An-Najah National University
Civil Engineering Department
Faculty of Engineering
Engineering Project Management
Course 465511
Nabil Al- Dmaidi
Your Expectations of Me

Be prepared
Be on time
Teach for full 3 hours period
Fair grading system
Front load the class work
Do not humiliate students
Practice golden rule
Provide real world examples
Make you think
This Course

- Focuses not only how project management process works
- But more importantly why it works
- **Not concentrate by project type**
- Construction, product development, large, small
- Rather, for individual who will manage a variety of projects
- **Designed to be used in pure organizations**
- Construction, research organizations, manufacturing firms, and the consulting firms
Topics

- Following this introductory chapter
- Evaluating and selecting projects
- Organizational environment
- Defining the project
- Developing a work breakdown structure
- Estimating time and cost
- Creating project network
- Identifying & managing risks associated with project
- Determining resources and allocating them
- Scheduling and leveling resources
- Reducing project time
- Monitoring project progress
- Covering more topics
Leadership & Management
Two Hour Session
Construction Model

Keep it Simple

- “Get Work”
- “Do Work”
- “Keep Score”
Owner Desires

- Better operational features
- Lower costs
- Quicker schedules
- Less risk
- Less hassle
Contractor Desires

- More work
- More profit
- Less hassle
Individual Desires

- Job satisfaction
- Job stability
- Less hassle
No Hassle

- No accidents
- No changes
- No cost increases
- No delays
My Less Hassle

- Sensitivity to people
- Win-Win relationships
- Trust
- Golden rule
- Ethics
- Partnering
- TQM
The Changing Environment

- You are **hired** for your technical skills
- You are **fired** for your lack of people skills
- You are **promoted** for your leadership & management skills
Our Greatest Need

Better Leadership
&
Management
Reason for Switching Contractors

- 15 % Better Product
- 15 % Better Cost
- 70 % People Nicer to Deal With
Knowledge Worker

The Changing Professional

- Society of white & blue collar worker
  - White collar workers plan & supervise
  - Blue collar workers do the work
- That model may be dying
- The new model
  - Knowledge worker
Knowledge Worker

- Current skills
- Move job to job
- Required continuing education annually
- Be competitive
Why Change

- In construction

40 Percent of the managers are working in a style they do not prefer
My Leadership Philosophy

- Establish an atmosphere of trust
- Be personally involved
- Be open
- Plan ahead
- Understand the mission
- Learn the job
- Know the boss
- Always have someone in charge
- Decentralize & delegate
- Take care of your people
YOUR MOLECULE

You
YOUR MOLECULE

- Place yourself in the middle
- Put the boss on top
- Your employees on the bottom
- Other players around

Note
- The line represents your relationship
- Place time spent with each
YOUR MOLECULE

Boss

You
YOUR MOLECULE

Boss

You

Employees
YOUR MOLECULE

You

Employees

City Inspectors

Boss
YOUR MOLECULE

- Most organizations / companies have five to six layers of molecules
- Do a molecule analysis for your boss
- Do a molecule analysis for your employees
Key to the molecule

- Spend your time working your molecule
WHERE DO YOU LEARN YOUR PEOPLE SKILLS?

Influences in developing people skills

- **Home** (31%)
  - Mom
  - Dad
  - Sibling

- **K to 12** (12%)
  - Teachers
  - Peers

- **University Education** (17%)
  - Professors
  - Peers

- **Books & Study & TV** (5%)
  - Self Improvement
  - Continuing Education

- **Church** (7%)
  - Family
  - Peers
  - Pastors

- **Clubs & Teams** (7%)
  - Team Mates
  - Coaches
  - Club Officer

- **Part Time Jobs** (21%)
  - Bosses
  - Peers
  - Customers

- **Professional Career**
  - Peers
  - Employees
  - Bosses
  - Good
  - Bad
  - 50%
Dangerous to become a Fireman

- Don’t let your in-box Drive you
- Don’t let your phone Use you
- Don’t let your staff Abuse you
- Don’t let your e-mail Mislead you
- Don’t be a Fireman
Management at West Point

- Goals & objectives are management tools
- Demand information to manage by
- Use thinking time
- Separate planning & operations
- Train your people for success
- Build the “corporate body”
- Know who’s on your “molecule”
- Manage agreement
Management leadership balance

Management  

Doing things right

Leadership  

Doing the right things
Power

The ability of one person to influence the behavior of another.
Position power

- Reward: Control over rewards
- Coercive: Control over punishments
- Legitimate: Position of formal authority
Personal power

- **Expert**: Has knowledge, useful information
- **Reference**: Has appealing personal traits
Styles of leadership

- Tells
- Sells
- Consults
- Shares
- Delegates
Choice of leadership style

- Nature of the task
- Power available to the leader
- Experience of the subordinates
- Culture of the organization
- Preferred Style of the leader
- Style preferred by subordinates
- Time available for task completion
Keys to leadership

- Trust your subordinates
- Develop a vision
- Keep your cool
- Encourage risk
- Be an Expert
- Invite dissent
- Simplify
Opportunities in leadership roles

- Look at every job as if it were an adventure
- Treat each new assignment as if it were a turnaround
- Ask other people to join in solving problems
- Stop unproductive routines & try something new
Opportunities in leadership roles

- Put idea gathering on your Master To-Do list
- Analyze failures and successes
- Foster collaboration by seeking inputs
- Use Power to strengthen others
- Enlarge people's sphere of influence
Leadership.....is the ability to get other people to do what they don’t want to do, and like it.
Leadership is action, not position

It’s not what you know when you start, it’s what you learn and put to good use.

Real leaders are ordinary people with extraordinary determination.

The speed of the leader determines the rate of the pack.
Thank You for Listening

- Know yourself
- Use the Golden Rule
- Keep updating your L & M Philosophy
- Adopt Life Long Learning
- Manage Your Own Career
Management Functions

- Planning
  - Where the organization wants to be in the future and how to get there.
Management Functions

- Organizing
  - Follows planning and reflects how the organization tries to accomplish the plan.
  - Involves the assignment of tasks, grouping of tasks into departments, and allocation of resources.
Management Functions

- **Leading**
  - The use of influence to motivate employees to achieve the organization's goals.
  - Creating a shared culture and values, communicating goals to employees throughout the organization, and infusing employees to perform at a high level.
Management Functions

Controlling
- Monitoring employees' activities, determining if the organization is on target toward its goals, and making corrections as necessary.
Management Skills

- Conceptual Skill—the ability to see the organization as a whole and the relationship between its parts.
- Human Skill—The ability to work with and through people.
- Technical Skill—Mastery of specific functions and specialized knowledge.
Decision Making

- **Decision**: a choice made from two or more alternatives.
- **Part of all four managerial functions**
- **Decisions are made on the basis of**:
  - Rationality
  - Bounded Rationality
  - Intuition
Rationality

- Problem is clear and unambiguous.
- Single goal.
- All alternatives are known.
- Clear and constant preferences.
- Maximum payoff.
- The decision is in the best interest of the organization—not the manager.
MANAGEMENT HIERARCHY

Management Level

TOP MANAGEMENT

MIDDLE MANAGEMENT

SUPERVISORS

Responsibility

LONG RANGE PLANNING

SHORT TERM PLANNING

EXECUTION

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What is a Project

A project is a complex, non routine, one-time effort limited by time, budget, resources, and performance specification designed to meet customer needs

Characteristics

- An establish objective
- A defined life span
- Involvement of several disciplines
- Unique (has never been done before)
- Within specific time, cost, performance requirements
Project Life Cycle

Level of effort

Definition
1. Goals
2. Specifications
3. Tasks
4. Responsibilities
5. Teams

Planning
1. Schedules
2. Budgets
3. Resources
4. Risks
5. Staffing

Execution
1. Status reports
2. Changes
3. Quality
4. Forecasts

Delivery
1. Train customer
2. Transfer documents
3. Release resources
4. Reassign staff
5. Lessons learned
Phase One

- Definition Stage
  - Defining Specifications
  - Establishing objectives
  - Determining tasks
  - Forming teams
  - Assigning responsibilities
- Low level of effort
Phase Two

- Planning Stage
  - Estimating time and cost
  - Scheduling activities and resources
  - Identifying and determining risks
  - Assigning teams
- Level of effort increases
Phase Three

- **Execution Stage**
  - Producing physical product
  - Collecting data
  - Monitoring project performance
  - Identifying the changes
  - Forecasting new measures

- **Highest level of effort**
Phase Four

- Delivery Stage
  - Training customer
  - Transferring documents
  - Releasing resources
  - Reassigning staff
  - Documenting lessons learned
- Low level of effort
The Importance of Project Management

- No longer a special-need for management
- Becomes a standard way of doing business
- **Many reasons**
  - Compression of the product life cycle
  - Global competition
  - Knowledge explosion
  - Increased customer focus
  - Small projects become a big problem
  - Some other reasons
Compression of Product Life Cycle

- Important driving force behind the shortening product life cycle
- Compare 1.5-3 years now to 10-30 years in past (30 years ago)
- Imply time to market a product
- Rule of thumb
  - A 6-month project delay can result in a 33% loss in product revenue share
- Approach
  - Relay on cross-functional teams
- PM provides an efficient way of doing this task
Global Competition

In today’s open market, not only we see cheaper product price, but also higher quality

Achieved by ISO 9000 certification

International standards covering from design stage to delivery stage for everything from banking to manufacturing

Not only has led the U.S. manufacturing operations to far east, but also transformation is a critical issue

PM provides an important discipline for achieving this task
Knowledge Explosion

- Increased the complexity of projects
- Use the latest know-how technology in material, equipment, and even required specialists
- Used to get this task done
Increased Customer focus

- Placed a premium on customer satisfaction
- No longer want generic products
- Want customized products and services
- Also promoted the development of the customized products and services
- Used to provide an efficient way to get these tasks done
The Problem of Small Projects

- To stay in the market, we should manage many projects concurrently
- Share resources across a portfolio of projects
- No idea of managing multiproject problem
- Sometimes, small projects carry the same risk as do large projects
- Approach
  - Prioritize them
- PM provides an important tool for achieving this task
Integrated Project Management Systems

- Selection and management of projects fail to support the strategic plan
- Written by one group
- Selected by another group
- And implemented by third group (project managers)
- Results in wasting resources

Approach
  - Need a system in which all parts are integrated
Integrated Management of Projects

Customer

Environmental analysis
External Internal

Firm mission, goals, strategies

Priorities

Management, facilities
Financial conditions

Signal
Opportunities and Threats

Political, social, economic, and technological

Projects
System

Environment and Culture

Scope
Work Breakdown Networks Resources Cost

Organization Leadership Teams Partners

Project Implementation

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Definition of a Project

From the Project Management Institute:

“A temporary endeavor undertaken to create a unique product or service”
Project Characteristics

- Temporary Endeavor
  - Has a distinct starting point and due date
- Create a unique product or service
  - Specific deliverable
  - Unique
Examples of a Project

- Installing a computer network in a building
- Opening a new store/factory
- Automating an assembly line
- Design a new car model
- Introducing a new car model
- Building a bridge
Other Project Characteristics

- Multidisciplinary
- Complex
- Conflict
- Can be part of a Program
  - Recurring series of projects
  - New planned product each time
Project Resources

- People
  - A team of people working together
- Money
- Equipment
- Time
Reasons for Using Project Mgmt.

