Chapter 3
Expediting the Execution of Projects

Success of a project is determined by completing the same within time and cost limits and maintaining the required quality standards. Maintaining the time-schedule of project, faces challenge due to two major reasons.

i. Sometimes allowable project duration is shorter than estimated normal duration. This may be due to over optimistic incorrect time estimate or enforced time constraints due to market forces. Execution of project in a shorter time frame, calls for expediting the work of project to meet the tight time schedule.

ii. Projects are dynamic and are carried out in changing environments under uncertainty. Among the factors liable to change the existing plan are: the revision of activities' duration estimates, delivery failures, changes in technical specifications, technical difficulties, unexpected weather conditions, and labor unrest. Due to environmental changes, it is very difficult to exactly maintain the project schedules.

So it is necessary to have a monitoring system that generates feedback for expediting the work wherever necessary.

3.1 Managing Multiple Projects

Many project-based organizations manage a number of simultaneous projects that share resources from a limited pool. In a study of two cases that involved 30 and 60 simultaneous projects respectively, Engwall and Jerbrant [2003] identified the following operational problems in multi-project environments:

i) The senior managers responsible for portfolio management ("portfolio management level") were overloaded with problems.

ii) Portfolio management did priority setting and resource re-allocation on almost daily basis.

iii) There was a continuous ongoing game of negotiations concerning access to
available resources and the allocation of certain individuals to specific projects.

iv) The management was primarily engaged in short term problem solving.

v) One project had negative effects on other projects - such as delays and missed deadlines. When one project had problems, other projects were affected directly.

vi) There was tough competition between projects and project managers kept resources working on their projects (unnecessarily) in order not to lose them.

vii) Priorities of projects change often. There was no clarity or guidelines concerning prioritization of projects.

Several authors (Elonen and Artto, 2003; De Maio et al, 1994; Platje et al, 1994; Hendriks et al, 1995) have highlighted conflicting interests and competition among project managers for limited resources as the main problems of managing multiple projects. In order to satisfy the demands of every client, work is pushed through the system. The client and the manager handling the project demand that their work be expedited on priority. Priorities are often set in an informal and intuitive manner.

3.2 Internal Prioritizing

Fulfilling the commitments is an important issue with managing multiple projects. The situation is bad when project firm has accepted too many projects. Each customer thinks that firm is working on his project actively and making good progress on it. But in reality, there is no way the firm can work on all of them at the same time. So the project managers often do internal or hidden prioritizing. They choose to get to some of the projects first, leaving the others for "later". In some other cases, instead of doing internal prioritizing, the project managers label all work as urgent. The staff is not able to know which work is really urgent and which one is not. They try to work on all projects at the same time. As a result all the projects progress too slowly.

There is need for a system to determine the priority of projects based on clear guidelines. There should be different levels of priority so that projects are expedited with appropriate strategy and intensity corresponding to their priority levels.
3.3 Strategies for Reducing Project Duration

Fariborz et al (1993) in their model have considered various strategies for reducing the duration of any project. Summary of these strategies is given as under:

i. Control: Making people work harder and more efficiently by better organizing, closer monitoring and giving incentive to people for higher productivity

ii. More time: Working for more time (without increasing project duration) by operating in shifts and overtime

iii. Resources: Extra resources (people, equipment and material) may be added to complete the tasks faster

iv. Change contract: Off-load work by sub-contracting activities and changing terms of contract for expeditious execution at higher cost

v. Change specification: Changing the specification of work to enable it to be done faster.

vi. Abort: Give up expediting and let a project overrun its schedule time. If possible it may be expedited later on to bring it progress closer to schedule.

In this thesis, the strategies for reducing the duration of any project may be referred to as 'Expediting Strategies'. Effectiveness of expediting will depend upon selection of expediting strategies and the intensity with which these strategies are implemented. An index for specifying the effectiveness of expediting may be defined as, "a factor \( k \), by which the original duration of a project is reduced when the project is expedited". So if original expected duration of a project is \( d_e \) with standard deviation \( \sigma \), on expediting its expected duration will become \((1-k)d_e\) with standard deviation \( \sigma \sqrt{1-k} \). The term 'k' may be referred as "Expediting Index".

