Chapter Seven
Money and Network Schedules
Money and network schedules:

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

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

- CPM provides a mean for relating time and money.
Money and network schedules (cont.):

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

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

1) Materials costs.

2) Labor costs.

3) Plant and equipment costs

4) Overhead costs and profit.
Activities cost:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>ES</th>
<th>TF</th>
<th>Cost ( $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>650</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>6</td>
<td>0</td>
<td>1300</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>400</td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>1450</td>
</tr>
<tr>
<td>H</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>500</td>
</tr>
<tr>
<td>E</td>
<td>6</td>
<td>10</td>
<td>6</td>
<td>1100</td>
</tr>
<tr>
<td>G</td>
<td>3</td>
<td>11</td>
<td>0</td>
<td>600</td>
</tr>
<tr>
<td>F</td>
<td>2</td>
<td>11</td>
<td>6</td>
<td>350</td>
</tr>
<tr>
<td>I</td>
<td>3</td>
<td>13</td>
<td>6</td>
<td>1000</td>
</tr>
<tr>
<td>J</td>
<td>8</td>
<td>14</td>
<td>0</td>
<td>1300</td>
</tr>
<tr>
<td>K</td>
<td>2</td>
<td>22</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Overtrading:

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

Total cost

Com. cost

Time

6/14/2010

Nabil Dmaiaidi
The time value of money:

- Is an estimate of the cost to construct a specific project, this include an acceptable allowance for profit and the successful submittal of the lowest bid to an owner resulting in the award of the contract.

- Ideal case, if the contractor estimated the cost of the project exactly, then the amount of profit realized will be exactly as originally allowed.
The time value of money (cont.):

- Is the value of the profit actually received the same as was originally anticipated?

- Time changes the value of the profit realized. Because of inflation and the delay in the actual receipt of all revenues the profit once realized will no longer permit the contractor to purchase the same value of goods as when the bid was originally submitted contractors are paid only after work has been performed, this lag or delay in the receipts of revenues is often a considerable time after the costs of construction are actually paid.
Interest rates:

- If inflation was zero and the interest rate was zero, it would be simple matter to assess profitability.
- If inflation is an extremely low level, interest rate are rarely at a level that they can be ignored.
- Contractors must be careful in selecting the appropriate interest rate to use for the analysis of positive and negative cash flow.
Contractor cash disbursements:

- Over all interest rate for deficit funds flow should reflect the cost of borrowing the money or if no money is borrowed the interest rate, should reflect the value of opportunities.
- That are forgone for internal funds that are used to meet financial obligations.
- The each flow analysis of a project entails an examination of the disbursement of funds and the receipt of funds.
- Their timing has a direct impact on the amount of cash available or the deficit to be realized at differing times during the construction of a project.
The disbursement of funds:

1- Labor:

- The cost of labor in a project can be substantial. A rough estimate puts labor at approximately one-third of the total cost of a construction project.

- However, this is largely depending on the type of project and the amount of work subcontracted.

- The timing of the disbursement of funds for labor is largely dictated by law.
The disbursements of funds (cont.):

- Hourly wages are paid weekly the primary difference between companies might be simply the day of the week on which the wages are actually paid, otherwise there are few differences the wage rates and any overtime pay should be included in the estimate as this information must be known prior to submitting the paid. The time of the payment of these wages is of particular concerns in the cash flow analysis.
The disbursements of funds (cont.):

- How is cash flow impacted when the equipment is owned by the company?

- A piece of equipment that has been purchased by the company, without any outstanding loans does adversely impact the cash flow of a company.

- However, the impact on cash flow of a company may be different than the impact on the cash flow on project because the company and the project are not viewed as being the same.
The disbursements of funds (cont.):

2- Equipment:

- Equipment used on project will generally fall into one of the categories:
  a- Equipment owned by two company.
  b- Equipment leased or rented by the company.

- For the cash flow analysis, the type of ownership doesn’t substantially affect the result. It is common that lease payments be made on a monthly basis. Rented equipment is paid for on a monthly basis. Unless the equipment is rented for shorter periods such as by the day or by the week.
The disbursements of funds (cont.):

For cash flow purpose, payment for renting the company owned equipment is generally an internal funds transfer that occurs at the end of each month. Thus, as far as the disbursement of funds is concerned, company owned equipment is often similar to outside-owned equipment.
The disbursements of funds (cont.):

3- Materials:

- The cost of materials in corporate in a construction project together with the labor and equipment costs continue the bulk of the costs of construction.

