How Project Management fits the Operations Management Philosophy

USING OPERATIONS TO COMPETE

Operations As a Competitive Weapon
Operations Strategy
Project Management

MANAGING PROCESSES

Process Strategy
Process Analysis
Process Performance and Quality
Constraint Management
Process Layout
Lean Systems

MANAGING VALUE CHAINS

Supply Chain Strategy
Location
Inventory Management
Forecasting
Sales and Operations Planning
Resource Planning
Scheduling
Bechtel is a $16.3 billion-a-year construction contractor that specializes in large projects.

It is successful because it is able to bring large projects in quickly and on time.

For each major project it organizes a project team and provides it with the supporting information systems and resources.

It utilizes a web-based communications system that provides access to project information electronically.

Team members have instant access to schedules, progress reports, drawings and messages.
Projects

- A **project** is an interrelated set of activities with a definite starting and ending point, which results in a unique outcome for a specific allocation of resources.

- The **three main goals of project** management are…
  1. Complete the project on time or earlier.
  2. Do not exceed the budget.
  3. Meet the specifications to the satisfaction of the customer.
Project management is a systemized, phased approach to defining, organizing, planning, monitoring, and controlling projects.

A collection of projects is called a program, which is an interdependent set of projects with a common strategic purpose.

A cross-functional effort: Even though a project may be under the overall purview of a single department, other departments likely should be involved.
Defining a project’s scope, time frame, allocated resources and objective, is essential.

A **Project Objective Statement** provides the objectives and essence of the project.

Time frame should be specific for start and ending of the project.

Necessary resources are also defined, either in dollar terms or in personnel allocation.
Selecting the right **project manager** is critical and specific skills are needed.

- **Facilitator**: Able to resolve conflicts, have leadership skills and a systems view.
- **Communicator**: Ability to keep senior management informed, communicate progress, and work with team members.
- **Decision Maker**: Able to organize members and make difficult decisions.

**Team members** need to be technically competent, dedicated, and able to work well with other team members.
Organizational Structure

- The relationship of a project manager to the team is determined by the firm’s organizational structure.

  - **Functional Structure**: The team is housed in a specific functional area. Assistance from other areas must be negotiated.

  - **Pure Project**: Team members work exclusively for the project manager, which is best for large projects.

  - **Matrix Structure**: A compromise between the functional and project structures. Members remain in various functional areas and the project manager coordinates across functional areas. Dual authority can cause problems.
Planning projects involves five steps:

1. **Defining the work breakdown structure** -- a statement of all work that has to be completed.

2. **Diagramming the network** -- a graphical network

3. **Developing the schedule** -- specifying start times for each activity

4. **Analyzing cost-time trade-offs**

5. **Assessing risks**
A **Work Breakdown Structure** is simply a statement of all work that has to be completed.

- Major work components are identified and then broken down into smaller tasks by the project team.
  - This process may involve a hierarchy of work levels.

- An **Activity** is the smallest unit of work effort consuming both the time and resources that the project manager can schedule and control.

- **Task Ownership**: Each activity must have an owner who is responsible for doing the work.
A Work Breakdown Structure (three levels) for a new business

Level 0: Entire Project
- Start a new business

Level 1
- Strategic plan
- Define business opportunity
- Plan for action
- Proceed with start-up plan

Level 2
- Provide staffing
- Provide physical facilities
- Establish business structure

Level 3
- Develop marketing plan
- Install operating control base
- Select bank
- Select name
- Find location
A Network Diagram visually displays the interrelated activities using nodes (circles) and arcs (arrows) that depict the relationships between activities.

Two network planning methods (PERT & CPM) were originally distinctive, but today the differences are minor and will be jointly referred to as PERT/CPM.

- PERT (Program Evaluation and Review Technique) was utilized when activity times involved risk.
- CPM (Critical Path Method) was used when activity times were certain.
Precedence relationships determine a sequence for undertaking activities, and specify that any given activity cannot start until a preceding activity has been completed.

In the **AON approach**, the nodes (circles) represent activities, and the arcs represent the precedence relationships between them.