Expediting a project will involve cost. A more effective strategy will normally involve greater cost. So expediting should be done only where it is necessary and appropriate expediting strategy should be adopted based on cost criteria. There is also a limit to the amount of work that can be expedited. For this, priority of individual project should be determined for selecting appropriate expediting
Expediting the Execution of Projects

strategy. Normally, this is done by informal and intuitive method. But it is desirable to follow a scientific basis for taking decisions relating to expediting of different projects.

3.4 Mathematical Model

In a multi-projects execution setup, projects arrive at random interval. The schedule for execution of these projects is prepared based on project parameters such as work content, expected duration, required due date for completion, value and importance of each project. However due to uncertainty factor, execution of projects deviates from the schedule and corrective control actions are taken. Expediting is a foremost control action for bringing the projects back to schedule.

For each project, expected (scheduled) start time and maximum allowable time limit for completing the project are specified. Some amount of margin duration may be allowed to the projects in the scheduled to account for uncertainty factors and to provide flexibility to the project plan. The amount of margin duration may vary depending upon criticality of project and other factors.

To formulate the mathematical model for expediting the execution of projects, let us consider the work progress of a project with passage of time. The variables used in the model are given below.

\[ t_{es} = \text{Expected start time of project} \]
\[ t_{as} = \text{Actual start time of project} \]
\[ d_{e} = \text{Expected duration of project} \]
\[ \sigma = \text{Standard deviation in expected duration of project} \]
\[ t_{m} = \text{Maximum allowable finish time} \]
\[ r = \text{Fraction of project completed at time of review 't'} \]
\[ a = \text{Probability of completing the project within given time} \]
\[ z = \text{Value corresponding to probability 'a'} \]

The two indexes, 'Expediting Index' and 'Criticality Index' used in the model are defined below.

When a certain work component is expedited, its duration is reduced or crashed.
Extent to which the duration is reduced will depend upon effectiveness of expediting. The effectiveness of expediting may be expressed in quantitative terms by an index ‘k’ and determined as under.

\[
  \text{Expediting index, } k = \frac{\text{Normal duration} - \text{Expedited duration}}{\text{Normal duration}}
\]

A project can have many paths having different durations. The path having the longest expected duration is called the critical path. The expected duration of critical path determines the project duration. But duration of some non-critical paths may be slightly less than the duration of critical path. If the activities of these paths are delayed, it may also delay the project. So to some extent these paths may also be considered as critical. Extent to which a path of a project is critical may be specified by an index, which is termed in this thesis as 'Criticality Index'.

The criticality index ‘\( \rho_i \)’ of a path ‘i’ may be defined as the ratio between expected duration of given path to expected duration of project.

\[
  \rho_i = \frac{\text{expected duration of the given path 'i'} \text{'} }{\text{expected duration of project}}
\]

When expected duration of a path is same as expected duration of project, the criticality index of path is 1 or the path is the critical path. For non-critical paths, the value of criticality index is less than 1.

Fraction of work completed with passage of time is shown in figure 3.1.

Figure 3.1: Progress of work of a project shown against passage of time
Expediting the Execution of Projects

If a project starts at expected start time $t_{es}$ and takes expected duration $d_e$, it is completed at point A. However due to uncertainty, the project may start late at time $t_{es}$. The rate of progress may also be slower. Let at time $t$, the project has progressed up to point B. If the project progresses at this rate, it may be completed beyond the maximum allowable limit, as shown by point C. However if the project is expedited, the rate of work progress is improved. So the project may be completed before allowable time limit as shown by point D. The above figure is based on expected rate of work progress. But due to uncertainty factor, the rate of work progress may improve even without expediting. However the probability of such occurrence may be much less. On the other hand rate of work progress may also become worse in spite of expediting. So probability aspects should be considered for taking decisions about expediting of projects.

In an uncertain environment, the assurance level (probability) of completing a project within expected duration $d_e$ is only 0.5. But for greater assurance level, either more time duration should be allowed to the project, or the project should be expedited. As per probability distribution, minimum time duration within which a project is expected to be completed with assurance level $\alpha$, is given by:

$$d_e + z\sigma \quad \text{where} \quad \alpha = 1 - \int_{-\infty}^{+\infty} \frac{-x^2}{\sqrt{2\pi}} \, dx$$

...(equation 3.1)

For a given assurance level $\alpha$ the value of $z$ can be calculated or directly read from normal distribution table. If time $(t_m - t_{es})$ allowable to a project is more than $(d_e + z\sigma)$, the project can be completed with required assurance $\alpha$ without any need for expediting.

i.e. if $(t_m - t_{es}) > (d_e + z\sigma)$ no expediting is required.

