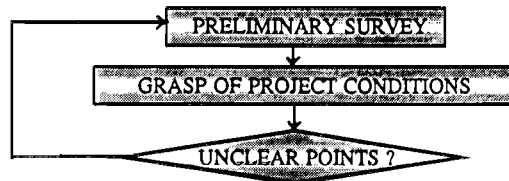
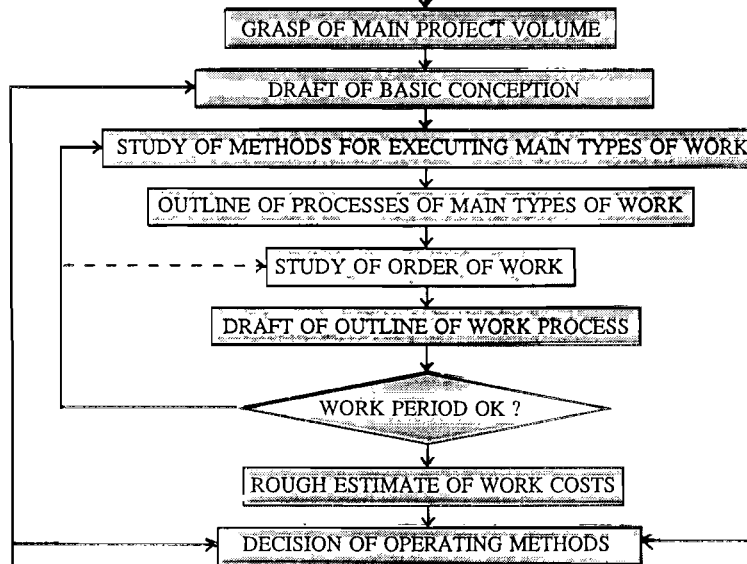


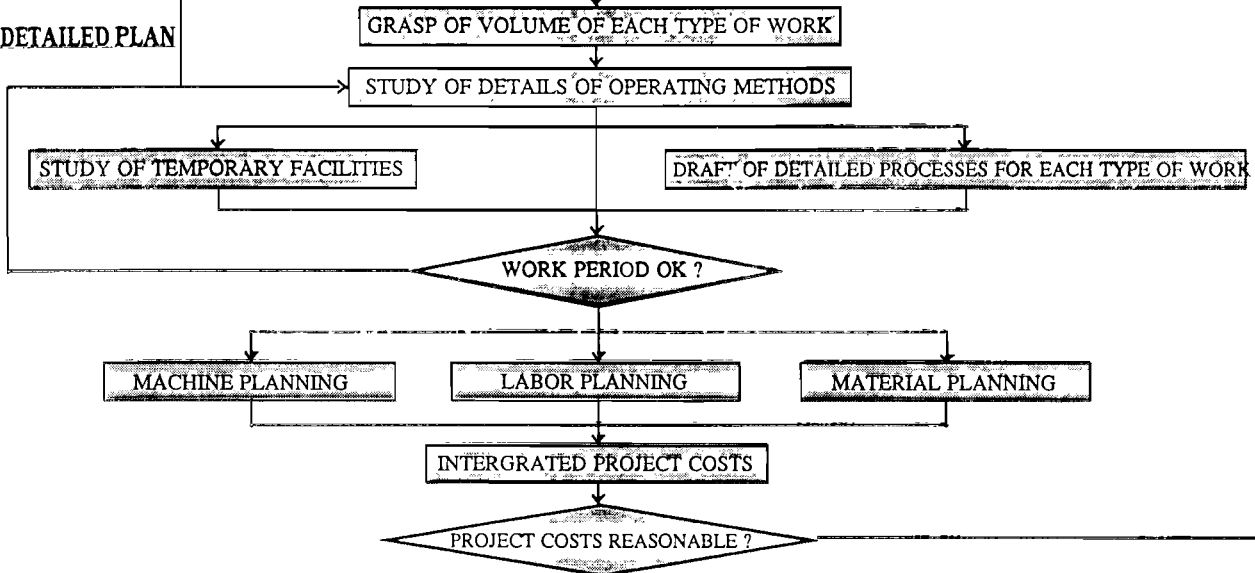
1) PRELIMINARY SURVEY



2) BASIC PLAN



3) DETAILED PLAN



4) MANAGEMENT PLANNING

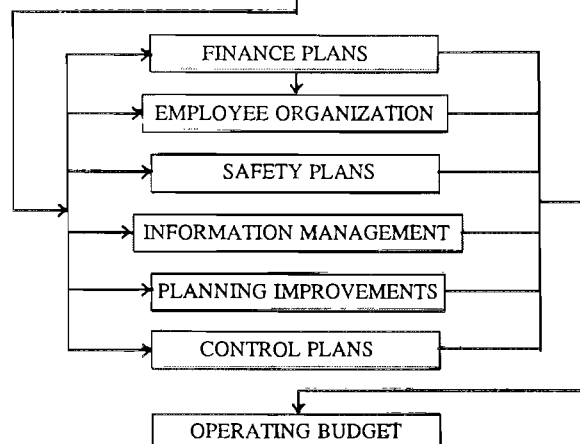
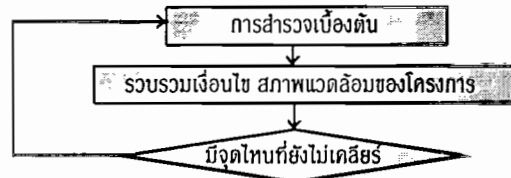
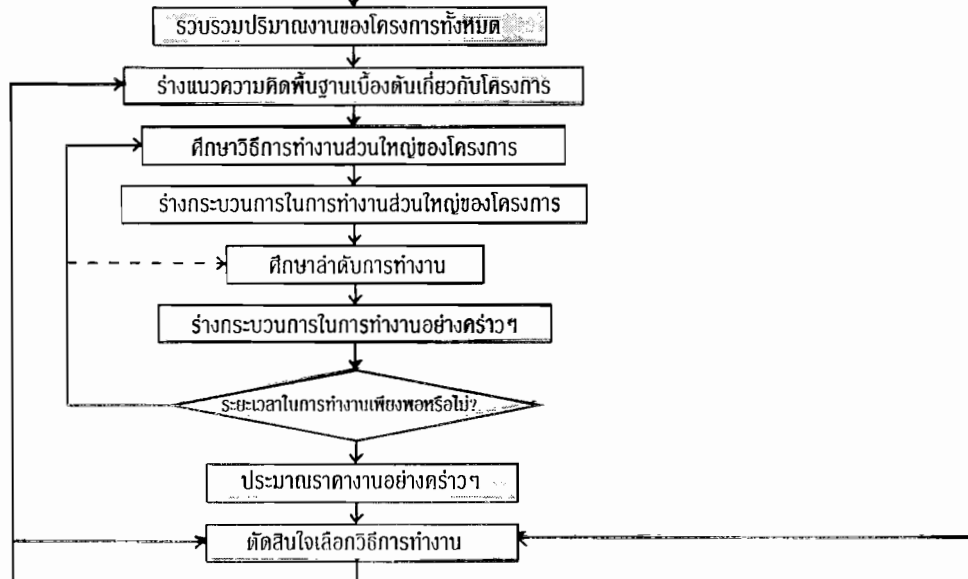