**Activity On Node approach**

```
S  T  U
```

“S” precedes “T” which precedes “U”
Activity Relationships

- S & T must be completed before U can be started.
- T & U cannot begin until S has been completed.
Activity Relationships

- **U & V can’t begin until S & T have been completed.**

- **U cannot begin until S & T have been completed. V cannot begin until T has been completed.**
Activity Relationships

T & U cannot begin until S has been completed; V cannot begin until both T & U have been completed.
## St. Adolf’s Hospital
### Example 3.1

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Immediate Predecessor(s)</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Select administrative and medical staff.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Select site and do site survey.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Select equipment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Prepare final construction plans and layout.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Bring utilities to the site.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Interview applicants and fill positions in nursing, support staff, maintenance, and security.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>Purchase and take delivery of equipment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Construct the hospital.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Develop an information system.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>Install the equipment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>Train nurses and support staff.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>Description</td>
<td>Immediate Predecessor(s)</td>
<td>Responsibility</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------------------------------------------------</td>
<td>--------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>A</td>
<td>Select administrative and medical staff.</td>
<td>—</td>
<td>Johnson</td>
</tr>
<tr>
<td>B</td>
<td>Select site and do site survey.</td>
<td>—</td>
<td>Taylor</td>
</tr>
<tr>
<td>C</td>
<td>Select equipment.</td>
<td>A</td>
<td>Adams</td>
</tr>
<tr>
<td>D</td>
<td>Prepare final construction plans and layout.</td>
<td>B</td>
<td>Taylor</td>
</tr>
<tr>
<td>E</td>
<td>Bring utilities to the site.</td>
<td>B</td>
<td>Burton</td>
</tr>
<tr>
<td>F</td>
<td>Interview applicants and fill positions in nursing, support staff, maintenance, and security.</td>
<td>A</td>
<td>Johnson</td>
</tr>
<tr>
<td>G</td>
<td>Purchase and take delivery of equipment.</td>
<td>C</td>
<td>Adams</td>
</tr>
<tr>
<td>H</td>
<td>Construct the hospital.</td>
<td>D</td>
<td>Taylor</td>
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<tr>
<td>I</td>
<td>Develop an information system.</td>
<td>A</td>
<td>Simmons</td>
</tr>
<tr>
<td>J</td>
<td>Install the equipment.</td>
<td>E,G,H</td>
<td>Adams</td>
</tr>
<tr>
<td>K</td>
<td>Train nurses and support staff.</td>
<td>F,I,J</td>
<td>Johnson</td>
</tr>
</tbody>
</table>
St. Adolf’s Hospital
Diagramming the Network

Immediate Predecessor

A —
B —
C A
D B
E B
F A
G C
H D
I A
J E,G,H
K F,I,J

Diagram:

Start

A —— F

B —— D

C —— G

E —— J

F —— K

G —— H

H —— J

I —— K

Finish
**Paths** are the sequence of activities between a project’s start and finish.

<table>
<thead>
<tr>
<th>Path</th>
<th>Time (wks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-I-K</td>
<td>33</td>
</tr>
<tr>
<td>A-F-K</td>
<td>28</td>
</tr>
<tr>
<td>A-C-G-J-K</td>
<td>67</td>
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<tr>
<td>B-D-H-J-K</td>
<td>69</td>
</tr>
<tr>
<td>B-E-J-K</td>
<td>43</td>
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</table>
The **critical path** is the longest path!

<table>
<thead>
<tr>
<th>Path</th>
<th>Time (wks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-I-K</td>
<td>33</td>
</tr>
<tr>
<td>A-F-K</td>
<td>28</td>
</tr>
<tr>
<td>A-C-G-J-K</td>
<td>67</td>
</tr>
<tr>
<td><strong>B-D-H-J-K</strong></td>
<td><strong>69</strong></td>
</tr>
<tr>
<td>B-E-J-K</td>
<td>43</td>
</tr>
</tbody>
</table>

Project Expected Time is 69 wks.
The following information is known about a project.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Activity Time (days)</th>
<th>Immediate Predecessor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7</td>
<td>--</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>A</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>B, C</td>
</tr>
<tr>
<td>E</td>
<td>4</td>
<td>D</td>
</tr>
<tr>
<td>F</td>
<td>3</td>
<td>E</td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td>E</td>
</tr>
</tbody>
</table>

Draw the network diagram for this project.
Application 3.1
Solution

<table>
<thead>
<tr>
<th>Activity</th>
<th>Activity Time (days)</th>
<th>Immediate Predecessor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7</td>
<td>--</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>A</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>B, C</td>
</tr>
<tr>
<td>E</td>
<td>4</td>
<td>D</td>
</tr>
<tr>
<td>F</td>
<td>3</td>
<td>E</td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td>E</td>
</tr>
</tbody>
</table>

Diagram:

Start → A(7) → B(2) → D(4) → E(4) → F(3) → G(5) → Finish
The project team must make time estimates for each activity.