Otherwise the project should be expedited.

The intensity of expediting required to complete a job within allowable time is determined by expediting index. Suppose the project is expedited with expediting index 'k', then minimum time required to complete the project with assurance level $\alpha$ is given by $(d_e + z\sigma)(1-k)$. So to ensure timely completion of project with assurance level $\alpha$, the time available for execution of project $(t_m - t_{es})$ should be more than $(d_e + z\sigma)(1-k)$.

i.e. $(t_m - t_{es}) > (d_e + z\sigma)(1-k)$
So expediting index \( k \) can be determined by the equation:

\[
k > 1 - \frac{t_m - t_{es}}{d_e + z\sigma} \quad \text{(equation 3.2)}
\]

Based on value of \( k \), appropriate expediting strategy can be decided at the start of the project.

As the project progresses, the actual progress of work may deviate from the plan due to uncertainty factor. So progress of project is reviewed periodically and appropriate decision for expediting the project can be taken based on status of project at that instance of time.

Suppose the project is reviewed at time \( t \) and at that instance estimated fraction of work completed is found to be \( r \). This amount of work has been done in time duration \((t - t_{es})\).

As per calculation, expected duration of time needed to complete \( r \) fraction of work is \( r.d_e \) with standard deviation \( \sigma \sqrt{r} \). So time required to complete \( r \) fraction of work for assurance level \( \alpha \) is given by, \( r.d_e + z\sigma \sqrt{r} \). So if actual time taken \((t - t_{es})\) is less than \( r.d_e + z\sigma \sqrt{r} \), the progress of work may be considered as satisfactory. To evaluate how fast the work on project has progressed, work progress index \( \eta \), may be computed as under.

\[
\eta = \frac{r.d_e + z\sigma \sqrt{r}}{t - t_{es}} \quad \text{(equation 3.3)}
\]

So if \( \eta > 1 \) the progress of project may be considered as satisfactory.

And if \( \eta > \frac{r.d_e + z\sigma \sqrt{r}}{r.d_e} \) the progress of project is faster than expected.

However it is to be determined if remaining portion of work can be completed with required assurance level \( \alpha \) within the due date. The time needed to complete remaining \((1-r)\) fraction of work for a given assurance level \( \alpha \) is given by, \((1-r)d_e + z\sigma \sqrt{1-r}\). So if allowable time for completing the remaining portion of project \((t_m - t)\), is less than \((1-r)d_e + z\sigma \sqrt{1-r}\), the project may need to be expedited.

Suppose the remaining portion of project is expedited with a strategy having
Expediting the Execution of Projects

expediting index ‘k’, the time required for doing the work is reduced by a factor ‘(1−k)’. To ensure completion of project at required assurance level ‘α’, this reduced time should be less than the remaining allowable time.

\[
(1 - r)dt + za_{1-r} < (t_m - t)
\]

or

\[
k > 1 - \frac{(t_m - t)}{(1 - r)dt + za_{1-r}}
\]

... (equation 3.4)

So based on above equation, value of ‘k’ can be determined and a suitable strategy for expediting the project can be selected accordingly. If remaining allowable time \((t_m - t)\), is greater than \((1 - r)dt + za_{1-r}\), the value of ‘K’ becomes negative. This indicates that expediting is not necessary.

The model requires that the “fraction of project completed” should be estimated at each review. In many cases, it may be quite difficult to objectively assess the fraction of work that has been completed. In such cases assessment can be done subjectively. For example, consider work of writing program code for a software module. It is difficult to objectively estimate what fraction of program code has been completed unless the coding is fully completed. But here the programmer can make some subjective assessment of what amount of his work has been completed. Subjective assessment may not be that accurate, but it is better than no assessment.

The actual time lapsed in execution of project \((t - t_m)\) should also be significant enough for drawing any meaningful conclusion. When a project is executed, the progress is not visible immediately. Progress in work is generally reported in multiple of some fixed amount, say 5% or 10%. In practice, if progress of work is less than this amount, it is sometimes ignored and reported as zero. So time lapsed in execution of project should be reasonable enough to draw any meaningful conclusion about progress of work.

