PV = - variance (project is behind schedule)

- EV is greater than AC = + variance (project is under budget)

- EV is smaller than AC = - variance (project is over budget)

Baseline Cost Table - Wooden Deck

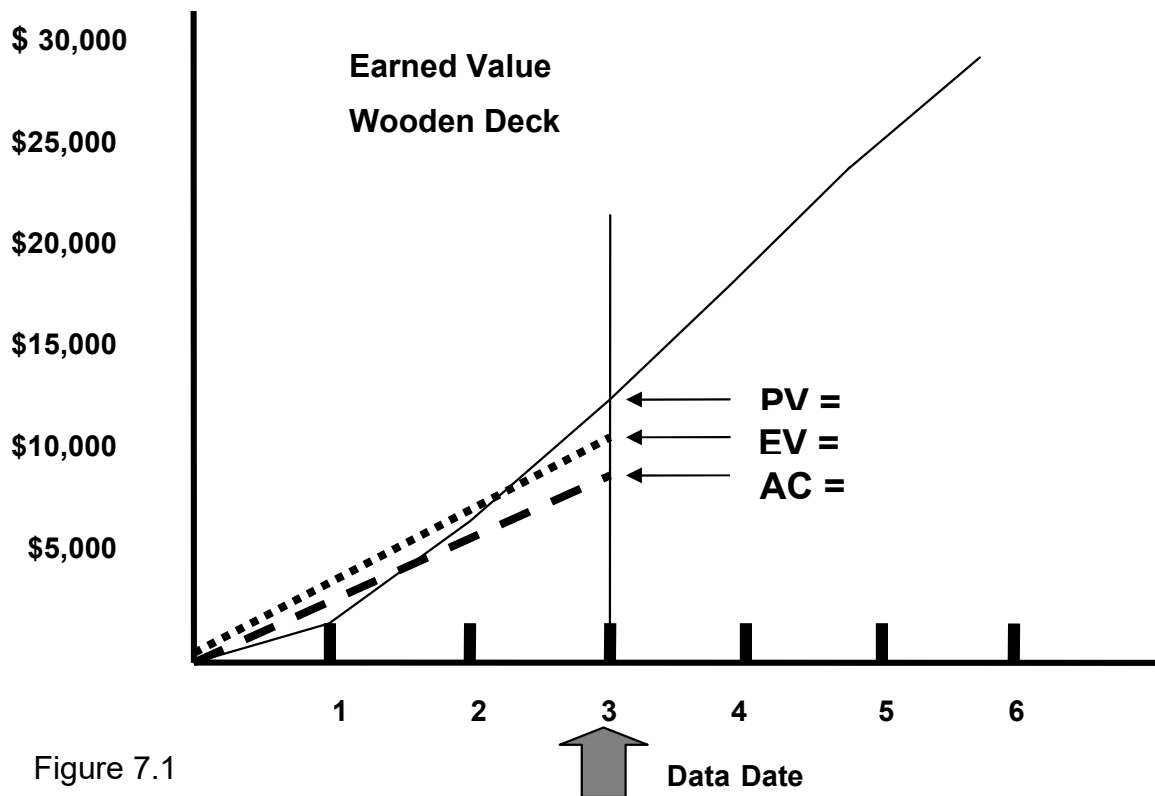| Week ⟍ Activity	1	2	3	4	5	6
Design	$1,000	$1,000				
Purchase		$6,000	$6,000			
Build				$5,000	$5,000	$5,000
Week Sub-Total	$1,000	$7,000	$6,000	$5,000	$5,000	$5000
End of Week	**$1,000**	**$8,000**	**$14,000**	**$19,000**	**$24,000**	**$29,000**

Chart 7.1

Figure 7.1

The example above shows the Data Date at the end of three weeks. The team has reported the completion of; 100% Design, 80% Purchase activities. The accounting department reported a cost of $ 11,000.

- EV = 100% of $2,000 + 80% of $12,000 = $11,600
- EV – PV = $ 11,600 - $14,000 = - $2,400 Variance
- EV – AC = $ 11,600 - $11,000 = + $600 Variance

At the end of week three the Wooden Deck project is behind schedule (negative variance, minus $2,400) and under budget (positive variance, $600).

Baseline Cost Table - Client Management System

Week / Activity	5	10	15	20
Design	$45,000			
Equipment		$236,000		
Software		$45,000	$27,000	
Integration		$45,000	$45,000	
Training				$32,000
Roll Out				$18,000
Week Sub-Total	$45,000	$326,000	$72,000	$50,000
End of Week	**$45,000**	**$371,000**	**$443,000**	**$493,000**

Chart 7.2

The example below shows the Data Date at the end of 10 weeks. The team has reported the 100% completion of Design and Equipment, 75% software and 50% of Integration. The accounting department reported a cost of $ 358,000.