DIAGRAM OF PLANNING PROCEDURE

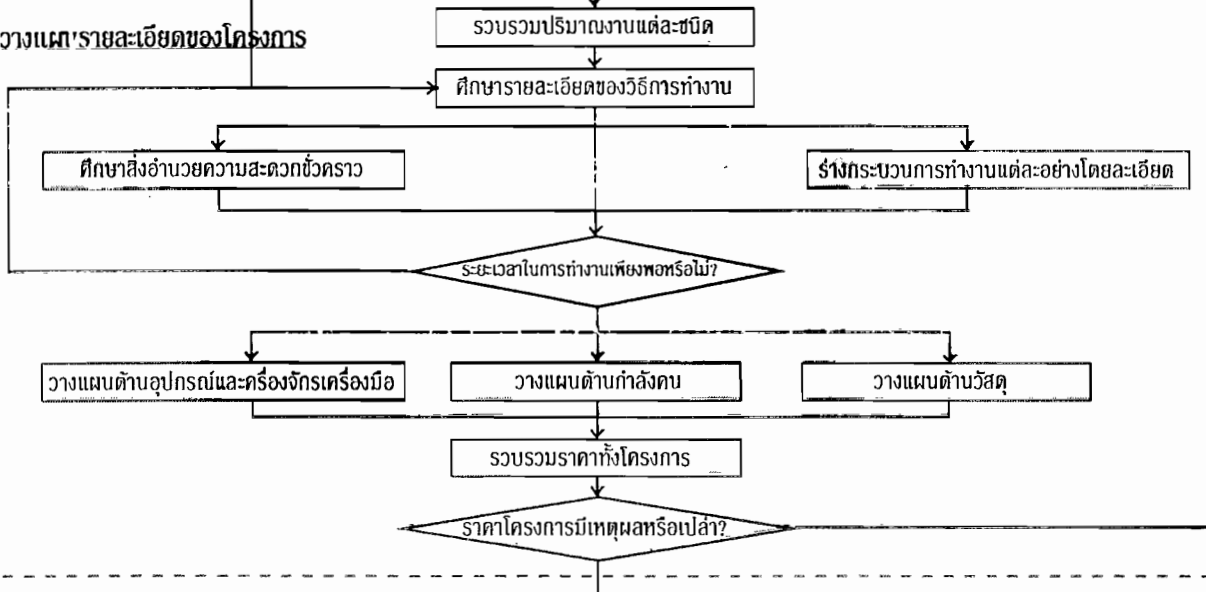
1)การสำรวจเบื้องต้น



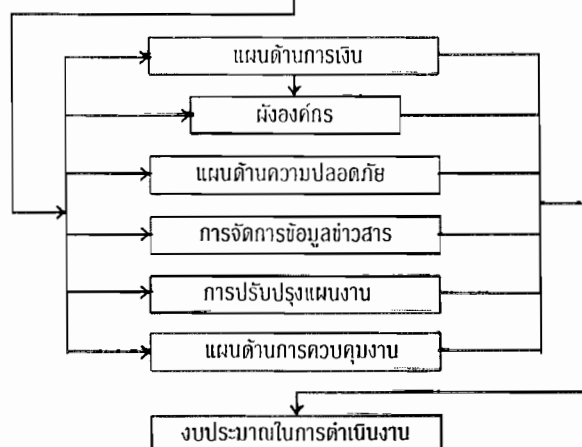
2)การวางแผนขั้นพื้นฐาน



3)วางแผนรายละเอียดของโครงการ



4)การบริหารและการจัดการ



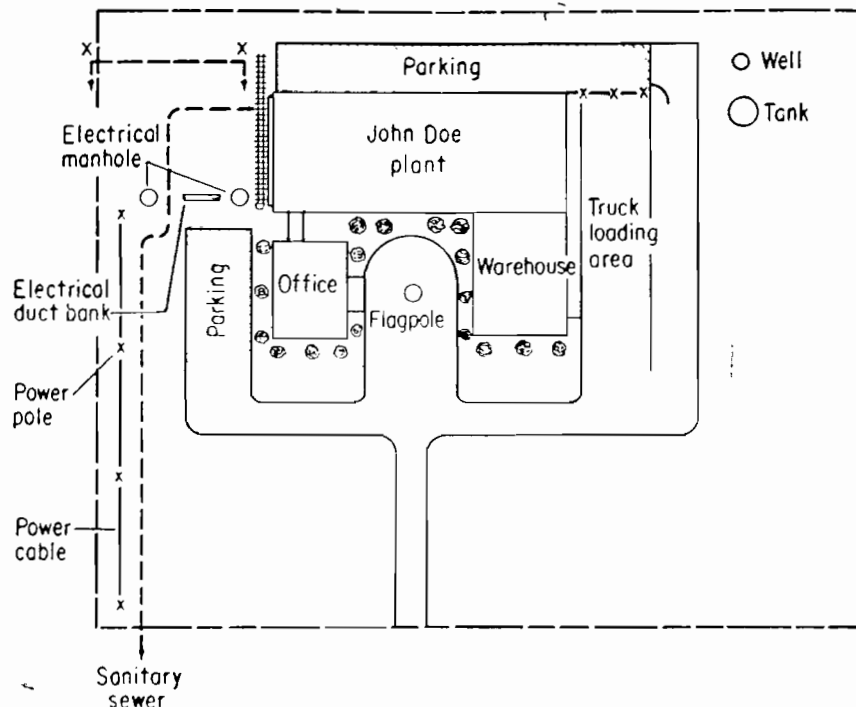


Figure 4.1 Site plan, John Doe project.

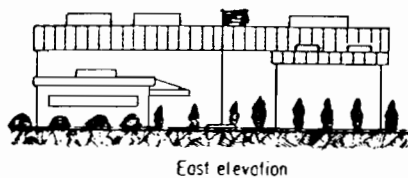
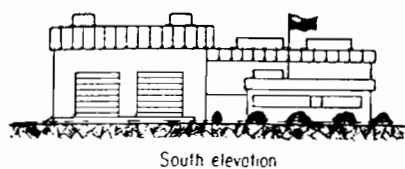
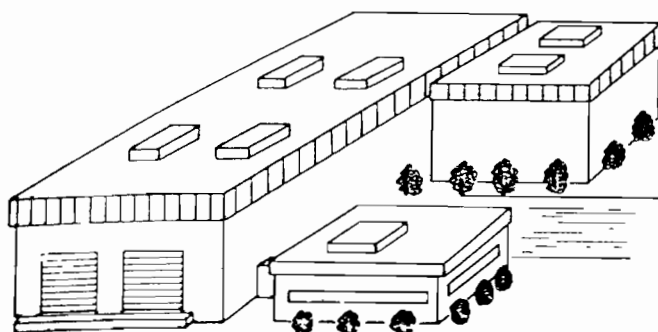


Figure 4.2 Building, John Doe Co., with elevations.

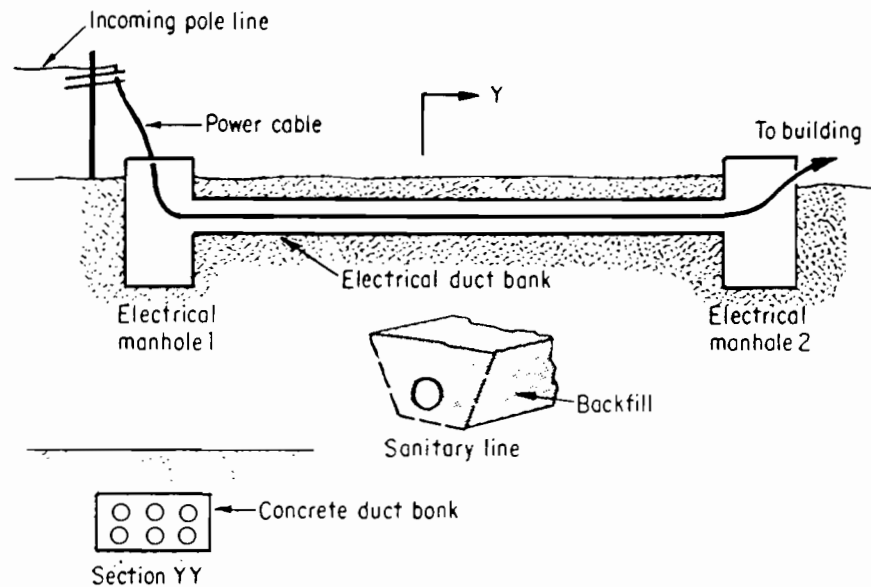


Figure 4.3 Electrical ductbank section XX. (See Fig. 4.1.)

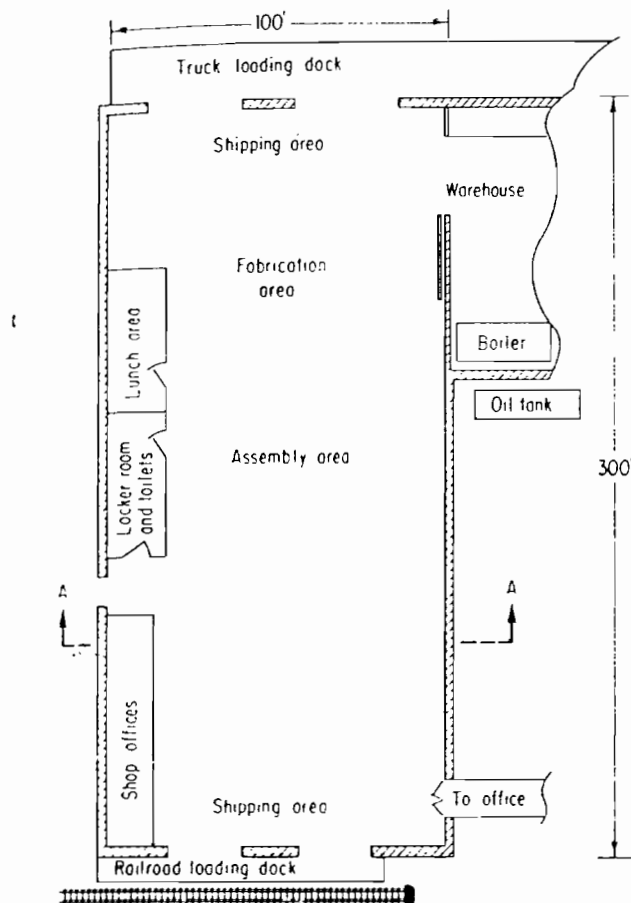


Figure 4.4 Plant floor plan.

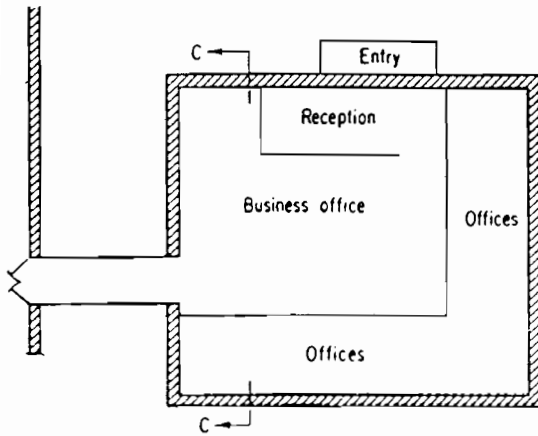


Figure 4.5 Office floor plan.

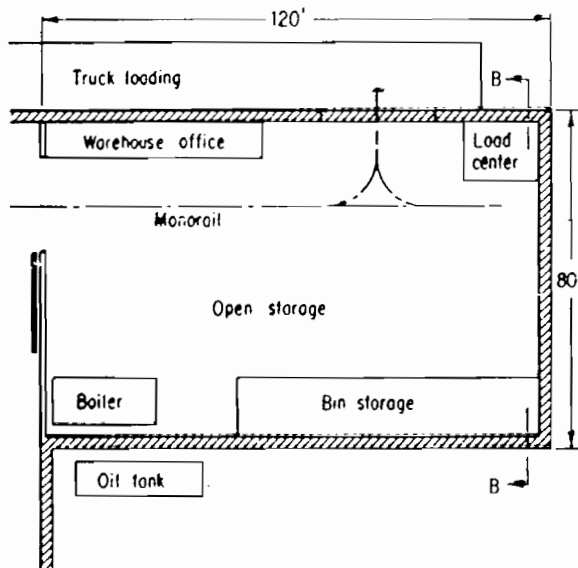
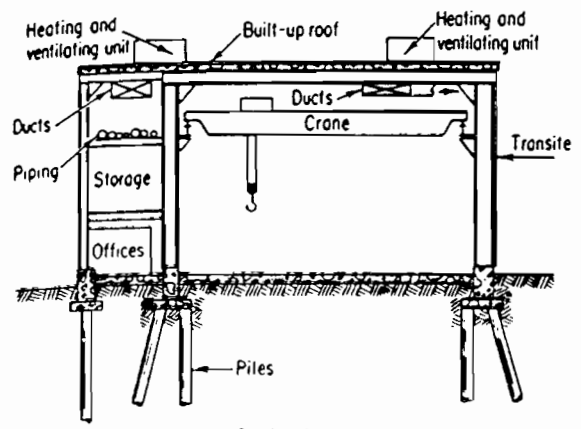
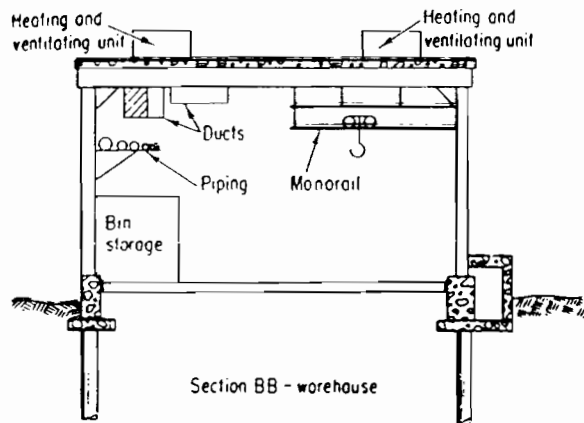


Figure 4.6 Warehouse floor plan.

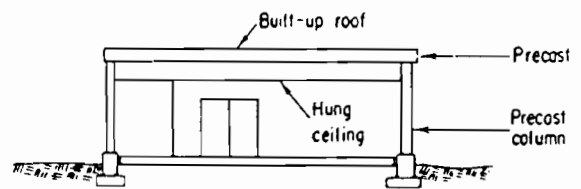


Section AA

Figure 4.7 Interior Section AA. (See Fig. 4.4.)



Section BB - warehouse



Section CC - office

Figure 4.8 Interior sections BB and CC. (See Figs. 4.5 and 4.6.)

การคำนวณ Network Diagram (AOA)

คำบางคำที่ควรทราบ

Early Start (E.S.)

