STRN322 – Construction Planning & Scheduling

Repetitive Scheduling Method

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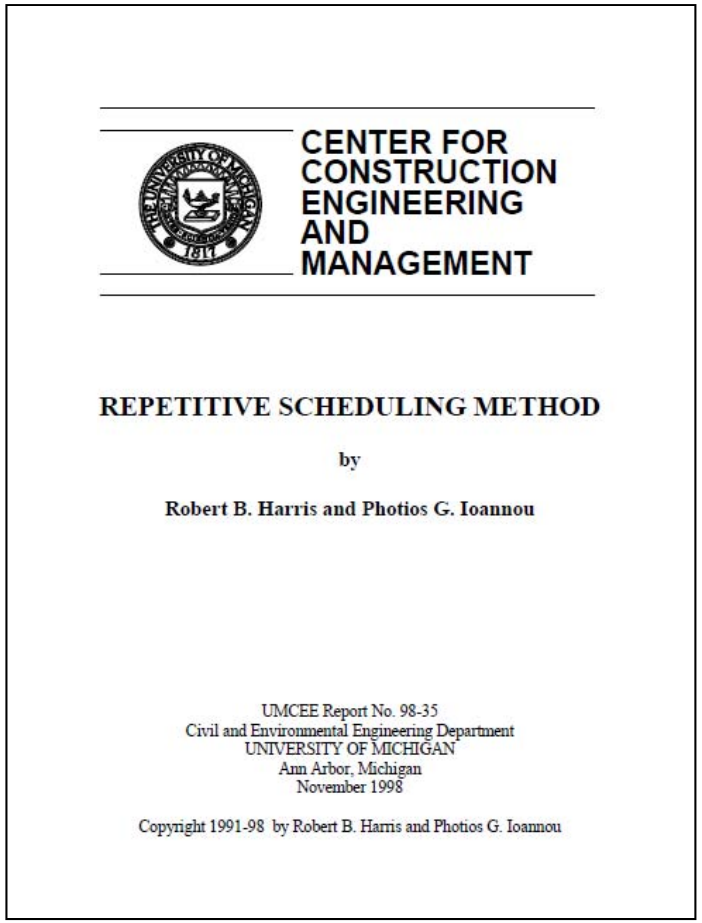
Reading Material

REPETITIVE SCHEDULING METHOD By Robert B. Harris and Photios G. Ioannou

UMCEE Report No. 98-35 Civil and Environmental Engineering Department UNIVERSITY OF MICHIGAN Ann Arbor, Michigan November 1998



CENTER FOR CONSTRUCTION ENGINEERING AND MANAGEMENT

REPETITIVE SCHEDULING METHOD

by

Robert B. Harris and Photios G. Ioannou

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What are repetitive projects?

- Projects that have a relatively small number of activities that are repeated across several units
- Examples include: Pipelines, highways, railways, high-rise buildings.

Other Names

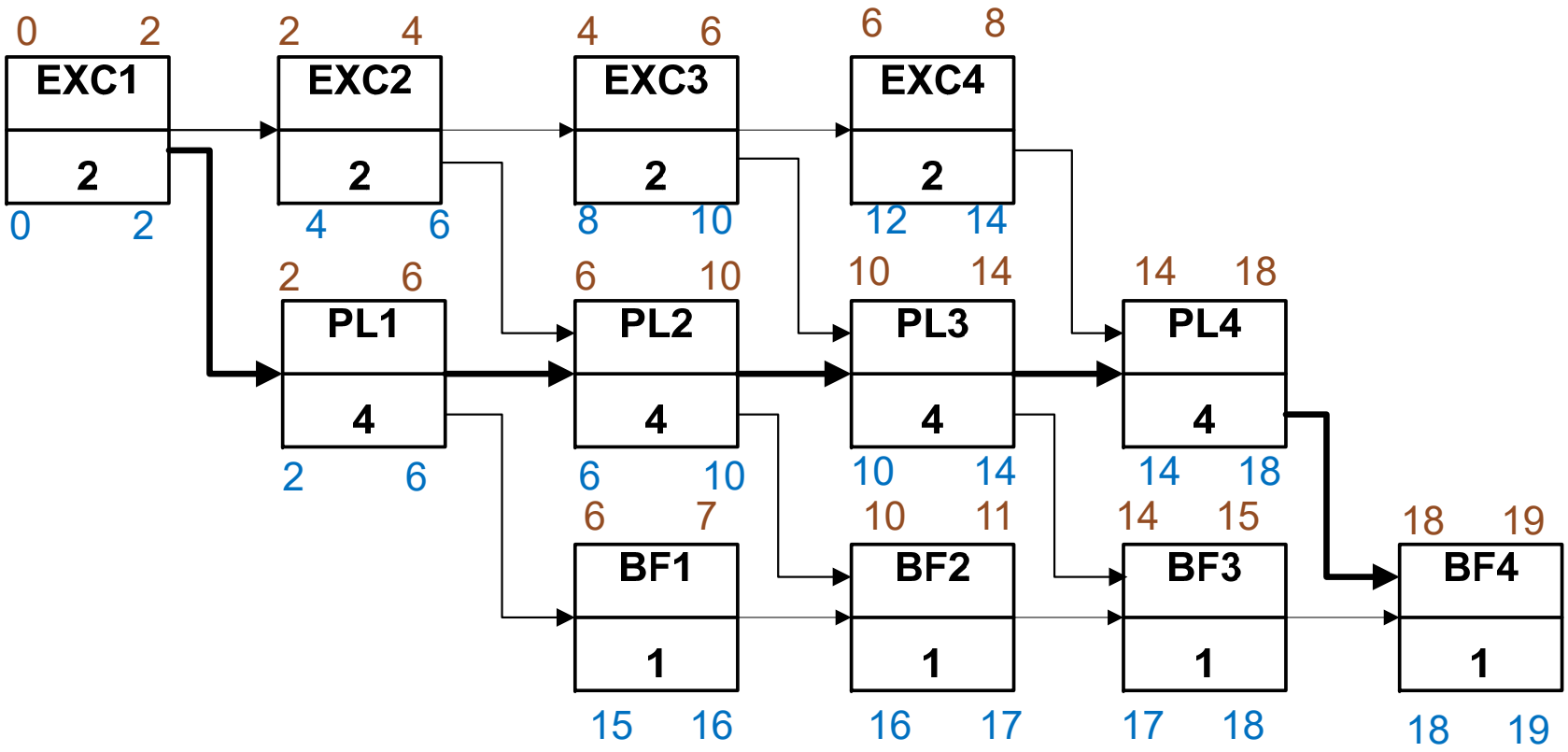
- *Line of Balance* (LOB) (O'Brien 1969, Carr and Meyer 1974)
- *Vertical Production Method (VPM) (O'Brien 1975, Barrie and Paulson 1978);*
- *Time-Location Matrix Model (Birrell 1980);*
- *Time Space Scheduling Method (Stradal and*
- Cacha 1982);
- *Disturbance Scheduling (Whitman and Irwig 1988);*

CPM vs RS

The construction of a 2 km pipeline involves three main activities that will take place in order; Excavation, Pipe laying and Backfill. The 2km project is divided into 4 sections of equal length to speed up project execution. After excavation of section-1 is complete, excavation in section-2 and pipe laying in section-1 can start. After pipe laying of section-1 is complete, pipe laying in section-2 and backfill of section-1 can start. The table below shows the activities, durations and IPA for each activity.

Activity	Description	Duration (days)	IPA
EX-1	Excavation - Section 1	2	-
EX-2	Excavation - Section 2	2	EX-1
EX-3	Excavation - Section 3	2	EX-2
EX-4	Excavation - Section 4	2	EX-3
PL-1	Pipe laying - Section 1	4	EX-1
PL-2	Pipe laying - Section 2	4	EX-2, PL-1
PL-3	Pipe laying - Section 3	4	EX-3, PL-2
PL-4	Pipe laying - Section 4	4	EX-4, PL-3
BF-1	Backfill - Section 1	1	Pl-1
BF-2	Backfill - Section 2	1	PL-2, BF-1
BF-3	Backfill - Section 3	1	PL-3, BF-2
BF-4	Backfill - Section 4	1	PL-4, BF-3

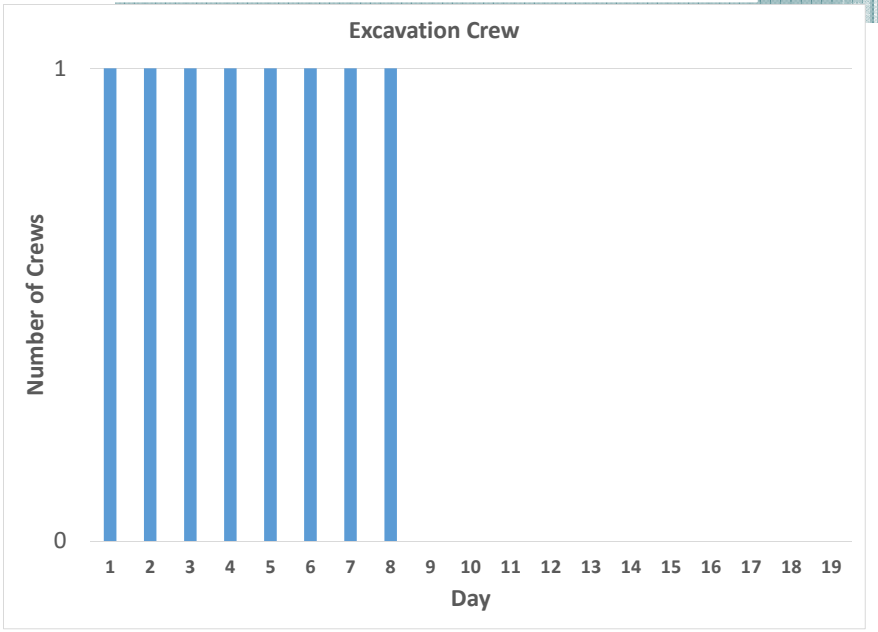
CPM vs RS

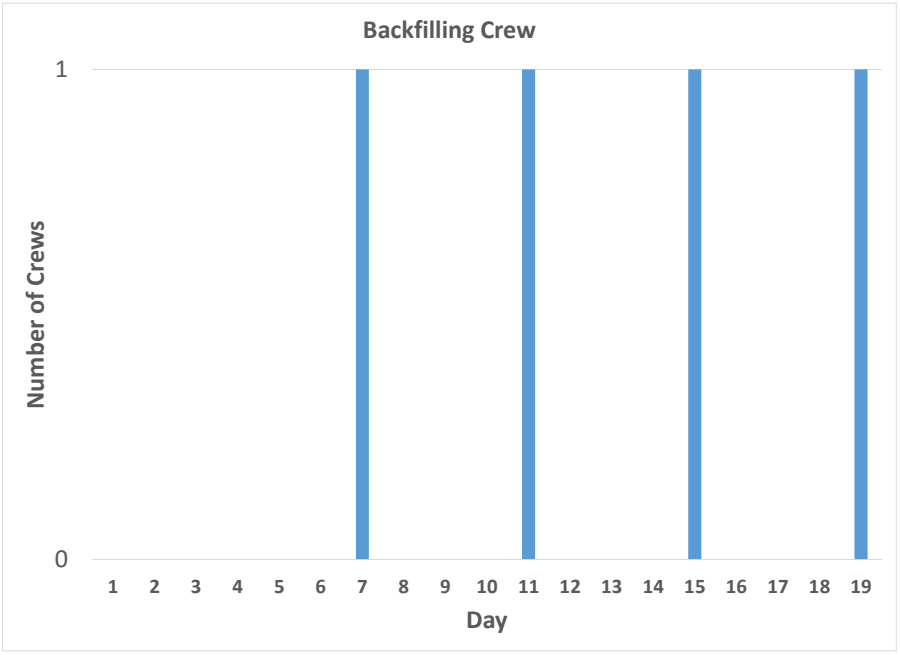


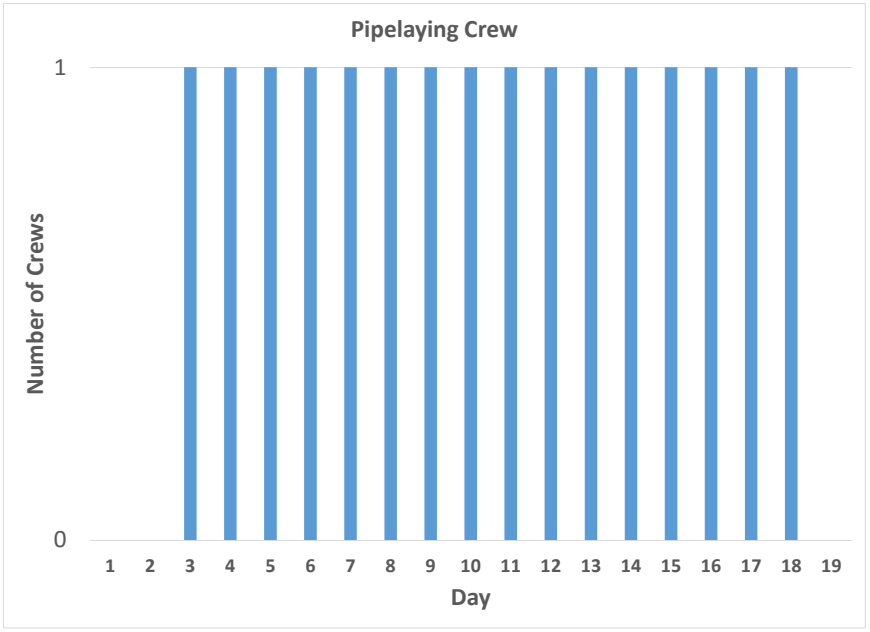
Should we execute this project on its early dates or late dates?