- How are payments made for material?

Materials are typically ordered from suppliers through purchase orders or purchase agreements it is common for materials to be delivered to the construction site before.
The disbursements of funds (cont.):

- The contractor has any obligation to pay for them.
- A shortly, after the materials are delivered to the site however the contractor is generally expected to pay for them the actual payment arrangement vary between supplier and these differences should be clearly understood.
- Materials ,are expected to be paid for approximately a month from the time of delivery.
The disbursements of funds (cont.):

4- Sub contractors:

- when a particular task requires specialized skills, certain work items might be sub contracted.
- Sub contractors typically request payment for services rendered on a monthly basis.

“pay when paid” provision essentially assure, the general contractors that they will not suffer a negative cash flow on the subcontracted work.
The disbursements of funds (cont.):

- It is also typical, for general contractors to include a provision in the sub contractor agreements that payment will be made to the subcontractors only after the general contractor has received payment for that work from owner.

- In addition, the general contractor will commonly withhold a portion of the payments due to the subcontractor as retainage stated as a percent, which is typically the same as retainage withheld from the general contractor by the owner.
The disbursements of funds (cont.):

5- Others:

- The general contractor, should have a clear understanding of all expenditures to be incurred on a project this includes the timing of the payments for these items.

- For example, insurance premiums, surety fees, various permits, and mobilization occur early in a project.

- A careful analysis should be made of all overhead items, whether project or office overhead to determine the timing of payments for these items.
Contract provisions that impact cash flow:

- The contractor must recognize that the cash flow to be realized on a particular project will be dictated to some extent by the contract.

- This is particularly true for the timing of the receipt of revenues so it is important that the contract documents be examined closely to fully understand how the contracted provisions will impact the cash flow on project.
Contract provisions that impact cash flow (cont.):

1- Payment schedule:

- The type of contract dictates the general nature of payment schedule.
  
  e.g., on a unit price contract the various pay items are enumerated in the bid itself. The list of pay items gives a clear idea of the information needed to conduct a cash flow analysis.

- Other items that are not always pay items in a contract include form work, scaffolding and shoring these items may be essential to deliver project, but do not, in themselves impact any value to the project.
Contract provisions that impact cash flow (cont.):

2- Retainage:

- It is common in the construction industry for the owner to withhold a stated percentage of the funds earned by the contractor as retainage.
- The common retainage amount seems (10%).
- Obviously retention has an adverse impact on the contractors cash flow.
Contract provisions that impact cash flow (cont.):

3- Material:

- Long-lead time items may be purchased early to ensure that they will be available when needed.

- The contractor should be examined to determine if payment will be made for materials that are properly stored on site (or elsewhere) or if payment will be made only upon installation.

- Of course, the storage of some materials may use up valuable space and require regular monitoring. These factors must be taken into consideration.
Contract provisions that impact cash flow (cont.):

4- Mobilization:
   - It can be a large cost item and the contract wording for the programs mobilization should be closely examined.

5- Monthly payment:
   - The impact on cash flow is more severe if the contractor is not paid until the 20th of the following month.

6- Final payments:
   - It is common to be made from (1-3) months after substantial completion. Generally its not made until after the punch list items have all been completed.
Owner policies and practices that impact cash flow:

- Only experience or trade talk can help a contractor gain in sight about an owner’s on-site practices.

- Obviously the owner actions either can be adverse to a contractor or they might be in the contractors favor.

- The extent of detail required varies for different parties as different purposes and being served.
The Cash-Flow Analysis:

- Is a very meaningful term to most contracts who must be sensitive to the issue of cash flow if they are to service.

- Cash flow analysis is an investigation of a project in which the focus is on the flow of money (including expenditures and revenues of money).

- It consists of a detailed examination of the disbursement of funds and the receipt of revenues.
The Cash-Flow Analysis (cont.):

- Two major reasons for conducting a cash flow analysis:
  1. It reveals surplus funds are available during a project or if a negative cash positive will occurring during construction.
  2. It helps in establishing a appropriate marl up on a bid.