กำหนดวันทำงานแต่ละงานสามารถเริ่มทำงานได้เร็วที่สุด

Early Finish (E.F.)

กำหนดวันทำงานแต่ละงานสามารถทำให้เสร็จสิ้นลงโดยเร็วที่สุด

Late Start (L.S.)

กำหนดวันทำงานแต่ละงานสามารถเริ่มได้ช้าที่สุด โดยไม่ทำให้งานทั้งโครงการล่าช้าออกไป

Late Finish (L.F.)

กำหนดวันทำงานแต่ละงานสามารถทำให้เสร็จสิ้นลงช้าที่สุด โดยไม่ให้งานทั้งโครงการล่าช้าออกไป

Critical Path (C.P.)

สายการทำงานที่ใช้ระยะเวลาการทำงาน ตั้งแต่ต้นจนจบเท่ากับระยะเวลาการทำงานของโครงการ หรือ เป็นสายการทำงานที่ใช้เวลามากที่สุด

การคำนวณ Network Diagram (AOA)

คำบางคำที่ควรทราบ

Free Float (F.F.)

จำนวนวันทำงานแต่ละงานสามารถเลื่อนออกไปได้ช้ากว่า ES เดิม โดยไม่ทำให้งานทั้งโครงการเสร็จช้ากว่ากำหนดเดิม และไม่ทำให้ ES ของงานที่ถัดไปต้องเลื่อนออกไปด้วย

Total Float (T.F.)

จำนวนวันทั้งหมดที่งานนั้นจะสามารถเลื่อนไปทำได้ช้ากว่า ES เดิมของตนได้ โดยจะไม่ทำให้งานทั้งโครงการต้องล่าช้ากว่ากำหนดเดิม แต่อาจทำให้ ES ของงานถัดมาต้องเลื่อนตามไปด้วย

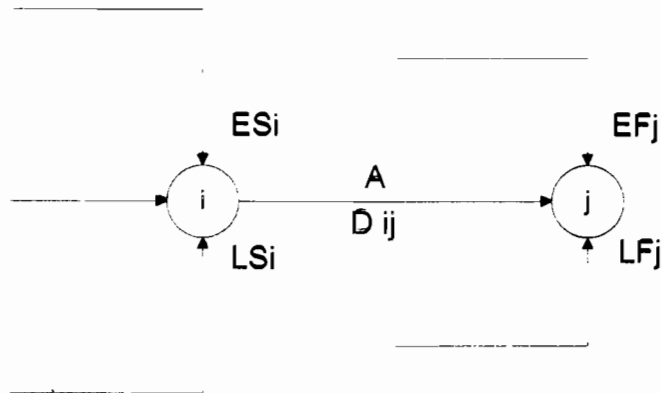
Independent Float (I.F)

จำนวนวันที่น้อยที่สุดที่จะสามารถเลื่อนออกไปทำได้ช้ากว่า ES เดิม โดยไม่มีผลกระทบใด ๆ กับการระยะเวลาในการดำเนินโครงการหรือกับ ES LS EF LF ของงานทั้งที่อยู่ก่อนหน้าและตามหลัง

Interference Float (I.F) หรือ SLACK

จำนวนวันที่จะสามารถเริ่มต้นได้ช้ากว่ากำหนดเดิมโดยไม่ทำให้ระยะเวลาในการดำเนินโครงการต้องล่าช้าออกไป หรือ
จำนวนวันที่จะสามารถเสร็จได้เร็วกว่ากำหนดเดิมที่เสร็จช้าที่สุด

ขั้นตอนการคำนวณ Network Diagram (AOA)



FORWARD PASS RULE

ที่จุดเริ่มต้นโครงการ

$$ES_i = 0$$

ที่ NODE ใดๆ

$$EF_j = ES_i + D_{ij} \text{ max}$$

ที่ NODE สุดท้าย

$$LF_j = EF_j$$

Backward Pass Rule.

ที่ NODE สุดท้าย

$$LF = EF$$

ที่ NODE ใดๆ

$$LS_i = LF_j - D_{ij} \text{ min}$$

ที่ จุดเริ่มต้นโครงการ

$$LS_i = 0$$

การคำนวณหา FLOAT

$$\begin{aligned} FF_{ij} &= EF_j - ES_i - D_{ij} \\ &= TF_{ij} - \text{HEAD SLACK} \end{aligned}$$

$$\begin{aligned} IF_{ij} &= EF_j - LS_i - D_{ij} \\ &= FF_{ij} - \text{TAIL SLACK} \end{aligned}$$

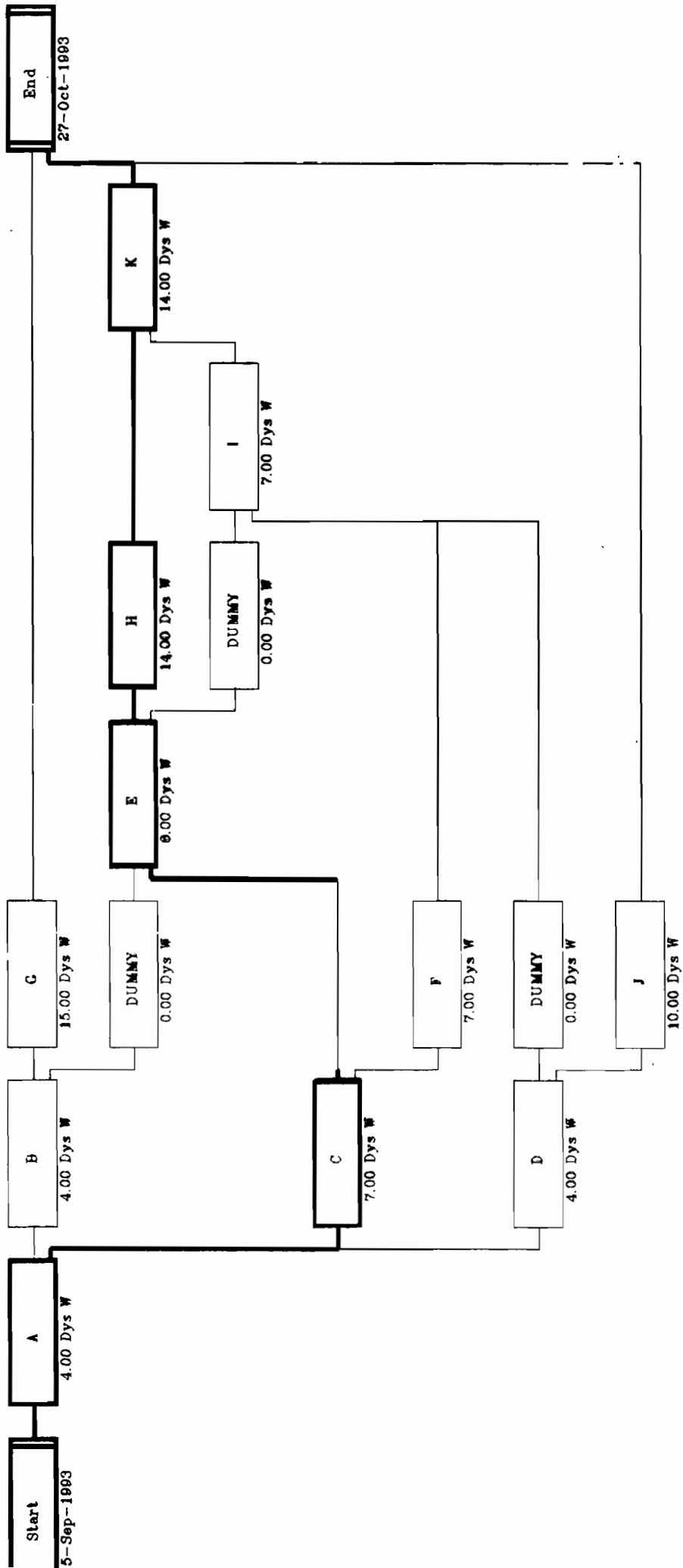
$$TF_{ij} = LF_j - ES_i - D_{ij}$$

$$\text{HEAD SLACK} = LF_j - EF_j$$

$$\text{TAIL SLACK} = LS_i - ES_i$$

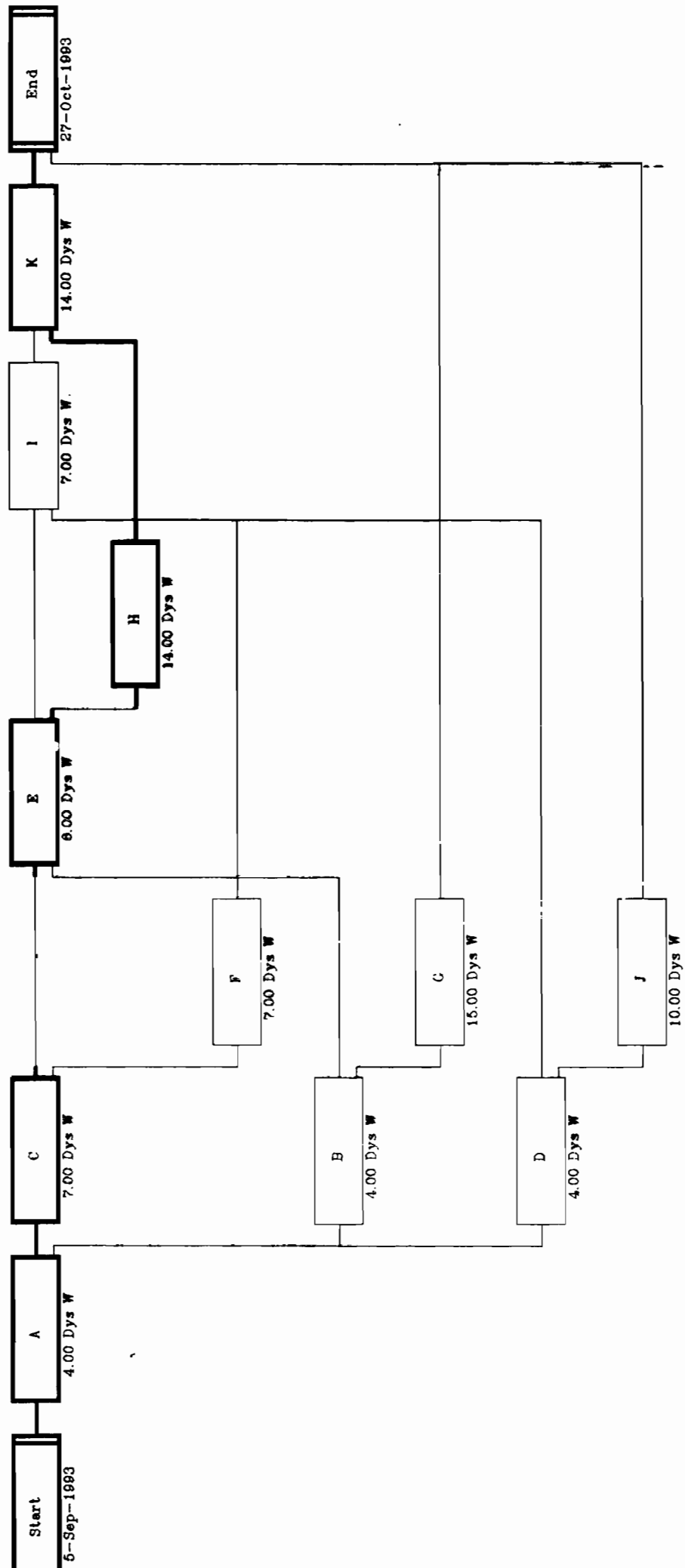
Example Project from Lecture
Project: LECTURE2

