CE 4990 - Construction Scheduling

Resource Restrained Scheduling[*]

February 3, 2012

Discussion on the Critical Path

A critical path helps identify the minimum project duration:

- - it is the longest uninterrupted sequence of activities in the network - moving from predecessor to successor, beginning to end.

- - it requires that activities start as early as their predecessors will allow (i.e. the so called "early-start schedule")

- - it requires that all critical activities start at their early start dates to avoid project delays

- - the links in the network diagram represents both resource and technical availability requirements

- - but the network diagram does not account for restrained resources or explicitly show the *uninterrupted deployment of resources*

The network diagram and the CPM does not help resolve the issue of scheduling with resource constraints and continuity.

Resource Restrained Scheduling: Repetitive Scheduling Method (RSM)

The RSM Problem: The scheduling problem posed by multiunit projects with repeating activities requires the *minimization of the project duration* given *resource continuity constraints* as well as *technical constraints*.

Assumptions:

- *Driving resource:* The most significant resource that is associated with an activity - all activities are assigned a single driving resource.

- The same driving resource is used for like activities in successive repeating units.

---

[*]This note refers to and directly reflects lessons from Harris, R.B. & Ioannou, P.G. (1998) "Scheduling Projects with Repeating Activities." *J. of Const. Eng. & Mgmt, ASCE*, 124(4), pp 269-278

Instead of using a network the RSM represents information on an XY-plot - where the X-axis is time and Y-axis represents the number of units of work completed. The repetitive units could be discrete for vertical construction project (such as hoisting sequences) or in continuous for horizontal construction projects (such as work progress measured in units of length for highways, pipelines, tunnels etc.).

Definitions:

- *Resource production rate (rpr_A):* The amount of work that can be accomplished by the resource in one time period.

$$rpr_A = \frac{Q_{A_i}}{T_{A_i}} \tag{1}$$

  where Q_{A_i} is the quantity of work in Activity A in the repeating unit i and T_{A_i} is the time needed to complete the Activity A in the repeating unit i. Typically Eq 1. is used to calculate the activity duration given the quantity of work.

- *Unit production rate (upr_A):* The number of repetitive units that can be completed by a resource durning an unit of time.

$$upr_A = \frac{1}{T_{A_i}} \tag{2}$$

  The upr_A is the slope of the production line in the RSM diagram.

The following relationship can be inferred:

$$upr_A = \frac{rpr_A}{Q_{A_i}} \tag{3}$$

Hence, if the resource production rate (rpr_A) remains constant, then the fractional difference in quantity of work Q_{A_i} and Q_{A_j} for different units i and j is used to scale the slope of the production line for successive repetitive units.

Rules:

- Given that the activity A precedes the activity B, then if $upr_B > upr_A$ then as the number of units increase, the two production lines will *converge*. Because of the desired continuous utilization of the resources from unit to unit, the convergence will place any dependency control towards the *last* unit in the sequence. See first case in figure addendum.

- Given that the activity A precedes the activity B, then if $upr_B < upr_A$ then as the number of units increase, the two production lines will *diverge*. Because of the desired continuous utilization of the resources from unit to unit, the convergence will place any dependency control towards the *first* unit in the sequence. See second case in figure addendum.

The Controlling Sequence: The controlling sequence is defined as the sequence of activities that establishes the minimum project duration, while maintaining all technical precedence, resource availability and resource constraints.

- It passes through *control points* that switch the may sequence from production lie to production line.

- All activities on the controlling sequence need not be critical activities from the CPM network - neither are all critical activities always part of the controlling sequence.

- On the controlling sequence, if a critical activity gets delayed then the project gets delayed, if a non-critical activity gets delayed, then the project may not be delayed, but a discontinuity in resource utilization is introduced.
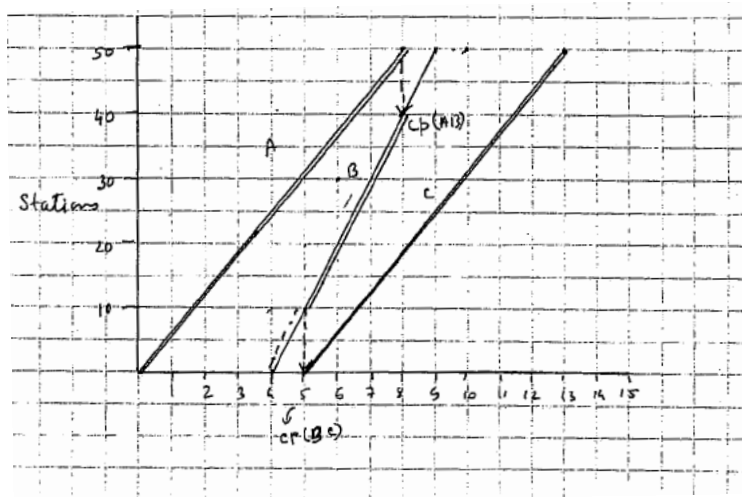
Figure 1: Paradoxical situation

Paradox: Consider the situation in Figure 1. If the activity B is rotated clockwise about the control point AB, it can be slowed down, thus shifting the control point BC to an earlier time. This will allow the activity C to start and finish earlier thus reducing the total project duration. This creates the paradoxical situation where the total project duration is reduced by slowing down an activity.

The lesson is: *The unit production rate of an activity should not be faster than the slowest preceding activity and the slowest succeeding activity.*