3.5 Illustration of the Model

To illustrate the model, some projects of a fictitious project organization are considered. Suppose it is required that the projects should be completed within maximum allowable time limit at assurance level of 95% (i.e. \(\alpha = 0.95\)). For this required assurance level ‘α’, the value of ‘z’ taken from normal distribution table is
Expediting the Execution of Projects

1.645. So expediting index ‘k’, required for timely completion of each project is determined by equation-2. The projects with fictitious data are shown in table 3.1.

Table 3.1: Decision for expediting the fictitious at start of project (t=0)

<table>
<thead>
<tr>
<th>Project</th>
<th>Expected duration ‘d_e’</th>
<th>Standard deviation ‘o’</th>
<th>Scheduled start time ‘t_{es}’</th>
<th>Maximum allowable time ‘t_m’</th>
<th>Expediting index ‘k’</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>5</td>
<td>0.5</td>
<td>0</td>
<td>6</td>
<td>-0.031</td>
</tr>
<tr>
<td>P2</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>0.067</td>
</tr>
<tr>
<td>P3</td>
<td>8</td>
<td>1</td>
<td>6</td>
<td>16</td>
<td>-0.037</td>
</tr>
<tr>
<td>P4</td>
<td>6</td>
<td>0.8</td>
<td>6</td>
<td>12</td>
<td>0.180</td>
</tr>
<tr>
<td>P5</td>
<td>4</td>
<td>0.5</td>
<td>8</td>
<td>15</td>
<td>-0.451</td>
</tr>
</tbody>
</table>

If for a project the value of ‘k’ is negative, it indicates that the project is not critical and it need not be expedited. So from above data, only the projects P2 and P4 need to be expedited.

A project can be expedited with varying intensity from ‘very low’ to ‘very high’. For our illustration purpose, fictitious values of effectiveness index of different priority levels are given in table 3.2.

Table 3.2: Hypothetical expediting strategies

<table>
<thead>
<tr>
<th>Priority level</th>
<th>Intensity of expediting</th>
<th>Expediting index (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Very low</td>
<td>0.1</td>
</tr>
<tr>
<td>S2</td>
<td>Low</td>
<td>0.2</td>
</tr>
<tr>
<td>S3</td>
<td>Moderate</td>
<td>0.3</td>
</tr>
<tr>
<td>S4</td>
<td>High</td>
<td>0.4</td>
</tr>
<tr>
<td>S5</td>
<td>Very high</td>
<td>0.5</td>
</tr>
</tbody>
</table>

So projects P2 and P4 are required to be expedited with strategy having minimum expediting index 0.067 and 0.180 respectively. So S1 and S2 are the appropriate priority level for projects P2 and P4 respectively. (see table 3.2).

However as time progresses, some projects may be delayed and some may...
Expediting the Execution of Projects

progress faster. Suppose the projects are reviewed at time \( t=5 \), and portion of work completed in each project is estimated. Work progress index and minimum value of expediting index for projects can then be determined by applying equation-3 and equation-4 respectively. This is tabulated in table 3.3.

<table>
<thead>
<tr>
<th>Project</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected duration ‘( d_e )'</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Scheduled start time ‘( t_{es} )'</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Maximum allowable time ‘( t_m )'</td>
<td>6</td>
<td>9</td>
<td>16</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Minimum value of ‘( k )' at time of review</td>
<td>-0.031</td>
<td>0.067</td>
<td>-0.037</td>
<td>0.180</td>
<td>-0.451</td>
</tr>
<tr>
<td>Actual start time ‘( t_{as} )'</td>
<td>0</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Fraction completed ‘( r )'</td>
<td>0.5</td>
<td>0.4</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Work Progress Index ‘( \eta )'</td>
<td>0.62</td>
<td>2.02</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Minimum value of ‘( k )'</td>
<td>0.675</td>
<td>0.341</td>
<td>-0.037</td>
<td>0.180</td>
<td>-0.451</td>
</tr>
</tbody>
</table>

From the table 3.3, it is seen that the project ‘P1’ which was not critical earlier, now needs to be expedited with strategy having minimum expediting index 0.675. But no strategy having such high expediting index is available. So project can be expedited with priority level ‘S5’ that has the highest expediting index of 0.5. However completing this project at 95% assurance level (\( \alpha=0.95 \)) cannot be ensured. The project P2 which was earlier expedited at very low intensity (priority level S1), now needs to be expedited with high intensity (priority level S4).