PERT Chart



Example Project from Lecture
Project: LECTURE1

ERT Chart



4. งาน A จะต้องเสร็จก่อนถึงจะเริ่มงาน B ได้
5. งาน C จะเริ่มได้หลังจากงาน B และ E เสร็จแล้ว
6. งาน I จะต้องทำหลังจากงาน H และ F
7. โครงการนี้เสร็จเมื่องาน I และ C เสร็จเรียบร้อยแล้ว

จากความสัมพันธ์ของงานต่าง ๆ ที่วิเคราะห์ได้ สามารถเขียนผังลูกศรได้ดังนี้
 ก. เขียนเส้นลูกศรแสดงความสัมพันธ์ของงานต่าง ๆ

1. A, D และ G เริ่มต้นโครงการ

2. H ทำหลังจาก G

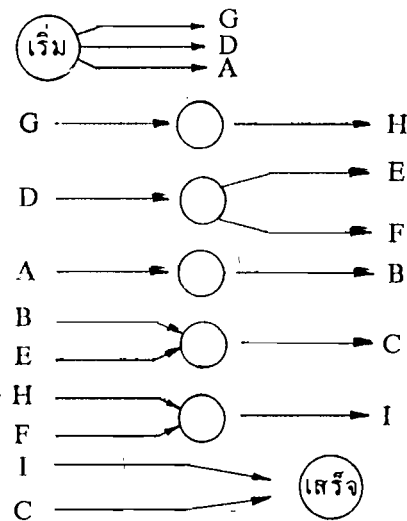
3. E และ F ทำหลังจาก D

4. A ก่อน B

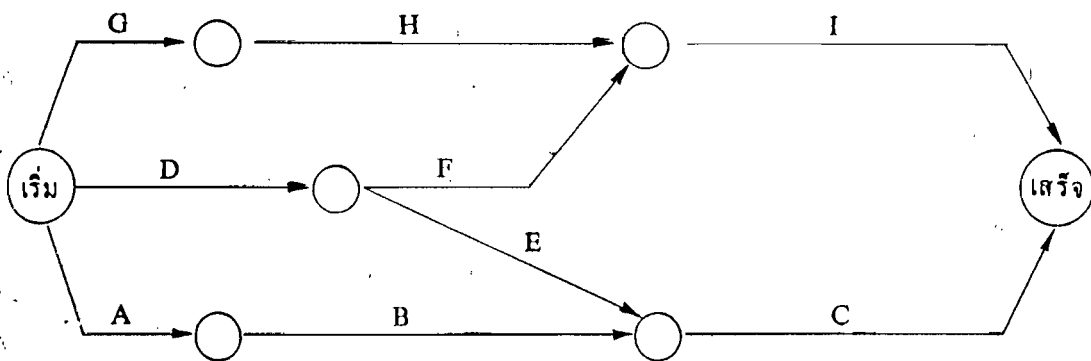
5. C ทำหลังจาก B และ E

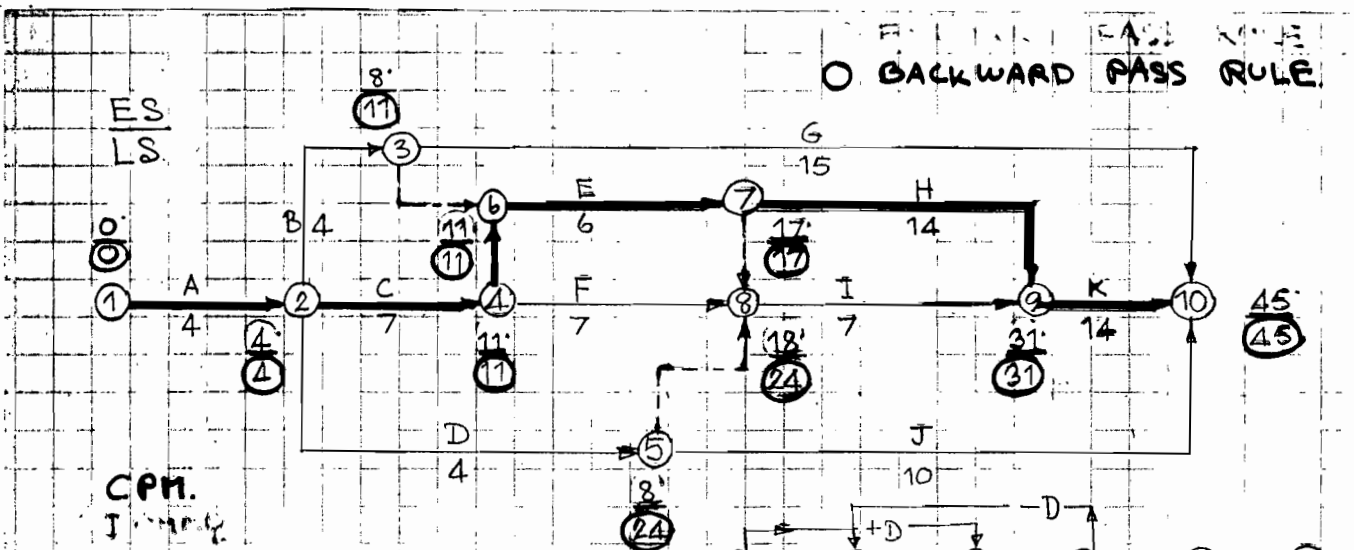
6. I ทำหลังจาก H และ F

7. โครงการเสร็จ เมื่อ I และ C เสร็จ



ข. นำเส้นลูกศรทั้งหมดมาประกอบรวมกันเป็นผังลูกศรโดยเริ่มต้นจากงาน ซึ่งเริ่มต้นโครงการ แล้วไล่ความสัมพันธ์ของงานต่าง ๆ ไปตามเส้นลูกศรที่แสดงไว้ในข้อ ก. จนกระทั่งเสร็จโครงการ ซึ่งจะเขียนผังลูกศรได้ ดังนี้





CPM
Timing

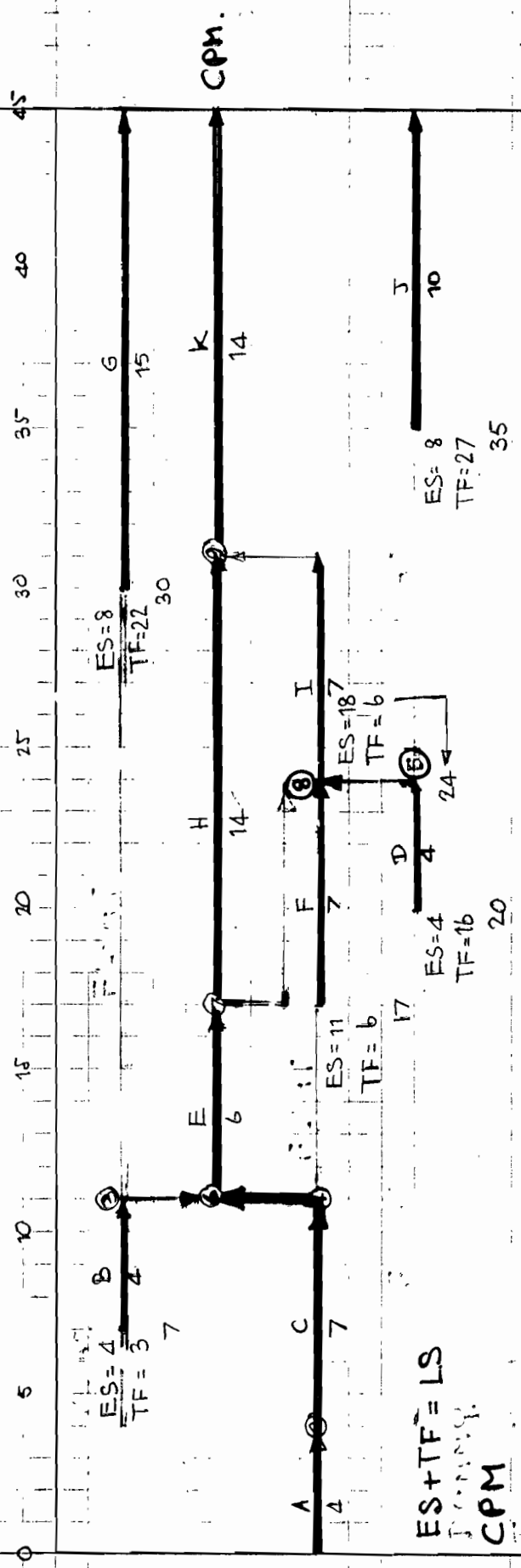
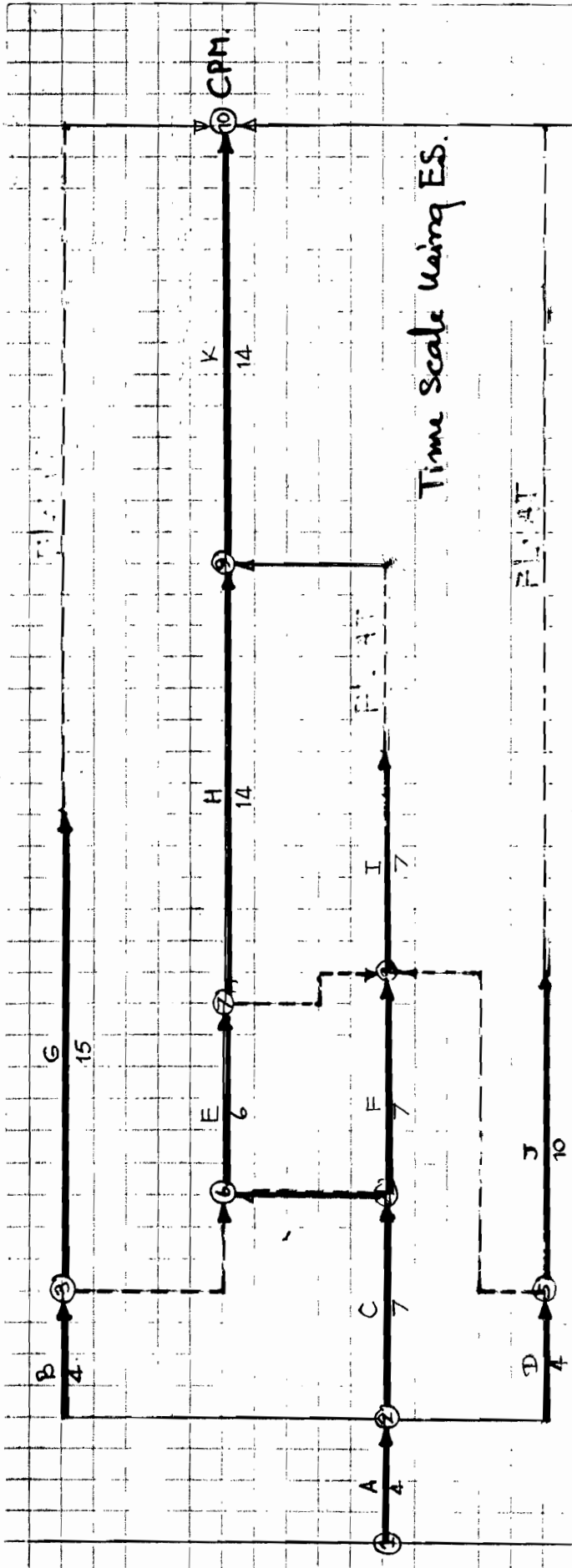
| Node | Activity | Duration | ES | LS | EF | LF | TF | FF |
|------|----------|----------|----|----|----|----|----|----|
| 1-2 | A | 4 | 0 | 0 | 4 | 4 | 0 | 0 |
| 2-3 | B | 4 | 4 | 7 | 8 | 11 | 3 | 0 |
| 2-4 | C | 7 | 4 | 4 | 11 | 11 | 0 | 0 |
| 2-5 | D | 4 | 4 | 20 | 8 | 24 | 16 | 0 |
| 6-7 | E | 6 | 11 | 11 | 17 | 17 | 0 | 0 |
| 4-8 | F | 7 | 11 | 17 | 18 | 24 | 6 | 0 |
| 3-10 | G | 15 | 8 | 30 | 23 | 45 | 22 | 22 |
| 7-9 | H | 14 | 17 | 17 | 31 | 31 | 0 | 0 |
| 8-9 | I | 7 | 18 | 24 | 25 | 31 | 6 | 6 |
| 5-10 | J | 10 | 8 | 35 | 18 | 45 | 27 | 27 |
| 9-10 | K | 14 | 31 | 31 | 45 | 45 | 0 | 0 |

