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IE 505 Production Planning and Control

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Lectures, Notes
Operations Management: Decision Making in the Operations Function

Outline

1. Project Management: Introduction
2. Network Representation
3. Critical Path Analysis
4. Steps in Project Scheduling & Analysis
5. Example: Building a House
6. Precedence Networks: AON
7. PERT: Project Evaluation and Review Technique

3. Performance (product or service produced)
2. Schedule (completion dates at intermediate milestones)
1. Cost (labor + material + support)

2. Objectives and Tradeoffs

- Military invasion
- Political campaign
- Making movies
- New-product introduction (prototyping)
- Manufacture of aircraft, ships, and large machines
- Building construction
- Techniques differ from ongoing production.

"Long-term," complex set of tasks - single final unit.

Introduction: Definition and Examples
Implementation

- Determine corrective action, need and choice
- Compare planned vs actuals
- Monitor actual time, cost, and performance

Control

- Assign Resources
- Develop detailed budget
- Develop start/end times for each task
- Estimate time and set sequence of tasks
- Develop a detailed work-breakdown structure

Scheduling

- Define major tasks and budget
- Decide organization, personnel
- Estimate total resources and time required
- Identify customer, product/service, objectives

Planning

1. Planning and Control in Projects
2. Scheduling
3. Control

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NETWORK REPRESENTATION
Network: collection of nodes and directed arcs

Event: a point in time (start/end of project or activity)

Activity: anything that involves work-content and/or resource(s) and/or cost and has a duration

2. Activity-relationship

1. Activity Definitions

2. Activity-relationship

1. Activity-relationship

2. Activity-relationship

2. Activity-relationship
Project has 5 activities: A, B, C, D and E

1. A, B don’t have immediate predecessors
2. A is the immediate predecessor of C
3. B is the immediate predecessor of D
4. C, D are immediate predecessors of E.

Use of dummy activities: dummies are used to represent precedence; they have zero work-content.
b) Activities A and B have a common predecessor (E), but different predecessors (C and D).

c) Activities C and D have a common successor (K), but different successors (I and J).

a) Activities F and G have the same predecessor (E) and the same successor (H).
CRITICAL PATH ANALYSIS
Activity Calculations

Event Calculations

Two types of calculations:

CP defines the minimum completion time of the project.

Objective is to find the longest (in time) path, and focus on this for your

Critical Path Analysis
4. EVENT SLACK $S_i^j \triangleq T_i^j - T_i^j$

3. CRITICAL PATH goes through the events for which $T_i^j = \min_j \{T_i^j - S_i^j\}$ where $j$ is an immediate successor of $i$.
Set $T_i^j = \min_j \{T_i^j - S_i^j\}$

Start from final node, set $T_i^f = \sum_j T_i^j (f)$, set $T_i^j$ and proceed to next event.

2. BACKWARD PASS for latest times of every event $i$.
Set $\bar{T}_i^j = \max_j \{\bar{T}_i^j + \bar{E}_i^j\}$
Set $0 = \bar{T}_i^1 (1)$, set $\bar{T}_i^j$ and proceed to previous event.

1. FORWARD PASS for earliest times of every event $i$.
Start from start node, set $T_i^1 = \sum_j T_i^j (1)$, set $T_i^j$ and proceed to next event.

The project can occur without delaying all predecessors are complete.

EVENT CALCULATIONS:

- $T_i^j$: Latest time event $i$ can occur without delaying all predecessors.
- $\bar{T}_i^j$: Earliest time event $i$ can occur assuming all predecessors are complete.
- $\bar{T}_i^j$: Time required for activity from event $i$ to event $i$. 

Critical Path Analysis
of a

where \( \{ (q) \subseteq \} \)\n
\[
\text{max} = (a) S \subseteq E
\]

\[
(a) f + (a) S \subseteq E = (a) H \subseteq E
\]

Set

Set for starting activities

I. FORWARD PASS for early times of every activity a

a late finish time of activity a = (a) H \subseteq T

a late start time of activity a = (a) S \subseteq T

a early finish time of activity a = (a) H \subseteq E

a early start time of activity a = (a) S \subseteq E

a time required for activity a = (a) t

3.2 Activity Calculations:
CP is the longest path of the network

There must be at least one CP in the network

Critical Path (CP) should be continuous

\( \text{where } q \text{ is an immediate successor of } a \)

\( \begin{align*}
(p) \text{FF} - \{(q) \text{SF} \} & = (p) \text{HF} \\
(p) \text{FF} - (p) \text{FT} & = (p) \text{SF} - (p) \text{ST} = (p) \text{FT}
\end{align*} \)

5. FREE SLACK or FLOAT

\( \begin{align*}
(p) \text{HF} - (p) \text{FT} & = (p) \text{SF} - (p) \text{ST} = (p) \text{HF} \\
(p) \text{HF} & = (p) \text{FT} \text{ or } (p) \text{ST} = (p) \text{HF}
\end{align*} \)