- **Temporary Duration**
  - Assigning responsibilities
  - Provide resources

- **Unique Features of a Project**
  - Requires organized approach
For a Successful Project

- Well-defined objectives
- Good communication
- Support of management/customer
- Feasible plan
- Reliable team
- Maintain control of budget/schedule
Skills for Project Management

- Good Planning
- Conflict Resolution
- Creativity
- Flexibility
- Negotiation
- Communication
  - Client
  - Subcontractors
  - Team
Dimensions of Project Management

- Performance
- Money
- Time

Plan should consider all of these before starting

Manager needs to track them during project
Stages of a Project

1) Conceptual Design
2) Preliminary Design
3) Detailed Design
4) Execution
5) Close
Project Selection Considerations

- Effectiveness
- Cost
- Time Required
- Resources Required
- Chance of success
Homework –

- Write 300-400 words describing a project that you have been involved in.
- In description, include the following:
  - Objective of project
  - Your role (client, manager, team member, …)
  - Success of project with respect to each of the dimensions of project management
  - Specific problem encountered during the implementation of the project and how you resolved it
Project Manager & Project Plan
Project Management: A Profession

- Project Management Institute
  - Over 100,000 members worldwide

- As a profession
  - Developed body of knowledge
  - Guidelines and standards for members
  - Journals and trade publications

- Organizations becoming more project oriented
Roles of a Project Manager

- Communicator
- Facilitator
- Decision maker
- Motivator
Project Communication

Client ←→ Project Manager ←→ Project Team

Project Manager
Project Manager’s Responsibilities

- Obtain Resources
- Overcome Obstacles
- Provide Leadership
- Achieve these through
  - Negotiation
  - Conflict Resolution
  - Persuasion
Selecting a Project Manager

- Credibility

- Political and Interpersonal Skills

- Motivation and Organization

- Ethical
Project Master Plan: Introduction

- Overview
- Objectives
- General Approach
Project Master Plan: Resources

- Schedule
- Personnel
- Resource Requirements
Project Master Plan: Wrap-up

- Evaluation Methods
- Potential Problems
- Contractual Details
Starting the Planning Process

- First Step: Define Objectives
- Other Preliminary Concerns
- Launch Meeting
Hierarchical Planning Process

- Complete list of all required tasks

- Steps:
  - List Main Objectives
  - List all tasks needed to achieve objectives – Level 1 Activities
  - List all tasks needed to achieve Level 1 Activities – Level 2 Activities
  - Continue breakdown to lowest level of detail
Project Action Plan

- All project activities
  - Resources required
  - Precedents
  - Duration
  - Person (s) responsible

- Milestones Identified
Work Breakdown Structure

- Hierarchy to divide project into separate jobs
  - Top level – overall project
  - Multiple levels depending on complexity of project
  - Bottom level – individual tasks
Work Breakdown Structures & Scheduling
Work Breakdown Structures

- Bill of Materials (BOM) format
Work Breakdown Structures

- Indented BOM format

Project

- Task 1
  - Subtask 1.1

- Task 2
  - Subtask 2.1
  - Subtask 2.2
  - Subtask 2.3

- Task N
WBS Level Names

1. Program
2. Project
3. Task
4. Sub Task
5. Work Package
6. Effort or Activity
WBS Level Names

- Common names & terms facilitate:
  - Communication
  - Understanding

- All parties should use a common level naming convention
When Developing a WBS

- Identify necessary tasks
- Don’t worry about the particular order—*yet*
- Don’t worry about particular details —*yet*
WBS Development Process

- **First:** Identify all work that needs to be done
- **Then:** Identify who, how long, when, and how much ($ and resources)
Estimating Work

- Estimate WBS to level of required accuracy
  - Granularity
- “Exact estimates” are oxymoronic (e.g., jumbo shrimp)
Scheduling

- The goal of scheduling is to maximize parallel activities to minimize time.
- Minimal time yields:
  - the most aggressive schedule
  - an ideal (unrealistic) target
The world will not stand still while a plan is being executed.
Multidisciplinary Teams

- Concurrent Engineering
  - Working in parallel
  - Useful structure for design projects
- Team has representatives from different areas
  - Design
  - Manufacturing
  - Finance
  - Marketing
  - Sales
Planning
MOST MANAGERS DO NOT LIKE PLANNING DUE TO THE FOLLOWING:

* It takes time.
* You have to think.
* It involves paper work.
* You are bound to systematic procedures.
* You are committed to achieve a specific result within a specified time period.
Effective Planning

An effective plan will be:-

* **Explicit** - stated in detail, leaving nothing merely implied.

* **Intelligible** - it must be understood and be comprehensible.

* **Flexible** - capable of accepting change.

* **Controllable** - capable of being monitored for control purposes.
Planning Fundamentals

- If the task is not understood, then during the actual task execution more knowledge is gained that, in turn, leads to changes in resource allocations, schedules, and priorities.
- If the task is well understood prior to being performed, much of the work can be preplanned.
- The more uncertain the task, the greater the amount of information that must be processed in order to ensure effective performance.
Reasons for Planning

- To eliminate or reduce uncertainty
- To improve efficiency of the operation
- To obtain a better understanding of the objectives
- To provide a basis for monitoring and controlling work
DEFINITION OF A PROJECT LIFE CYCLE

1. CONCEPTUAL PHASE
2. FEASIBILITY AND PRELIMINARY PLANNING PHASE
3. DETAILED PLANNING PHASE
4. IMPLEMENTATION PHASE
5. CONVERSION OR TERMINATION PHASE

- Resources Utilized
- PMO
PLANNING QUESTIONS OFTEN ASKED

Who plans the project?

Who executes the project?

Who is responsible for monitoring work and controlling work?

Who is responsible for providing feedback regarding the planning and execution phases of a project?

The Line Manager(s) ?
The Project Manager ?
Both Parties ?
Project Manager’s Responsibility

- Project Manager will define:
  - Goals and objectives
  - Major milestones
  - Requirements
  - Ground rules and assumptions
  - Time, cost, and performance constraints
  - Operating procedures
  - Administrative policy
  - Reporting requirements
Line Manager’s Responsibility

- Line manager will define:
  - Detailed task descriptions to implement objectives, requirements, and milestones
  - Detailed schedules and manpower allocations to support budget and schedule
  - Identification of areas of risk, uncertainty, and conflict
Senior Management’s Responsibility

- Senior management (project sponsor) will:
  - Act as the negotiator for disagreements between project and line management
  - Provide clarification of critical issues
  - Provide communication link with customer’s senior management
THE SEVEN PHASES OF A PROJECT

1. Wild enthusiasm
2. Disillusionment
3. Chaos
4. Search for the guilty
5. Punishment of the innocent
6. Promotion of the non-participants
7. Define the requirements
Planning/Scheduling Tools

- Scheduling
  - MS Project
  - ABT Workbench
  - Timeline
- Others
  - Estimation Tools
  - Risk Analysis Tools
  - etc.
Defining Requirements

- The statement of work (SOW)
- The project specifications
- The milestone schedule
- The work breakdown structure (WBS)
STATEMENT-OF-WORK (SOW)

COMPLEXITY IS DETERMINED BY TOP MANAGEMENT, CUSTOMER AND/OR USER GROUP(S)

FOR INTERNAL PROJECTS:
SOW IS PREPARED BY THE PROJECT OFFICE AND/OR USER GROUP(S)
POINTS TO ADDRESS WHEN DEVELOPING A STATEMENT-OF-WORK

- Purpose - objectives
- Exclusions - what should not be done
- Quantities - how many
- Schedule - when the work will be started/completed
- Deliverables (i.e... work done)
- Acceptance criteria - what method will be used to accept deliverables
- Responsibility - department, office or...
WHO PREPARES THE STATEMENT-OF-WORK (SOW)

- Preparation of internal SOWs
  - Project office and/or user groups

- Preparation of external SOWs
  - Dependent on situation, & complexity
  - Project manager/ line managers and project sponsor
  - Client who may have the capabilities
  - Client may decide to contract out to an independent body
  - Client may contract your services
STATEMENT-OF-WORK RISKS

IF A STATEMENT OF WORK IS MISINTERPRETED, IS IT NORMALLY IN FAVOR OF THE CLIENT OR CONTRACTOR?
Statement of Work

Elements

- General scope of the work
- Objectives and related background
- Contractor’s tasks
- Contractor end-item performance requirements
- Reference to related studies, documentation, and specifications
- Data items (documentation)
- Support equipment for contract end-item
Statement of Work

Elements

- Customer-furnished property, facilities, equipment, and services
- Customer-furnished documentation
- Schedule of performance
- Exhibits, attachments, and appendices
Problem Areas

- Project objectives/goals are not agreeable to all parties.
- Project objectives are too rigid to accommodate changing priorities.
- Insufficient time exists to define objectives well.
- Objectives are not adequately quantified.
- Objectives are not documented well enough.
- Efforts of client and project personnel are not coordinated.
- Personnel turnover is high.
Misinterpretation Areas

- Mixing tasks, specifications, approvals, and special instructions
- Using imprecise language ("nearly," "optimum," "approximately," etc.)
- No pattern, structure, or chronological order
- Wide variation in size of tasks
- Wide variation in how to describe details of the work
- Failing to get third-party review
IF A STATEMENT OF WORK IS MISINTERPRETED, IS IT IN FAVOR OF THE CONTRACTOR OR CUSTOMER?
PURPOSE OF WBS

IT IS TO STRUCTURE AN ASSIGNED PROJECT INTO VARIOUS ACTIVITIES IN ORDER THAT:

- Detailed planning can be performed
- Costs and budgets can be established
- Objectives can be linked to available resources in a logical manner
- Specific authority and responsibility can be assigned
WORK BREAKDOWN STRUCTURE

- Can be developed using a top-down or bottom-up approach
- Can be hardware-related, function-related, or a combination
- Depth of WBS must balance out management effort against planning accuracy (influences technical and cost control)
- For accuracy purposes the WBS should be taken down several levels
- The WBS must be structured for
Work Breakdown Structure (WBS)

- The total program can be described as a summation of subdivided elements.
- Planning can be performed.
- Costs and budgets can be established.
- Time, cost, and performance can be tracked.
- Objectives can be linked to company resources in a logical manner.
- Schedules and status-reporting procedures can be established.
Work Breakdown Structure (WBS) (Continued)

- Network construction and control planning can be initiated.
- The responsibility assignments for each element can be established.
IN SETTING UP A WORK BREAKDOWN STRUCTURE THE ACTIVITIES MUST:

- Have clearly defined start dates
- Have clearly defined end dates
- Must be able to be used as a communicative tool in which you can communicate the expected results
- Be estimated on a “total time duration” not when the individual activities start or end
- Be structured so that a minimum of project office control and documentation (i.e. forms) are necessary
# WORK BREAKDOWN STRUCTURE (WBS)

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>1</td>
<td>Total Program</td>
</tr>
<tr>
<td>2</td>
<td>Project(s)</td>
</tr>
<tr>
<td>3</td>
<td>Task(s)</td>
</tr>
<tr>
<td>4</td>
<td>Subtask(s)</td>
</tr>
<tr>
<td>5</td>
<td>Work Package(s)</td>
</tr>
<tr>
<td>6</td>
<td>Level of Effort</td>
</tr>
</tbody>
</table>

Most common type: Six-Level Indented Structure
THE WBS BREAKS WORK DOWN INTO SMALLER ACTIVITIES THUS REDUCING THE RISK THAT ANY MAJOR OR MINOR ITEM WILL BE OMITTED