FF = ...

FF = ...

TF = 0

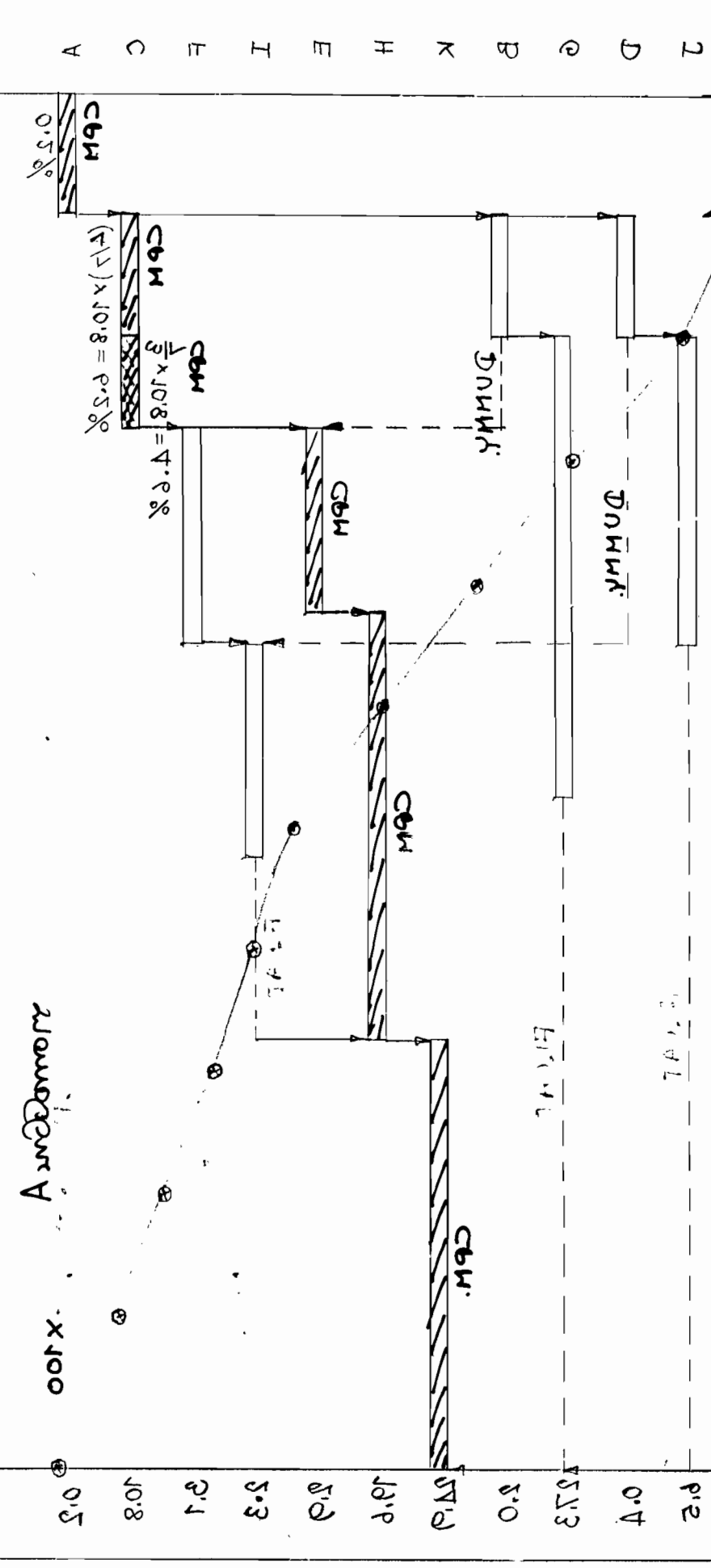
TF = 5



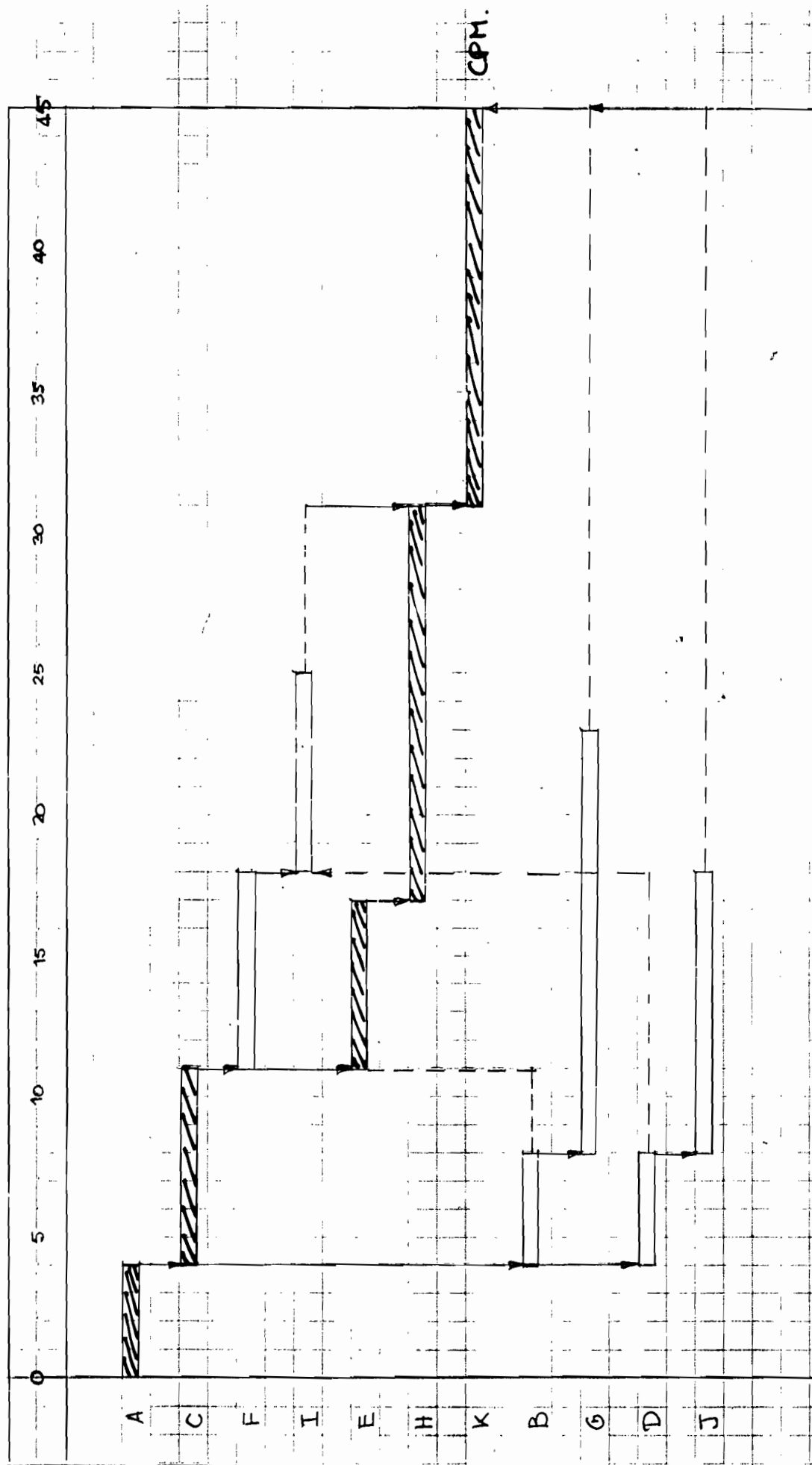
Time scale using TF or LS

1, 2, 3

| | | | | | | | | | | |
|---|-----|------|------|------|------|------|------|------|-----|-----|
| ⑤ | 0.5 | 50'5 | 21'8 | 25'1 | 20'0 | 20'0 | 21'0 | 21'3 | 100 | |
| ⑦ | 0.5 | 12'4 | 13'9 | 14'0 | 15'3 | 2'0 | 9'0 | 2'5 | 8'2 | 100 |
| 2 | 0 | 8 | 15 | 19 | 50 | 54 | 58 | 35 | 39 | 44 |



0 2 10 12 30 32 30 32 40 42 %



Event 0. The project starts.

- 0-1 *Clear site.* Necessary before any survey work can start.
- 1-2 *Survey and layout.* Cannot start before the site is cleared; otherwise, many of the survey stakes would be lost in the clearing operation.
- 2-3 *Rough grade.* Cannot start until the area has been laid out. This activity ties up the whole site with earth-moving equipment.
- 3-4 *Drill well.* Cannot start until the rough grading operation is completed.
- 4-5 *Install well pump.* Cannot be done until well is completed and cased.
- 5-8 *Underground water piping.* Although this might be started earlier, the site contractor prefers to work from the pump toward the building site.
- 3-6 *Water tank foundation.* After the rough grading, these simple foundations can be installed.
- 6-7 *Erect water tank.* Obviously, the water tank cannot be erected until the foundations are poured.
- 7-8 *Tank piping and valves.* Cannot be fabricated and erected until the tank is completed.
- 8-13 *Connect piping.* The water piping cannot be linked up until both sections are completed.
- 3-9 *Excavate for sewer.* Can be started after rough grading.
- 9-11 *Install sewer and backfill.* Immediately follows the sewer excavation, working from the low point uphill.
- 3-10 *Excavate for electrical manholes.* Can start after rough grading.
- 10-11 *Install electrical manholes.* Cannot start until the excavation is completed.
- 11-12 *Install electrical duct bank.* Is started after the electrical manholes are complete. The start of this also depends upon the completion of the sewer line, since that line is deeper than the duct bank.
- 3-12 *Overhead pole line.* Can be started after the site is rough-graded.
- 12-13 *Pull in power feeder.* Can start after both the duct bank and the overhead pole line are ready to receive the cable.