Resource Profile Early Dates

Backfilling crew will have to be interrupted for 3 days in between each section

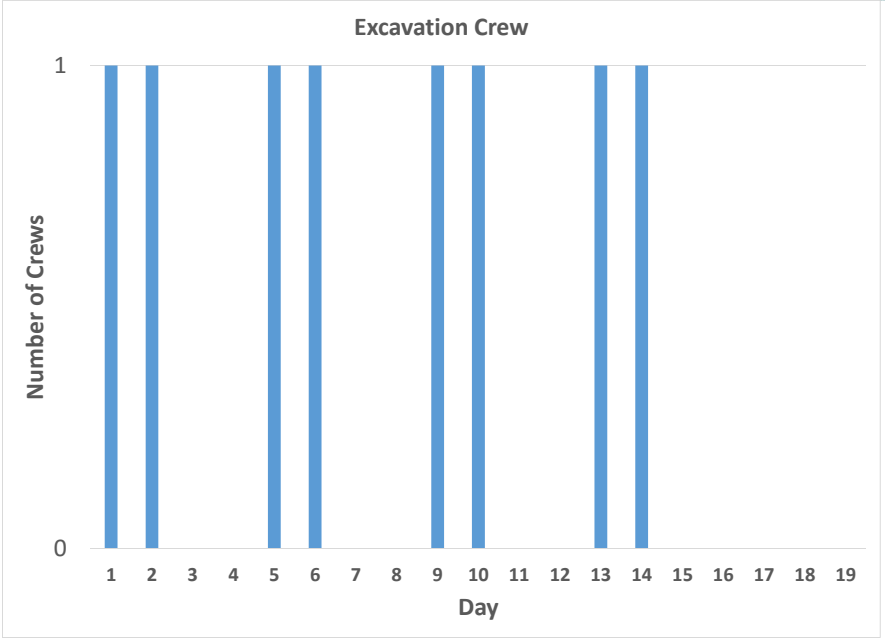


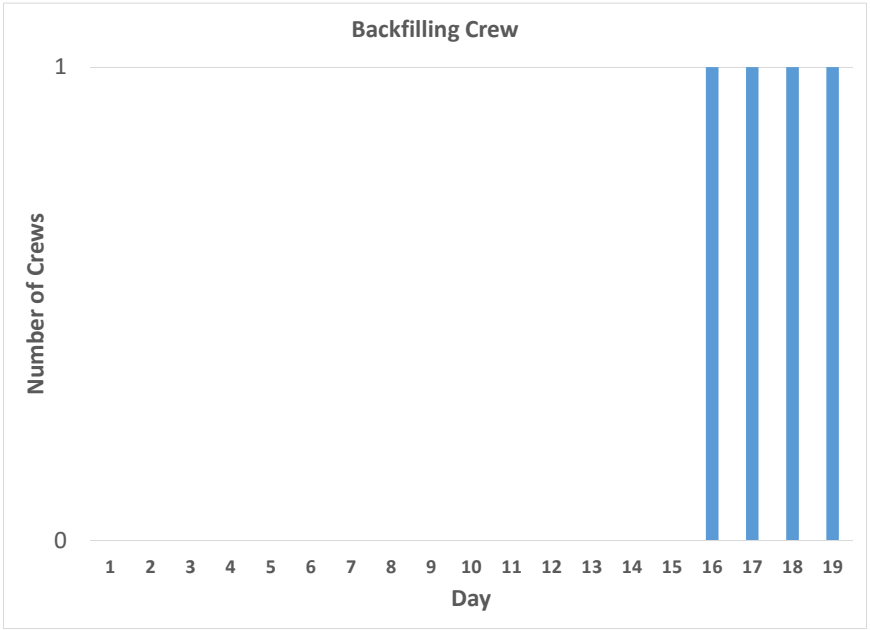


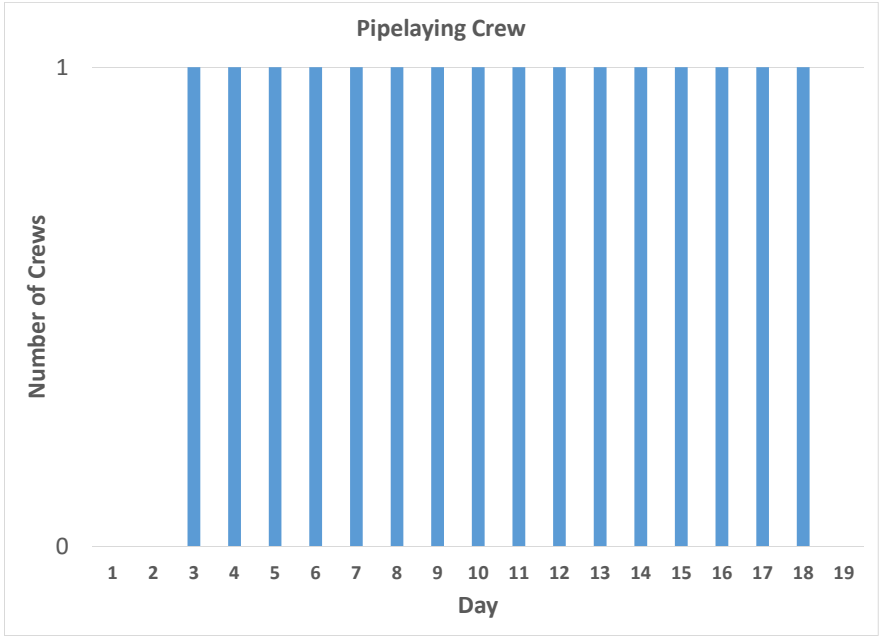


Resource Profile Late Dates

<u>Excavation crew</u> will have to be interrupted for 2 days in between each section





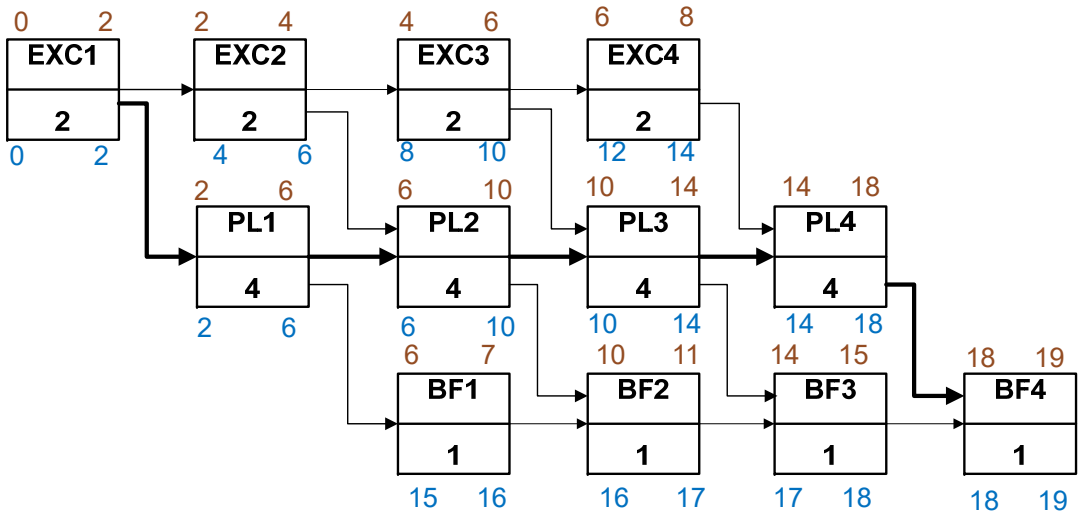


CPM vs RS

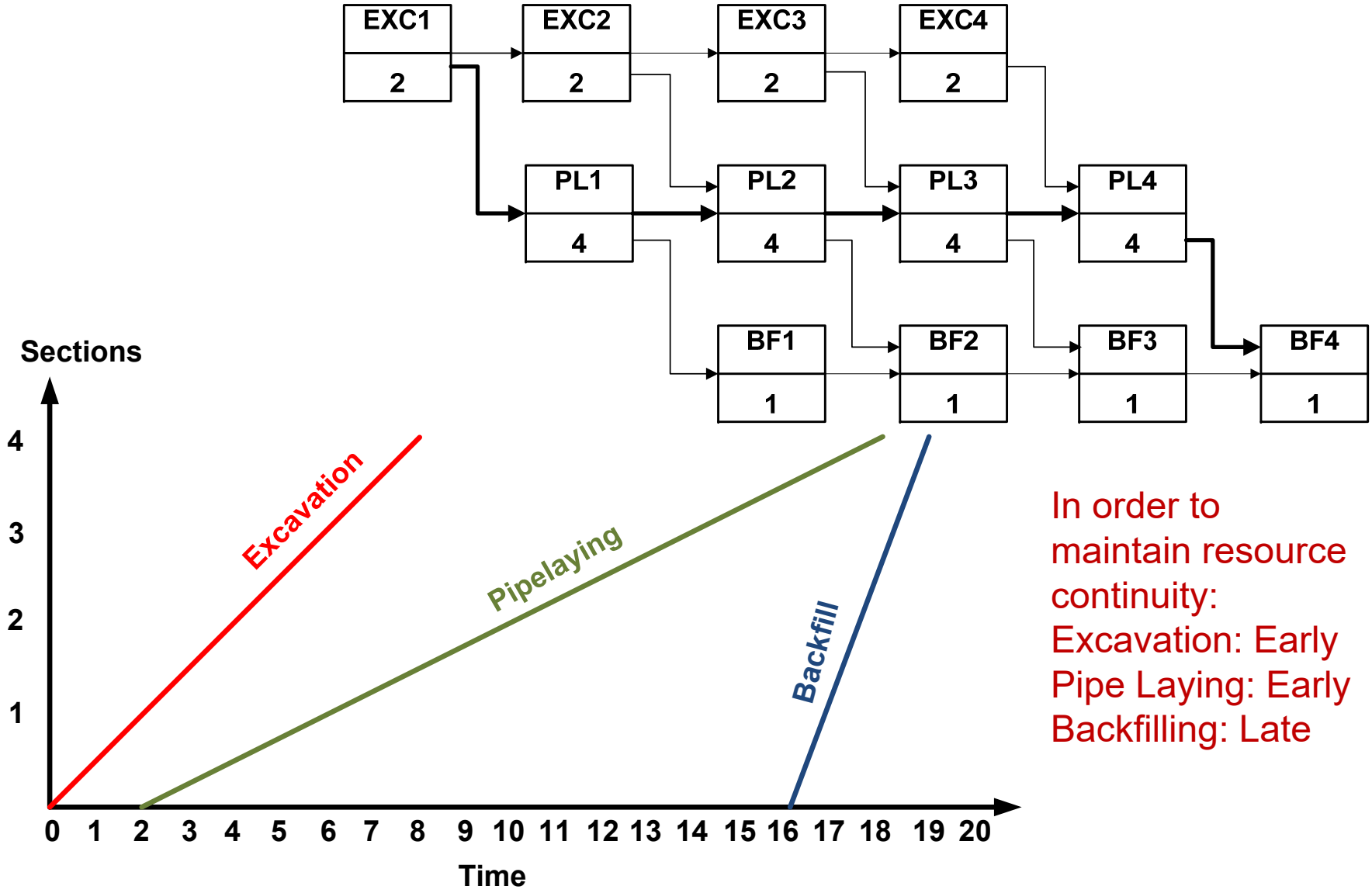
Should we execute this project on its early dates or late dates?