- Other parties will also how an interest in such analysis (such as Bankers, sureties, insurance carriers, equipment dealers, credit-reporting agencies, clients (owners), business partners).
Negative cash position:

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

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

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

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

- And the contractor may invest this surplus funds for short duration.
The present worth of the cash flow:

- The simplest analysis is to convert the value of all funds to an equivalent present worth amount at the time of bid submittal or contractor award.

- This can be done by taking the present worth of the difference between the anticipated funds receipts and anticipated disbursements.

- The analysis can be performed effectively if the flow of the funds is accurately predicted and if an appropriate interest is utilized.
The present worth of the cash flow (cont.):

- The analysis could be carried on further to include the influence of varying the lines when the monthly payments are received.
- It is common for a general contractors profit margin to be about (2-3)%.
- It is obvious the cost flow analysis can have a significant impact on the decisions of a company.
Cumu. Expenditures & Revenues

Cash-Flow Curve for revenue and expenditures

Time (Months)

REVENUES

EXPENDITURES

AMOUNT OF NEGATIVE CASH FLOW

RETAINAGE RELEASE

6/14/2010
Nabil Dmaiadi
Time-cost trade-off:

- It is possible that the originally project duration is not necessarily the least time solution nor the least cost schedule for the project in spite of the fact that each activity within the project was originally planned to be done in the most efficient (list cost manner).

- Project cost elements:

  1- Direct costs:
  
  Related to putting the facility components in place. They represent the resources used by an activity (material, labor and equipment).
Time-cost trade-off (cont.):

- The costs of materials and the cost of the subcontractor work tend to be relatively fixed or not subject to considerable variance.

- Over estimates on the productivity will result in a longer duration to complete the project while under estimated the costs will be below budget for that work item and the time to complete the activity will also be reduced.
Time-cost trade-off (cont.):

2- Indirect job costs (job overhead):

- Costs that could not be attributed to a specific work item. (such as, site offices, superintendents, security fence & etc).
- These costs are generally incurred whether or not productive work work achieved.
- Longer project duration will result in higher indirect costs.
Time-cost trade-off (cont.):

3- Operating Overhead costs (company overhead):

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

- These costs continue as long as the company exists even one project is running.
Time-cost trade-off (cont.):

4 - Profit:

- As with overhead, profit is company-specific and represents the access monies earned by a firm over its total costs.

- It is provide investors with return on their investment in the company.

- It is necessary to consider a profit as a “cost” of a project.
Time-cost trade-off (cont.):

- It is necessary to look at the combination of project costs to determine the overall cost of a project.

- By examining further the relationship between time (e.g., project & activity duration and costs), it can be determined how decision about one of the duration) about one of these considerations relate to the other.
A major issue in dealing with the trade-offs between time and cost in determining exactly how much additional money is necessary to decrease an activity’s duration.

The specific problem is to determine the cost required to shorten an activity’s duration by one day.

This cost per day then represents the slope of the curve that plots the cost of an activity’s against the duration of the activity.
Time-cost trade-off (cont.):

- The shape of the time-cost relationship for activities varies depending on the nature of the means required to make the time reductions.

- The straight line relationship between activity duration and cost will be assumed when project compression occurs.
Time-cost trade-off (cont.):
Logic of Time-Cost Trade-Off:

- **Assumption # (1):**
  - Increasing or decreasing an activity’s duration will lead to increased direct costs for that activity.

- **Assumption # (2):**
  - Decreasing a project’s duration will lead to lower indirect costs.
General relation of direct costs to project duration
General relation of indirect costs to project duration
Logic of Time-Cost Trade-Off (cont.):

- **Assumption # (3):**
  - A project’s duration can be decreased by decreasing the duration of one or more critical activities on the critical path.

- **Assumption # (4):**
  - Decreasing a project’s duration may increase or decrease the total cost of a project depending upon whether the additional direct costs required to decrease the activity duration are greater or less than indirect costs savings of decreasing the project’s duration.
General relation of project costs to project duration

- **Total project costs**
- **Direct costs**
- **Indirect costs**

6/14/2010
Nabil Dmaiaidi
Logic of Time-Cost Trade-Off

- In performing time-cost trade-off analysis it is necessary to determine the cost of decreasing the critical path by one day.