Event 13. The site preparation and utilities work are complete. Figure 4.10 represents the foundation and concrete work for the John Doe project.

- 13-14 *Building layout.* Necessary before foundation work can start.
- 14-15 *Drive and pour piles.* After layout, this is the first step in the plant and warehouse foundation work.
- 15-16 *Excavate.* Follows piping. This is fine grading to finish grade.
- 16-17 *Pour pile caps.* Starts after the fine grading.
- 17-18 *Form and pour grade beams.* These are poured across the exterior pile caps in this project.
- 18-21 *Form and pour railroad loading dock.* This dock is essentially an extension of the grade beams.
- 18-22 *Form and pour truck loading dock.* This dock, at the opposite end of the building from the railroad dock, also backs on the grade beams.
- 18-19 *Backfill and compact.* Cannot start until the grade beams are ready to contain the fill.
- 19-20 *Underslab plumbing.* Cannot be installed until the backfill is complete.
- 20-22 *Underslab conduit.* Is installed after the plumbing because the plumbing lines are deeper.
- 22-29 *Form and pour slabs.* The loading dock sides and underslab preparation must be completed before the slabs are poured.
- 14-23 *Excavate for office building.* Can start after the building layout work is complete.
- 23-24 *Spread footings.* Can be placed after the excavation is done.
- 24-25 *Form and pour grade beams.* Are poured on top of the spread footings.
- 25-26 *Backfill and compact.* Is done after the grade beams are finished.
- 26-27 *Underslab plumbing.* Is installed in the backfill.
- 27-28 *Underslab conduit.* Is installed on top of the plumbing lines.
- 28-29 *Form and pour slabs.* Can be done after the underslab preparations are complete.

Event 29. The foundations and concrete contract are completed. Figure 4.11 represents the erection of the framework for the plant and warehouse and also the closing-in of those buildings.

- 29-30 *Erect structural steel.* Follows the completion of foundations.
- 30-31 *Plumbing and bolt steel.* Of course, this cannot be done until the steel has been erected.
- 31-32 *Erect craneway and crane.* Can be done after the steel is bolted up. To make rigging easier, it is planned before the installation of the bar joists system.
- 31-33 *Erect monorail track.* Although this is not as difficult to erect as the craneway, it is convenient to erect it before the bar joists.
- 33-34 *Erect bar joists.* Can start after structural steel and major rigging are erected.
- 34-35 *Erect roof planks.* Cannot be done until the bar joists system is complete.
- 35-37 *Single ply roofing.* Goes on top of the roof planks.
- 35-36 *Erect siding.* Follows the roof planking for safety reasons and because the flashing detail makes it more practical.

Event 37. The building is closed in, and interior work can start. Figure 4.12 represents the interior work for the plant and warehouse. At this point, the general, mechanical, and electrical contractors can initiate activities.

- 37-38 *Set electrical load center.* Located on the slab in the warehouse. This is a package unit.
- 37-43 *Power panel backing boxes.* Can be mounted on the masonry walls and structural steel.
- 38-43 *Power conduit.* Main runs start after the electrical load center is set in place.
- 43-49 *Install branch conduit.* These runs follow the installation of the main conduit runs and the backing boxes for the power panels.
- 49-50 *Pull wire.* Follows completion of the conduit system.
- 50-54 *Terminate wires.* These are terminated after the panel internals are in place.
- 55-56 *Ringout.* After the wiring is connected, the circuits are checked out.
- 45-51 *Room outlets.* Start after branch conduit and drywall are complete.

Logical restraints 49-45 and 44-45 operate as spreaders. If 44-45 were not there, "ceramic tile" would depend on "branch conduit." If 49-45 were not there, "pull-wire" would depend upon "drywall."

- 51-56 *Install electrical fixtures.* Follows the completion of the room outlets.
- 37-39 *Masonry partitions.* Start as soon as the building is closed in.
- 39-42 *Hung ceiling.* Is supported on the masonry partitions.
- 37-42 *Exterior doors.* Can be hung after the building is closed in but must be installed prior to the drywall.
- 42-44 *Drywall.* Cannot start until the building is weathertight and the partitions are framed out. (Includes studs and door bucks.)
- 44-58 *Hang interior doors.* Can follow drywall installation.
- 44-48 *Ceramic tile.* Can follow drywall.
- 48-53 *Paint rooms.* Follows the drywall and ceramic tile installation.
- 53-57 *Floor tile.* Should be held off until the room painting is complete.
- 57-58 *Furnishings.* Are installed last.
- 53-58 *Plumbing fixtures.* Are installed after painting.
- 37-46 *Install heating and ventilating units.* Can be installed after the built-up roofing; they are on the roof.
- 46-52 *Ductwork.* Can be installed after the heating and ventilating units and room drywall are complete.
- 52-58 *Insulate heating and ventilating ducts.* Cannot be done until the ductwork is in place.

- 37-41 *Erect boiler and auxiliaries.* Equipment is in the warehouse, and erection is best done after the warehouse is closed in. The unit is small enough to move through the regular shipping door opening.
- 41-47 *Preoperational check.* A routine check after the boiler is installed.
- 37-40 *Fabricate piping systems.* Can be done after the building is closed in.
- 40-47 *Testing piping.* Follows completion of the piping systems.
- 37-47 *Install fuel oil tank.* Is planned to start after the building siding is on so that the excavation will not interfere with the siding work.
- 47-58. *Light off the boiler.* Cannot be done until the piping systems are tested, boiler is checked out, and fuel oil tank is ready.
- 37-58 *Install monorail.* Can be done any time between the close-in and completion of the building.

Figure 4.13 represents the structure and interior work for the office building. At the owner's request, this follows the completion of the plant and warehouse, which occurs by event 58.

- 58-59 *Erect precast.* The first operation in the office building, since the foundations were prepared previously.
- 59-60 *Erect roof.* Naturally must follow the erection of the structure. Since it uses the same crane rigging, it follows closely
- 60-61 *Exterior masonry.* Follows the roof erection.
- 60-76 *Package air conditioning.* Can be set as soon as the roof is completed.
- 61-77 *Ductwork.* Can commence when the building is closed in. If started earlier, this operation would interfere with the masonry scaffolds.
- 61-63 *Built-up roofing.* Follows masonry so that the roofers are not mopping tar on the masons. That might be called preferential logic, since the operation could physically commence at event 60.
- 61-62 *Exterior doors.* Installation must wait for the door bucks, which go up with the masonry.
- 61-68 *Glazing.* Is done in the windows which went up with the exterior masonry.
- 61-64 *Piping installation.* Can start after the exterior masonry is closed in.
- 61-65 *Install backing boxes.* Since the boxes mount on the masonry and structure, the installation can start after the masonry is placed.

- 63-80 *Paint exterior.* Starts after the roofing is on and the doors are installed.
- 64-67 *Test piping.* Follows the piping installation.
- 65-66 *Install conduit.* Follows backing boxes, since this is smaller branch conduit rather than a main feeder.
- 66-74 *Pull wire.* Done after the conduit is in place.
- 67-67 *Metal studs.* Follow the piping tests and the conduit installation, since portions of these systems are embedded in or behind the drywall.
- 68-69 *Drywall.* Cannot start until the building is weathertight ("glaze," "roofing," and "exterior doors") and the metal studs are installed.
- 69-70 *Restraint*
- 69-73 *Ceramic tile.* Also follows drywall.
- 70-71 *Wood trim.* Placed after the drywall.
- 71-72 *Paint interior.* Follows the wood trim.
- 72-80 *Floor tile.* Follows the painting in order to protect the tile.
- 73-80 *Lavatory fixtures.* Installed after the interior painting and ceramic tile in order to protect the fixtures.
- 74-75 *Install electrical panel internals.* Follows the pulling of wires.
- 75-79 *Terminate wires.* Follows the installation of panel internals.
- 76-79 *Electrical connections (air conditioning).* Follow the air-conditioning equipment installation and the electrical panel installation.
- 77-78 *Install ceiling grid.* Is preceded by ductwork and the drywall.
- 78-80 *Acoustic tiles.* Can be installed after the ceiling grid is installed and the interiors are painted.
- 79-80 *Ringout.* Of electrical systems; comes after systems are complete.
- 37-93 *Area lighting* 19
- 37-92 *Access road* 1. 14
- 37-91 *Grade and ballast railroad siding*
- 37-90 *Pave parking areas*
- 37-80 *Perimeter fence*
- 91-58 *Railroad siding.* Follows grading and ballast of the bed.

C 7

The access road, parking, and railroad siding have to be ready by the completion of the plant and warehouse (event 58). The final activities for the office building include

58-80 *Erect flagpole*

58-94 *Fine grade*

94-80 *Seed and plant*

In preparing the six sections of the CPM description of the John Doe project, the standard routine of considering the overall project by its several physical components has been followed. This family of individual networks can be effective. If drawing space is a limitation, the drawings could be sheets 1 through 6 of one network.

Logic Changes—Examples

If the initial logic is incorrect or the situation changes, the network is changed by adding to, deleting from, or revising the logic network. For instance:

Example 1 What changes to the John Doe network would be required to run the office building in parallel with the plant and warehouse?

solution To run the office building in parallel with the plant and warehouse, only two activities must be changed:

28-29 Connects directly to the start of the office. To do this, change 28-29 to 28-99.

58-59 Must be unconnected from the warehouse completion. Change 58-59 to 99-59.

Example 2 If the sewer passes under the water tank location, what work sequence changes are necessary?

solution If the sewer passes under the water tank foundations, activity 9-11, install sewer, will have to precede 3-6, tank foundations. Don't do this with restraint 11-3 or you will have a loop. First add a spreader restraint between event 3 and the start of tank foundations.