Schedule the activities such that the resources are continuous without interruption

→ The resource drives the schedule



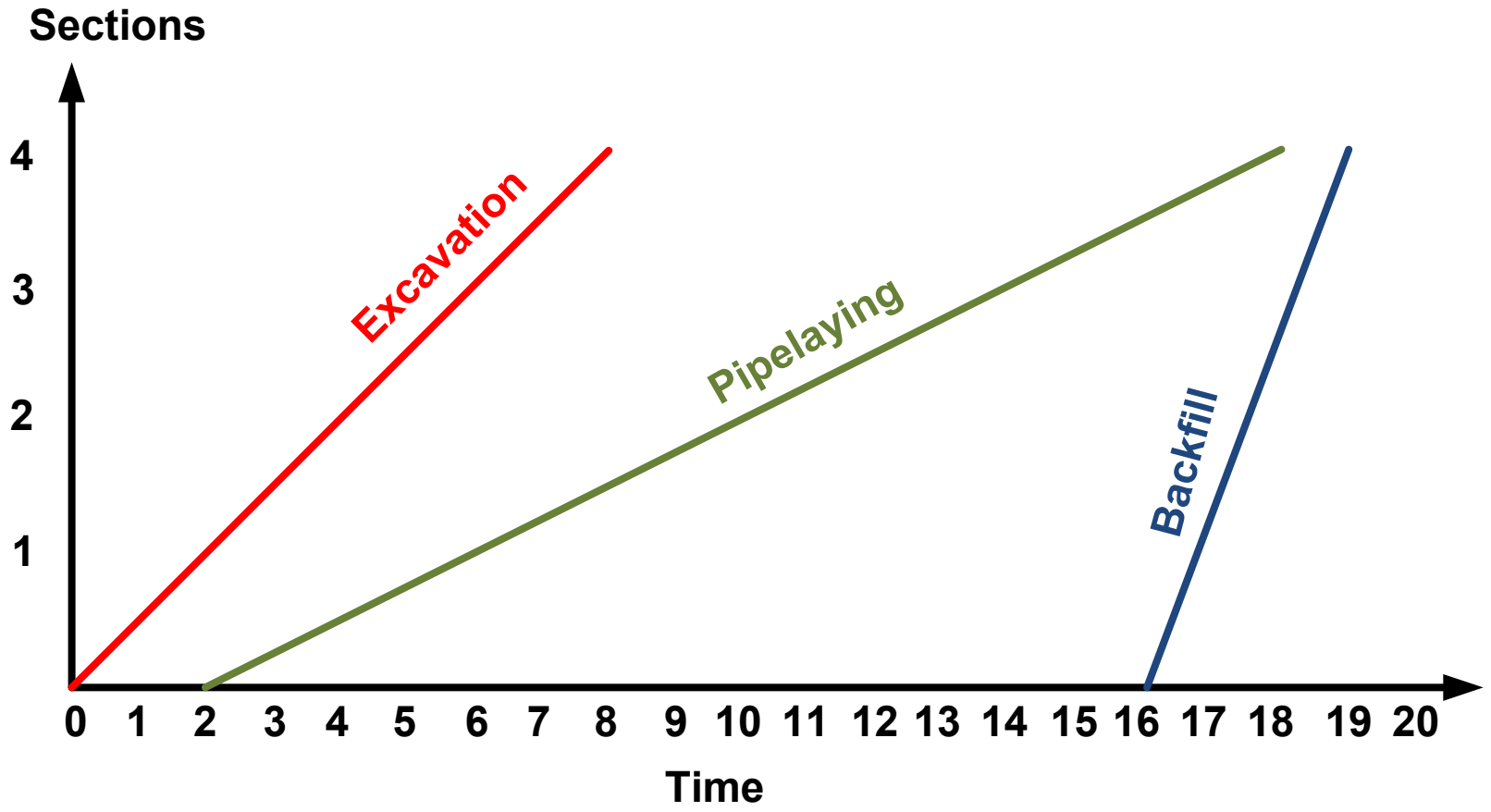
CPM vs RS



In order to maintain resource continuity:
Excavation: Early
Pipe Laying: Early
Backfilling: Late

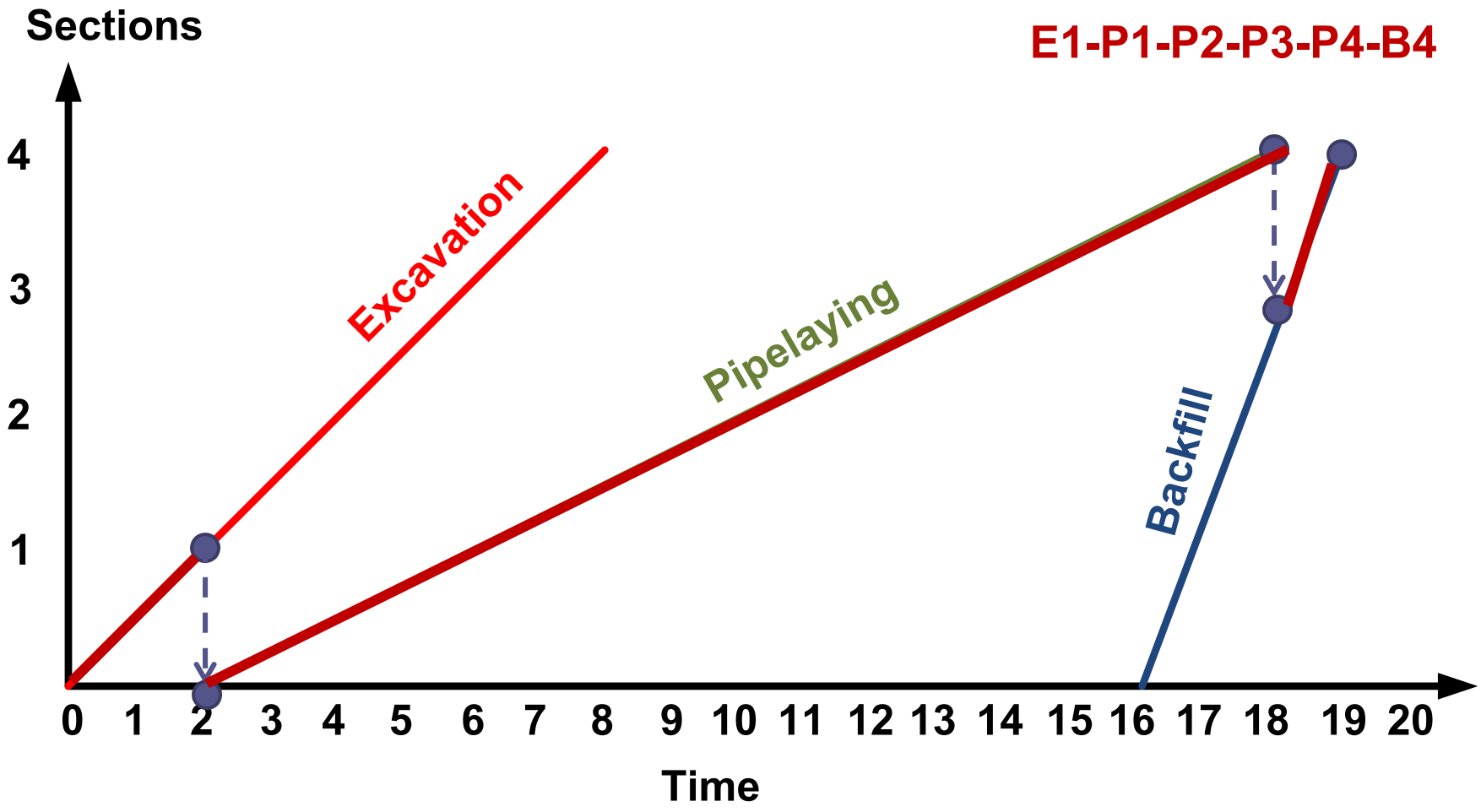
Controlling Sequence in RS

What is the critical path for this project?



Controlling Sequence in RS

In repetitive schedules the critical path is called the "controlling sequence"



How to define activities in RS?

- Activities should have unique resources usage

HVAC installation requires:
1 electrical crew
1 mechanical crew

Define 2 activities:
Install HVAC electrical
Install HVAC mechanical

Steel erection crew will do:
1- erecting columns,
2- erecting trusses,
3- installing bracing,
4- placing roof purlins,
5-placing wall girts

Define 1 activity: Steel Erection

Production Rates in RS

Resource Production Rate

- the amount of work that can be accomplished by the resource in one time period

$$rpr_A = \frac{Q_{Ai}}{T_{Ai}}$$

Unit Production Rate

- the number of repetitive units that can be accomplished by a resource during a unit of time.

$$upr_{Ai} = \frac{1}{T_{Ai}}$$

rpr_A: the resource production rate (e.g. m/day, m3/hour, etc…)
upr_A: the unit production rate; (unit/day, section/week, etc…)
Q_{Ai}: is the quantity of work in activity, A, in any repeating unit, i;
T_{Ai} :is the time needed to complete the A activity in unit i.

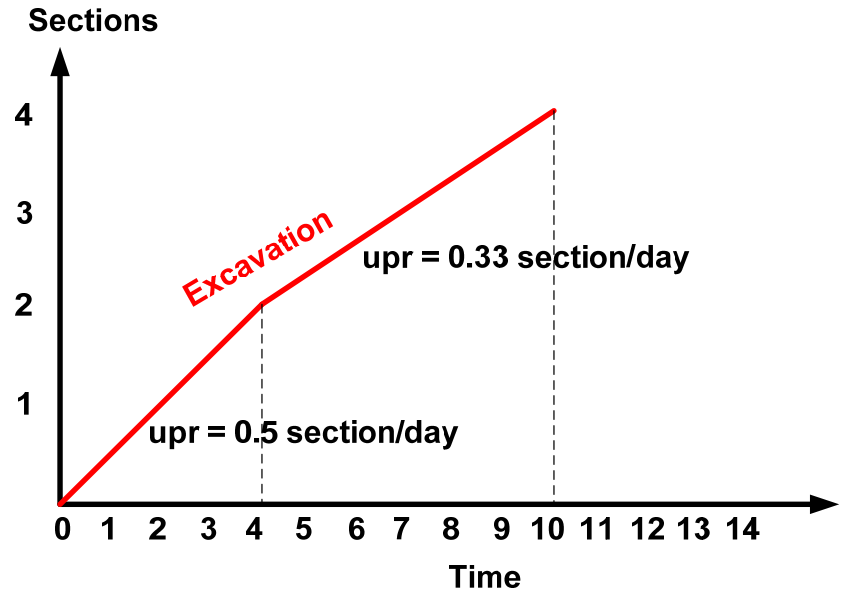
Variable Production Rates

Activity	Description	Quantity (m3)
EX-1	Excavation - Section 1	4000
EX-2	Excavation - Section 2	4000
EX-3	Excavation - Section 3	6000
EX-4	Excavation - Section 4	6000

