**Topic 2: Managing Projects**

**Overview**

This topic examines the approach to the management of projects which involves planning, scheduling and implementing and controlling the development of projects. It involves the application of the CPM and Pert approaches to schedule the development and control the progress of the projects.

Learning Outcomes

By the end of this topic, you will be able to:

1. plan the activities of a project and develop the network of the activities using CPM to determine the critical path and then use PERT approach to determine the most likely time to complete the project.
2. estimate the cost-time trade off and project crashing to complete the project on time as decided in the contract.
3. explain the differences between CPM and PERT and their applications in project management.
4. uphold the ethical principles and to deal with ethical issues in project management..

Introduction

2.1 Managing a project is challenging and involving high risk due to unnecessary delays. Therefore it requires careful planning and thorough scheduling and controlling in order to complete the project within the time frame.

2.2 Planning involves setting the goals, defining the project the project and team

organisation. It involves breaking the project down into components and then

establishing the activities in each component. Next the activities are organised into a network in terms of their relationships and their sequential arrangement in the form of a hierarchy. The network can be in the form of AON (activity on the node) or AOA (activity on arrow).

2.3 Scheduling where it involves getting people, money and supplies to specific activities and relates activities to each other. The manager develops the scheduling chart to observe the progress of each activity and to identify and remedy problem areas. The CPM and PERT approaches are applied to develop the scheduling chart.

2.4 CP is used to determine the critical path where it is the longest time to complete the project However, circumstances may change and the CP may be changed,. What then should be the most expected time frame to complete the project? To find this, PERT approach is used. It helps to determine the probability to complete the project according to the CP time frame. If the probability to complete the project within the CP time frame then the necessary adjustments need to be made on the critical path activities so that the project can be completed within the agreed time frame.

2.5 Controlling of the project involves close monitoring of resources, costs, quality and budgets. Should there be any deviations the necessary remedies are carried out to ensure the completion of the project on time.

**Lecture Notes**

2. Managing Projects (Main Paper)

A project is a one-shot set of activities with a definite beginning and ending point. The activities must be done in a particular order as they have precedence relationships, and they take place in real time. The key thing is the project is a one-time occurrence and will not be repeated.

Managing a project is very challenging. The risk can be very high as costs can easily overrun and unnecessary delays can occur. It requires careful planning and thorough scheduling and controlling in order to complete the project within the time frame.

**The management of projects involves three phases:**

1. Planning – goal setting, defining the project and team organisation.

* It involves breaking the project down into components and then establishing the activities in each component.
* It also requires the designing of a network of activities for the project to provide the means to identify their relationships and their sequential arrangement in the form of a hierarchy.

E.g. In the case of Milwaukee Paper Manufacturing Incorporation a network of activities

is as shown in the table below.

Activities Description Immediate predecessors

A Build internal components -

B Modify roof and floor -

C Construct collection stacks A

D Pour concrete & install frame A, B

E Build high temperature burner C

F Install pollution control device C

G Install air pollution control device D, E

H Inspect & test F, G

F

A C

E

Start H

D

B G

A Complete Network (using CPM approach)

Definition of a project network

A project network is a diagram of all the activities and the precedence relationships that exist between these activities in a project.

The network above shows the “activities on the node” (**AON**).

Another approach is to show the “activities on the arrows” (**AOA**).

If we were to draw the above project network in the AOA approach, then it would be:

C

2 4

A (Construct Stack) F

(Install

(Build Internal Dummy Activity Controls)

1 components) (Build 6 H 7

Burner) E (Inspect/Test)

(Modify B

Roof/Floor) G (Install

Pollution Device)

3 D 5

(Pour concrete/Install Frame)

A number represents an event. Dummy activities are common in AOA networks. They do not really exist in the project and take zero time.

2. **Scheduling**

It involves getting people, money and supplies and putting them into specific activities and relating activities to each other. Concurrently the manager charts the schedules for personnel needs in terms of skills (management, engineering or pouring concrete, for example). He also makes charts for the supply of materials. The charts popularly used are the Gantt Charts.

An example of a Gantt Chart for project scheduling:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Project activity | Week 1 | 2 | 3 | 4 |
| Study English 1 | [------------ | ------] |  |  |
| Study History 102 |  | [------------ | ------] |  |
| Study Math 5 |  |  |  |  |
| Study concepts since last exam |  | [------------ | ------] |  |
| Study materials on Exam 1 & 2 |  |  | [---------] |  |
| Study psychology 1 |  |  |  | [----] |

Characteristics of Gantt Charts

1. Activities are planned.
2. Order of performance is documented.
3. Activity time estimates are recorded.
4. Overall project time is developed.