- EV = 100% ($45K, $336K) + 75% ($72K) + 50% ($90K) = $380,000
- EV – PV = $ 380,000 - $ 371,000 = + $9,000 Variance
- EV – AC = $ 380,000 - $ 358,000 = + $22,000 Variance

At the end of week 10 the Client Management System project is ahead of schedule (positive variance, $ 9,000) and under budget (positive variance, $22,000).

Using variance to determine whether the project cost and schedule is following the plan is important detail information for the project manager and the project team. But, managers and executives do not need all the details. They want the bottom line. Taking a basic feature from statistical process control, the control chart, senior managers and executives can be informed and monitor project work in a simple visual manner by using a control chart.
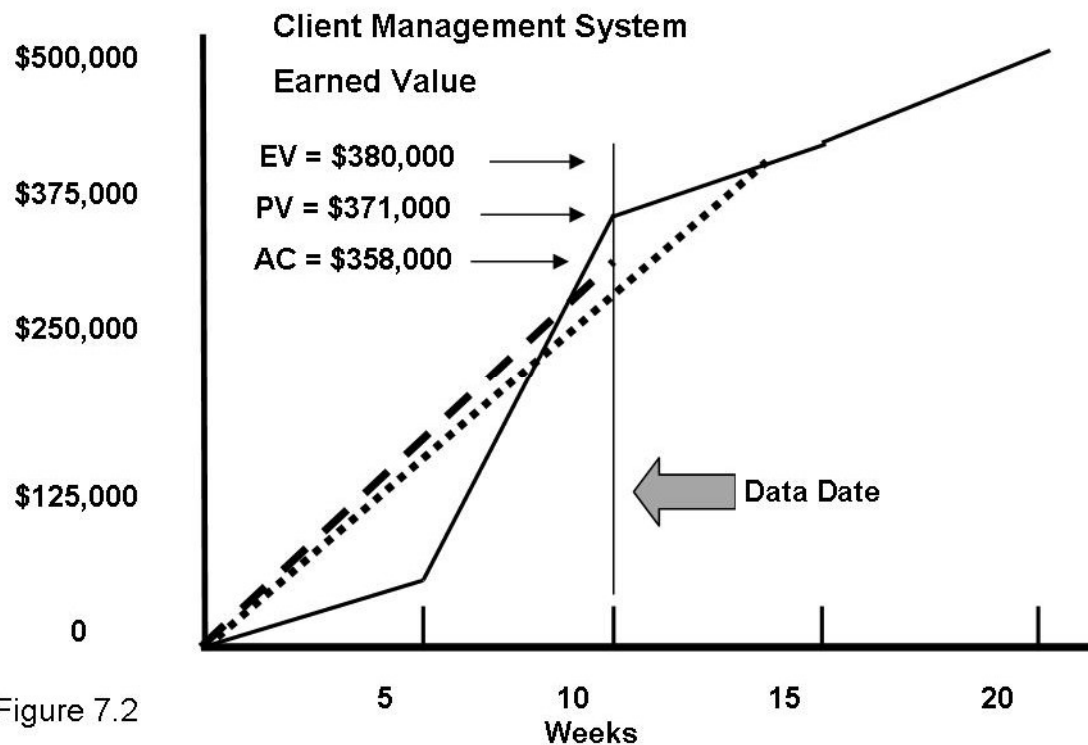
Quality Project Management

Figure 7.2

The control chart[12] is a tool used to determine if a business process is in a state of statistical control. The center line of the chart is determined by the statistical mean of the process observed; i.e. manufacturing, assembly, testing, etc. The upper and lower control limits indicate when the process is considered out of control. Observations are posted to the chart at predetermined intervals. If observations fall within the control limits, then the process is said to be in control. When an observation falls outside the control limits, investigation is made to determine if any action is necessary.

In a project management control chart, the center line indicates that the schedule and cost are going according to plan. The metric value = 1. The upper and lower control limits are set by management and represent the tolerance for schedule and budget variance. The project management observations are project reporting periods and functions of earned value. There are two indices. There is a schedule performance index (SPI) and a cost performance index (CPI).