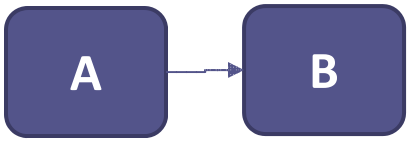
$$upr_{Ai} = \frac{rpr_A}{Q_{Ai}}$$

Assuming excavation production rate of 2000 m^3/day

rpr = 2000 m^3/day

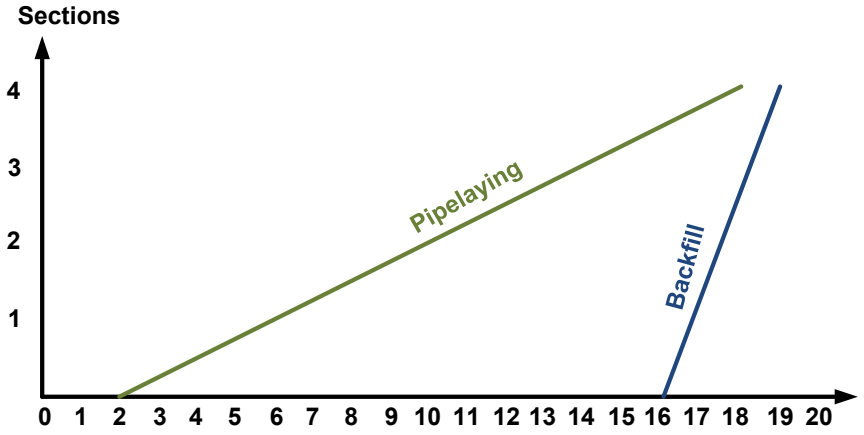


Finish to Start Relationships



Converging

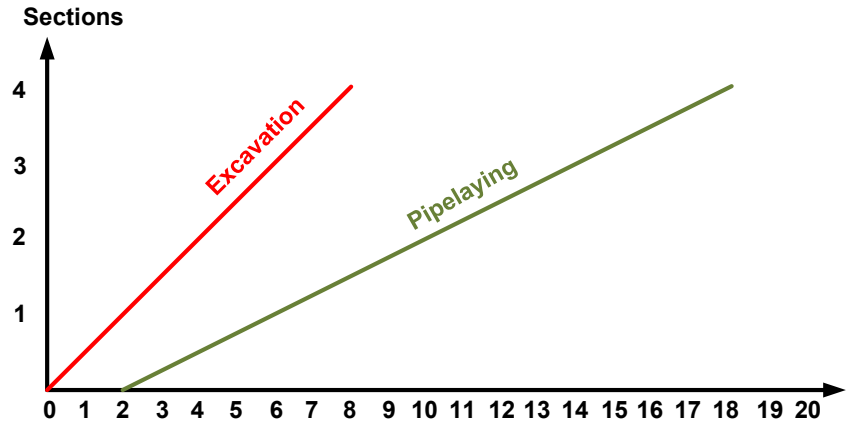
Rate of B is faster than rate of A



Relationship is governed by the **Finish** of the preceding activity

Diverging

Rate of B is slower than rate of A



Relationship is governed by the **Start** of the preceding activity

Finish to Start Relationships in RS with Convergence

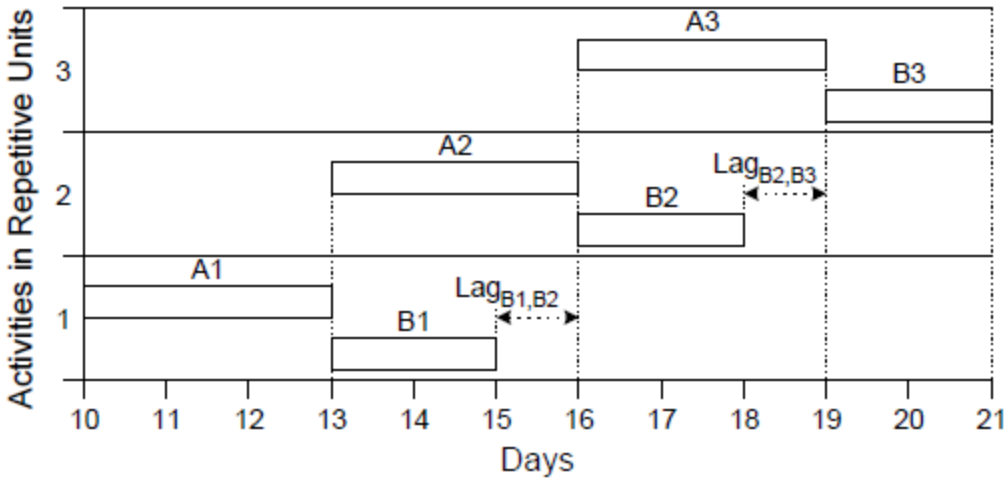
In this case, the finish of the **last** unit of A controls the start of B.

The control point $cp_F(AB)$ is located at unit 3 as shown

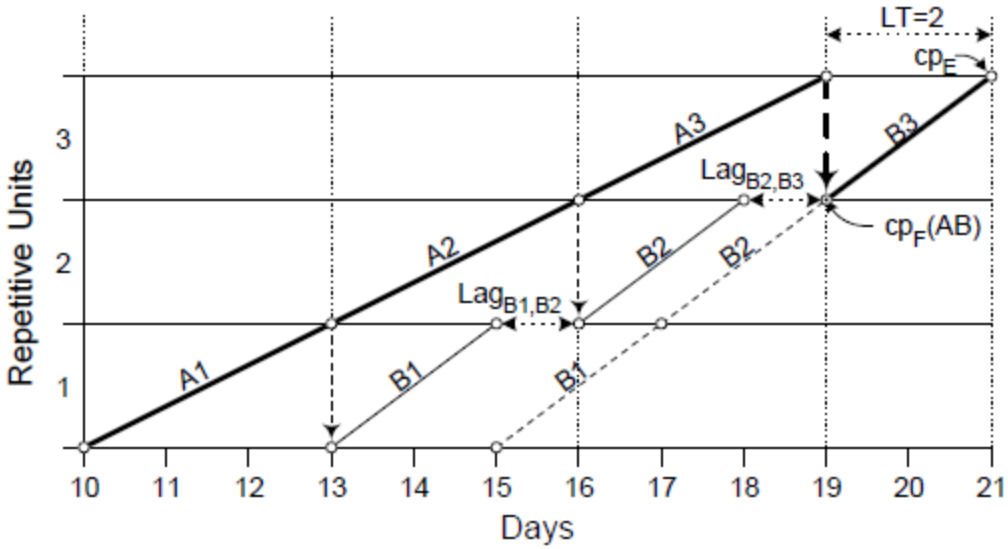
The control point is called a **finish** control point as it refers to the last unit in sequence

Once the point $cp_F(AB)$ is found we simply draw the production line for B passing through it

Corresponds to a finish-to-finish relationship between A and B



(a)



Finish to Start Relationships in RS with Divergence

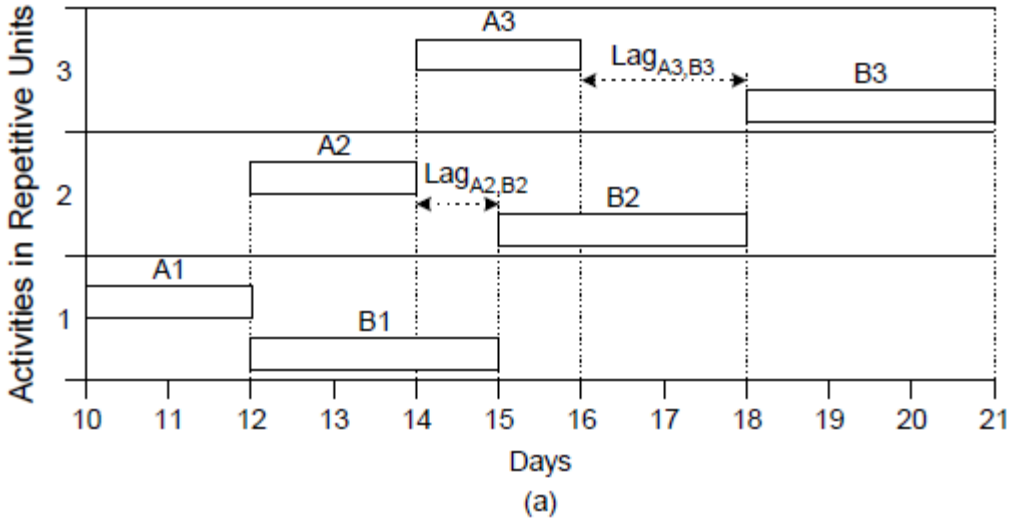
In this case, the finish of the **first** unit of A controls the start of B.

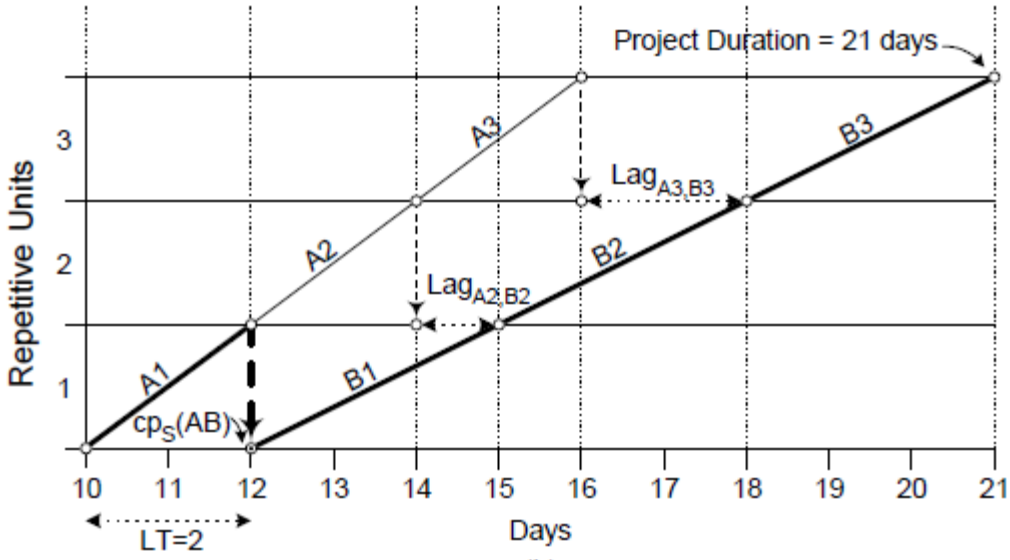
The control point $cp_S(AB)$ is located at unit 1 as shown

The control point is called a **start** control point as it refers to the first unit in sequence

Once the point $cp_F(AB)$ is found we simply draw the production line for B passing through it

Corresponds to a start-to-start relationship between A and B

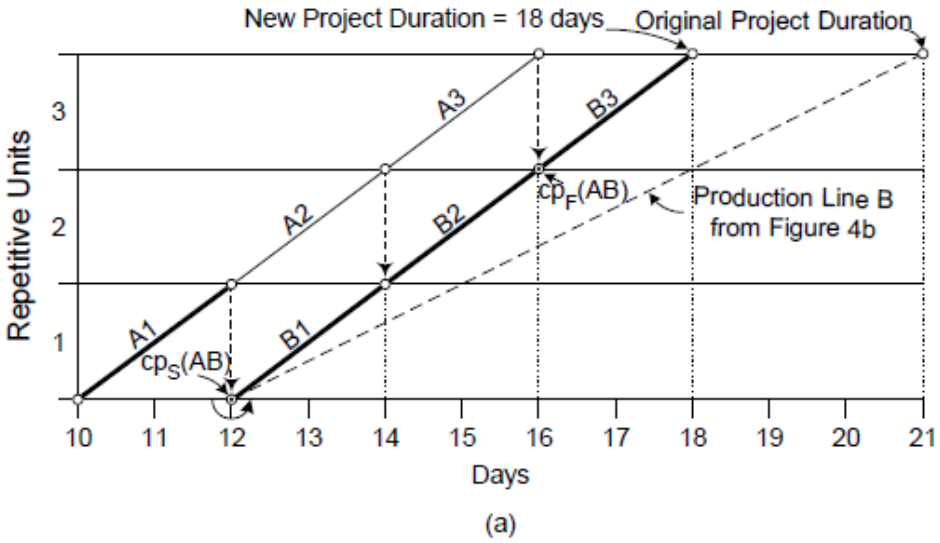




Increasing production rate with FS relationships

Suppose that the crew for each B activity of Figure 4 is increased by fifty percent (to be 0.5 units/day)