Activity times may be risky, in which case a probability distribution can be used (CPM).

For this project the times will be certain.

Activity slack is the maximum length of time that an activity can be delayed without delaying the entire project.

For St. Adolf’s we can’t go beyond 69 weeks.
Earliest Start Time (ES) is the latest earliest finish time of the immediately preceding activities.

Earliest Finish Time (EF) is an activity’s earliest start time plus its estimated duration.

Latest Start Time (LS) is the latest finish time minus the activity’s estimated duration.

Latest Finish Time (LF) is the earliest latest start time of the activities that immediately follow.

For simplicity, all projects start at time zero.
What AON Nodes look like

Determined by the earliest finish time of the precedent activity. If there are two or more precedent activities, this time is the same as precedent activity with the latest “Earliest Finish” time.

Slack

Determined by the earliest finish time of the precedent activity. If there are two or more precedent activities, this time is the same as the latest “Earliest Finish” time.

Slack is the difference, if any, between the earliest start and latest start times (or the earliest finish and latest finish times).

The earliest you can complete an activity -- determined by adding the activity time to the earliest start time.

The latest you can finish an activity without delaying the project completion date. It is the same as the Latest Start time of the next activity. If there are two or more subsequent activities, this time is the same as the earliest of those “Latest Start” times.

\[ S = LS - ES \quad \text{or} \quad S = LF - EF \]
Earliest Start and Earliest Finish Times

Example 3.2
Earliest Start and Earliest Finish Times

The Critical Path takes 69 weeks

Example 3.2
**Latest Start and Latest Finish Times**

Example 3.2
Example 3.2
A **Gantt Chart** is a project schedule, usually created by the project manager using computer software, that superimposes project activities, with their precedence relationships and estimated duration times, on a time line.