WBS: SIX-LEVEL STRUCTURE

<table>
<thead>
<tr>
<th>LEVELS</th>
<th>RESPONSIBILITY</th>
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<tbody>
<tr>
<td>1</td>
<td>Usually specified by the client and managed by the project manager.</td>
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<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Generated by contractor for in-house control and managed by the functional manager(s).</td>
</tr>
<tr>
<td>5</td>
<td></td>
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<tr>
<td>6</td>
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Planning accuracy is dependent on the WBS level selected. The lower the level the greater is the planning accuracy but the higher the management cost.
WBS Tasks

- Have clearly defined start and end dates
- Be usable as a communications tool in which results can be compared with expectations
- Be estimate on a “total” time duration, not when the task must start or end
- Be structured so that a minimum of project office control and documentation (i.e., forms) is necessary
DEVELOPING A WORK BREAKDOWN STRUCTURE (WBS)

UTILITY CAR (1.00.00)

- PROTOTYPE DEVELOPMENT (1.1.0)
- ADVANCED DEVELOPMENT (1.2.0)
- PRE-PRODUCTION QUALIFICATION (1.3.0)
- FINAL PRODUCTION (1.4.0)
WBS Example

<table>
<thead>
<tr>
<th>WBS LEVELS</th>
<th>1 PROGRAM</th>
<th>2 PROJECT</th>
<th>3 TASK</th>
<th>4 SUBTASK</th>
<th>5 WORK PACKAGE</th>
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</tbody>
</table>
WBS Interfacing

Benefits

- The responsibility assignment matrix
- Network scheduling
- Costing
- Risk analysis
- Organizational structure
- Coordination of objectives
- Control (including contract administration)
Work Package Control
Point

FUNCTIONAL ORGANIZATION

WORK PACKAGES
WBS Work Packages

- Represents units of work at the level where the work is performed
- Clearly distinguishes one work package from all others assigned to a single functional group
- Contains clearly defined start and end dates that are representative of physical accomplishment
- Target is 80 hours and about two weeks, but depends on size/nature of the project.
WBS Packages (Continued)

- Specifies a budget in terms of dollars, man-hours, or other measurable units
- Limits the work to be performed to relatively short periods of time to minimize the work-in-process effort
Knowing When To Pull The Plug
REASONS WHY PLANS FAIL

- Corporate goals not understood lower down in the organization/company
- Plans encompass too much in too little time
- Poor financial estimates
- Plans based upon insufficient data
- Poor staff requirements
- Insufficient time allocated for project estimating
OTHER REASONS WHY PLANS FAIL

- No attempt made to systemize the planning process
- Planning was performed by a planning group
- No one knows the ultimate objectives
- No one knows the major milestone dates
- Project estimates are best guesses and are not based on any standards, or history
- No one bothered to see if there would be personnel available with the necessary skills
- People not working towards the same specs
- Constant shuffle of personnel in and out of the project with little regard for the schedule
- Change of management and their objectives.
- Change(s) in the macro environment
Stopping Projects

- Final achievement of the objectives
- Poor initial planning and market prognosis
- A better alternative is found
- A change in the company interest and strategy
- Allocated time is exceeded
- Key people leave the organization
- Personal whims of management
- Problem too complex for the resources available
Behavioral Stoppages

- Poor morale
- Poor human relations
- Poor labor productivity
- No commitment by those involved in the project
Ways to Terminate

- Orderly planned termination
- The “hatchet” (withdrawal of funds and removal of personnel)
- Reassignment of people to higher priority efforts
- Redirection of efforts toward different objectives
- Burying it or letting it die on the vine (i.e., not taking any official action)
Termination Problem

Areas

- Worker morale
- Reassignment of personnel
- Adequate documentation and wrap-up
Planning For Project Completion
Planned Closure

- Transferring responsibility
- Completion of project records
  - Historic reports
  - Post project analysis
- Documenting results to reflect “as built” product or installation
- Acceptance by sponsor/user
- Satisfying contractual requirements
Planned Closure (Continued)

- Releasing resources
  - Reassignment of project office team members
  - Disposition of functional personnel
  - Disposition of materials
- Closing out work orders (financial closeout)
- Preparing for financial payments
Updating The Project Diary

- Every successful project maintains good records
- Periodic and frequent updates
- Complete update on termination
  - Including “as built” documentation
Managing Scope Changes

- Need a solid process here
- Don’t lose ideas
  - Capture every idea, catalog it, save it, along with evaluations
- Evaluate every potential scope change
  - Desirability
  - Cost in time, money and quality
  - Feasibility
Change Management

- YOU CANNOT MANAGE YOUR CUSTOMER WITHOUT MANAGEMENT OF YOUR PROJECT MANAGEMENT PROCESS.

- WHEN YOUR CUSTOMER INITIATES A CHANGE REQUEST, YOU MUST BE ABLE TO PREDICT IMMEDIATELY THE IMPACT ON SCHEDULE, COST AND TECHNICAL PERFORMANCE.
# Unmanaged vs. Managed Changes

<table>
<thead>
<tr>
<th>Where <strong>TIME</strong> is invested</th>
<th>How <strong>ENERGY</strong> is invested</th>
<th>Which <strong>RESOURCES</strong> are used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unmanaged Change</strong></td>
<td>• Back-end</td>
<td>• Senior Management and key players only</td>
</tr>
<tr>
<td></td>
<td>• Rework</td>
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<td>• Enforcement</td>
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<td>• Compliance</td>
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<td></td>
<td>• Supervision</td>
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<tr>
<td><strong>Managed Change</strong></td>
<td>• Front-end</td>
<td>• Stakeholders (internal)</td>
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<tr>
<td></td>
<td>• Education</td>
<td>• Suppliers</td>
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<tr>
<td></td>
<td>• Communication</td>
<td>• Customers</td>
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<td></td>
<td>• Planning</td>
<td></td>
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<td></td>
<td>• Improvements</td>
<td></td>
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<tr>
<td></td>
<td>• Value-Added</td>
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</tr>
</tbody>
</table>
Cost of Corrections

- Definition: $1
- Preliminary Planning: $5
- Detailed Planning: $25
- Execution: $100
- Implementation/Conversion: $1000
Integrated Processes for The 21st Century

Concurrent Engineering
Project Management
Total Quality Management
Risk Management
Change Management
Planning

- The road to project failure is paved with poor plans

**PLANNING: Influencing the future by making decisions today based on missions, needs and objectives.**

- It is an art not science.
Planning is NOT a one time activity
Categories of planning:

- Time
- Cost
- Resources
- Quality
- Contingency
Time Planning

- When to start
- when to finish
- Time plans will be transformed to schedule (time scale)
Time planning steps

1) Divide project into component parts

2) Sequencing component parts in order of accomplishment

3) Assign durations to each component part
Cost Planning

- Allocating direct and indirect costs to the project components
- Expenditure/revenue
- (cost / schedule integration)
Resources Planning

Construction Resources includes:

- money
- Material
- Human resources
- Equipments and tools

Check if the needed resources are available or NOT.
Eliminate idle time.

Resources should be planned considering the budget.
Attention to critical resources for project success
Quality Planning

- what is the minimum accepted quality?
- Should I exceed the required quality?
- How can I achieve this quality?
Contingency (Risk) Planning

- Planning for variability and uncertainty

- “What if” planning to include items subject to variability which are significantly impact project cost and time
Integrating Planning

- Integration of time, cost and resource planning against the same basic structure (WBS)
- Resource budgeting against time
- Cost budgets plotted against time
Thousands of tasks

- The psychologists say our brains can normally comprehend around 7-9 items simultaneously.

- So, divide and subdivide the project.
The WBS
(Work Breakdown Structure)

- It is used to break down the project from one main and relatively big entity into smaller, defined, manageable and controllable units, usually called work groups (packages) or tasks, or, at the finest level of detail (which is undesirable) activities.
Take care!!!

- The deeper you go into the lower levels of the WBS, the more detailed knowledge you’ll need to know.
Who develops the WBS?

- A WBS is developed by the A/E at the end of the design phase
- and/or by the bidders during the proposal (procurement phase)
The CWBS
(Contract Work breakdown Structure)

- After contract award, the project manager expands the WBS into a contract work breakdown structure (CWBS).

- As the initial step in the PLANNING process.
House
1.0

Structure
1.1

Electrical
1.3

Mechanical
1.2

Level 1

Earth work
1.1.1.1

Foundation
1.1.1.2

Structural elements
1.1.2.1

Super structure
1.1.2

HVAC
1.2.1

Piping
1.2.2

Excavation
- Blinding
- Footings
- Tie beams
- Ground slab

Backfilling

Leveling

Level 3

Finishing
1.1.2.2

Plaster

Tile

Painting

Doors & windows

Level 4

CWBS prepared by the Contractor project manager

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Uses of the WBS

- The WBS is used to report program status externally to the owner.
- The CWBS is used internally to plan the program in detail and to collect status information on a periodic basis for the lowest level of the CWBS, namely the schedule activities.
- The basis for technical planning and project achievement.
- Assign responsibilities.
The CWBS

- it is a major task to undo.

  Why???

- Because cost collections begins at a CWBS element,
Conclusion

- The work breakdown structure defines the product elements (work packages).
- And their interrelations to each other and to the product.
- The WBS mostly ends with project tasks.
- Using the tasks you can extract project’s activities.
Construction scheduling
Construction scheduling

- What is the difference between a schedule and a Plan?

- The schedule: putting the plan in time scale.

- Schedule: what would be done in a certain time and who will be working.
Most Common Scheduling methods

- common scheduling methodologies:
  - Bar Chart (Gantt Chart)
  - Critical Path Method (CPM)
  - PERT (program Evaluation & Review Technique)
  - Linear Scheduling Method (LSM)
Bar Chart or Gantt chart
Advantages of Bar / Gantt Chart

1) Plan, schedule and progress are all depicted graphically on a single chart
2) Easily read
3) Provides simple way to schedule small projects
4) Provides summary display of more detailed plans and schedules.
5) Best used for management briefings
Bar Chart or Gantt chart

Activity

Time (weeks)

Current time

A
B
C
D
E
F
Disadvantages of Bar / Gantt Chart

1) Activity dependencies cannot adequately be shown.
2) Difficult to determine how activity progress delays affect project completion.
3) Difficult to establish and maintain for large projects
Critical Path Method (CPM)

- Two basic methods of analysis:

1) ADM -- Arrow Diagramming Method or Activity On Arrow (AOA) or I-J Method
2) PDM -- Precedence Diagramming Method Activity On Node (AON) Method
1) ADM -- Arrow Diagramming Method

- Activity on Arrow (AoA) or noun as i – j method
- In The ADM the activity represented by an arrow.
- The arrow head represents the relation with other activities (interdependency).
- It looks like the following figure
The Excavation activity OR activity i - j with duration of 7 (time unit)
ADM -- Arrow Diagramming Method

- Linear sequencing
- Summation of all activities durations = total duration

Form work
10 2

Steel rebar
11 1

Pour concrete
12 1

Cure concrete
13 7

Total Duration = 2 + 1 + 1 + 7 = 11 days
ADM -- Arrow Diagramming Method

10 → Plumbing
11 → Electrical conduit
12 → Door frames
13 → Windows frames
14 → walls plaster
15 →

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ADM -- Arrow Diagramming Method

1. Sitting out
2. Excavate foundation
3. Order timber
4. make Formwork
5. erect Formwork
6. 

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Dummy activities
 Dummy activities

- Dummy activity has ZERO duration and Does NOT consume resources.

1) Dummies help in activities identification
Dummy activities

If activity R follows P and activity S follows T

does the above figure depict the statement.???
What about this
Dummy activities

If the method statement changed that activity S is dependent on both activities P & T. and activity R dependent on P only.