The control point $cp_S(AB)$ still controls the position of B

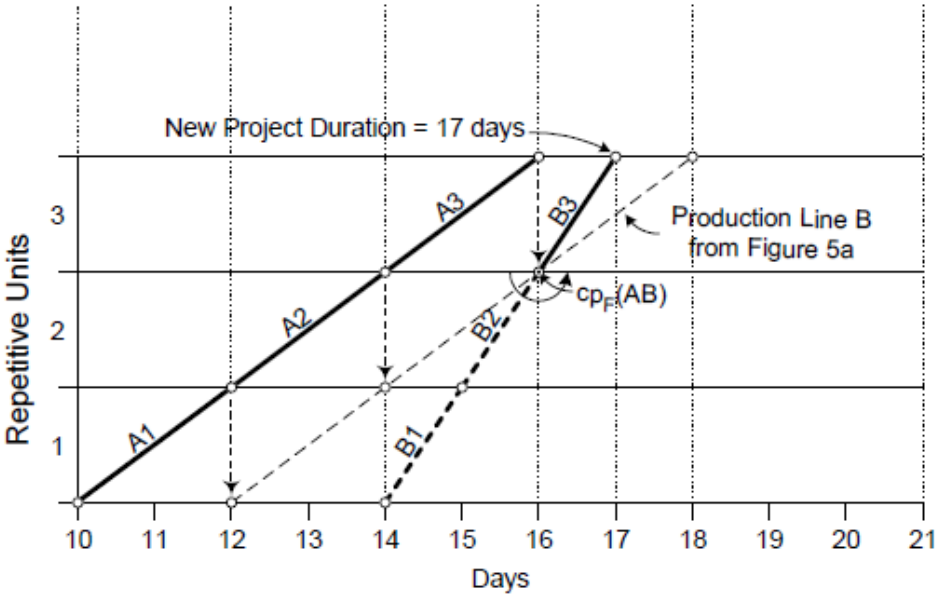


(a)

Suppose that the crew for each B activity of Figure 4 is increased to be 1 unit/day

Continuing to rotate about $cp_S(AB)$ would violate the FTS relationship between A and B

Now, the control point $cp_F(AB)$ controls the position of B



Start to Start Relationships in RS with Convergence

Assumer there is a SS relationship with lag of 2 days between A and B

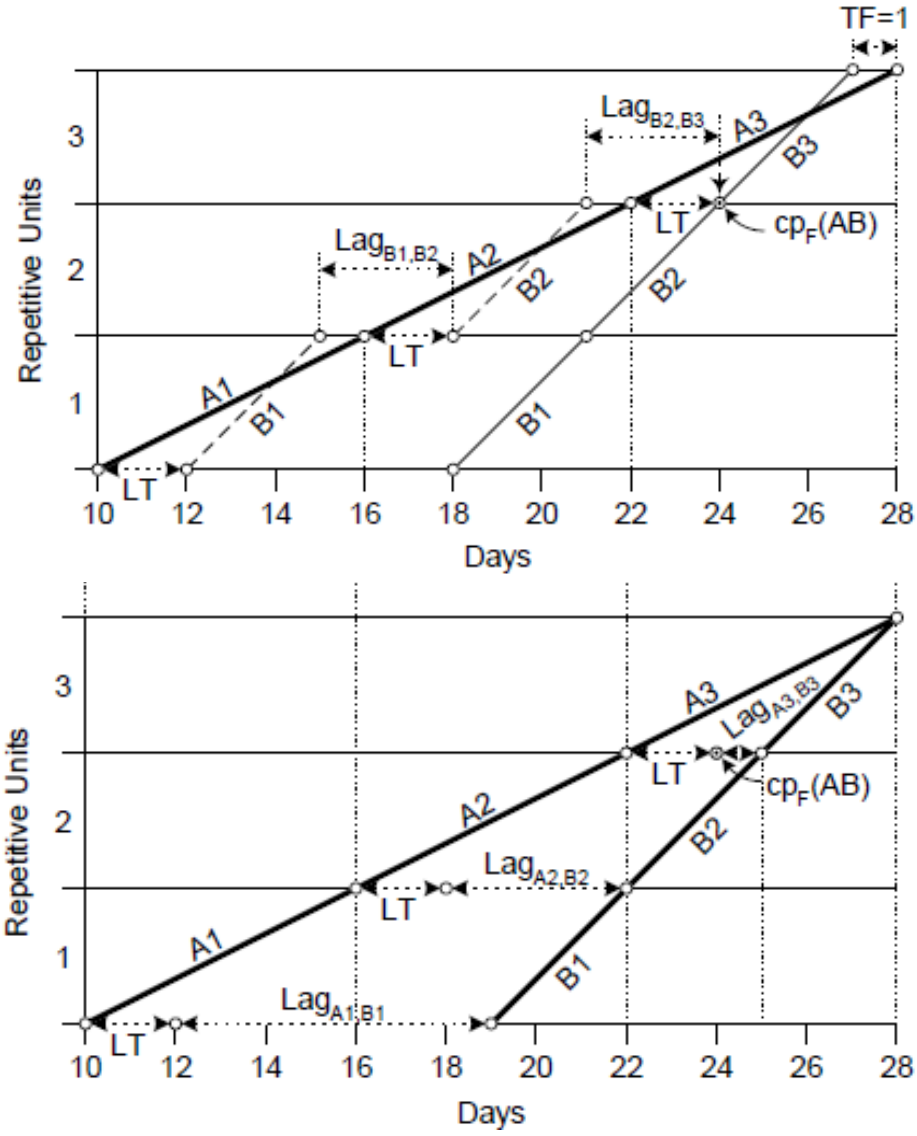
upr_A = 1/6 units/day
upr_B = 1/3 units/day

In this case, the start of the **last** unit of A controls the start of B.

The control point $cp_F(AB)$ is located at unit 3 as shown

Note that there is a TF of 1 day for activity B

An alternative production line can be drawn where both activities are critical



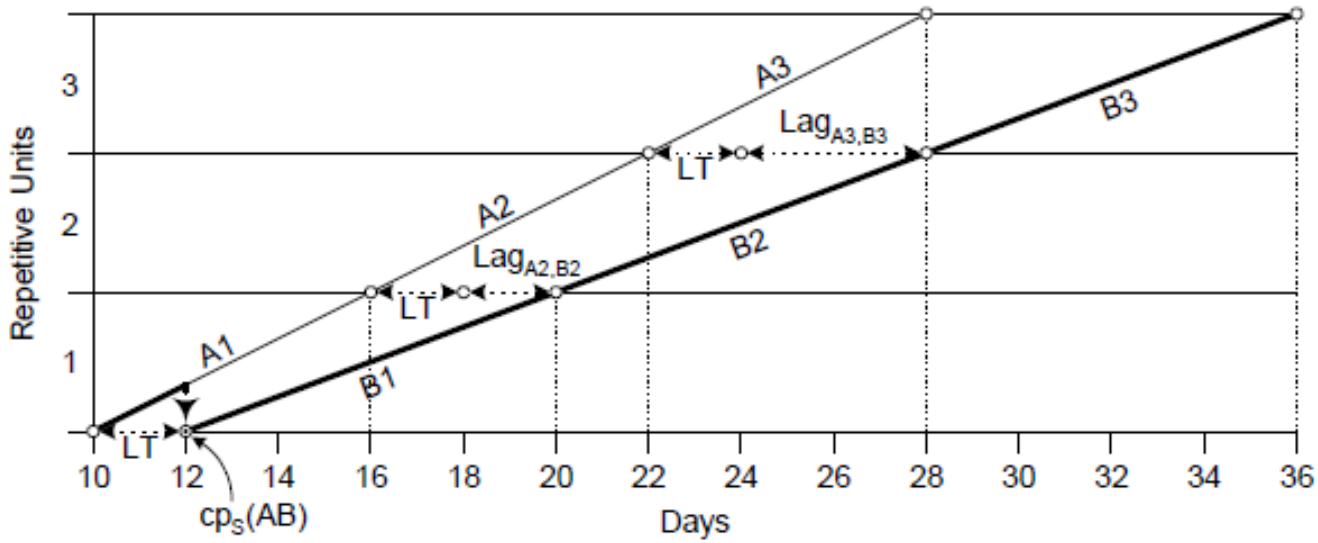
Start to Start Relationships in RS with Divergence

Assume there is a SS relationship with lag of 2 days between A and B

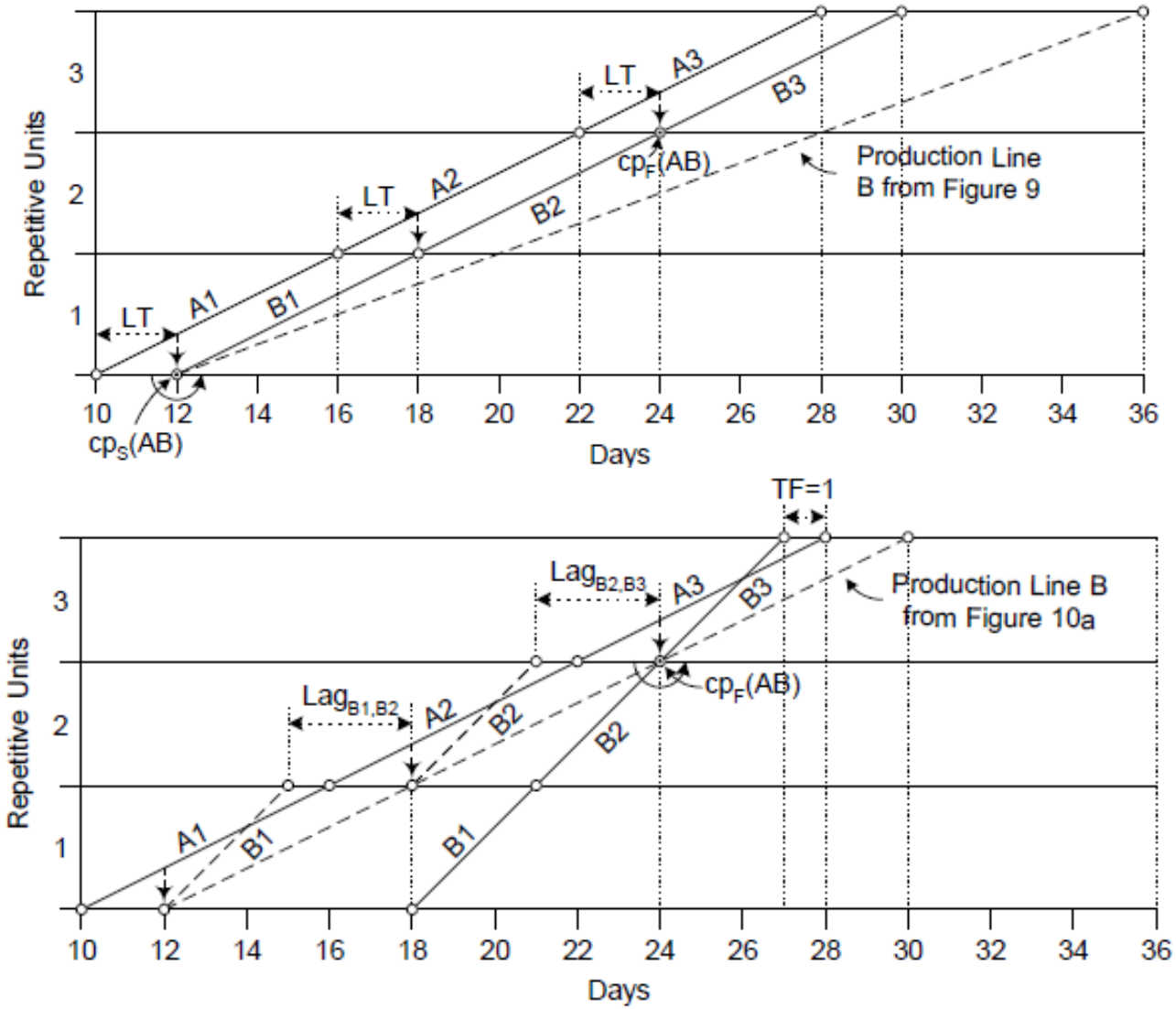
upr_A = 1/6 units/day
upr_B = 1/8 units/day

In this case, the start of the **first** unit of A controls the start of B.

The control point $cp_S(AB)$ is located at unit 1 as shown



Increasing production rate with STS relationships



The controlling sequence

- In RSM, the chain, or sequence of activities, that establishes the minimum project duration is called the *controlling sequence. This sequence maintains all technical* precedence, resource availability, and resource continuity constraints, and passes through control points which switch the sequence from production line to production line.
- The controlling sequence is found by tracing along production lines from the project finish to the project start while shifting from one production line to the next at the defined control points.