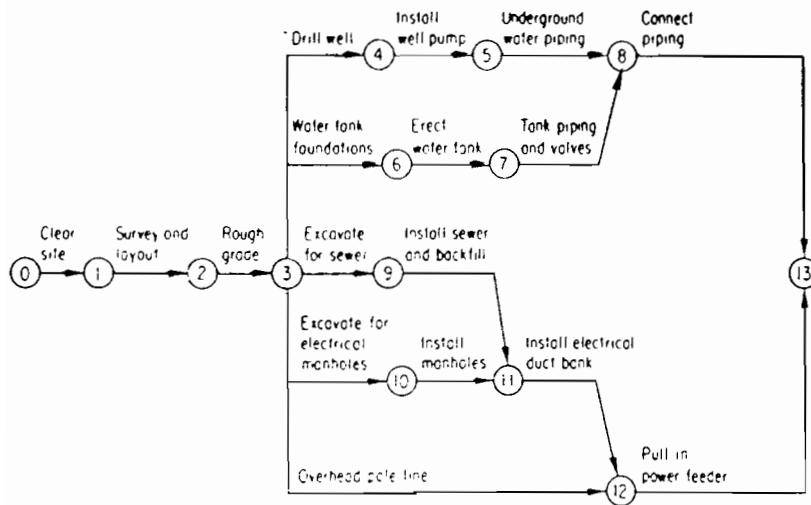


Figure 4.9 CPM network, site preparation, and utilities.

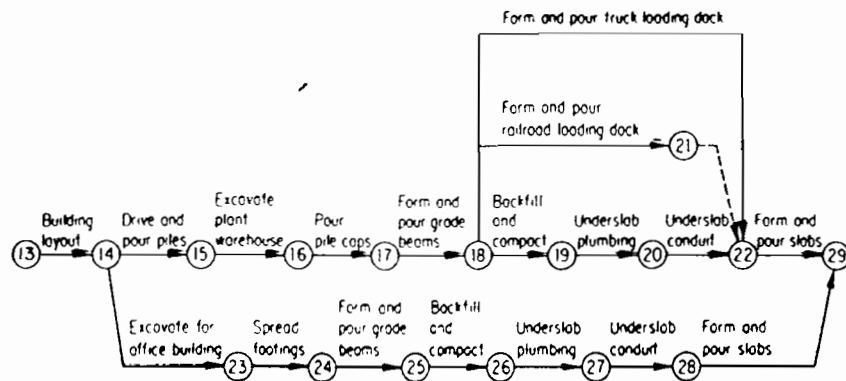


Figure 4.10 CPM network, foundation contract.

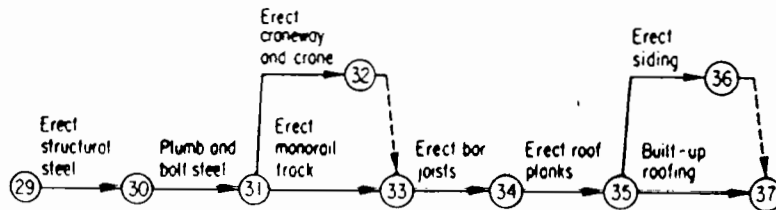


Figure 4.11 CPM network: close-in, plant, and warehouse.

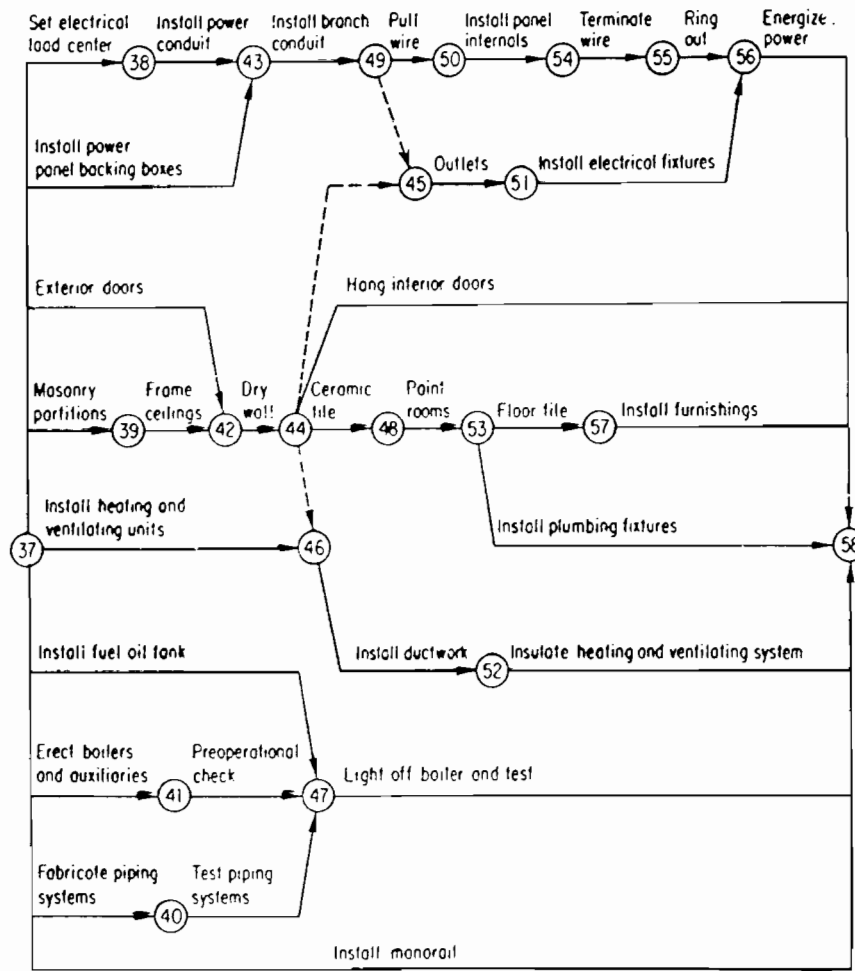


Figure 4.12 CPM network: interior work, plant, and warehouse.

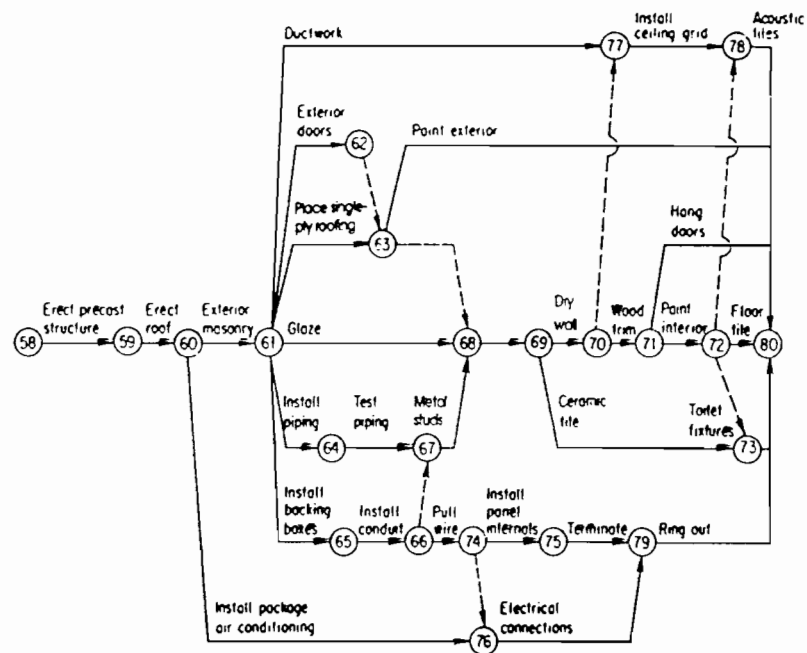


Figure 4.13 CPM network: office building.

Figure 4.14 represents the site work, which starts when the structural work is completed (event 37). Note that random numbering was used for this diagram because all digits up to 80 had been used in preceding sections of the diagram. All the following can commence when the structural contractor moves off the site.

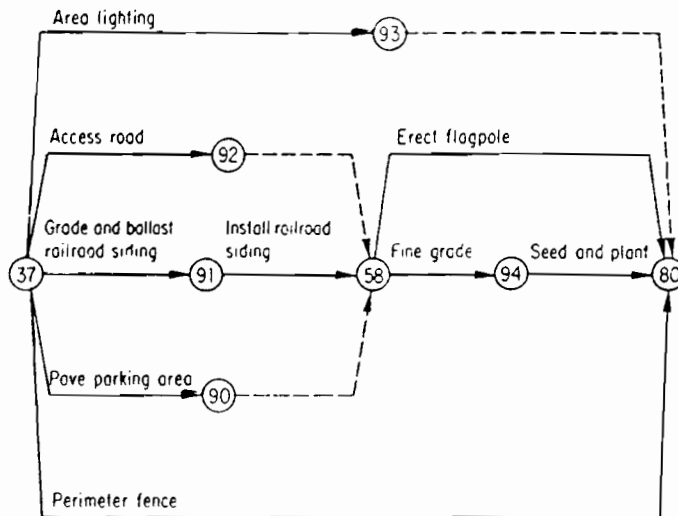


Figure 4.14 CPM network: site work.

An estimate of the time required for these activities, based on materials and takeoff, is

| Activity | Quantity | Project time, days |
|---|--|--------------------|
| 0-1 Clear site | Four acres @ 2 dozer-days per acre by four dozers. | 2 |
| 1-2 Survey and layout | Set control traverse—1½ days; layout, grade, and line—½ day. | 2 |
| 2-3 Rough grade | One acre, move 1000 yd, two dozers @ 250 yd ³ /day. | 2 |
| 3-9 Excavate for sewer | Approximate cross section at deep end (10-ft depth) is 12 yd ² by 667 yd in length. Averaging approximately 4000 yd ³ , clamshell with 2-yd bucket @ 100 yd ³ /h. | 5 |
| 9-11 Install sewer and backfill | 2000 ft @ 60 ft/h—33 h. | 4 |
| 3-10 Excavate for two electrical manholes | @ 2 h per manhole, say. | 1 |
| 10-11 Install two electrical manholes | 800 ft ² forms total @ 100 ft ² per team-hour—8 h. Crew setup time—4 h; pour concrete—4 h; strip—8 h. | 4 |
| 11-12 Install electrical duct | 800-ft conduit @ 2 ft/h—400 worker-hours per 10-person crew. Concrete follows by 1 day. | 6 |
| 3-12 Overhead line | 1800 ft, set 24 poles—one crew, 3 days; string wire—3 days. | 6 |

Informal time estimates for these are:

| Activity | Brief description | Assumed crew size | Project time, days |
|---------------------------------------|---|-------------------|--------------------|
| 0-1 Clear site | Four acres, four bulldozers | 5 | 3 |
| 1-2 Survey and layout | Four acres, benchmarks available | 3 | 2 |
| 2-3 Rough grade | One acre, two dozers | 3 | 2 |
| 3-9 Excavate for sewer | Average depth 5 ft, 2000 ft long | 5 | 10 |
| 9-11 Install sewer and backfill | | 5 | 5 |
| 3-10 Excavate for electrical manholes | Two manholes, 5 ft deep | 2 | 1 |
| 10-11 Install electrical manholes | Poured in place | 4 | 5 |
| 11-12 Install electrical duct | 200-ft-long by 5-ft-deep 4-in conduit, straight run | 7 | 3 |
| 3-12 Overhead line | 1800 ft | 4 | 6 |

These lists were prepared independently:

| Activity | Informal estimate, days | Formal estimate, days |
|-----------------------------------|-------------------------|-----------------------|
| 0-1 Clear site | 3 | 2 |
| 1-2 Survey | 2 | 2 |
| 2-3 Rough grade | 2 | 2 |
| 3-9 Excavate for sewer | 10 | 5 |
| 9-11 Install sewer | 5 | 4 |
| 3-10 Excavate electrical manholes | 1 | 1 |
| 10-11 Install electrical manholes | 5 | 4 |
| 11-12 Electrical duct bank | 3 | 6 |
| 3-12 Overhead pole line | 6 | 6 |

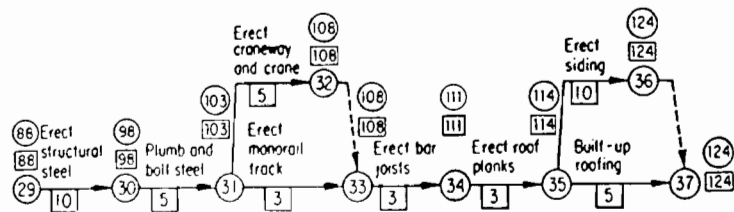


Figure 5.11 Close-in of plant and warehouse with early and late event times.