2) Dummy activities help to maintain the logic of the network
Exercise: draw arrow diagram for the following project.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Predecessor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>--</td>
</tr>
<tr>
<td>B</td>
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<td>A</td>
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<td>C</td>
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<td>B &amp; C</td>
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<td>J</td>
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<td>G &amp; H</td>
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<tr>
<td>K</td>
<td>4</td>
<td>I &amp; H</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td>K &amp; J</td>
</tr>
</tbody>
</table>
The Arrow Network will be:
Network calculations

- **Forward Pass**: deals with the early start and early finish

- **Backward Pass**: deals with the late start and late finish
Example

Beginning of the day convention

Forward Pass calculations to determine the early start and early finish dates

\[ EF = ES + \text{Duration} \]
Example

Backward pass calculations to determine the late start and late finish dates

\[
\text{LS} = \text{LF} - \text{Duration}
\]
## Tabular Schedule

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>ES</th>
<th>EF</th>
<th>LS</th>
<th>LF</th>
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</tbody>
</table>
Early / Late times schedule

Both Early / Late Times Schedule
Total Float (TF)

\[ TF = LS - ES \text{ OR } LF - EF \]

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>ES</th>
<th>EF</th>
<th>LS</th>
<th>LF</th>
<th>TF</th>
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</tr>
</tbody>
</table>

**TF:** The amount of time that an activity can be delayed before it impacts the project completion.

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The critical path: is the longest path in the network and the shortest possible duration.
Determining the Critical Path
Determining the Critical Path

The Critical path passes through activities where TF = 0
## Early Schedule

<table>
<thead>
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<th>Activity</th>
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<th>EF</th>
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<td>20</td>
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</tbody>
</table>
Bar / Gantt chart Early Start / Finish

EF = ES + D
# Early / Late Schedule

<table>
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<th>Duration</th>
<th>ES</th>
<th>EF</th>
<th>LS</th>
<th>LF</th>
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</tbody>
</table>
Bar / Gantt Chart Late Start / Finish

LS = LF - D
**Total Float (TF):** The amount of time an activity can be delayed without delaying the overall project completion.

\[ TF = LF - EF = LS - ES \]

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
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<th>EF</th>
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<td>20</td>
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<td>0</td>
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</tbody>
</table>
2) PDM Precedence Diagramming Method Activity On Node (AON) Method

- PDM is the primary method in use today.
- Used by most of the computer software.

  ➢ MS Project
  ➢ Primavera
PDM Precedence Diagramming Method

- The PDM depicts activities as NODES in the network linked with logic lines.
- The node representing the activity.
- Arrow representing relationship / dependency
- PDM should be read left to right
PDM Precedence Diagramming Method

- PDM looks like the following:

- The shape of the node could be any shape
PDM vs. ADM

ADM

1 2 3

4 5 6

PDM

A

B

C

D

=
PDM vs. ADM

ADM

1 → 2 → 3 → 4 → 5
A → B → C → D

PDM

A → B
A → C
A → D

=
Exercise

- Draw a PDM for the following activities.

<table>
<thead>
<tr>
<th>Activity Label</th>
<th>Activity Description</th>
<th>Predecessor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Lay out</td>
<td>--</td>
</tr>
<tr>
<td>B</td>
<td>Excavation</td>
<td>A</td>
</tr>
<tr>
<td>C</td>
<td>place formwork</td>
<td>B</td>
</tr>
<tr>
<td>E</td>
<td>purchase steel</td>
<td>--</td>
</tr>
<tr>
<td>F</td>
<td>bend steel</td>
<td>E</td>
</tr>
<tr>
<td>G</td>
<td>place steel</td>
<td>C,F</td>
</tr>
<tr>
<td>H</td>
<td>order concrete</td>
<td>--</td>
</tr>
<tr>
<td>D</td>
<td>place concrete</td>
<td>G,H</td>
</tr>
</tbody>
</table>
The PDM will be:
Exercise

- Draw a PDM for the following activities.

<table>
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<tr>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>D</td>
<td>B,C</td>
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<td>E</td>
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</tbody>
</table>
Solution
Activities Relationships

Types of relations between activities:

1) Finish to start – FS
2) Start to Finish – SF
3) Finish to Finish – FF
4) Start to Start - SS
1) Finish to start – FS Relationship

- The traditional relationship between activities.
- Implies that the preceding activity must **finish** before the succeeding activities can **start**.
- Example: the plaster must be finished before the tile can start.
Concrete curing an activity which consumes no resources other than time

28 days is delay time or LAG means that: deshuttering can start 28 days after Concrete has been poured
3) Star to Finish – SF relationship

- Appear illogical or irrational.
- Typically used with delay time OR LAG.
- The following examples proofs that it is logical.
2) Star to Finish – SF relationship

The concrete supplier stipulates 5 days order before delivery.

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3) Finish to Finish – FF relationship

- Both activities must finish at the same time.
- Can be used where activities can overlap to a certain limit.
Finish to Finish – FF relationship

- Set flagpole in the hole
- Position flagpole in the hole
- Backfill hole
- FF
Finish to Finish with delay relationship

Erect scaffolding → Remove Old paint

sanding

painting → inspect → Dismantle scaffolding

FF/1

FF/2
4) Start to Start – SS relationship

- Clean surface
- Spread grout
- Set tile
- Clean floor area

SS
Precedence Network Calculations

- The basic information that should be calculated in the precedence network are:

1) Early activity start (ES)
2) Early activity finish (EF)
3) Late activity start (LS)
4) Late activity finish (LF)
5) Free Float (FF)
6) Total Float (TF)
Precedence Network Calculations

- **ES**: the earliest time that an activity can start as determined by the latest of the early finish times of all immediately preceding activities.

- **EF**: the earliest time that an activity can finish, determined by \( EF = ES + D \)

- **LS**: the latest time that an activity can start without delaying the project completion. \( LS = LF − D \).

- **LF**: the latest time that an activity can be finished without delaying the project completion, as determined by the earliest of the late starts of the immediately succeeding activities.
Precedence Network Calculations

- **FF**: the amount of time that an activity can be delayed before it impacts the start of any succeeding activities.
- **TF**: the amount of time that an activity can be delayed before it impacts the project completion.
- **Lag**: the amount of time that exists between the **EF** of an activity and the **ES** of a specified **succeeding** activity.

\[ \text{LAG}_{AB} = \text{ES}_B - \text{EF}_A \]
Precedence Network Calculations

1) Forward pass calculations

4) Backward pass calculations

5) Calculate total Float (TF = LS – ES OR LF – EF)

2) Calculate the Lag (LAG_{AB} = ES_B - EF_A)

3) Calculate the Free Float (FF) FF = \text{min} \_ \text{LAG}

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6) Determine the Critical Path

The critical path passes through the critical activities where TF = 0

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Bar / Gantt chart

Early Start / Finish

\[ EF = ES + D \]
Bar / Gantt chart

Late Start / Finish

LS = LF - D
Exercise

1) Forward pass calculations

4) Backward pass calculations

2) Calculate the Lag (\( \text{LAG}_{AB} = \text{ES}_B - \text{EF}_A \))

3) Calculate the Free Float (FF) \( \text{FF} = \min \text{LAG} \)

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6) Determine the Critical Path

5) Calculate total Float (TF = LS – ES OR LF – EF)
Activities Duration

- **Activity duration**: is the estimated time required to complete an activity.

- Activity duration mainly calculated based on:
  1) the quantities take off.
  2) labor or machines productivity rates.
Activities Duration

- Durations could be estimated by experience. (previous similar jobs)

- If experience not available, others experience could be utilized.

- If not, handbooks of productivity rates are available provide the required information.
Activities Duration

- Activity duration can be calculated as follows:

\[
\frac{\text{quantity of the work}}{\text{crew hours}} = \text{crew hours}
\]

- \(\frac{\text{qty}}{\text{crew hour}}\) is the productivity rate.
- Time unit is hours could be changed to working days.
Activities Duration

- Example: assume that you have a floor tile area of 600 M², and the productivity rate of a tile mason and one helper is 1.5 M²/hour.

- By applying the previous equation:

  \[
  \frac{600 \text{ M}^2}{1.5 \text{ M}^2/\text{h}} = 400 \text{ hours}
  \]

- If the time unit is working day (8 hours):

  \[
  \frac{400 \text{ hours}}{8 \text{ hours}} = 50 \text{ days}
  \]
Activities Duration

By using two tile masons and two helpers:

\[
\frac{600 \text{ M}^2}{2 \times 1.5 \text{ M}^2/\text{h}} = 200 \text{ hours}
\]

- If the time unit is working day (8 hours):

\[
\frac{200 \text{ hours}}{8 \text{ hours}} = 25 \text{ days}
\]
Activities Duration

By using 3 tile masons and 3 helpers:

\[
\frac{600 \text{ M}^2}{3 \times 1.5 \text{ M}^2/\text{h}} = 133.3 \text{ hours} = 134 \text{ hours}
\]

- If the time unit is working day (8 hours):

\[
\frac{134 \text{ hours}}{8 \text{ hours}} = 16.75 \text{ days} = 17 \text{ days}
\]

- Time preferably should be rounded up:
Activities Duration

By using 4 tile masons and 4 helpers:

\[
\frac{600 \text{ M}^2}{4 \times 1.5 \text{ M}^2/\text{h}} = 100 \text{ hours}
\]

If the time unit is working day (8 hours):

\[
\frac{100 \text{ hours}}{8 \text{ hours}} = 12.5 \text{ days} = 13 \text{ days}
\]
Activities Duration

- Assume in the previous example that this activity is critical and should be finished within 5 days:

- If the working day is 8 hours:

  \[ 5 \text{ days} \times 8 \text{ hours} = 40 \text{ hours} \]

- Apply the equation:

  \[
  \frac{600 \, \text{M}^2}{X} = 40 \text{ hours}
  \]

  \[ X = 15 \, \text{M}^2 / \text{h} \text{ is the productivity rate} \]

- The crew size should be \( 15 / 1.5 = 10 \) gangs
Activities Duration Vs. Direct Cost

- Having defined an activity duration, it means that the planner have already defined the number of resources that will be employed in a particular activity.

- Knowing activity duration and resources employed, it is simple to estimate the activity direct cost.
example

- If the daily production rate for a crew that works in an activity is 175 units/day and the total crew cost per day is 100 $. The material unit cost is 1 $.

- a. Calculate the time and cost it takes the crew to finish 1400 units
- b. Calculate the total unit cost.
Solution

- Activity duration = \( \frac{\text{Qty}}{\text{crew output}} \)
  \[ = \frac{1400}{175} = 8 \text{ days} \]

- Crew cost = 8 days \( \times \) 100 $/day = 800 $

- Material cost = 1400 unit \( \times \) 1 $ = 1400 $

- Total direct cost = Labor cost + Material Cost
  \[ = 800$ + 1400$ = 2200$ \]

- Total Unit cost = total cost / quantity
  \[ = \frac{2200$}{1400}$ = 1.57 $/unit \]
<table>
<thead>
<tr>
<th>Some Factors that affects Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Weather.</td>
</tr>
<tr>
<td>2) Availability, quality and training of operatives.</td>
</tr>
<tr>
<td>3) Familiarity with the work.</td>
</tr>
<tr>
<td>4) Quality of workmanship specified.</td>
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<td>5) Quality of management/supervision.</td>
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<tr>
<td>6) Size and completion date of project.</td>
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<tr>
<td>7) Length and incidence of holidays.</td>
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<tr>
<td>8) Repetitiveness of the work.</td>
</tr>
<tr>
<td>9) Physical constraints of the site. Such as access, size, storage space and etc.</td>
</tr>
</tbody>
</table>
1) Weather

- Allowance for weather is important for activities duration.