Types of Repetitive Projects

Discrete Repetition

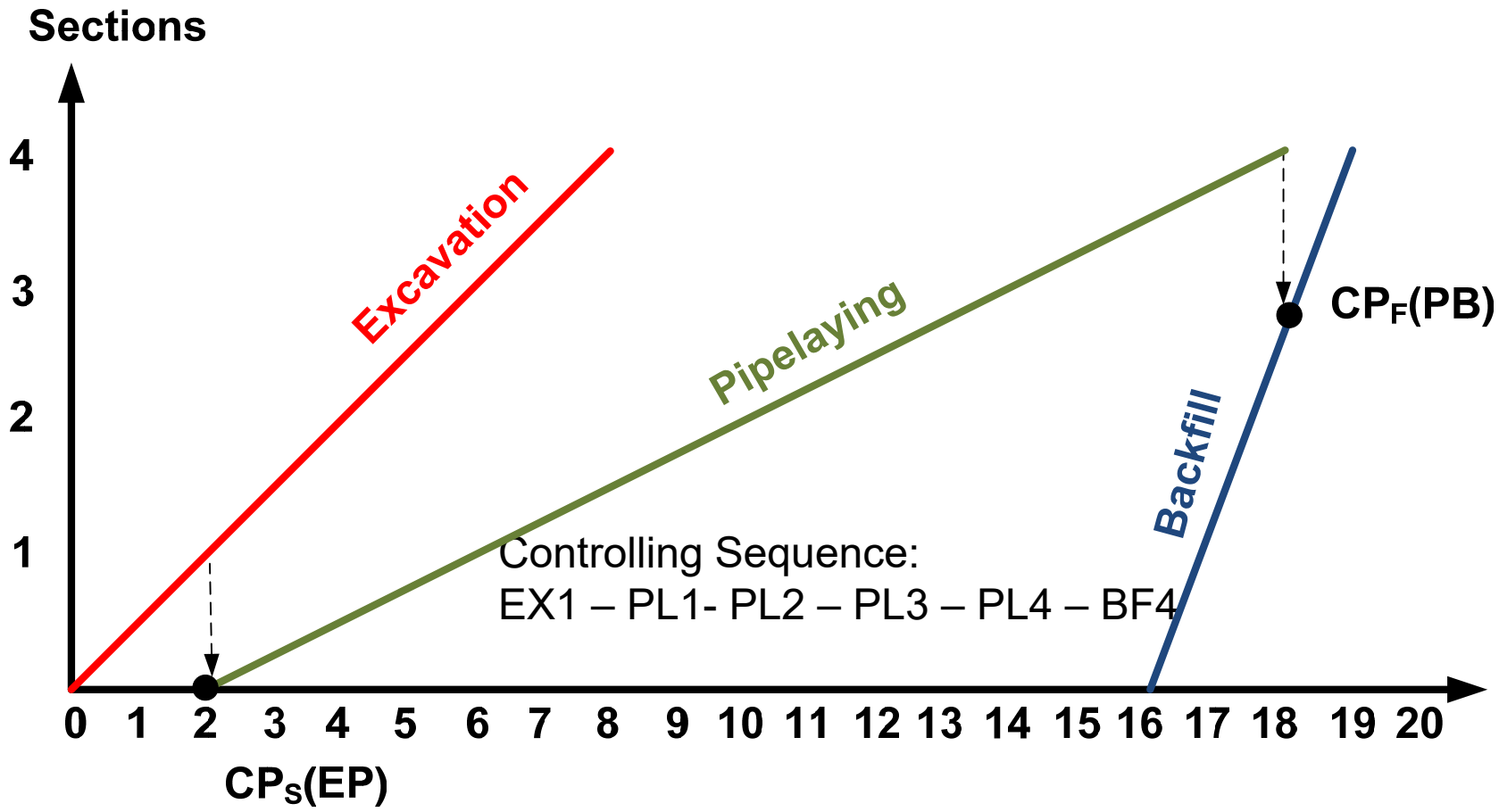
- Units large and considered are discrete separate items.
- Item n cannot start until item n-1 has been completed
- Example high-rise buildings, sections of a pipeline
- Controlling sequence at specific units

Continuous Repetition

- Units are very small and can be considered continuous
- Usually and measured in distance
- Examples roads, pipelines, railways
- Controlling sequence ???