- Activity slack is useful because it highlights activities that need close attention.
- **Free slack** is the amount of time an activity’s earliest finish time can be delayed without delaying the earliest start time of any activity that immediately follows.
  - Activities on the critical path have zero slack and cannot be delayed without delaying the project completion.
<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Preceded By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>0 wks</td>
<td>Mon 9/18/06</td>
<td>Mon 9/18/06</td>
<td></td>
</tr>
<tr>
<td>A: Select Staff</td>
<td>12 wks</td>
<td>Mon 9/18/06</td>
<td>Fri 12/8/06</td>
<td>1</td>
</tr>
<tr>
<td>B: Select Site</td>
<td>9 wks</td>
<td>Mon 9/18/06</td>
<td>Fri 11/17/06</td>
<td>1</td>
</tr>
<tr>
<td>C: Select Equipment</td>
<td>10 wks</td>
<td>Mon 12/11/06</td>
<td>Fri 2/18/07</td>
<td>2</td>
</tr>
<tr>
<td>D: Prepare Construction Plans</td>
<td>10 wks</td>
<td>Mon 11/23/06</td>
<td>Fri 1/26/07</td>
<td>3</td>
</tr>
<tr>
<td>E: Bring Utilities to Site</td>
<td>24 wks</td>
<td>Mon 11/23/06</td>
<td>Fri 5/4/07</td>
<td>3</td>
</tr>
<tr>
<td>F: Interviews/Fill Positions</td>
<td>10 wks</td>
<td>Mon 12/11/06</td>
<td>Fri 2/16/07</td>
<td>2</td>
</tr>
<tr>
<td>G: Purchase Equipment</td>
<td>35 wks</td>
<td>Mon 2/19/07</td>
<td>Fri 10/19/07</td>
<td>4</td>
</tr>
<tr>
<td>H: Construct Hospital</td>
<td>40 wks</td>
<td>Mon 1/23/07</td>
<td>Fri 11/2/07</td>
<td>5</td>
</tr>
<tr>
<td>I: Develop Information System</td>
<td>15 wks</td>
<td>Mon 12/11/06</td>
<td>Fri 3/23/07</td>
<td>2</td>
</tr>
<tr>
<td>J: Instal Equipment</td>
<td>4 wks</td>
<td>Mon 11/6/07</td>
<td>Fri 11/20/07</td>
<td>6, 8, 9</td>
</tr>
<tr>
<td>K: Train Staff</td>
<td>8 wks</td>
<td>Mon 12/3/07</td>
<td>Fri 1/1/08</td>
<td>7, 10, 11</td>
</tr>
<tr>
<td>Task Name</td>
<td>Start</td>
<td>Finish</td>
<td>Late Start</td>
<td>Late Finish</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>1: Start</td>
<td>Mon 9/18/06</td>
<td>Mon 9/18/06</td>
<td>Mon 9/18/06</td>
<td>Mon 9/18/06</td>
</tr>
<tr>
<td>2: A: Select Staff</td>
<td>Mon 9/18/06</td>
<td>Fri 12/6/06</td>
<td>Mon 10/2/06</td>
<td>Fri 12/22/06</td>
</tr>
<tr>
<td>3: B: Select Site</td>
<td>Mon 9/18/06</td>
<td>Fri 11/17/06</td>
<td>Mon 9/18/06</td>
<td>Fri 11/17/06</td>
</tr>
<tr>
<td>4: C: Select Equipment</td>
<td>Mon 12/11/06</td>
<td>Fri 2/16/07</td>
<td>Mon 12/25/06</td>
<td>Mon 3/2/07</td>
</tr>
<tr>
<td>5: D: Prepare Construction Plans</td>
<td>Mon 11/20/06</td>
<td>Fri 1/26/07</td>
<td>Mon 11/20/06</td>
<td>Fri 1/26/07</td>
</tr>
<tr>
<td>6: E: Bring Utilities to Site</td>
<td>Mon 11/20/06</td>
<td>Fri 5/4/07</td>
<td>Mon 5/21/07</td>
<td>Fri 11/2/07</td>
</tr>
<tr>
<td>7: F: Interviews/Fill Positions</td>
<td>Mon 12/11/06</td>
<td>Fri 2/16/07</td>
<td>Mon 9/4/07</td>
<td>Fri 11/50/07</td>
</tr>
<tr>
<td>8: G: Purchase Equipment</td>
<td>Mon 2/1/07</td>
<td>Fri 10/10/07</td>
<td>Mon 3/5/07</td>
<td>Fri 11/2/07</td>
</tr>
<tr>
<td>9: H: Construct Hospital</td>
<td>Mon 1/26/07</td>
<td>Mon 1/26/07</td>
<td>Mon 1/26/07</td>
<td>Mon 1/26/07</td>
</tr>
<tr>
<td>10: I: Develop Information System</td>
<td>Mon 12/11/06</td>
<td>Fri 3/23/07</td>
<td>Mon 8/20/07</td>
<td>Fri 11/30/07</td>
</tr>
<tr>
<td>11: J: Install Equipment</td>
<td>Mon 11/5/07</td>
<td>Fri 11/30/07</td>
<td>Mon 11/5/07</td>
<td>Fri 11/30/07</td>
</tr>
<tr>
<td>12: K: Train Staff</td>
<td>Mon 12/3/07</td>
<td>Fri 1/11/08</td>
<td>Mon 12/3/07</td>
<td>Fri 1/11/08</td>
</tr>
<tr>
<td>13: Finish</td>
<td>Fri 1/11/08</td>
<td>Fri 1/11/08</td>
<td>Fri 1/11/08</td>
<td>Fri 1/11/08</td>
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</tbody>
</table>
Example 3.3
Calculate the four times for each activity in order to determine the critical path and project duration.

<table>
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<tr>
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<th></th>
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<th></th>
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<td>0</td>
<td>7</td>
<td>7</td>
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<tr>
<td>B</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>4</td>
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<tr>
<td>F</td>
<td>3</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The critical path is A-C-D-E-G with project duration of 24 days.
Application 3.2
Critical Path and Project Duration

<table>
<thead>
<tr>
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<td>7</td>
<td>9</td>
<td>9</td>
<td>11</td>
<td>9-7=2</td>
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<td>C</td>
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<td>11</td>
<td>11</td>
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<td>D</td>
<td>4</td>
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<td>11</td>
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<td>E</td>
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<td>19</td>
<td>19</td>
<td>24</td>
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</tbody>
</table>

The critical path (bold path) is A-C-D-E-G with project duration of 24 days.
There are always cost-time trade-offs in project management.