- Schedule Performance Index is EV / PV = SPI

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[12] J. Oakland, *Statistical Process Control,* ISBN 0-7506-5766-9, 2002

- Cost Performance Index is EV / AC = CPI

The diagram below is a typical project control chart showing SPI reported observations. Note that periods 1, 3, 9 are below the center line with 9 below the lower control limit. Observation 9 needs immediate attention. The remainders are either on the center line or above. Even if the project is reported ahead of schedule, as shown by observation 5, above 1.1, it could indicate other concerns. Further investigation is necessary.
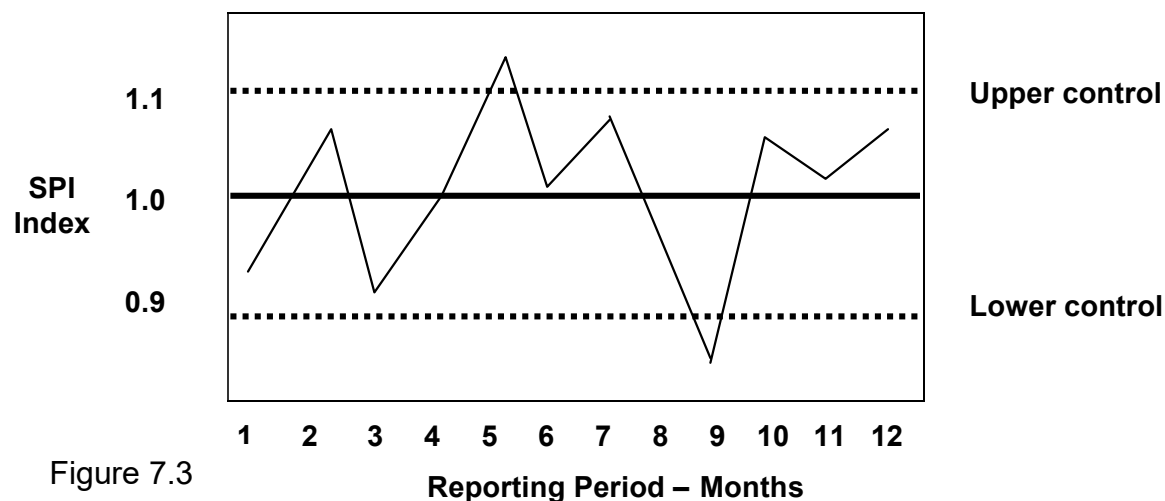

Figure 7.3

At the end of week 10 the Client Management System project was reported ahead of schedule with a positive variance and also under budget with a positive variance. The following are the performance indices.

- SPI = \$380,000 / \$371,000 = 1.03
- CPI = \$380,000 / \$358,000 = 1.06

Another feature available when using Earned Value Management is the ability to estimate the cost of the project at completion more accurately. The following formula is used to estimate the cost at completion (EAC).

Estimate at Completion = Actual Cost + (Budget at Completion – Earned Value)

- EAC = AC + (BAC – EV)

Quality Project Management

At the end of week 10, the Client Management System project was reported ahead of schedule and under budget. The estimate at completion is shown below.

- EAC = $358,000 + ($493,000 - $380,000) = $471,000

The calculation for estimate at completion shows the project cost is $ 22,000 under budget. The Earned Value icon provides the project team and management with current information, variances and indices, which are measurable and action-oriented. It is the responsibility of the project manager and the project team to continue monitoring and using the earned value data to meet the challenge of quality.

The Seven Icons © - Analytical Tool

As discussed in the introduction, the Seven Icons © may also serve as an analytical tool to determine the condition of an ongoing project at any time in the life of the project. Whether it is assigned to a professional project manager or someone new to project work, or whether the project is almost complete, in the middle, or just starting, using the icons as a checklist, the status of the project will be revealed. In any case, every question needs to be asked in order for management action to be determined.

The Seven Icons © Checklist

Icon	Question	Yes	No
WBS	Does the project have a WBS?	Review and update the WBS using the remaining work content.	Determine what work content remains. Create a WBS.
CPM/ Bar Chart	Does the project have a schedule?	Review and update the schedule. Check the logic and durations.	Examine the WBS and develop a schedule for the remaining work.
T Chart	Does the project have a formal project team with written assignments?	Review skill sets and assignments and check against logic and duration estimates.	Use schedule logic and duration estimates to determine personnel skill set needs and draw a T chart.
Budget The Bars	Does the project have resources, people, material and dollars allocated to specific activities?	Review allocation estimates against actual resources used.	Use schedule activities and estimates and allocate resources.
Baseline	Does the project have a spending rate plan?	Compare actual spending with spending rate plan (PV).	Use the allocated resources (Budget The Bars) to draw a spending plan (PV).
Earned Value	Does the project have a method to measure performance?	Compare original budget against actual cost. EV- AC= Variance	Compare original budget for deliverables against actual cost. EV- AC= Variance