- It's particularly critical for excavation and earth moving activities.

- Tow approaches to tackle delay due to weather conditions:
1) Weather Cont.

1) **First approach:** each activity has an added allowance of possible delays due to weather. Fixed percentage is added to each activity for this purpose. (e.g. 10% delay, one day added to a 10 days duration).

But, it produces difficulties for activities with long duration, if these activities are not sensitive to weather.
1) Weather Cont.

2) Second approach: adding a single allowance at the end of the project.

This method works best if the work activities have more or less the same sensitivity to weather. And the weather does not vary significantly from period to period.
1) Weather Cont.

- A delay activity could be added separately to the network represents the weather delay.
2) Availability, Quality and training of operatives

- The more available workmanship, the more flexible is the resources allocation.

- If the quality should conform to high standards, the required time to do the work will increase.

- The more trained workmanship, the more is the productivity rate.
3) Familiarity with the work.

- If the workmanship is familiar with the work, the production rate is higher.

- The higher production rate, the less is the duration. (recall duration formula)
4) Quality of workmanship specified.

- Not all workmanship have the same production rates.
- It varies from nation to another.
- Consider the nationality of the workers.
5) Quality of management/supervision

- The heart of the project management system is CONTROLLING.

- The workmanship should feel that there is someone who is controlling them, otherwise, their production may fall.
6) Size and completion date of project.

- Big size sites need longer time to shift material, manpower and equipments.
- More care for critical activities to complete the project on time.
7) Length and incidence of holidays.

- For actual schedules calendar days are used. Which normally have holydays, anniversaries, etc.

- This time will increase the activities durations which coincide with holydays.
8) Repetitiveness of the work.

- Repetitiveness of the work should increase production rate.

- The more production rate, the less is the duration.
9) Physical constraints of the site.

- These constraints normally increases activities durations. Such as access to the site,
- Conditions of the work site. Congested site hinders performing the work as expected.
- Small Storage spaces leads to material shortage.
Construction activities

- Anything that must be accomplished in order to complete the project may be considered as activity.
Types of Construction activities

1) production/construction activity.
2) Procurement activity.
3) Management activity.
production/construction.

- **production/construction activities:** activities that relate directly to the physical efforts of creating the project.

  - E.g. Concrete work, plaster, tile and etc.
  - Usually use traditional resources, labor, material and equipments.
Procurement.

- **Procurement activities**: These activities include arranging for the acquisition of materials, money, equipment and manpower.

- Influence the start of production activities.

- Should be incorporated in the network if they are long or special orders.
Management.

- **Management activities:** support and administrative tasks.

- Such as, preparing inspection reports, obtain shop drawing approvals. Tracking submittal approval and tests.
Pour concrete

Order concrete

Production Activity

Management Activity

procurement Activity

inspection

steel reinforcement
Constraints

- The reason why two activities must be done in particular order can be termed as constraint.

- Without constraints on a project, all activities theoretically can begin on the first day of construction.
## Types of construction Constraints

1. Physical constraints.
2. Resource constraints.
5. Environmental constraints.
7. Contractual constraints.
8. Regulatory constraints.
Physical constraints.

- Physical constraints exist due to physical process of construction.

- Physical constraints defined by “HOW” the project is to be carried out. (Method of construction).

- You need to erect formwork before you can cast concrete.
Resource constraints

- These constraints imposed wherever two activities cannot be carried out simultaneously because insufficient resources are available.

- E.g. Two activities require a crane to be performed and you have just one crane. So, they should not be performed at the same time.

- E.g. The amount of required concrete per day exceeds the production capacity of a batch plant.
Safety constraints.

- Safety constraints imposed by safety requirements through performing the work.
- Sometime imposes that two activities could not be performed at the same time due to non-safe work conditions. (E.g. overhead and ground level work at the same area.)
- Imposes specific sequence of the work. (E.g. erecting of scaffolding before external paints can start)
- Imposes non-working days due to extremely hot or cold days.
Financial constraints

- Financial constraints: high cost activities could be delayed due to non-availability of cash requirements during construction.

- The amount of cost a company can pay within a specific period of time usually limited. So, try to avoid overlap between high cost activities.
Environmental constraints.

- Environmental constraints include restrictions to the work to avoid environmental violations.

- E.g. not working in certain area during specific times to avoid affecting proliferation of eagles, fish run.
Management constraints.

- Management constraints reflect decisions of management that result in a reasonable benefit of the company.

- E.g. the management decided to borrow from your project resources to be utilized in another project.

- E.g. the management decided to extend the new year holiday another 2 days.
Contractual constraints

- The owner may impose constraints on the construction process.

- E.g. the owner may require a particular phase of the project to be fully completed and occupied before start construction of next phase.

- And he may require to minimize the noise and dust because that portion is occupied and in operation.
Regulatory constraints.

- These type of constraints related to the regulations of the area of construction. Imposed by municipality, government, etc.

- E.g. if the construction site in the downtown, heavy vehicles like concrete mixers prohibited to access the site in a specific times of the day. So, you can just cast concrete at night.
Impacts of constraints on the network

In the initial definition of the network, it is desirable to minimize the number of constraints, because excessive constraints have the following impact of the project.

1) Reduce scheduling flexibility.
2) Lengthen project duration.
3) Generally increase project costs.
4) Confuse basic scheduling logic.
Impacts of constraints on the network

- The imposition of constraints in the network results in linear ordering of activities. Which is not desired. (recall: the linear order of activities prolong the project duration and set most of the activities as critical).
Impacts of constraints on the network

- Only physical constraints should be considered in the early preparation of the network.
- Other constraints can be deferred until actual schedule of activities. Where it can be determined that:
  1) the constraints are not met by the schedule.
  2) It can be addressed by shifting of activities within their available float time.
Resources Allocation & Leveling
Resources Allocation & Leveling

- So far, the network analysis has been considered using one resource only which is time.

- Construction activities in practice use other resources like labor, material, equipment and money.

- Moreover, the network analysis considered no limitations of the traditional resources (labor, material, equipment and money) which is not the case in practice.
Resources Allocation
&
Resources Leveling

- A time only network assumes that any other needed resources are available at any time.

- E.g. if the excavation activity requires three large mechanical excavators, A time only network assumes that these excavators are available on site at the required time. This seems to be uneconomic situation.
When project duration is fixed (Resources Leveling)
resources aggregation diagram (Histogram)

- It is a graphical representation of the resources aggregation vs. project’s duration. And it shows the project resources demand along its duration for different time units, daily, weekly or monthly.

- And it’s important to the contractor to know the amount of needed resources to carry out the job and to check their availability, in addition, the resources histogram shows the fluctuation in the resources demand and enables the scheduler to obtain even resources demand.
Resource Aggregation

- Resources aggregation: is a summation of the resources that are used to carry out the program on a *time period basis*. For example, day to day, or week to week.
resources aggregation
Priorities & Sorts

- The activities making up the network must be listed in order of their priority of resources allocation.
- The network shows the logical sequence of activities. (predecessor and successor).
- The listing of activities must therefore reflects the dependency of some activities.
## Activities Sort

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>ES</th>
<th>TF</th>
<th>Resource unit</th>
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Activity sort reflects the logic sequence of the network.
## Major Sort

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Activity sort with ES time as Major sort
## Major & Minor Sorts

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Activity sort with ES time as Major sort & TF as Minor Sort
Early start resources aggregation

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Late start

Another histogram can be obtained if Late start considered. Shows different resources demand.

And many histograms can be obtained considering a different time in the network.

Each histogram shows different resources demand.
## Late start Sort

<table>
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Activity sort with LS time as Major sort & TF as Minor Sort
Late start resources aggregation diagram (Histogram)

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Activity sort with ES time as Major sort & TF and duration as Minor Sorts

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# Activities Sort

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Activity sort with LS time as Major sort & TF and duration as Minor Sorts
Late start resources aggregation

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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</tr>
</tbody>
</table>

Total Labor: 8 8 8 8 8 2 2 2 2 2 2 15 15 11 11 12 20 20 17 17 6 6
Late start resources aggregation diagram
Early start

Late start

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Early/Late start resources aggregation diagram
Smoothing/Leveling

- Let us program activity F to start by its late start day which is day 17
- And activity I to start by day 14.
- The resulting resources aggregation histogram will be as follows:
Smoothing/Leveling

- Let us program activity H to start by its late start time.

- So its resources demand starts with its Late start date.

- The resulting resource aggregation and histogram will be as follows:
<table>
<thead>
<tr>
<th>Total</th>
<th>Labor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

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Time: 2 4 6 8 10 12 14 16 18 20 22
Smoothing/Leveling

- Let us program

1) activity D to start on 10\textsuperscript{th} day.
2) activity B to start by its early start time 6\textsuperscript{th} day.
3) activity H to start on 12\textsuperscript{th} day.
4) activity E to start 11\textsuperscript{th} day.
5) activity F to start by late start 17\textsuperscript{th} day.
6) activity I to start by late start 19\textsuperscript{th} day

- The resulting resource aggregation and histogram will be as follows:
Smoothing/Leveling

- In case activity D is splitable activity. It could be interrupted to be carried out in tow parts.

- Let us program activity B to start on the 7\textsuperscript{th} day.

- And activity H to starts by its Late start day.

- And activity E to start on the 14\textsuperscript{th} day.

- The resulting resource aggregation and histogram will be as follows:
Early start resources aggregation

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Early Start or Early Finish

- There are many solutions between the limits of Early Start and Late start.

- The optimal solution is zero fluctuation histogram. Which is hard to be achieved.

- It is preferred to solve the problem toward the Early start resources aggregation diagram.

**WHY?!**
**Early Start or Early Finish**

- Because if there are labor availability problems to be overcome, they will occur in the early beginning of the project.

- By other words, if the program based on the Late Start date, it means that all the activities are Critical, and any labor problem will affect the project completion.
When Resources are Limited

Resources Allocation
When Resources are Limited

Resources Allocation

- The previous method of resources aggregation has been carried out within a fixed project duration.
- The basic objective was to optimize the use of the resources and to know the amount of resources needed to carry out the job on time period basis.
- And to maintain the network based duration.
Allocation within resources restraints

- Another situation which you may face in practice is the restricted resources availability.

- Where you have to carry out the job with the available resources only.

- In this case the project duration may be prolonged to suit the availability of the restricted resources.
Resources Allocation

<table>
<thead>
<tr>
<th>Activity</th>
<th>Desc.</th>
<th>Duration</th>
<th>LS</th>
<th>EF</th>
<th>FF</th>
<th>TF</th>
<th>LF</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>8H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>C</td>
<td></td>
<td>7H</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
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<td>F</td>
<td></td>
<td>8H</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Early start resources aggregation

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| Total Labor | 8  | 16 | 16 | 16 | 16 | 16 | 13 | 13 | 13 | 7  | 7  | 7  | 7  | 7  | 10 | 8  | 8  | 8  | 4  |

**Early start resources aggregation diagram (Histogram)**

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Solve the schedule

- Assume that the available labors in the company restricted to 10 helpers, and the company decided to carry out the job without resorting to hire more labor.

- The resulting program will exceed the Early finish date based on the network.
Resources based scheduling
Scheduling limited resources

- Tow methods of examination:
  1) Series method
  2) Parallel method
Rules for scheduling activities with limited resources

1) schedule activities to start as soon as their predecessors have been completed.