- You can complete a project early by hiring more workers or running extra shifts.
- There are often penalties if projects extend beyond some specific date, and a bonus may be provided for early completion.

**Crashing** a project means expediting some activities to reduce overall project completion time and total project costs.
The total project costs are the sum of direct costs, indirect costs, and penalty costs.

Direct costs include labor, materials, and any other costs directly related to project activities.

Indirect costs include administration, depreciation, financial, and other variable overhead costs that can be avoided by reducing total project time.

The shorter the duration of the project, the lower the indirect costs will be.
To assess the benefit of crashing certain activities, either from a cost or a schedule perspective, the project manager needs to know the following times and costs.

- **Normal time** (NT) is the time necessary to complete an activity under normal conditions.
- **Normal cost** (NC) is the activity cost associated with the normal time.
- **Crash time** (CT) is the shortest possible time to complete an activity.
- **Crash cost** (CC) is the activity cost associated with the crash time.
Cost to Crash per Period

\[
\text{The Cost to Crash per Period} = \frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Normal Time} - \text{Crash Time}}
\]

\[
\frac{\text{CC} - \text{NC}}{\text{NT} - \text{CT}}
\]
Cost-Time Relationships in Cost Analysis

St. Adolf’s Hospital

Estimated costs for a 2-week reduction, from 10 weeks to 8 weeks

Crash cost (CC)

Linear cost assumption

Normal cost (NC)

Direct cost (dollars)

Time (weeks)

(Crash time) (Normal time)
The objective of cost analysis is to determine the project schedule that minimizes total project costs.

A minimum-cost schedule is determined by starting with the normal time schedule and crashing activities along the critical path in such a way that the costs of crashing do not exceed the savings in indirect and penalty costs.
Use these steps to determine the minimum cost schedule:

1. Determine the project’s critical path(s).
2. Find the activity or activities on the critical path(s) with the lowest cost of crashing per week.
3. Reduce the time for this activity until...
   a. It cannot be further reduced or
   b. Until another path becomes critical, or
   c. The increase in direct costs exceeds the savings that result from shortening the project (which lowers indirect costs).
4. Repeat this procedure until the increase in direct costs is larger than the savings generated by shortening the project.
### Direct Cost and Time Data for the St. Adolf’s Hospital Project

<table>
<thead>
<tr>
<th>Activity</th>
<th>Normal Time (NT)</th>
<th>Normal Cost (NC)</th>
<th>Crash Time (CT)</th>
<th>Crash Cost (CC)</th>
<th>Maximum Time Reduction (wk)</th>
<th>Cost of Crashing per Week (CC-NC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>$12,000</td>
<td>11</td>
<td>$13,000</td>
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<td>$1,000</td>
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<td>7</td>
<td>64,000</td>
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<td>7,000</td>
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<tr>
<td>C</td>
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<td>4,000</td>
<td>5</td>
<td>7,000</td>
<td>5</td>
<td>600</td>
</tr>
<tr>
<td>D</td>
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<td>16,000</td>
<td>8</td>
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<td>2,000</td>
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<td>E</td>
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<td>F</td>
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<td>10,000</td>
<td>6</td>
<td>16,000</td>
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<td>1,500</td>
</tr>
<tr>
<td>G</td>
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<td>500,000</td>
<td>25</td>
<td>530,000</td>
<td>10</td>
<td>3,000</td>
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<td>H</td>
<td>40</td>
<td>1,200,000</td>
<td>35</td>
<td>1,260,000</td>
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<td>10</td>
<td>52,500</td>
<td>5</td>
<td>2,500</td>
</tr>
<tr>
<td>J</td>
<td>4</td>
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<td>1</td>
<td>13,000</td>
<td>3</td>
<td>1,000</td>
</tr>
<tr>
<td>K</td>
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<td>5</td>
<td>34,000</td>
<td>1</td>
<td>4,000</td>
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<tr>
<td>Totals</td>
<td></td>
<td>$1,992,000</td>
<td></td>
<td></td>
<td></td>
<td>$2,209,500</td>
</tr>
</tbody>
</table>

Shorten first activity.
Step 1: The critical path is: B-D-H-J-K.

Step 2: The cheapest activity to crash is “J” at $1000.

Step 3: Crash activity J by its limit of three weeks because the critical path remains unchanged.

The new project length becomes 66 weeks.