When the projects are reviewed again say at time \( t=10 \), the same procedure is followed to determine work progress, work progress index and expediting index. For illustration purpose hypothetical data is tabulated in table 3.4.

From the table 3.4 it is seen that project P4 needs to be expedited with highest possible intensity. So expediting with highest intensity (priority level S5) should be adopted for this project. The project P3 should be expedited with high intensity (priority level S4). Expediting need not be done for project P5.
Expediting the Execution of Projects

Table 3.4: Status of projects at time (t = 10)

<table>
<thead>
<tr>
<th>Project</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected duration '(d_e)'</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Scheduled start time '(t_{es})'</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Maximum allowable time '(t_{m})'</td>
<td>6</td>
<td>9</td>
<td>16</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Minimum value of 'k' at time of review</td>
<td>0.675</td>
<td>0.341</td>
<td>-0.037</td>
<td>0.180</td>
<td>-0.451</td>
</tr>
<tr>
<td>Actual start time '(t_{as})'</td>
<td>0</td>
<td>2</td>
<td>9</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Fraction completed 'r'</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.20</td>
<td>0.00</td>
</tr>
<tr>
<td>Work Progress Index '(\eta)'</td>
<td>--</td>
<td>--</td>
<td>0.00</td>
<td>0.60</td>
<td>*</td>
</tr>
<tr>
<td>Minimum value of 'k'</td>
<td>--</td>
<td>--</td>
<td>0.378</td>
<td>0.665</td>
<td>-0.037</td>
</tr>
</tbody>
</table>

* Indicates that time lapsed in execution of project (\(t - t_{sa}\)) is too short to determine '\(\eta\)'

3.6 Correction Factor for Non-Critical Activities

Priority level of project is based on expected project duration and uncertainty in duration specified by standard deviation in duration. The project duration is the sum of duration of activities of the critical path. So when priority level of project is specified, it is applicable to the critical activities and not to all activities of a project. For non-critical activities necessary correction may be done for determining the priority level.

A project can have many paths having different durations. Suppose expected duration and standard deviation in duration of a particular non-critical path is \(d_i\) and \(\sigma_i\) respectively. So the criticality index '\(\rho_i\)' of path 'i' is determined as ratio between \(d_i\) and \(d_e\).

\[
\rho_i = \frac{d_i}{d_e} = \frac{d_i + z\sigma_i}{d_e + z\sigma}
\]

If activities of critical paths are expedited with intensity 'k' then activities of non-critical paths may be expedited with lower intensity '\(k_i\)'.

As per equation 2, the minimum value of expediting index for activities of critical path, 'k' is:

\[
k = 1 - \frac{t_m - t_{es}}{d_e + z\sigma}\quad \text{or}\quad 1 - k = \frac{t_m - t_e}{d_e + z\sigma}
\]
Expediting the Execution of Projects

Similarly minimum value of expediting index for activities of non-critical path, 'k_i' is:

\[ 1 - k_i = \frac{t_m - t_{es}}{d_i + z\sigma_i} \quad \text{or} \quad 1 - k_i = \frac{t_m - t_e}{\rho_i (d_e + z\sigma)} \]

So expediting index for non-critical activities 'k_j' may be determined by using the equation:

\[ 1 - k_i = \frac{1 - k}{\rho_i} \quad \text{...(equation 3.5)} \]

Since \( c_i \) is less than 1, the value of \( k_i \) is less than \( k \). So the activities of non-critical paths should be expedited with lesser intensity than that is required for activities of critical path. If value of \( k_i \) is less than zero, the activities of the path need not be expedited irrespective of priority level of project.

3.7 Conclusion

Expediting of projects is very important for minimizing project delays. But when projects are expedited based only on intuitive judgment, it sometimes results in incurring expenditure on expediting projects that are not warranted. Determination of objective measures such as expediting index is useful in selecting priority level without any subjective bias. When numbers of projects are being executed simultaneously, each project is competing with the other for utilizing maximum share of organization resources. Determination of priority level of projects provides a basis for distribution of resources among projects. It also makes it easier for the project manager to incur extra expenditure for expediting a project. The idea of expediting can also be extended to other areas such as:

- Inventory Management: for expediting supplies from vendors
- Marketing Management: for expediting shipment of goods and realization of payments
- Production planning: for expediting jobs at different work stations

Expediting is an integral part of control. It has wide applicability and scope for further research in project management and in other areas.