2) if more than one activity using a specific limited resources can be scheduled, priority is given to the activity with early Late Start. (LS as Major Sort)

3) If tow or more activities have the same Late start, give priority to the activity with least Total Float. (TF as Minor Sort)

4) If the activities have the same Total Float in the minor sort, give the priority to the activity with the Largest Number of Resources.

5) If the activities are tied in the number of resources, give priority to the activity that has already started.
Resources Allocation

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## Activity list

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>LS</th>
<th>TF</th>
<th>Resource unit</th>
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<tr>
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<td>20</td>
<td>0</td>
<td>4 H</td>
</tr>
</tbody>
</table>

Activity sort with LS time as Major sort & TF as Minor Sort
Money and Network Schedules
Money and network schedules

- Reminder, cost was one of the elements of project constraints triangle (COST, TIME & QUALITY)

- An effective management tries to minimize and integrate the above mentioned elements.
Money and network schedules

- CPM provides a mean for relating time and money.

- The application of resources to a project (materials, manpower and machinery) related to another resource which is MONEY.

- The value of the resources for each activity represents a component of project cost.
Construction costs includes:

1) Materials costs.
2) labor costs.
   a) direct cost
   b) indirect cost
3) plant and equipment costs
4) overhead costs
   a) job overhead costs (site)
   b) operating overhead costs (head office)
5) profit.
Project Cash Flow

- It is quite significant to the contractor to know the amount of money that would be spent in each stage of the project. (Expenditures) **CASH OUT**

- And compare it to the amount of money that would be received. (Income) **CASH IN**

- When studying cash flow, it is very important to determine the actual dates when the expenditures (cost) will take place.
The curve represents the cumulative expenditures of a project direct and indirect Costs over time is called the S-curve.
Project Income (Cash In)

- The flow of money from the owner to the contractor is in the form of progress payments.
- Estimates of work completed are made by the contractors periodically (usually monthly)
- These estimates are based on evaluations of the percentage of total project completion or actual field measurements of quantities placed.
Retention

- Retention is the amount of money retained by the owner from every invoice, before a payment is made to the contractor.

- This is to ensure that the contractor will continue the work and that no problems will arise after completion.

- This retainage amount ranges from 5% to 10%
Cumulative income

$
Project cash flow

- A project’s cash flow is the difference between the project’s Expenditures and income

Cash flow = Cash in – Cash out
= Income - Expenditures
Cash Flow Analysis

- Cash flow analysis consists of a detailed examination of funds disbursement (expenditures) and the receipt of revenue.

- Cash flow shows if surplus fund available during project, or if negative cash position will occur during construction.

- The cash position of contractor during project whether positive or negative is important.
Negative cash position

- Negative cash position means that the revenues obtained from a project insufficient to meet the financial obligations (expenditures) of the project.

- In this case other fund from the company or from outside sources must be used.
Positive cash position

- Positive cash position means that the revenues obtained from a project exceed the financial obligations (expenditures) of the project.

- In this case surplus (extra) fund available with the contractor.

- And the contractor may invest this surplus funds for short duration.
Overtrading

- Overtrading: arises when the current liabilities of a company exceed the current assets, even though the business is solvent.
Minimizing Contractor Negative Cash Flow

- It is very essential to the contractor to minimize his negative cash flow because this may hinder him during performing the contract due to lack of financial resources.

- The procedures the contractor may follow to minimize negative cash flow are:
Minimizing Contractor Negative Cash Flow

1) Asking for advanced or mobilization payment

2) Loading of rates, in which the contractor increases the prices of the earlier items in the bill of quantities. This ensures more income at the early stages of the project.

3) Adjustment of work schedule to late start timing in order to delay payments. In this case, the contractor should be aware that delay might happen will affect the project completion time and may subject him to liquidated damages.

4) Reduction of delays in receiving revenues.

5) Achievement of maximum production in the field to increase the monthly payments.

6) Reducing the retention.

7) Adjust the timing of delivery of large material orders to be with the submittal of the monthly invoice.

8) Delay in paying labor wages, equipment rentals, material suppliers and subcontractors.
Advanced Payments

- This is amount of money paid to the contractor for mobilization purposes. Then, it is deducted from contract progress payment.

- The contractor may request an advanced or mobilization payment from the owner. This shifts the position of the income profile so that no negative cash position will occur.
Effect of advanced payment on improving cash flow
Time-Cost Trade-Off

Some amount of knowledge brings more......
Time-Cost Trade-Off

- Projects managers seek the work to be carried out at minimum cost.

- Therefore, they are prone to minimum cost duration (Normal Duration).

- Unfortunately, minimum cost & minimum duration rarely coincide.
Time-Cost Trade-Off

- The cost of an activity depends mainly on the amount of used resources.

- Adding more resources to an activity increases the cost, but not necessarily result in proportionate decrease in the duration.
Time & Cost Theoretical Relationship

![Graph showing theoretical relationship between Direct Cost and Duration](image_url)
Time-Cost Trade-Off

For the following discussions it is important to remember:

- Direct costs: Related to putting the facility components in place. They represent the resources used by an activity. (material, labor and equipment).
Time-Cost Trade-Off

- Indirect job costs (job overhead): costs that could not be attributed to a specific work item. (such as, site offices, superintendents, security fence & etc)

- These costs are generally incurred whether or not productive work accomplished.

- Longer project duration will result in higher indirect costs.
Time-Cost Trade-Off

- Operating Overhead costs (company overhead): If the cost cannot be attributed to any specific job, they are operating overhead costs, costs of running business. (head office costs, communications & etc).

- These costs continue as long as the company exists even one project is running.
Logic of Time-Cost Trade-Off

- Assumption: increasing or decreasing project's duration will lead to increased direct costs for the project.
Direct Costs

Project duration

General relation of direct costs to project duration
Logic of Time-Cost Trade-Off

- Assumption: *decreasing a project’s duration will lead to lower indirect costs.*
Indirect Costs

Project duration

indirect costs

General relation of indirect costs to project duration
Logic of Time-Cost Trade-Off

- Assumption: *A project’s duration can be decreased by decreasing the duration of one or more critical activities on the critical path.*
Assumption: Decreasing a project’s duration may increase or decrease the total cost of a project depending upon whether the additional direct costs required to decrease the activity duration are greater or less than indirect costs savings of decreasing the project’s duration.
Project Costs

Total project costs

Direct costs

Indirect costs

Project duration

General relation of project costs to project duration
Time-Cost Trade-off

- The previous analysis suggests that in performing Time-Cost Trade-off analysis, it is necessary to determine the cost of decreasing the critical path by one time unit (day, month & etc).
- The cost will vary depending upon which activity duration decreased.
- Usually, select the activity with least shortening costs. (lowest additional cost per day of shortening) to minimize the additional costs of shortening.
Reducing Project Duration

- As the critical path of the network decreased, some non-critical activities lose some amount of their total float.
Reducing Project Duration

- As the projects duration decreases, the number of critical paths through the network increases.
Reducing Project Duration

- If more than one critical path exist, it is necessary to reduce all critical paths in the network simultaneously, which becomes expensive.
Four Different Solutions for Each Network

- The schedule can be viewed in several different ways in order to satisfy the client. A client may wish to perform the project in the least cost, or in the least time. Or in any manner satisfies him.

1) **All Normal**: the original network and activity duration result in all normal solution, based on each activity being performed in its “NORMAL” least cost manner.

Remember, it is not necessarily the least cost or least time solution to schedule a project.
2) **Least Cost:** considering both direct and indirect costs, it may be possible to find a project duration that minimizes these total costs. By paying more to decrease one or more critical activity (direct cost) and save greater indirect costs. (Means that the result will be total cost saving.)
Project Costs

Total project costs

Direct costs

indirect costs

Project duration

General relation of project costs to project duration
3) **Least Time:** A project can be shortened beyond its least cost duration. Until a point reached where no activities in the critical path can be physically shortened regardless of how many resources are applied. (results in higher costs)
Four Different Solutions for Each Network

4) **All crash:** in this solution, every activity has been shortened as much as physically possible. Its duration the same as the least time solution, but its costs greater. Because the direct cost increases without further reductions in the indirect costs.

- **A fully crashed schedule occurs when all activities shortened to their shortest possible duration.**
Four Different Solutions for Each Network

All crash

- It is not an efficient approach since some non-critical activities will be shortened without having any shortening influence on the project duration.
Logically reducing Project Duration

- The logical approach is to shorten those activities that contribute to reduce the project duration.

- To begin the time-cost trade-off in a rational manner, basic calculations needed.

- First compute the early start and early finish times for each activity.
Reducing Project Duration to shortest possible duration

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Reducing Project Duration to shortest possible duration
## Duration-Cost Data

<table>
<thead>
<tr>
<th>Activity</th>
<th>Normal Duration</th>
<th>Crash Duration</th>
<th>Normal Cost</th>
<th>Crash Cost</th>
<th>days to Shorten</th>
<th>cost per Shorten</th>
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<td>450</td>
<td>800</td>
<td>1</td>
<td>350</td>
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</tbody>
</table>
Logically reducing Project Duration

- By computing the link lag values between activities. \((\text{Lag} = \text{ES}_B - \text{EF}_A)\). It is logical that there is at least one path between the first activity and last activity where lag values are 0.

- These activities forming the critical path. (other solution can be derived by computing TF).

- In the previous network. Activity A, B, F, H and L forming the critical path.
Logically reducing Project Duration

- To shorten the project’s duration it is essential to shorten one of the critical activities. A or B or F or H or L.

- Without shortening the project will end after 28 days with a cost of $5300.

- This is the normal duration cost. And any decrease in duration will increase the direct cost.

- The following table shows information about activities.
Identifying activities for 1\textsuperscript{st} compression cycle

<table>
<thead>
<tr>
<th>Activity</th>
<th>A</th>
<th>B</th>
<th>F</th>
<th>H</th>
<th>L</th>
</tr>
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<tbody>
<tr>
<td><strong>Cost/day</strong></td>
<td>∞</td>
<td>200$</td>
<td>150$</td>
<td>250$</td>
<td>350$</td>
</tr>
</tbody>
</table>

- Cannot be shortened
- Least cost activity to shorten

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# Summary of the first compression cycle

<table>
<thead>
<tr>
<th>Cycle #</th>
<th>Activity to shorten</th>
<th>Can be shortened</th>
<th>NIL</th>
<th>Days shortened</th>
<th>Cost per day</th>
<th>Cost per cycle</th>
<th>Total cost</th>
<th>Project duration</th>
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<tbody>
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<td>0</td>
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<td>2</td>
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Identifying activities for 2\textsuperscript{nd} compression cycle

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<th>H</th>
<th>L</th>
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<tr>
<td>Cost/day</td>
<td>$\infty$</td>
<td>$\bullet$ 200$</td>
<td>$\infty$</td>
<td>250$</td>
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<tr>
<td>350$</td>
<td>$\infty$</td>
<td>$\bullet$ 200$</td>
<td>$\infty$</td>
<td>250$</td>
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## Summary of the 2\textsuperscript{nd} compression cycle

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<th>Cost per day</th>
<th>Cost per cycle</th>
<th>Total cost</th>
<th>Project duration</th>
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<td>150 $</td>
<td>300 $</td>
<td>5600</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>200</td>
<td>200</td>
<td>5800</td>
<td>25</td>
</tr>
</tbody>
</table>
Identifying activities for 3\textsuperscript{rd} compression cycle