- Naturally, the critical activity with the least direct cost slope (lowest additional cost per day of shortening) will be selected first to minimize the cost of shortening the project.
### Activities Sort

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>LS</th>
<th>TF</th>
<th>Resource</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>8 H</td>
<td>200</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>9 H</td>
<td>450</td>
</tr>
<tr>
<td>D</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>9 H</td>
<td>900</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>7 H</td>
<td>500</td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td>11</td>
<td>0</td>
<td>5 H</td>
<td>250</td>
</tr>
<tr>
<td>E</td>
<td>4</td>
<td>15</td>
<td>8</td>
<td>4 H</td>
<td>400</td>
</tr>
<tr>
<td>I</td>
<td>9</td>
<td>16</td>
<td>0</td>
<td>8 H</td>
<td>450</td>
</tr>
<tr>
<td>F</td>
<td>8</td>
<td>17</td>
<td>6</td>
<td>5 H</td>
<td>1200</td>
</tr>
<tr>
<td>H</td>
<td>6</td>
<td>19</td>
<td>8</td>
<td>2 H</td>
<td>900</td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td>25</td>
<td>0</td>
<td>4 H</td>
<td>1500</td>
</tr>
</tbody>
</table>

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

6/14/2010
The previous analysis suggests that in performing Time-Cost Trade-off analysis, it is necessary to determine the cost of decreasing the critical path by one time unit (day, month & etc).

Usually, select the activity with least shortening costs. (lowest additional cost per day of shortening) to minimize the additional costs of shortening.
Reducing Project Duration

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

- Thus, the extent to which an activity can be shortened and still has the effect of shortening the project is limited by the amount of total float exists in the parallel activities.
Reducing Project Duration

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

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

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

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

- **Remember,** it is not necessarily the least cost or least time solution to schedule a project.
Four Different Solutions for Each Network

2) *Least Cost:* considering both direct and indirect costs, it may be possible to find a project duration that minimizes these total costs. By paying more to decrease one or more critical activity (direct cost) and save greater indirect costs. (Means that the result will be total cost saving.)
General relation of project costs to project duration

Total project costs

Direct costs

Indirect costs

Project Costs

Project duration

6/14/2010

Nabil Dmaiadi
Four Different Solutions for Each Network

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

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

All crash

- A fully crashed schedule occurs when all activities shortened to their shortest possible duration.

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

- It wouldn’t be cost effective to randomly select any activity for shortening, this should be done in a rational manner.

- To begin time-cost trade-off in a systematic fashion Basic computations should be done:
  a. First compute ESD & EFD for each activities.
  b. Compute the link lag value, for each link between activities (LAG\textsubscript{AB} = ESD\textsubscript{B} – EFD\textsubscript{A}).
Logically Reducing Project duration:

- It should be clear that there is at least one path between the first activity and last activity in the network for which all the link lag values are 0. (The critical path). (other solution can be derived by computing TF).

- If the project is to be shortened, it is imperative that the duration of one of the activities on the critical path is to be shortened.
Logically Reducing Project duration:

- The logical choice for the first activity to be shortened is the activity which has the lowest incremental cost for making duration reductions.

- The selection of the activity to shorten must be based solely on the minimum cost per day and not the cost of the cycle.
Reducing Project Duration to shortest possible duration

Example:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>H</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES</td>
<td>6/14/2010</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LS</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dur.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>16</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>EF</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FF</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>TF</td>
<td>13</td>
<td>3</td>
<td>7</td>
<td>20</td>
<td>13</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>LF</td>
<td>19</td>
<td>4</td>
<td>4</td>
<td>23</td>
<td>19</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Nabil Dmaiaidi
Logically reducing Project Duration

- In the previous network. Activity (A,B,F,H and L) forming the critical path.
- (The path with zero lag from the first to the last activity in the network).
- Any shortening of the project will result in an increase of the direct cost of the project.
Logically Reducing Project duration:

The table below represents the duration – cost data for a project:

<table>
<thead>
<tr>
<th>Activity no.</th>
<th>Normal Duration</th>
<th>Crash Duration</th>
<th>Normal Cost ($)</th>
<th>Crash Cost ($)</th>
<th>Days to shorten</th>
<th>Cost per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>800</td>
<td>800</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>4</td>
<td>1000</td>
<td>1600</td>
<td>3</td>
<td>200</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>4</td>
<td>300</td>
<td>500</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>2</td>
<td>400</td>
<td>800</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>1</td>
<td>100</td>
<td>200</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>F</td>
<td>7</td>
<td>5</td>
<td>500</td>
<td>800</td>
<td>2</td>
<td>150</td>
</tr>
<tr>
<td>G</td>
<td>8</td>
<td>4</td>
<td>200</td>
<td>1400</td>
<td>4</td>
<td>300</td>
</tr>
<tr>
<td>H</td>
<td>7</td>
<td>6</td>
<td>350</td>
<td>600</td>
<td>1</td>
<td>250</td>
</tr>
<tr>
<td>J</td>
<td>5</td>
<td>3</td>
<td>700</td>
<td>850</td>
<td>2</td>
<td>75</td>
</tr>
<tr>
<td>K</td>
<td>3</td>
<td>2</td>
<td>500</td>
<td>1000</td>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>L</td>
<td>5</td>
<td>4</td>
<td>4500</td>
<td>800</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>
Logically Reducing Project duration:

- Assume the following information exist about the various activities:

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

- **Cannot be shortened At any cost**
- **Least cost activity to shorten**
Logically Reducing Project duration:

- Without shortening the project will end after 27 days with a cost of 5300 $. This is the normal duration cost.

- Other consideration (such as overhead, liquidated damages provisions, changes or needs of other project) may make it desirable to complete the project in a shorter or longer duration.
Logically reducing Project Duration

- From the previous table, it can be noticed that activity F has the least incremental shortening cost. (150 $ per day).

- E.g. Shortening F for 2 days costs 150 x 2 = 300 $.

- Bear in mind, activities for shortening selected based on cost per day. Not on cycle cost basis.
Logically reducing Project Duration

- How many days activity F could be shortened?
- The answer in computing the Network Interaction Limit (NIL).
- So, reducing activity F by 2 days will affect the link lag values of the succeeding activities and TF of parallel activities.
Logically reducing Project Duration

- This can be determined graphically by drawing a line vertically down through the network. This vertical line will pass through the activity or activities being shorted and through any positive link lags that may be in the path of the line.

- A zero value link line can be crossed if it’s value will be increased by the activity duration, being reduced.
If activity F is shortened the link lag values of E-H & G-K will be reduced by the same # of days.
Summary of the first compression cycle

<table>
<thead>
<tr>
<th>Cycle #</th>
<th>Activity to shorten</th>
<th>Can be shortened</th>
<th>NIL</th>
<th>Days shortened</th>
<th>Cost per day</th>
<th>Cost per cycle</th>
<th>Total cost</th>
<th>Project duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>5300</td>
<td>28</td>
</tr>
<tr>
<td>1</td>
<td>F</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>150 $</td>
<td>300 $</td>
<td>5600</td>
<td>26</td>
</tr>
</tbody>
</table>

- The point at which one of the link lag values becomes 0 is known as NIL.
- By observing activity F it can be shortened by two days which is smallest of the link lag values or the NIL and the max # of days that an activity can be shortened.
Identifying activities for 2\textsuperscript{nd} compression cycle:

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

- As no additional critical paths were created when activity F was shortened by two days the same activities are still under consideration. As is readily observable activity should now be shortened.
Identifying activities for 2\textsuperscript{nd} compression cycle:

- Activity B can be shortened a total at 3 days at a cost of $200 per day. This is the lowest cost activity to shorten. The line drawn through the activity B and none zero link lag values shown that the NIL is one day. Activity B is shortened one day. Link lag values for C-F & G-K become zero.