The scheduling chart enables the manager to observe the progress of each activity and to identify and remedy problem areas. However the Gantt Chart does not adequately illustrate the interrelationships between the activities and the resources and is used for simple projects. As a consequent, PERT (Program evaluation and review technique) and CPM (Critical path method) are used because they have the ability to take into account precedence relationships and interdependency of activities. They are used for complex projects.

Project scheduling serves several purposes:

1. It shows the relationship of each activity to others and to the whole project.
2. It identifies the precedence relationships among activities.
3. It encourages the setting of realistic time and cost estimates for each activity.
4. It helps make better use of people, money and material resources by identifying

critical bottle necks in the project.

In the case of Milwaukee Paper Manufacturing, the times required for each of the 8

activities are as follows:

Activities Description Time (weeks)

A Build internal components 2

B Modify roof and floor 3

C Construct collection stacks 2

D Pour concrete & install frame 4

E Build high temperature burner 4

F Install pollution control device 3

G Install air pollution control device 5

H Inspect & test 2

Total 25

**How long the project will take to finish?**

**Step 1**

We use CPM (Critical Path Method) to find the longest time to complete the project and this is known as the **Critical Path**.

First calculate the earliest time an activity can start (ES) and then the earliest time an activity can finish (EF).

Second calculate the latest start (LS) i.e. the latest time an activity can start so as not to delay the project and the latest finish (LF) i.e. latest time the activity has finished so as not to delay the project.

These times are entered in the nodes of the network. The upper half in each node represents the ES and EF while the lower half the LS and LF of an activity.

Activity name of symbol

A

Earliest time an Earliest time an

activity can start ES EF activity can finish

(Earliest start) (Earliest finish)

LS LF

(Latest start) (Latest finish)

Latest time an Latest time an activity

activity can start has to finish without

without delaying 2 affecting the delay of

the completion completion time of the

time of the project project

Activity duration (weeks)

The network diagram for Milwaukee Paper Manufacturing Incorporation is as shown:

4 F 7

0 A 2

10 13 Slack=6

0 2 3

2 C

Slack=0 2 4 E

2 4 4 8

2

0 Start 0 Slack= 0 4 8 Slack=0 13 H 15

4

0 0 13 15

0 3 D 7 G 2

8 13 Slack=0

0 B 3 4 8

4 8 13

1 4 5

3 Slack=1 Slack=0

Slack=1

From the above setting, a two-pass process consisting of a ***forward pass*** and a ***backward pass*** is used. The early start and early finish times (ES and EF) are determined during the forward pass. The late start and late finish times (LS and LF) are found during the backward pass.

Slack time = time an activity can delay but it would not delay the project . Slack time = LS – ES or Slack time = LF – EF

Critical path = 15 weeks

Slack time = 8 weeks

For Milwaukee Paper Manufacturing project, the CP = 15 weeks. However, in reality situation or circumstance may cause the C P of 15 weeks to vary.

***What then is the most expected time frame to complete the project?***

**Step 2**

As CPM cannot provide this answer, we refer to the PERT approach which has 3 time estimates:

1. Optimistic time (a) = project completed on time as envisaged.
2. Pessimistic time (b) = project may not complete as scheduled.
3. Most likely time (m) to complete the project.

\* Use the formula to find the expected activity time:

t = (a + 4m + b)/6

\* To calculate the dispersion or variance of activity completion time, use the formula:

Variance = (b – a)/6 2

Probability of 1 in 100 Probability of 1 in 100

of < (a) occurring of > (b) occurring

Optimistic time (a) Most likely time (m) Pessimistic time (b)

For example:

Calculate the variance of activity F (installation of pollution control device)

a = 1 week, m = 2 weeks and b = 9 weeks

The expected time to complete the project = a + 4 m + b/6

= 1 + 8 + 9/6

= 18/6

= 3 weeks

The variance for activity F = (b – a)/6 2 = 9 – 1/6 2

= (8/6)2

= 64/36

= 16/9

= 1.78 weeks

Basing on the above calculations, the expected times and variances for all the activities in the project are shown in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Activity | Optimistic | Most likely | Pessimistic | Expected time | Variance |
|  | a | m | b | t = (a+4m +b)/6 | (b - a)/6 2 |
| A | 1 | 2 | 3 | 2 | .11 |
| B | 2 | 3 | 4 | 3 | .11 |
| C | 1 | 2 | 3 | 2 | .11 |
| D | 2 | 4 | 6 | 4 | .44 |
| E | 1 | 4 | 7 | 4 | 1.00 |
| F | 1 | 2 | 9 | 3 | 1.78 |
| G | 3 | 4 | 11 | 5 | 1.78 |
| H | 1 | 2 | 3 | 2 | .11 |

**What is the probability of project completion?**

**Step 3**

The CP analysis said that it is 15 weeks.

However there are significant variations in the times estimated for the 8 activities. If there is any variation of the time in the activities on the critical path then overall project completion would be delayed.

To know the answer, we have first to calculate the variances of the activities in the critical path to have an idea of the variance of the overall project.

α2p = project variance = ∑(variances of activities on the critical path)

= 0.11 + 0.11 + 1.00 + 1.78 + 0.11 = 3.11

Project standard deviation αp = √Project variance = √3.11 = 1.76 weeks

Having known the standard deviation to be 1.76 weeks, what is the probability that the project will be finished on or before 16 weeks?

To find this answer, we need to find the area under the normal curve. This is the area to the left of the 16th week. We use the standard normal equation i.e.

Z = (Due date - expected date of completion)/αp

= 16 weeks – 15 weeks/1.76

= 0.57 standard deviation

Referring to the normal table, Z value of 0.57 to the right of the mean indicates a probability of 0.7157. Therefore there is a 71.57% chance that the pollution control equipment can be put in place in 16 weeks or less.

Probability (r =16 weeks) 0.57 standard deviation

is 71.57%

15 16 Time (week)

The shaded area to the left of the 16th week (71.57%) represents the probability that the project will be completed in less than 16 weeks.

Another example:

If the project is expected to be completed in 17 weeks what is the probability that it will be done?

Z = (17- 15)/1.76 = 2/1.76 = 1.136 standard deviations

Referring to the normal table, Z value of 1.136 to the right of the mean indicates a probability of 87.2%.. Therefore there is an 87.2% chance that the pollution control equipment can be put in place in less than 17 weeks.

What is the due date that the project can be completed with a 99% probability?

Z = (Due date – expected date of completion)/ αp

Due date = Expected date of completion + (Z x αp)

= 15 + (2.33\* x 1.76)

= 15 + 4.1

= 19.1 weeks

(\* 2.33 is obtained from the Normal Table)

Probability of 0.99

Probability of 0.01

Z

0

2.33 standard deviations

What is the date of the project completed with a chance of 95%

Due date = 15 + (1.65 x 1.76)

= 15 + 2.90

= 17.90 weeks

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**Variability in completion time of non critical paths**.

When there is variability in activity times, it is important to investigate the variability in the completion times of activities on noncritical paths.

For example activity D in the Milwaukee Paper’s project, it is a noncritical activity with a slack of 1 week. How is this variability in D’s time affect the probabilities of project completion times.

D has a variance of .44 and the pessimistic completion time for D is 6 weeks. This implies that if D ends up taking its pessimistic time to finish, the project will not finish in 15 weeks, even though D is not in the critical activity. Therefore it is necessary to reduce the variability of noncritical activities especially those with large variances.

Determining the variance and probability of completion for noncritical path is the same manner as the above examples.

αp2 = Project variance for non-critical activities = 0.11 + .0.44 + 1.78 = 2.33

αp = standard deviation = √2.33 = 1.52

Z = (Due date – expected date of completion)/ αp

= 16 – 15/1.52 = 0.65

Z value of 0.65 to the right of the mean indicates a probability of 0.7422.

This means there is a probability of 74.22% chance that the project will be completed in

16 weeks or less than 16 weeks.

If the project is to be completed in 17 weeks what is the probability that will take place?

If Z = 17 – 15/1.52 = 2/1.52 = 1.315 standard deviation

Z value of 1.315 to the right of the mean indicates a probability of 0.9049 i.e. 90.49%

chances of competing the project in 17 weeks or less than 17 weeks.