4. TOTAL SLACK or FLOAT

\( \text{Critical Path} \) goes through the activities for which

\( \{(q) \text{ST} \} \text{minimum} = (p) \text{FT} \)

Set where \( q \) is an immediate successor of \( a \)

\( \begin{align*}
(p) \text{FT} - (p) \text{FT} & = (p) \text{SF} - (p) \text{ST} = (p) \text{FT} \\
(p) \text{FT} & = (p) \text{FT} \text{ for final activities}
\end{align*} \)

2. BACKWARD PASS for late times of every activity \( a \)

Critical Path Analysis
Steps in Project Scheduling & Analysis
6. Cash Flow calculations
5. Finally, optionally perform resource aggregation and leveling
4. Draw bar chart based on time analysis results
3. Time Analysis: Forward and Backward Scheduling

between jobs.
2. Draw the project network, so as to reflect the logical relationships

Optionally list their resource requirement(s).
1. List all jobs with their description and estimated duration.

Steps in Project Scheduling & Analysis
EXAMPLE: BUILDING A HOUSE
Only one type of resource — men are interchangeable.

**Assumption**

<table>
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<th>Time Labor</th>
<th>I</th>
<th>II</th>
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<td>1</td>
<td>Clean House and Deliver</td>
<td>I wk</td>
<td>0 men</td>
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<tr>
<td>2</td>
<td>Do Wiring</td>
<td>2 wks</td>
<td>2 men</td>
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<td>3</td>
<td>Procure Electrical Fittings</td>
<td>6 wks</td>
<td>2 men</td>
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<td>4</td>
<td>Erect Building</td>
<td>8 wks</td>
<td>1 man</td>
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<td>5</td>
<td>Procure Bricks</td>
<td>3 wks</td>
<td>1 man</td>
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<td>6</td>
<td>Lay Foundation</td>
<td>2 wks</td>
<td>2 men</td>
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<td>7</td>
<td>Procure Sand and Cement</td>
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<td>8</td>
<td>Dig Foundation</td>
<td>I wk</td>
<td>0 men</td>
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<tr>
<td>9</td>
<td>Clear Lot</td>
<td>I wk</td>
<td>1 man</td>
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<td>10</td>
<td>Issue Permit</td>
<td>6 wks</td>
<td>0 men</td>
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5.1. List of Jobs
2. Storable resources: can be used at any time
   e.g., man hours, machine hours, ...

1. Non-storable resource: lost if not used

Types of resources

Example: Building a house
One starting event, and one ending event.

Example: Building a house

5.2. Project Network
Example: Building a house

5.3 Time Analysis

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Example: Building a house

IE 502: PROJECT PLANNING AND CONTROL
5.4 Bar Chart and Resource Aggregation

Example: Building a House
Example: Building a house
\[ \frac{L}{N} = R^a \]

- Average resource required

\[ R_n \]

- User defined resource limit

a. Evaluation of time constrained problems

2.2. Resource constrained

2.1. Time constrained

2. Problem classes

Ideal: \[ R^t = R^a \] for all \( t \)

\[ R^t \]

- Resource available at time \( t \)

\[ R^u \]

- Resource used at time \( t \)

1. Characterization of an „optimal“ schedule

5.5* Objective evaluation of resource profiles

Example: Building a house
\[
\frac{\bigcap_{\Delta} \mathcal{A}}{\bigcup_{\Delta} \mathcal{Y}} = \mathcal{E}
\]

Efficiency:

\[
\forall \mathcal{B} \subseteq \mathcal{Y} = \forall \mathcal{A} \subseteq \mathcal{Y}
\]

If \( \mathcal{A} \)'s and \( \mathcal{B} \)'s are defined around \( \mathcal{R}_n \):

\[
\forall \bigcup_{\mathcal{B}} \bigcap_{\mathcal{A}} = \forall \bigcup_{\mathcal{R}_n} \bigcap_{\mathcal{X}}
\]

Example: Building a house
Remaining Total Float is also used as an evaluation criterion along with

\[
\frac{p_L}{p_L - p_L} - 1 = \mathcal{F}
\]

b. Evaluation of resource constrained problems

Example: Building a house
Reading Assignment: Section 9.3 (Time costing methods)
PRECEDENCE NETWORKS: AON
Note that Early and Late times are different from AOA case.
PERT
PROJECT EVALUATION AND REVIEW TECHNIQUE
4. Variance of completion time is sum of $\sigma_i^2$'s on CP

3. Expected completion time is sum of $E_i$'s on CP

2. Find CP based on $E_i$'s

1. Compute $E_i$'s for all activities

Basic Step:

$$\frac{9}{p-q} = \sigma$$

$$\frac{9}{q+w+m+p} = \mu$$

For a beta distribution, mean and standard deviations are:

Most likely activity time

$$m = \mu$$

Maximum activity time

$$q = q$$

Minimum activity time

$$a = a$$

Generalization of CPM to allow uncertainty in activity times. Define:

Project Evaluation and Review Technique: PERT