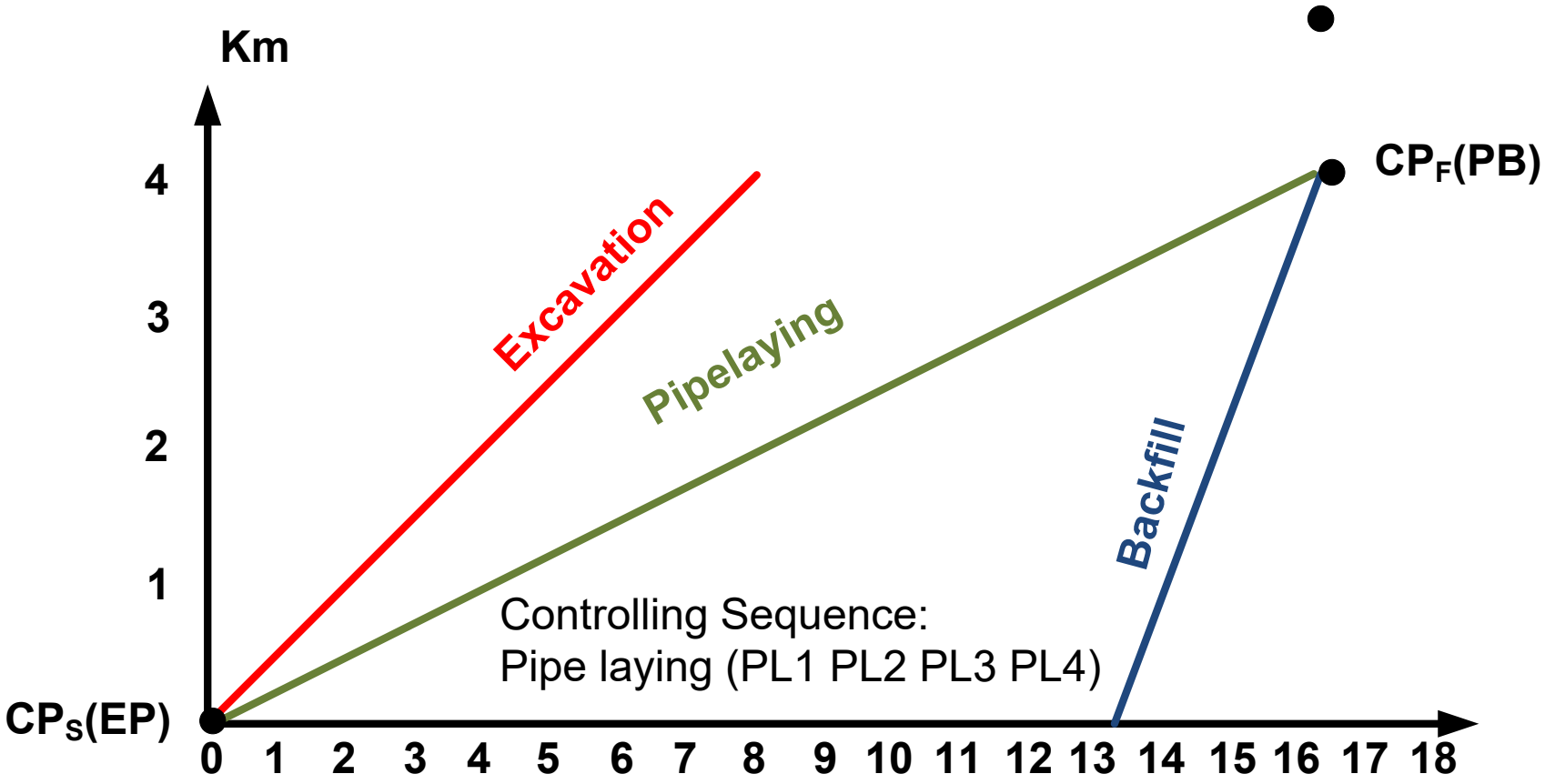
Discrete Repetitive Schedule

We cannot start section n until section n-1 is complete



Continuous Repetitive Schedule

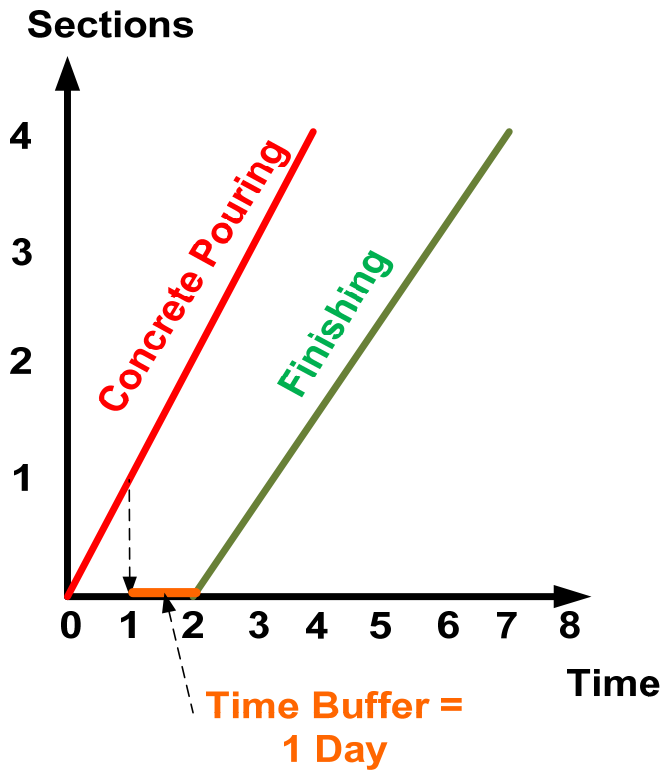
Each section is infinitely small



Types of Buffers

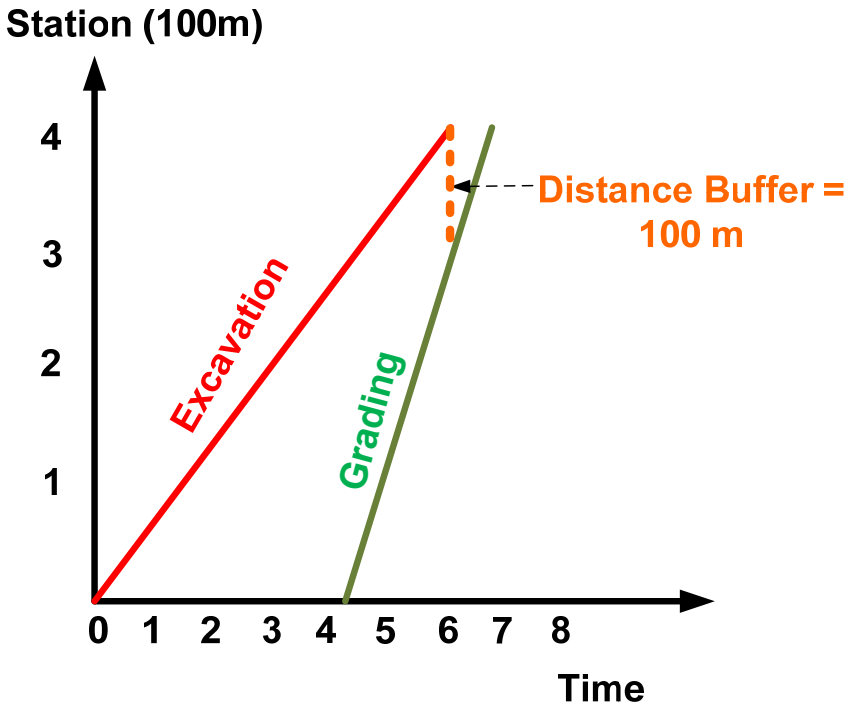
Time Buffers

- Time Lag between activities on different sections

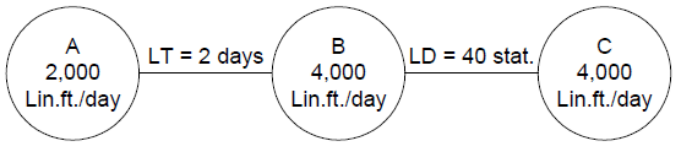


Distance Buffers

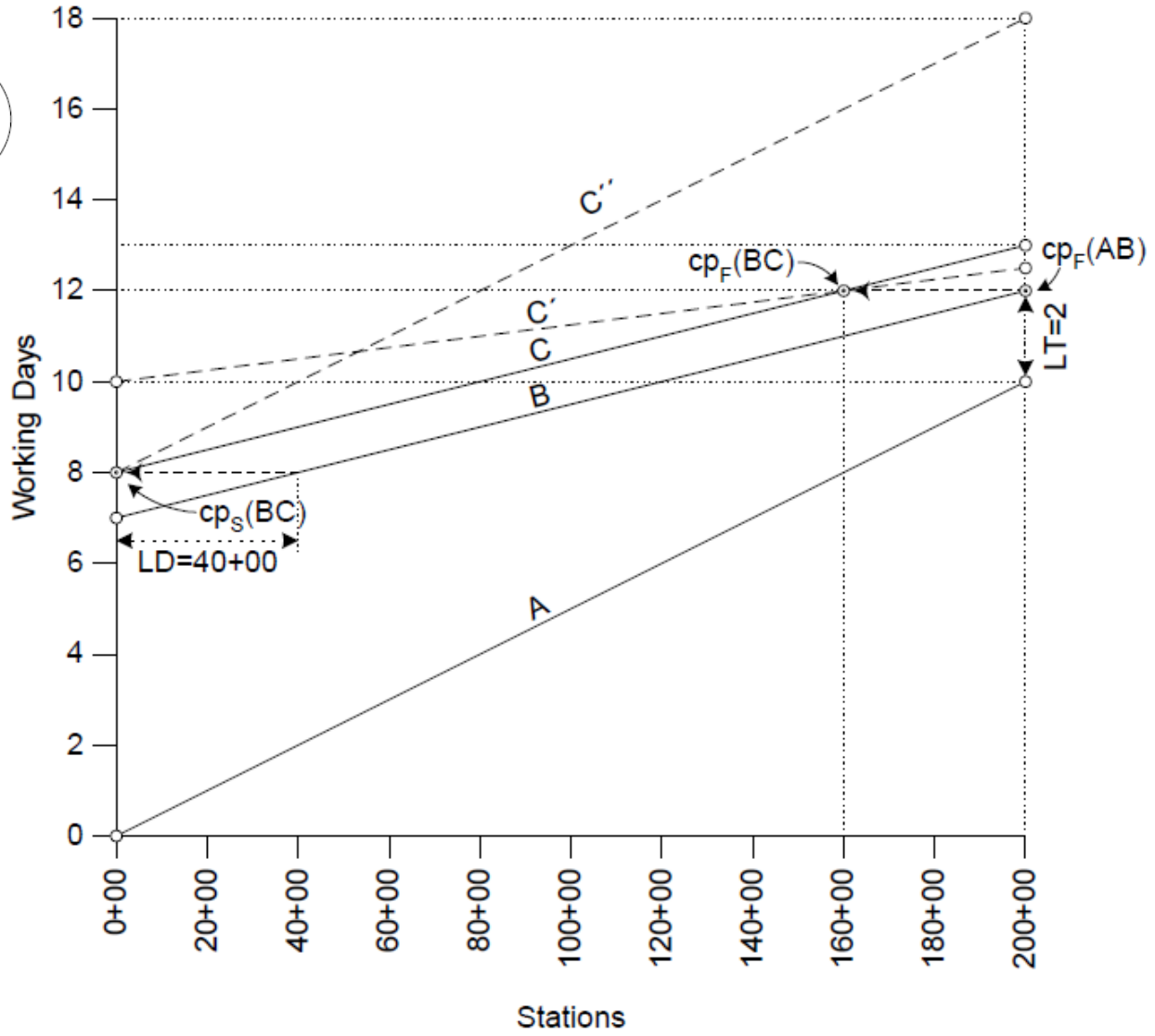
- Minimum separation distance between two activities along a continuous repetitive project



Highway Construction using RS

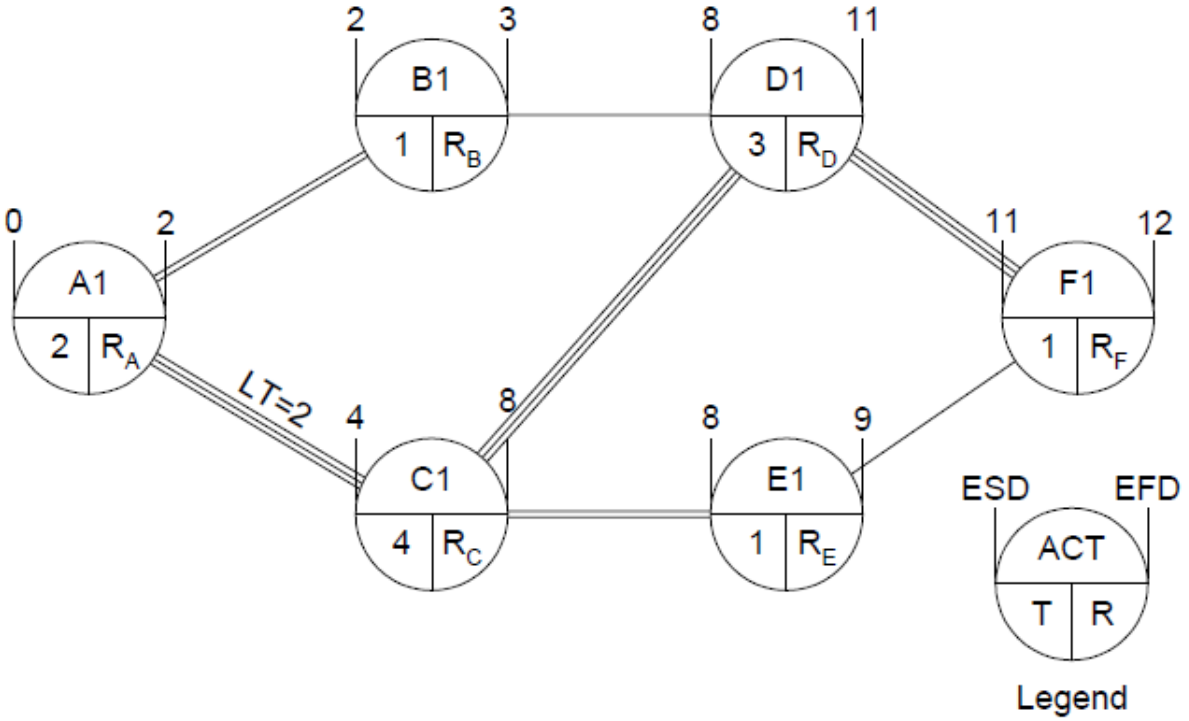


In highway construction, it some times common to represent distance on the x-axis

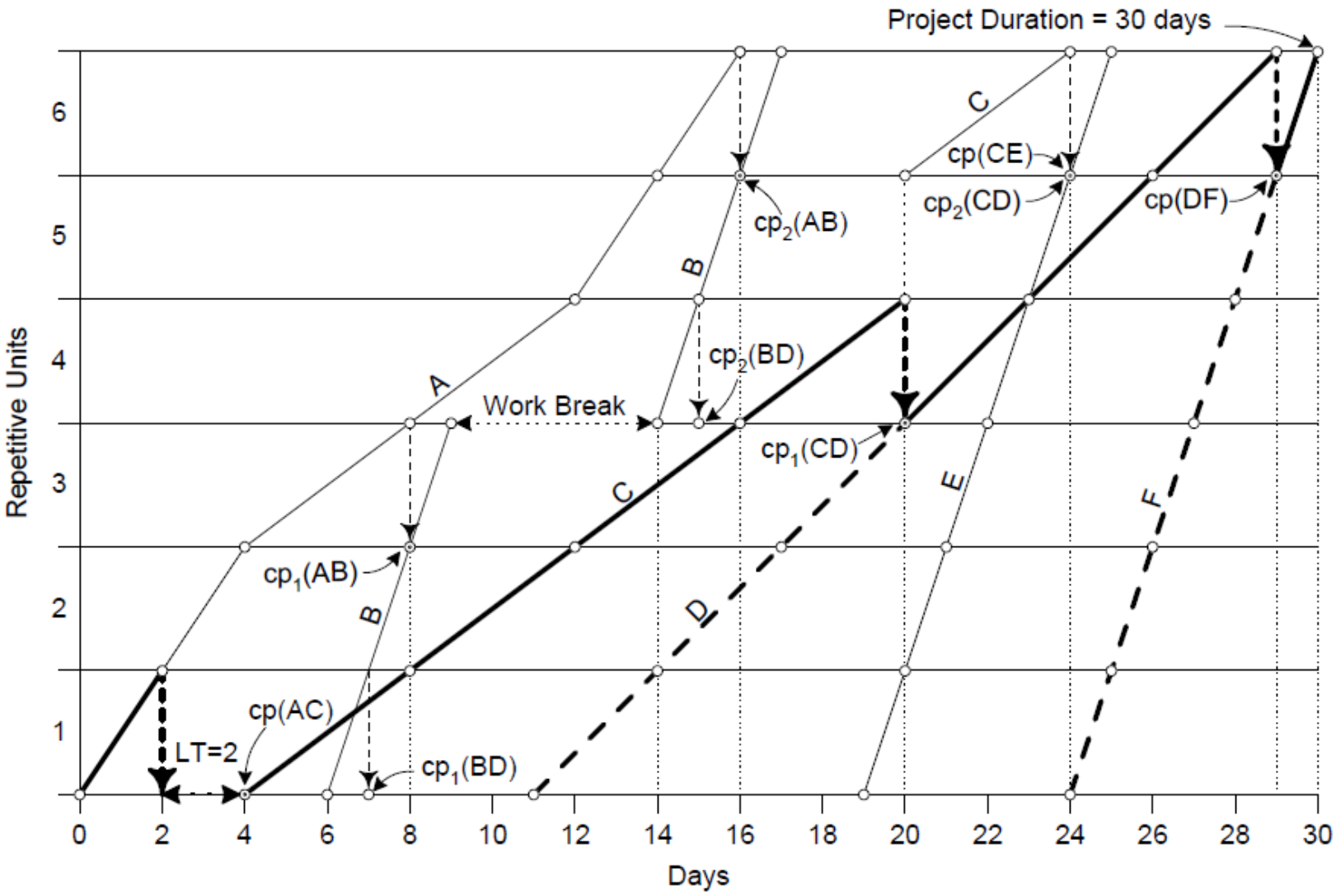


Example

Using the Linear Scheduling method draw the diagram for the following activities that are repeated over six units. The following information is given:
1- Quantity of work in units 3 and 4 for activity A are double those in other units
2- The activity in B requires the subcontractor to take a mandatory break to replenish supplies
3- There is no work for activity C in unit 5