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***What has been found so far about the implementation of the project of Melwaukee Paper Manufacturing Incorporation are as follows:***

1. The project’s expected completion date is 15 weeks.
2. There is a 71.57% chance that the equipment will be in place within the 16-week deadline.
3. Five activities (A, C, E, G and H) are on the critical path . If any one of these is delayed for any reason, the entire project will be delayed.
4. Three activities (B, D F) are not critical and have some slack time built in. This means that the manager can borrow from their resources and if necessary he may be able to speed up the whole project.
5. A detailed schedule of activity starting and ending dates, slack, and critical path activities is as follows:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Activity | Earliest Start  ES | Earliest Finish  EF | Latest Start  LS | Latest Finish  LF | Slack  LS - ES | On Critical  Path |
| A | 0 | 2 | 0 | 2 | 0 | Yes |
| B | 0 | 3 | 1 | 4 | 1 | No |
| C | 2 | 4 | 2 | 4 | 0 | Yes |
| D | 3 | 7 | 4 | 8 | 1 | No |
| E | 4 | 8 | 4 | 8 | 0 | Yes |
| F | 4 | 7 | 10 | 13 | 6 | No |
| G | 8 | 13 | 8 | 13 | 0 | Yes |
| H | 13 | 15 | 13 | 15 | 0 | Yes |

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**Cost-Time Trade Offs and Project Crashing**

When implementing a project, it is possible to confront with;

1. behind the schedule
2. completion time has been moved forward.

As a consequence some of the remaining activities need to be speeded up to finish the project by the desired due date. This can be done by “project crashing” i.e. by shortening the duration of a project in the cheapest way possible.

In CPM, each activity has a normal/standard time (i.e. expected time) and a normal cost. In the case of a crash time, there is also a crash cost of the activity which is usually higher than the normal cost.

Normally it is possible to shorten an activity by adding extra resources (equipment, people) to it.

The amount of time can be shortened in an activity depends on the difference between normal time and crash time. It may not be possible to shorten all activities. In certain activities there may not be any possibility to shorten the time e.g. heat treatment of a an object in the furnace.

Similarly the cost of crashing (or shortening) an activity depends on the nature of the activity. Speeding up a project should be done at the least additional cost. So to crash any activity the following must be considered:

1. The amount by which an activity is crashed is permissible.
2. The shortened activity duration must enable the project to be finished by the due date.
3. The total cost of crashing is as small as possible.

There are 4 steps to crash a project:

1. What is the crash cost per week?

( Crash cost - Normal cost)

Crash cost per week =

(Normal time - Crash tome)

1. Use the current activity time, find the critical path(s) in the project network. Identify the critical activities.
2. If there is only one critical path select the activity on this CP that:

(a) can still be crashed

(b) the smallest crash cost per period crash this activity by one period.

If more than one CP select one activity from each CP such t6hat (a) each selected activity can still be crashed and (b) the total crash cost per period of all selected activities is the smallest. Crash each activity by one period.

Note: that the same activity may be common to more than one CP.

1. Update all activity times.

If the desired due date has been reached. Stop. If not, return to step 2.

Suppose at Milwaukee Paper Manufacturing has been given 13 weeks instead of 16 weeks to install the pollution control equipment.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Activity | Time (weeks) | | Cost(s) | | Crash cost per week | Critical path |
| Normal | Crash | Normal | Crash |
| A | 2 | 1 | 20,000 | 22,750 | 750 | yes |
| B | 3 | 1 | 30,000 | 34,000 | 2,000 | no |
| C | 2 | 1 | 26,000 | 27,000 | 1,000 | yes |
| D | 4 | 3 | 48,000 | 49,000 | 1,000 | no |
| E | 4 | 2 | 56,000 | 58,000 | 1,000 | yes |
| F | 3 | 2 | 30,000 | 30,500 | 500 | no |
| G | 5 | 2 | 80,000 | 84,500 | 1,500 | yes |
| H | 2 | 1 | 10,000 | 19,000 | 3,000 | yes |

How to calculate crash cost for activity B:

( Crash cost - Normal cost)

Crash cost per week =

(Normal time - Crash tome)

= 34,000 – 30,000/ 3-1

= 4,000/2

= 2,000

The CP activities A-C-E-G-H show that A has the least crash cost of $750.

Therefore it should crash activity A by 1 week to reduce project completion time to 14 weeks.

Similarly a new path is created i.e. B-D-G-H with the completion time of 14 weeks. Now further crashing needs to be done to the two CPs. In each CP one activity can still be crashed. It is likely to choose B and C as each is $1,000 per week i.e. a total of $2,000 for both activities.