<table>
<thead>
<tr>
<th>Activity</th>
<th>A</th>
<th>B,C</th>
<th>F</th>
<th>H</th>
<th>L</th>
<th>Cost/day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\infty$</td>
<td>300</td>
<td>$\infty$</td>
<td>250$</td>
<td>350$</td>
<td></td>
</tr>
</tbody>
</table>

Dr Nabil Dmaidi 394
Summary of the 3rd compression cycle

<table>
<thead>
<tr>
<th>Cycle #</th>
<th>Activity to shorten</th>
<th>Can be shortened</th>
<th>NIL</th>
<th>Days shortened</th>
<th>Cost per day</th>
<th>Cost per cycle</th>
<th>Total cost</th>
<th>Project duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<td>--</td>
<td>5300</td>
<td>28</td>
</tr>
<tr>
<td>1</td>
<td>F</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>150 $</td>
<td>300 $</td>
<td>5600</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>200</td>
<td>200</td>
<td>5800</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
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<td>2</td>
<td>1</td>
<td>250</td>
<td>250</td>
<td>6050</td>
<td>24</td>
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</tbody>
</table>
Identifying activities for 4\textsuperscript{th} compression cycle

<table>
<thead>
<tr>
<th>Activity</th>
<th>A</th>
<th>B,C</th>
<th>F</th>
<th>H</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost/day</td>
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<td>∞</td>
<td>∞</td>
<td>350$</td>
</tr>
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</table>
## Summary of the 4th compression cycle

<table>
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<tr>
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<th>Activity to shorten</th>
<th>Can be shortened</th>
<th>NIL</th>
<th>Days shortened</th>
<th>Cost per day</th>
<th>Cost per cycle</th>
<th>Total cost</th>
<th>Project duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>--</td>
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<td>5300</td>
<td>28</td>
</tr>
<tr>
<td>1</td>
<td>F</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>150 $</td>
<td>300 $</td>
<td>5600</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>200</td>
<td>200</td>
<td>5800</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>H</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>250</td>
<td>250</td>
<td>6050</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>B,C</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>300</td>
<td>600</td>
<td>6650</td>
<td>22</td>
</tr>
</tbody>
</table>
## Identifying activities for 5th compression cycle

<table>
<thead>
<tr>
<th>Activity</th>
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<th>B,C</th>
<th>F</th>
<th>H</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost/day</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
<td>350$</td>
</tr>
</tbody>
</table>
# Summary of the 5th compression cycle

<table>
<thead>
<tr>
<th>Cycle #</th>
<th>Activity to shorten</th>
<th>Can be shortened</th>
<th>NIL</th>
<th>Days shortened</th>
<th>Cost per day</th>
<th>Cost per cycle</th>
<th>Total cost</th>
<th>Project duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>5300</td>
<td>28</td>
</tr>
<tr>
<td>1</td>
<td>F</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>150 $</td>
<td>300 $</td>
<td>5600</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>200</td>
<td>200</td>
<td>5800</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>H</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>250</td>
<td>250</td>
<td>6050</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>B,C</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>300</td>
<td>600</td>
<td>6650</td>
<td>22</td>
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<tr>
<td>5</td>
<td>L</td>
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<td>1</td>
<td>350</td>
<td>350</td>
<td>7000</td>
<td>21</td>
</tr>
</tbody>
</table>
Identifying activities for 6\textsuperscript{th} compression cycle

<table>
<thead>
<tr>
<th>Activity</th>
<th>A</th>
<th>B,C</th>
<th>F</th>
<th>H</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost/day</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
<td>∞</td>
</tr>
</tbody>
</table>
Project Monitoring and Control

- Project control can be divided as follows:

- First: monitoring, understanding what is happening on a project. Obtaining information about project by some means.

- Second: Control, is the action taken in response to the information obtained.
Construction time

- Construction progress generally measured in DAYS.

- Tow general uses of the term day:
  - Calendar day: Any day of the year.
  - Working day: consist of weekdays excluding holydays.
Monitoring Project status

- Some means of Information retrieval:
  - Photography
  - Check-off lists
  - Bar chart.
# Check-off list

<table>
<thead>
<tr>
<th>ID</th>
<th>Activity Description</th>
<th>Scheduled Start</th>
<th>Scheduled Finish</th>
<th>Actual Start</th>
<th>Actual Finish</th>
<th>Status %</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.01</td>
<td>5th floor columns</td>
<td>24</td>
<td>28</td>
<td>26</td>
<td>30</td>
<td>50</td>
<td>Weather delay</td>
</tr>
</tbody>
</table>
Communicating the Schedule
Communicating the Schedule

- **Anticipated User**
  - Top management - No need for great details
  - Middle Management - looking for detailed breakdown covering long time span.
  - Low-level Management - Superintendents, foreman - detail information, cover short period of time.

- **Communicating Devices**
  - Verbal and written instructions and reports
  - Tabular format
  - Graphical representation
    - bar chart
    - time scaled
Time-Scaled Arrow Diagram
Remodeling Chemical Laboratory
Project Control
Project Control

- Major objectives for a good control plan:
  1. Should accurately represent the work.
  2. Permit deviations to be detected, evaluated and forecasted.
  3. Should make provision for periodic corrective actions.
Level of Control

- Small projects - low cost - short duration
  - Detailed network
  - Reporting mechanism
- Middle-sized projects (300 activities)
  - Detailed network
  - Summary network
  - Area and craft network
Target Activities Properties

- The scheduler has to choose between early start schedule or target schedule.

**Two Major Considerations:**

1. The way in which the resources are applied to the activity.
2. The manner in which the activity is to be measured.

- In all the previous work we assumed that each activity has a constant rate of utilization.
We will keep this assumption knowing that the most probable one is:

- If an activity has expended a third of its cost, the activity is said to be one-third finished.
- The most important consideration in measuring the completion of activities is that the measure should be consistent throughout the project.
Target Activity Durations

(c) Variable resource rates

(d) Increasing resource rates

(c) Decreasing resource rates

(b) Probably as practiced

(a) As assumed

Planned activity duration

Resource rate

Resource rate

Resource rate

Resource rate

Resource rate
Monitoring the Project

1. Feedback from direct contact
   - Efficient but requires close cooperation between the manager and field personnel.
Monitoring the Project (cont.)

2. Feedback from photography
   - Record progress and provide permanent documentation of the work.
   - Tell nothing about the time taken to perform the work.
3. Feedback from check-off list

- Planner prepares a check-off list that is started, to be continued, or to be finished in the next time interval.
- Effective if the reporting periods are short “Daily, Weekly” and small number of activities involved.
- Disadvantage: false reporting
Monitoring the Project (cont.)

4. Feedback from bar chart
5. Feedback from networks

**Advantage:**
Superintendent has complete information about the status of the project.

**Disadvantage:**
Diagram may appear confusing to field personnel.
Setting the Target Schedule

Early Start Schedule: As Target for Control
- Problem:
  Required high effort to keep the plan working

Late Start Schedule As Target for Control
- Problem:
  Because every activity is timed to start as its latest, project overruns are sure to follow.
Target Schedule

- Activities may be positioned early or late start or somewhat in between.
- Non-critical activities allow intermediate start.
Anticipated target S-Curve

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The S-Curve field

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### Sample Project Cost Data

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration (Days)</th>
<th>Rate ($/Day)</th>
<th>Total Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2500</td>
<td>1000</td>
<td>2,500,000</td>
</tr>
<tr>
<td>B</td>
<td>1720</td>
<td>3400</td>
<td>5,808,000</td>
</tr>
<tr>
<td>C</td>
<td>3300</td>
<td>900</td>
<td>2,970,000</td>
</tr>
<tr>
<td>D</td>
<td>5100</td>
<td>500</td>
<td>2,550,000</td>
</tr>
<tr>
<td>E</td>
<td>6,200</td>
<td>1200</td>
<td>7,440,000</td>
</tr>
<tr>
<td>F</td>
<td>2500</td>
<td>1000</td>
<td>2,500,000</td>
</tr>
<tr>
<td>G</td>
<td>1,100</td>
<td>1000</td>
<td>1,100,000</td>
</tr>
</tbody>
</table>
Early Start Tree
Late Start Tree

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Target Network

DR. Nabil Dmaidi
Project S-Curve

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Actual Versus Target S-Curves

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Earned Value
“Earned Value” – Official View

- The budgeted cost of the work to be performed
  - Also known as BCWP
  - Each task in the WBS is assigned a BCWP based on its individual cost.
  - Project BCWP is total of all task BCWP
“Earned Value” – Other View

- Use of EV when contracting for an external customer is different
- EV of a task is always $0 unless a payment is made on completion of the task.
  Usually happens at major milestones only
- EV of the project is how much the customer will have paid by final delivery.
- This usage does not work for classic variance analysis, so tuck it away in the back of your mind.
Variance

- Any schedule, technical performance or cost deviation from a specific plan.
- Used by all levels of management to verify budgeting and scheduling.
Variance (con’t)

- Must compare scheduling and budget variance at the same time
  - Cost variance: deviations from the budget – not a measure of work scheduled vs work completed
  - Schedule variance: deviations from work planned – not a measure of changes in cost
Primary Measurement Methods

- Measurable efforts
  - Discrete increments of work with definable schedule and tangible results (i.e., real tasks with a deliverable)

- Level of effort
  - Work that is not in discrete, measurable tasks (e.g., project management)
Basic Cost Measurements

- **BCWS**: Budgeted Cost of Work Scheduled
  - How much you plan to pay

- **BCWP**: Budgeted Cost of Work Performed
  - How much you intended to pay for what’s been done so far

- **ACWP**: *Actual* Cost of Work Performed
  - What it’s really cost you to do the work completed so far.
Determining Cost Variance

Cost Variance is easy:

\[ CV = BCWP - ACWP \]

If CV < 0, then you’ve got a cost overrun
Schedule Variance

- Also quite simple:

\[ SV = BCWP - BCWS \]

In this case, if \( SV < 0 \), then you’re behind schedule
Normalization

- Both CV and SV are usually expressed as percentages to allow simple comparison:

\[
\begin{align*}
CVP &= \frac{(BCWP - ACWP)}{BCWP} \\
    &= \frac{CV}{BCWP} \\
SVP &= \frac{(BCWP - BCWS)}{BCWS} \\
    &= \frac{SV}{BCWS}
\end{align*}
\]
Example Project

- Schedules to spend $100K in each of first 4 weeks
- Actuals at end of week 4: $325K
  - BCWS = $400K
  - ACWP = $325K
- What conclusions can you draw?
  - CV = BCWS – ACWP
  - CV = $400K - $325K = $75K
  - Under budget
- Is project on schedule?
Example Project (con’t)

- Suppose BCWP is $300K
- What conclusions now?
  - SV = BCWP – BCWS
  - SV = $300k - $400K = -$100K
  - Behind schedule
Where to Draw the Line

- How much variance to allow depends on a number of factors:
  - Life-cycle phase
  - Length of life-cycle phase
  - Length of project
  - Type of estimate
  - Accuracy of estimate
Sample Variance Thresholds

- **Section**
  - > $7500 and > 25% of costs
  - > $25K and > 10%
  - > $200K

- **Department**
  - > $20K and > 25%
  - > $75K and > 10%
  - > $400K

- **Division**
  - > $100K and > 10%
Performance Indices (con’t)

- Cost Performance Index
  - CPI = BCWP/ACWP
- Schedule Performance Index
  - SPI = BCWP/BCWS