The project completion time is 69 weeks.
The direct costs for that schedule are $1,992,000.
The indirect costs are $8000 per week.
Penalty costs after week 65 are $20,000 per week.
Total cost is $2,624,000 for 69 weeks
($1,992,000 + 69($8000) + (69 –65)($20,000)
St. Adolf’s Hospitals

Example 3.4

Finding the minimum cost schedule: Stage 1

- The project completion time is 69 weeks.
- The direct costs for that schedule are $1,992,000.
- The indirect costs are $8000 per week.
- Penalty costs after week 65 are $20,000 per week.
- Total cost is $2,624,000 for 69 weeks.

Crashing by 3 weeks saves $81,000 for a new total cost of $2,543,000.

Savings is 3 weeks of indirect costs (3 * $8000 = $24,000)
plus 3 weeks of penalties (3 * $20,000 = $60,000)
less the cost of crashing (3 * $1,000 = $3,000)
Step 1: The critical path is still B-D-H-J-K.

Step 2: The cheapest activity to crash per week is now D at $2,000 a week.

Step 3: Crash D by 2 weeks.

- The first week of reduction saves $28,000 by eliminating both the penalty and indirect costs (but $2,000 goes toward crashing costs.)
- The second week of reduction had no penalty, so it saves only the indirect costs of $8,000.

Total cost is now $2,511,00 ($2,543,00 - $28,000 - $8,000 + $4,000)
Shortening D and J have created a second critical path, A-C-G-J-K. Both critical paths are 64 weeks.

Both must now be shortened to realize any savings in indirect costs.
The alternatives are to crash one of the following combination of activities: A-B, A-H, C-B, C-H, G-B, G-H, or

- Crash activity K which is on both critical paths.
  - (J and D have already been crashed.)
- The cheapest alternative is to crash activity K.
- It can only be crashed by one week at a cost of $4,000
- The net savings are $8,000 − $4,000 = $4,000
- Total project cost now becomes $2,507,000
The critical paths remain the same but are now both 63 weeks.
• B and C are the only remaining activities that can be crashed simultaneously without exceeding the potential savings of $8000 per week in indirect costs.

• Crash activities B and C by two weeks (the limit for activity B)

• Net savings are \( 2(8000) - 2(7600) = 800 \)

• Total project costs are now $2,506,200
St. Adolf’s Hospital Summary

The minimum cost schedule is 61 weeks. Activities J, D, K, B, and C were crashed for a total savings of $117,800

<table>
<thead>
<tr>
<th>Stage</th>
<th>Crash Activity</th>
<th>Time Reduction (wks)</th>
<th>Resulting Critical Path(s)</th>
<th>Project Duration (wks)</th>
<th>Project Direct Costs, Last Trial (000)</th>
<th>Crash Cost Added (000)</th>
<th>Total Indirect Costs (000)</th>
<th>Total Penalty Costs (000)</th>
<th>Total Project Costs (000)</th>
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<tbody>
<tr>
<td>0</td>
<td>—</td>
<td>—</td>
<td>BDHJK</td>
<td>69</td>
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<td>—</td>
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<td>80.0</td>
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<td>15.2</td>
<td>498.0</td>
<td>0.0</td>
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</table>
Risk is a measure of the probability and consequence of not reaching a defined project goal.

A major responsibility of the project manager at the start of a project is to develop a risk-management plan.

A Risk-Management Plan identifies the key risks to a project’s success and prescribes ways to circumvent them.
Categories of Project Risk

- **Strategic Fit**: Projects should have a purpose that supports the strategic goals of the firm.

1. **Service/Product Attributes**: If the project involves new service or product, several risks can arise.
   - Market risk comes from competitors.
   - Technological risk can arise from advances made once the project has started, rendering obsolete the technology chosen for service or product.
   - Legal risk from liability suits or other legal action.

2. **Project Team Capability**: Involves risks from the project team itself such as poor selections and inexperience.

3. **Operations Risk**: Information accuracy, communications, and project timing.
The Statistical Analysis approach requires that activity times be stated in terms of three reasonable time estimates for each activity.

1. **Optimistic Time** \((a)\) is the shortest time in which an activity can be completed if all goes exceptionally well.
2. **Most Likely Time** \((m)\) is the probable time for an activity.
3. **Pessimistic Time** \((b)\) is the longest time required.