However looking at activity G, which is a common activity for both CPs and the crash cost is only $1,500 per week.

Therefore, to crash the project to 13 weeks (from 15 weeks) it is possible to crash activity A by 1 week and activity G by 1 week. The total additional cost = 750 v+ 1500 = $2,250.

This is important because a contract may include bonus or penalty for early or late finishes.

**3. Project Controlling**

It involves close monitoring of resources, costs, quality and budgets. Control also includes receiving feedbacks to revise the project plan and to shift resources to where they are needed most. Many programmes are available for the above purpose such as Primavera, MacProjecr, Pertmaster, Time Line and Microsoft Project. These programmes produce many types of reports such as:

1. detailed cost breakdowns for each task,
2. total program labour curves,
3. cost distribution tables,
4. functional cost and hour summaries,
5. raw material and expenditure forecasts,
6. variance reports,
7. time analysis reports and
8. work status reports.

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**PERT and CPM FRAMEWORK**

Both follow the same 6 basic steps:

1. Define the project and prepare the work breakdown structure.
2. Develop the relationships among the activities. Decide which activities must precede and which must follow others.
3. Draw the network connecting all the activities.
4. Assign time and/or cost estimates to each activity.
5. Compare the longest time path through the network. This is called the **critical path**.
6. \*Use the network to help plan, schedule, monitor and control the project. Note:

Finding the **critical path** is the most important thing in controlling a project. The activities on the critical path represent the tasks that will delay the entire project if they are not completed on time. Managers must be able to complete the critical tasks by identifying noncritical activities and replanning, rescheduling and reallocating labour and financial resources.

Major differences between PERT and CPM

1. PERT employs three time estimates for each activity. These time estimates are used to

compute expected values and standard deviations for the activity.

2. CPM makes the assumption that activity times are known with certainty and hence

requires only one time factor for each activity.

3. Both help to plan, schedule, monitor and control the project.

PERT and CPM are important because they can help answer questions such as the following about projects with thousands of activities:

1. When will the entire project be completed?
2. What are the critical activities or tasks in the project – that is, which activities will delay the entire project if they are late?
3. Which are the noncritical activities – the ones that can run late without delaying the whole project’s completion?
4. What is the probability that the project will be completed by a specific date?
5. At any particular date, is the project on schedule, behind schedule, or ahead of schedule?
6. On any given date, is he money spent equal to, less than, or greater than the budgeted amount?
7. Are there enough resources available to finish the project on time?
8. If the project is to be finished in a shorter amount of time, what is the best way to accomplish this goal at the least cost?

**How PERT and CPM complement each other?**

1. CPM help to determine the Critical Path.

2. PERT help to determine the time frame for the completion of the project.

3. Both help to plan, schedule, monitor and control the project.

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**Ethical issues faced by project manager**

Project managers face ethical issues on a daily basis. Their behaviours form the ethical codes. They may face situations such as:

* offers of gift from contractors;
* pressure to alter status reports to mask the reality of delays;
* false reports for charges of time and expenses; and
* pressures to compromise quality to meet bonus or penalty schedules.

Research has shown that good leadership and a strong organisational culture are necessary to have proper ethical practice in the organisation. However most people tend to have their own set of ethical standards and values. One way to establish a reasonable code of ethics is to use the Project Management Institute’s ethical codes.

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**A Critique of PERT and CPM**

|  |  |
| --- | --- |
| Advantages of PERT | Limitations of PERT |
| 1. Especially useful when scheduling and controlling large projects. 2. Straightforward concept and not mathematically complex. 3. Graphical networks help highlight relationships among project activities. 4. Critical path and slack time analyses help pinpoint activities that need to be closely watched. 5. Project documentations and graphs point out who is responsible for various activities. 6. Applicable to a wide variety of projects. 7. Useful in monitoring not only schedules but costs as well. | 1. Project activities have to be clearly  defined, independent and stable in their  relationships.  2. Precedence relationships must be  specified and networked together.  3. Time estimates tend to be subjective and  are subject to fudging by managers who  fear the dangers of being overly  optimistic or not pessimistic enough.  4. There is the inherent danger of placing  too much emphasis on the longest, or  critical, path. Near-critical paths need to  be monitored closely as well. |

(Source: Southwestern University (pp. 136-137) in OM, 2017, Herzer, Render &

Munson, A.)