Analysis
  - CPI > 1.0 → exceptional performance
  - CPI < 1.0 → poor performance
  - Similar for SPI
Management Reserve

- The padding always added to a project for unexpected costs that are *within* project scope
  - *Not* an allowance for changes to scope
  - *Not* part of the cost estimate
- Added by upper management, not the project manager.
Management Reserve

- Contracted Cost
- Actual Cost
- Management Reserve
- Released Budget

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451
Government Requirements

- Cost reporting must include
  - BCWS
  - BCWP
  - ACWP
  - Estimated cost at completion
  - Budgeted cost at completion
  - Cost and schedule variances with explanations
  - Traceability
Variance Analysis Questions

- What is the problem causing the variance?
- What is the impact on time, cost and performance?
- What is the impact on other efforts, if any?
- What corrective action is planned or under way?
- What are the expected results of the corrective action?
Performance Problems

- BCWP calculations rely on “percent complete” for the “most accurate calculation.
- How do you know how much cost/time has really been planned for tasks that are in progress?
Determining % Complete

- Allocate by percent time spent – but what if you spend more time than allocated?
- Allocate 50% at start of task, 50% at end of task
- Allocate 100% at start of task
- Allocate 100% at end of task
  - Best solution if you keep tasks small
- Allocate value at Milestones (as mentioned earlier when contracting)
- others
Budget at Completion

- **BAC**
  - The sum of all BCWS
  - What the project *should* cost
  - Contains all direct and indirect costs
Estimate at Completion

- **EAC**
  - Cumulative actuals + estimate to complete
  - Best guess at final cost
  - Produced periodically
Variance at Completion

- **VAC**
  - \( VAC = BAC - EAC \)
Summary

- Cost, in the form of Earned Value or BCWS, can be used to analyze progress of a project.
- Both cost and schedule variance must be analyzed to make sense of what’s happening.
Earned Value Analysis
Earned Value Analysis (EVA)

Foundations of modern cost control

What’s more important?

- Knowing where you are on *schedule*?
- Knowing where you are on *budget*?
- Knowing where you are on *work accomplished*?

Earned Value Analysis (EVA) addresses all three:

- It compares the PLANNED amount of work with what has actually been COMPLETED to determine if COST, SCHEDULE, and WORK ACCOMPLISHED are progressing as planned.
Input data for EVA

- Activity schedule, usually in the form of a bar chart.
- Budgeted cost for each activity.
- Percent complete for each activity.
- Cost to date for each activity.
Earned Value Reporting - Costs

- Budgeted Cost of Work Performed (BCWP) = earned value of project
- Actual Cost of Work Performed (ACWP)
- Cost Variance (CV) – Difference between earned and actual costs for the completed work
- Cost Performance Index (CPI or CI)

\[ CV = BCWP - ACWP \]

\[ CPI = \frac{BCWP}{ACWP} \]

- CPI = 1, on budget
- CPI < 1, over budget
- CPI > 1, under budget
Earned Value Reporting - Schedule

- Budgeted Cost of Work Performed (BCWP)
- Budgeted Cost of Work Scheduled (BCWS)
- Schedule Variance (SV)

\[
SV = BCWP - BCWS
\]

\[
SPI = \frac{BCWP}{BCWS}
\]

SPI = 1, on schedule
SPI < 1, behind schedule
SPI > 1, ahead of schedule

- Schedule Performance Index (SPI or SI)

Difference between the value of work that was planned for completion and the value of the work that was actually completed
Earned Value Reporting

From: Verzuh (modified)
Earned Value Reporting – Activity A Example

<table>
<thead>
<tr>
<th>Week</th>
<th>BCWS</th>
<th>BCWP</th>
<th>ACWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

From: SBG
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## Earned Value Reporting – Activity B Example

<table>
<thead>
<tr>
<th>Week</th>
<th>BCWS</th>
<th>BCWP</th>
<th>ACWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>1000</td>
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<tr>
<td>3</td>
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<td>500</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>500</td>
<td>500</td>
</tr>
</tbody>
</table>
# Earned Value Reporting – Activity C Example

<table>
<thead>
<tr>
<th>Week</th>
<th>BCWS</th>
<th>BCWP</th>
<th>ACWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>814</td>
<td>300</td>
<td>814</td>
</tr>
<tr>
<td>2</td>
<td>814</td>
<td>400</td>
<td>686</td>
</tr>
<tr>
<td>3</td>
<td>814</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>4</td>
<td>814</td>
<td>428</td>
<td>400</td>
</tr>
</tbody>
</table>

![Graph with BCWP, BCWS, and ACWP lines]

From: SBG

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Earned Value Reporting – Project (Activities A, B, C) Example

<table>
<thead>
<tr>
<th>Week</th>
<th>BCWS</th>
<th>BCWP</th>
<th>ACWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2114</td>
<td>1800</td>
<td>2314</td>
</tr>
<tr>
<td>2</td>
<td>2114</td>
<td>1900</td>
<td>2186</td>
</tr>
<tr>
<td>3</td>
<td>2114</td>
<td>1300</td>
<td>1800</td>
</tr>
<tr>
<td>4</td>
<td>1114</td>
<td>1128</td>
<td>1100</td>
</tr>
</tbody>
</table>

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### Earned Value Reporting – Project
(Activities A, B, C) Example

<table>
<thead>
<tr>
<th>Week</th>
<th>BCWS</th>
<th>BCWP</th>
<th>ACWP</th>
<th>CI</th>
<th>SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$2,114</td>
<td>$1,800</td>
<td>$2,314</td>
<td>0.78</td>
<td>0.85</td>
</tr>
<tr>
<td>2</td>
<td>4,228</td>
<td>3,700</td>
<td>4,500</td>
<td>0.82</td>
<td>0.88</td>
</tr>
<tr>
<td>3</td>
<td>6,342</td>
<td>5,000</td>
<td>6,300</td>
<td>0.79</td>
<td>0.79</td>
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<tr>
<td>4</td>
<td>7,456</td>
<td>6,128</td>
<td>7,400</td>
<td>0.83</td>
<td>0.82</td>
</tr>
</tbody>
</table>

**Graphs:**
- **SI (Schedule Index):**
  - Week 1: 0.85
  - Week 2: 0.88
  - Week 3: 0.79
  - Week 4: 0.82

- **CI (Cost Index):**
  - Week 1: 0.78
  - Week 2: 0.82
  - Week 3: 0.79
  - Week 4: 0.83

From: SBG

Dr Nabil Dmaidi
Earned Value Reporting – Project (Activities A, B, C) Example

Graph shows trend of cost and schedule indices

From: SBG
### Class Exercise: BCWS

#### Schedule and Estimated Costs

<table>
<thead>
<tr>
<th>Task</th>
<th>Est. Cost</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
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Example:  
10,000 x 100%  
+ 112,000 x 25%  
= 38,000
## Class Exercise: BCWP

### Actual Percent Performed per Week

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<tr>
<th>Task</th>
<th>Est. Cost</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
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↓ Data Date

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# Class Exercise: ACWP

## Actual Costs

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<th>Week 7</th>
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↓ Data Date

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**Class Exercise: SPI and CPI**

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<th>Week 1</th>
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<th>Week 6</th>
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</table>
Rolling Up EVA Measures

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Risk Management
Basic Concept

Risk management focuses on:
- Known unknowns
- Proactive management
The alternative to proactive management is reactive management, also called crisis management. This requires significantly more resources and takes longer for problems to surface.
RISK MANAGEMENT

- RISK MANAGEMENT FOCUSES ON THE FUTURE

- RISK AND INFORMATION ARE INVERSELY RELATED
RISK MANAGEMENT (CONT.)

- Historically, we focused our attentions on schedule and cost risk management.
- Today, our primary emphasis is on technological risk management:
  - Can we design it and build it?
  - What is the risk of obsolescence?
Definition Of Risk

Risk = \text{f}(\text{Likelihood, Impact})

• Likelihood is the probability of occurrence
• Impact is the amount at stake
Tolerance For Risk

- Risk avoider
- Risk neutral
- Risk lover
Decision-Making Categories

- Complete uncertainty
- Relative uncertainty (partial information)
- Complete certainty
Developing and Using Payoff Tables

Establishing the procedure to follow

Construct the Payoff table

Decision-making under certainty
Maximin Approach
Maximax Approach
Minimax regret Approach
Insufficient Reason Approach

Decision-making under complete uncertainty

Decision-making under risk

Expected Monetary Value (EMV) Approach
Expected Opportunity Loss (EOL) Approach
Expected Value of Perfect Information (EVPI) Approach
FIVE STEPS TO DEVELOP PAYOFF TABLE

- List all the alternatives.
- List the future consequences of each alternative.
- Assess the degree of certainty that these combinations will materialize.
- Decide on a decision criterion.
Risk Management Processes

- Risk planning
- Risk assessment
  - Risk identification
  - Risk analysis/quantification
- Risk handling
- Risk monitoring
Developing Contingency Plans
Types Of Risks (General)

- Business risks
- Insurable (pure) risk
  - Direct property damage
  - Indirect consequential loss
  - Legal liability
  - Personnel
Types Of Risk (PMI Method)

- External – unpredictable
- External – predictable
- Internal – non-technical
- Internal – technical
- Legal
Risk Types at Boeing

- Financial risks
- Market risks
- Technical risks
- Production risks
Risk Handling

- Assumption (retention)
- Avoidance
- Control (mitigation)
- Transfer
Risk Quantification

Program Summary

Stage I
- Design
- Test
- Manu.
- Cost

Stage II
- Design
- Test
- Manu.
- Cost

Guidance
- High
- Medium
- Low

Warhead
- High
- Medium
- Low

Legend
Special Topics In Risk Management
Future Risks

Inexperienced

Customer’s Knowledge

Experienced

Simple

Complex

Contract Type

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Future Risks

Customer’s Knowledge

Inexperienced

Experienced

Simple

Complex

Contract Type

INCREASING RISKS
How Much Risk Is Acceptable?

- High tolerance for risk
- Medium tolerance for risk
- Low tolerance for risk
Degrees of Downstream Risk

Low Risk

- R&D
- Manufacturing
- Marketing

Time
Degrees of Downstream Risk

Moderate Risk

R&D

Manufacturing

Marketing

Time

Information Exchange
Degrees of Downstream Risk

High Risk

R&D

Manufacturing

Marketing

Time
# Prioritization of Risks

<table>
<thead>
<tr>
<th>First (Highest) Priority</th>
<th>Schedule</th>
<th>Cost</th>
<th>Technical Performance or Quality</th>
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</tr>
</tbody>
</table>

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Risk Controls

Too Long

Too Many Risk Management Filters and Gates

No Risk Plan

Low

High

Appropriate

Schedule Length

Risk Controls

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Risk Control Measures

Intensity of Controls

Range of Controls

Extreme

Low

Low

Risk Intensity

High

Standard Controls
Which Method to Use?

- **Avoidance**
- **Transfer**
- **Reduction**
- **Assumption**

*Guidelines*

*Rigid Policies/Procedures*

*Tolerance for Risk*

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The Risk-Reward Matrix

- **Risk**
  - High
  - Medium
  - Low

- **Reward**
  - Low
  - Medium
  - High

- **Quality of Resources Needed**
  - Low
  - Medium
  - High

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Interacting Risks

Product Feature A

Desirable

Undesirable

Undesirable

Desirable

Specification Limit
On Characteristic B

Product Feature B

Dr Nabil Dmaidi
Risk Planning

- Poor Risk Management
- Technical Inability

Performance

Customer Expectations

Actual Performance

Time