- Always examine the number of days that an activity can be shortened and the number of days in the NIL ad select the smallest of these two value.
## Summary of the 2nd compression cycle

<table>
<thead>
<tr>
<th>Cycle #</th>
<th>Activity to shorten</th>
<th>Can be shortened</th>
<th>NIL</th>
<th>Days shortened</th>
<th>Cost per day</th>
<th>Cost per cycle</th>
<th>Total cost</th>
<th>Project duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>5300</td>
<td>28</td>
</tr>
<tr>
<td>1</td>
<td>F</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>150 $</td>
<td>300 $</td>
<td>5600</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>200</td>
<td>200</td>
<td>5800</td>
<td>25</td>
</tr>
</tbody>
</table>

6/14/2010  
Nabil Dmaiaidi
Identifying activities for 2\textsuperscript{nd} compression cycle:

- The new project duration is 24 days and the cost of compression is $5800. This last day of compression was achieved at a cost of $200 per day.

- Note that activity C is now additional critical activity and link lag value of G-K is 0.
Identifying activities for 2\textsuperscript{nd} compression cycle:

- To further reduce project duration consideration must be given to shortening activities B & C (jointly), activity H or activity L in this case, the decision is based solely on costs. Activity H is selected for shortening.

- The NIL for shortening activity H is two days (link lag value of J-L) but activity H can be shortened only one day, so activity H will be shortened by one day. The project duration is now 23 days and the cost is $6050.
Identifying activities for 2\textsuperscript{nd} compression cycle:

- After activity H is shortened by one day, note that link no link lag values become 0 after step 3.

- The next iteration of time compression in the network considers activity B & C (together) and activity L.
## Summary of the 3rd compression cycle

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

6/14/2010

Nabil Dmaiadi
Identifying activities for 3\textsuperscript{rd} compression cycle

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

6/14/2010

Nabil Dmaiaidi
# Identifying activities for 4\textsuperscript{th} compression cycle

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

6/14/2010  Nabil Dmaiadi
Identifying activities for 4th compression cycle

- The least costly options is to shorten activities B&C. note that if B or only C were to be shortened. The project duration would remain the same.

- When activity B&C are jointly shortened, the section cut in the network passes through. Link line K-L and link line F-K the NIL can now be determined. To shorten activity B&C, the NIL is 3. The link lag value of link line K-L.
## Summary of the 4th compression cycle

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

6/14/2010  
Nabil Dmaiadi
Logically Reducing Project duration:

- Carful study of the network will reveal that in this compression step the link lag value of F-K will increased as activity B&C are shortened. This compression cycle will result in the link line F-K becoming positive.

- By shortening the duration of activity B&C, the start finish dates of activity F will also be shortened, but this will not shorten the start of activity K.

- The start date of activity K will dictated by the finish of activity G. As activity G is not altered by this compression step.
Logically Reducing Project duration:

- The start of activity K is similarly unaltered. A review of the activity data shows that activity B and activity C can each be shortened by only two days. Thus the compression in this step will be two days.

- The link lag value for link F-K was increased by two days while this may appear odd, it simply means that activity F will be completed earlier than originally scheduled but that the completion date of activity G has not changed. Thus the start date of activity K is not changed in these compression cycle.
Logically Reducing Project duration:

- The only activity remaining can be shortened is activity L. NIL for activity L is $\infty$. A section cut through the network will not cut through any link lines so NIL is limit less the compression is determined by the number of days that activity L can be shortened, namely one day.

- At this point the network can’t be shortened further. This point is reached whenever all activities in a critical path can no longer be shortened. While there are other activities that can be shortened. The project duration would not be altered by doing so.
### Identifying activities for 5th compression cycle

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

6/14/2010

Nabil Dmaiaadi
### Summary of the 5th compression cycle

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

6/14/2010

Nabil Dmaiaidi
Identifying activities for $6^{th}$ compression cycle

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

6/14/2010
Nabil Dmaiaidi
Logically Reducing Project duration:

- Note that the values if cost/day, increase consistently this is a quick check to determine if an obvious error right have been made. The values must increase in each successive compression step.

- In some rare cases the values could be equal, in this case the scheduler actually may have more than one possible activity one activity to shorten at a given cost/day.
Logically Reducing Project duration:

- When this occurs, the scheduler must decide which activities to shorten first. Some sort of prioritization must occur.

- As a general rule, under such circumstances higher priority should be given to the activity that occurs earlier in the network. Other factors may also be present that might establish a different priority.