The expected time for an activity thus becomes...

\[ t_e = \frac{a + 4m + b}{6} \]
Probabilistic Time Estimates

Beta Distribution

Optimistic, Mean, Pessimistic

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Probabilistic Time Estimates

Normal Distribution

Area under curve between $a$ and $b$ is 99.74%
Example 3.5

St. Adolf’s Hospital
Probabilistic Time Estimates

Calculating Means and Variances

Mean

\[ t_e = \frac{a + 4m + b}{6} \]

Variance

\[ \sigma^2 = \left( \frac{b - a}{6} \right)^2 \]
Example 3.5

Calculating Means and Variances

Activity B

<table>
<thead>
<tr>
<th>Optimistic</th>
<th>Most Likely</th>
<th>Pessimistic</th>
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</thead>
<tbody>
<tr>
<td>(a) 7</td>
<td>(m) 8</td>
<td>(b) 15</td>
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</tbody>
</table>

$$t_e = \frac{7 + 4(8) + 15}{6} = 9 \text{ weeks}$$

$$\sigma^2 = \left( \frac{15 - 7}{6} \right)^2 = 1.78$$
<table>
<thead>
<tr>
<th>Activity</th>
<th>Optimistic ($a$)</th>
<th>Likely ($m$)</th>
<th>Pessimistic ($b$)</th>
<th>Expected Time ($t_e$)</th>
<th>Variance ($\sigma^2$)</th>
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<td>6</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Example 3.6

St. Adolf’s Hospital
Analyzing Probabilities

Probabilities

Critical Path = B - D - H - J - K

\[ T = 72 \text{ days} \quad T_E = 69 \text{ days} \]

\[ \sigma^2 = \sum \text{(variances of activities)} \quad z = \frac{T - T_E}{\sqrt{\sigma^2}} \]

\[ \sigma^2 = 1.78 + 1.78 + 2.78 + 5.44 + 0.11 = 11.89 \]

\[ z = \frac{72 - 69}{\sqrt{11.89}} \]

From Normal Distribution appendix

\[ P_z = .8078 \approx .81 \]
Example 3.6

St. Adolf’s Hospital
Probability of Completing Project On Time

Length of critical path

Normal distribution:
Mean = 69 weeks;
\( \sigma = 3.45 \) weeks

Probability of meeting the schedule is 0.8078

Probability of exceeding 72 weeks is 0.1922

Project duration (weeks)

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St. Adolf’s Hospital

Probability of Completing Project On Time

Example 3.6

Probabilities

Critical Path = A - C - G - J - K

\[ T = 72 \text{ days} \quad T_E = 67 \text{ days} \]

\[ \sigma^2 = \sum (\text{variances of activities}) \quad z = \frac{T - T_E}{\sqrt{\sigma^2}} \]

\[ \sigma^2 = 0.11 + 2.78 + 7.11 + 5.44 + 0.11 = 15.55 \]

\[ z = \frac{72 - 67}{\sqrt{15.55}} = 1.27 \]

From Normal Distribution appendix

\[ P_z = .8980 \approx .90 \]
Resource-Related Problems

- **Excessive Activity Duration Estimates**: Many time estimates come with a built-in cushion that management may not realize.

- **Latest Date Mentality**: The tendency for employees to procrastinate until the last moment before starting.

- **Failure to Deliver Early**: Even if the work is completed before the latest finish date.
Path Mergers occur when two or more activity paths combine at a particular node. Both paths must be completed up to this point, which will eliminate any built-up slack.

Multitasking is the performance of multiple project activities at the same time. Work on some activities is delayed for other work.

Loss of Focus by a manager can happen if the critical path changes frequently.
The Critical Chain Approach

- **Critical Chain** is the sequence of dependent events that prevents a project from completing in a shorter interval and recognizes resource as well as activity dependencies.

- **Time Estimates**: The most likely time \((m)\) is used to build the critical chain project plan. The difference between it and the pessimistic time \((b – m)\) is used to develop the time buffers.

- **Buffers**: Once the critical chain and all paths feeding it are identified, time buffers can be added to protect the chain.

- Using **Latest Start Schedules** has the advantage of delaying project cash outlays.

- **Project Control**: Managers, using the critical chain approach, must control the behavioral aspects of their projects.
SLACK CALCULATIONS AFTER ACTIVITIES A AND B HAVE BEEN COMPLETED
Project Life Cycle

- Definition and organization
- Planning
- Execution
- Close out

Resource requirements vs. Time

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