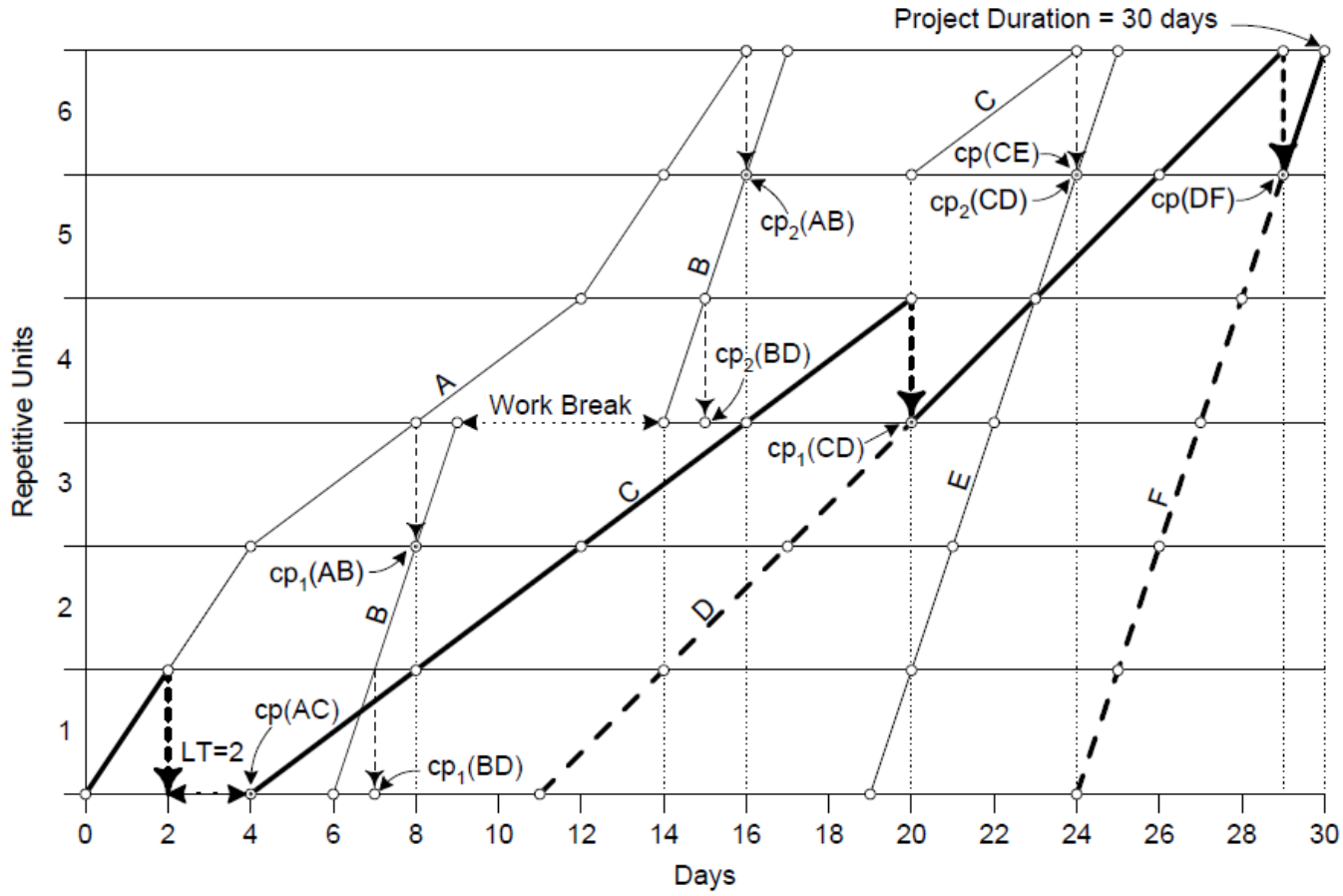


Example


Project Duration = 30 days
Repetitive Units
Days
Work Break
LT=2
cp(AC)
cp(CE)
cp(DF)
cp$_1$(AB)
cp$_2$(AB)
cp$_1$(BD)
cp$_2$(BD)
cp$_1$(CD)
cp$_2$(CD)
A
B
C
D
E
F
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
1
2
3
4
5
6

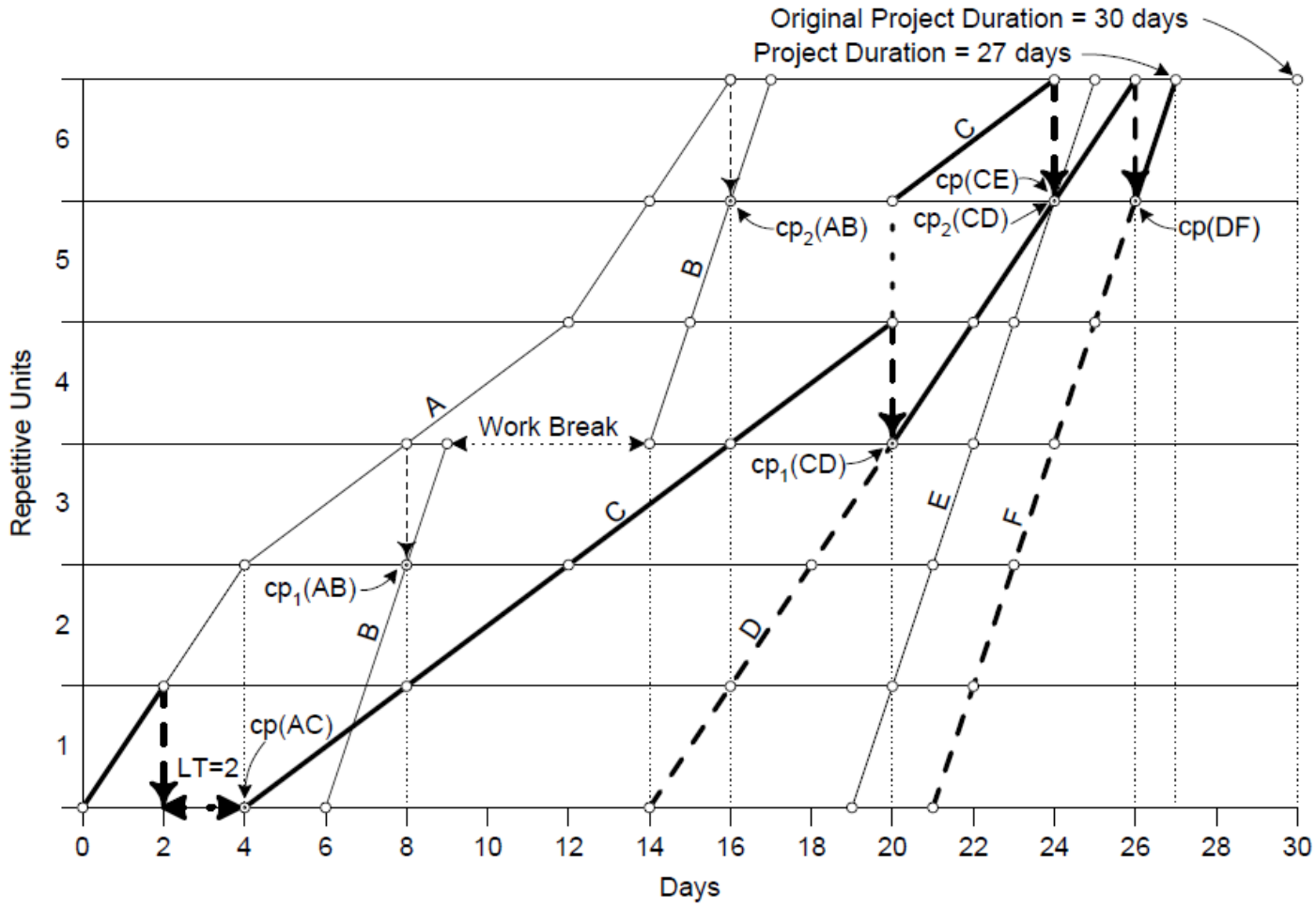
Example

Controlling Sequence:
A1-C1-C2-C3-C4-D4-D5-D6-F6



Example

What if we want to reduce project duration….
Try increasing the production rate of D to 0.5 units/day



Integrating CPM and LS

- In some projects, a single scheduling technique cannot be used throughout the project
- Some linear projects have non-repetitive components
  - Roadway with bridges, ramps, culverts
  - Canal with irrigation structures and bridges
  - Railway with bridges, culverts and crossings
- In these cases CPM and LS need to be integrated

Integrating CPM and LS

It has been decided to upgrade a 6000 foot stretch of a two-lane road traversing a gently rolling area. The profile of the road shows a hill on the west 1500 feet of the stretch with a four percent grade both up and down. A center 1500 foot portion of the stretch is depressed where the road crosses a small stream passing through a 50 inch diameter Corrugated Metal Pipe. The grade in this stretch is two percent down to the stream and three percent up toward the east. The hill followed by the sag in the roadway appears to be a cause of several accidents.

The road surface along the entire 6000 feet is in poor condition because of inadequate drainage. The old base course was too thin and had become plugged with silt over the years. Also, flood waters have tended to pond upstream of the culvert indicating the need for greater culvert capacity. To remedy these ills, it has been decided to replace the CMP culvert with a concrete box culvert about eight feet high, nine feet wide, and eighty feet long. Clearly, the construction of the culvert will be a major part of the total project. In addition, the road grade will be flattened, the base material will be replaced, and the road will be resurfaced.

Box Culvert Example

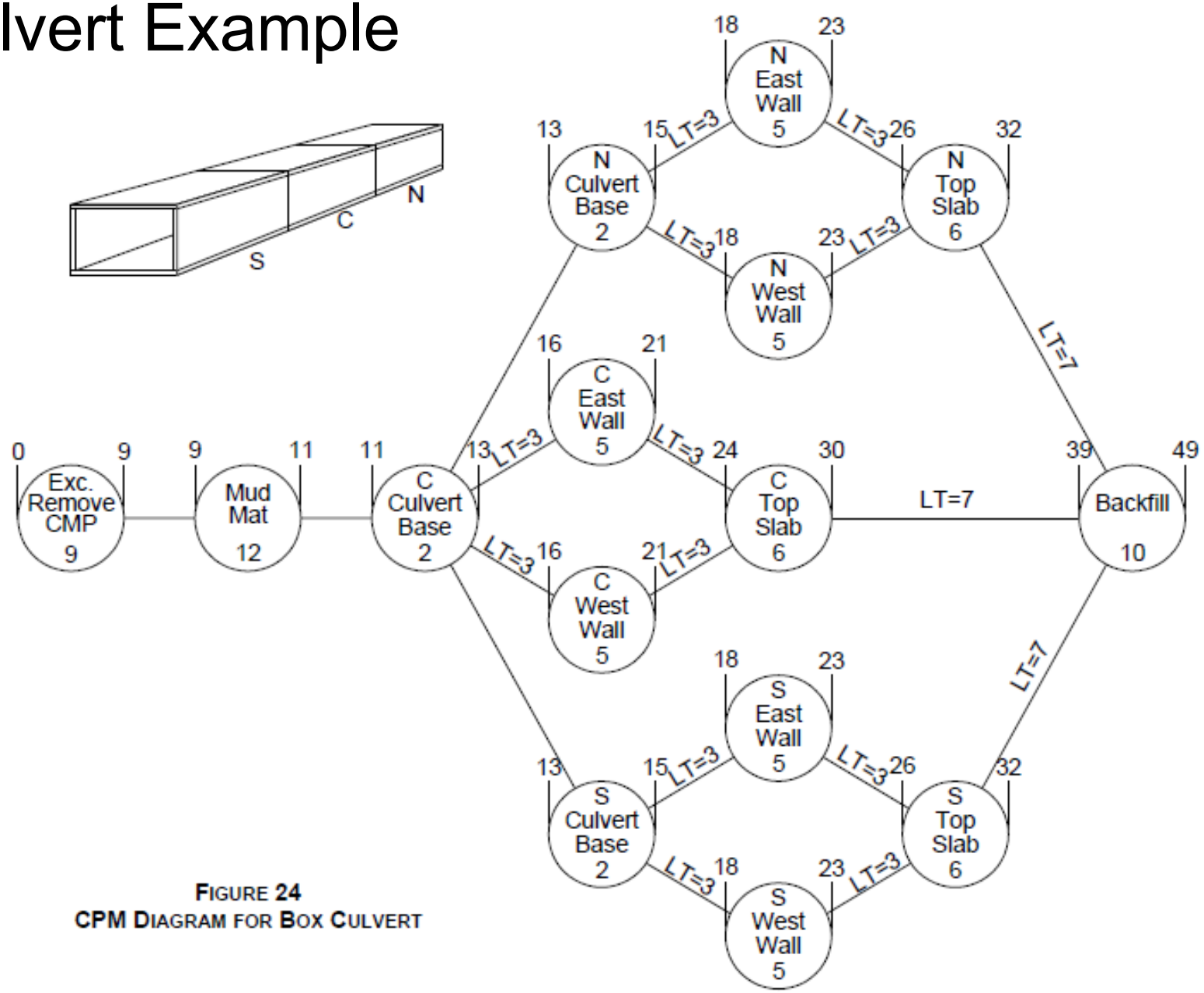


FIGURE 24
CPM DIAGRAM FOR BOX CULVERT

Box Culvert Example