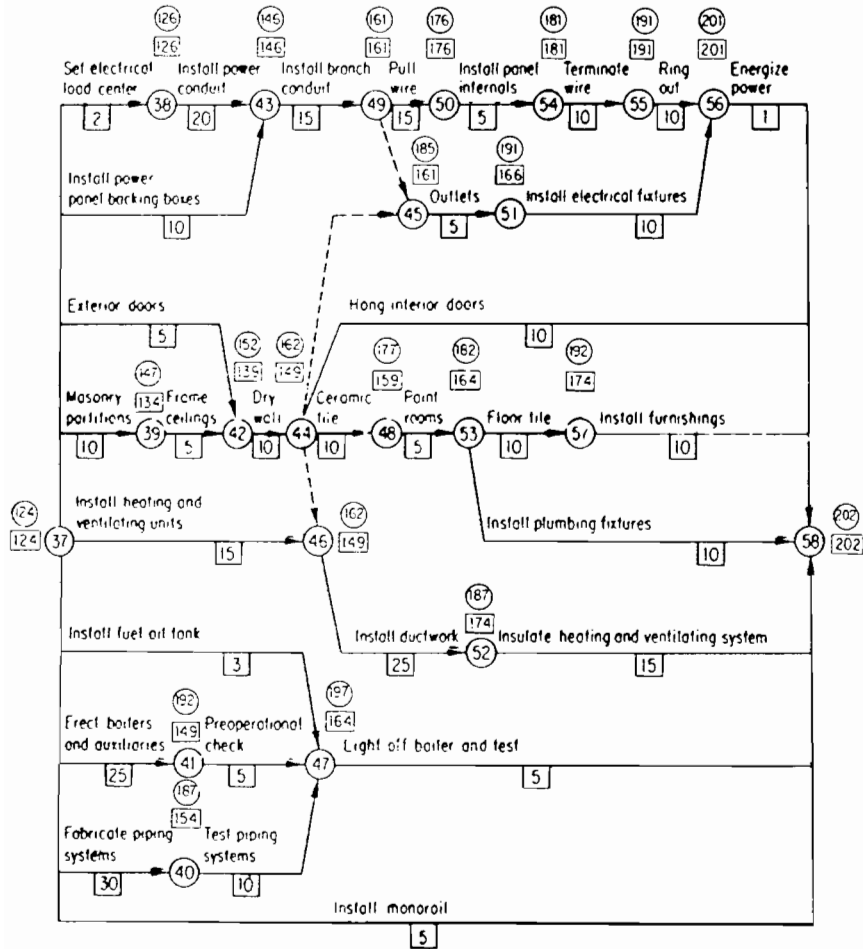


Figure 5.12 Interior work with early and late event times.

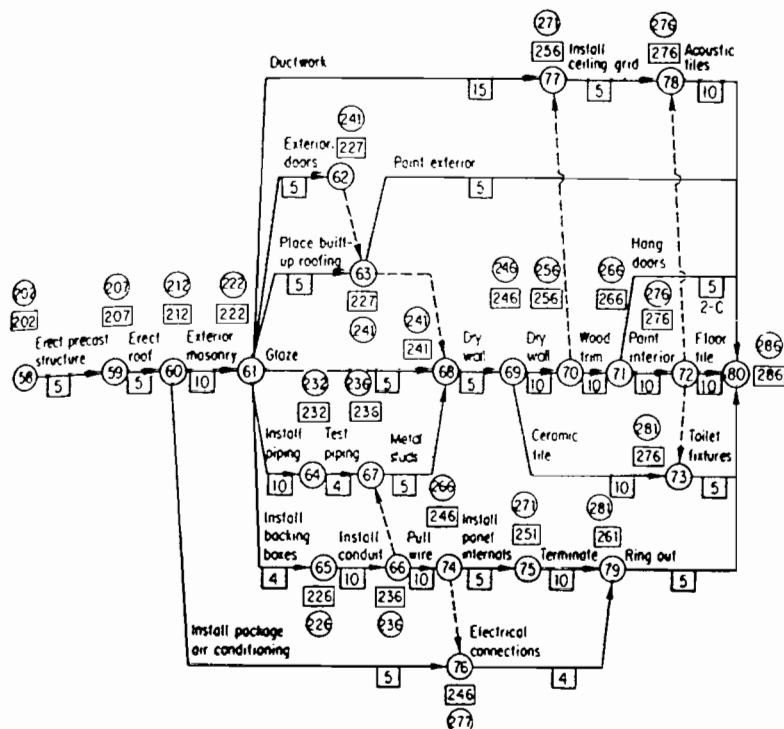


Figure 5.13 Office building with early and late event times.

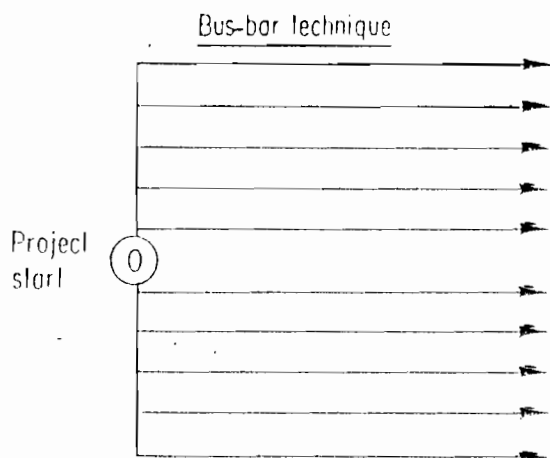
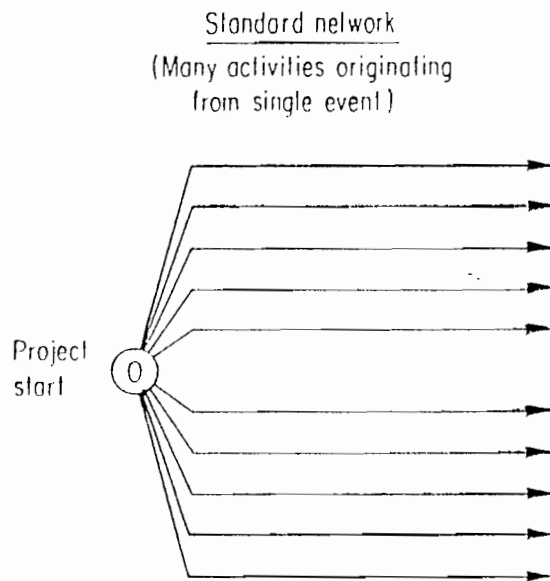


FIG. 3.12 Bus-bar technique.

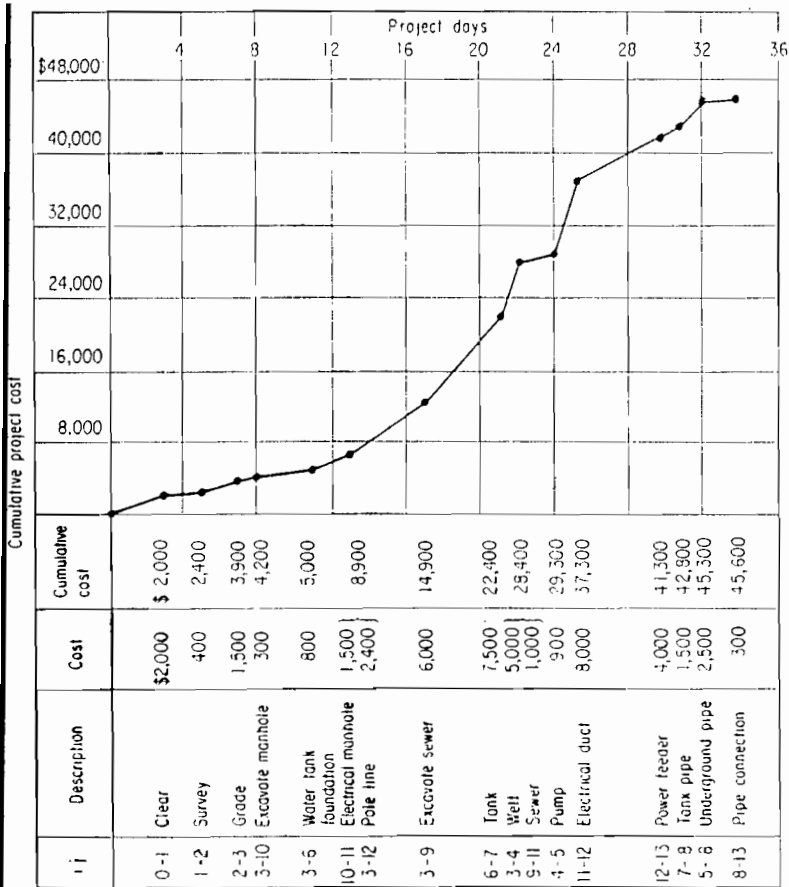


FIG. 14.5 Cost versus time, early finish basis.

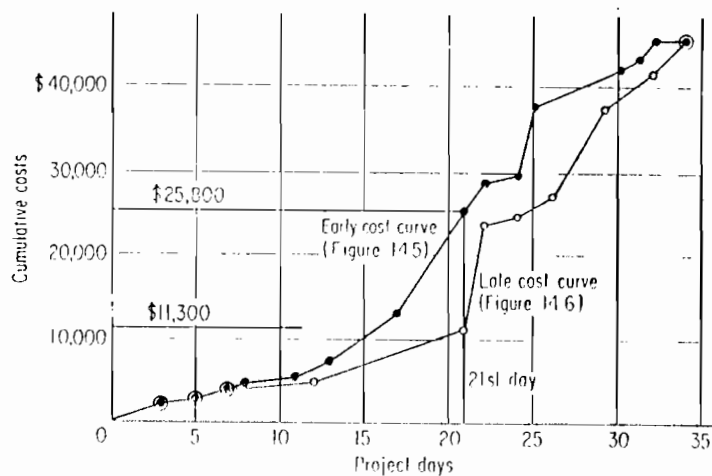
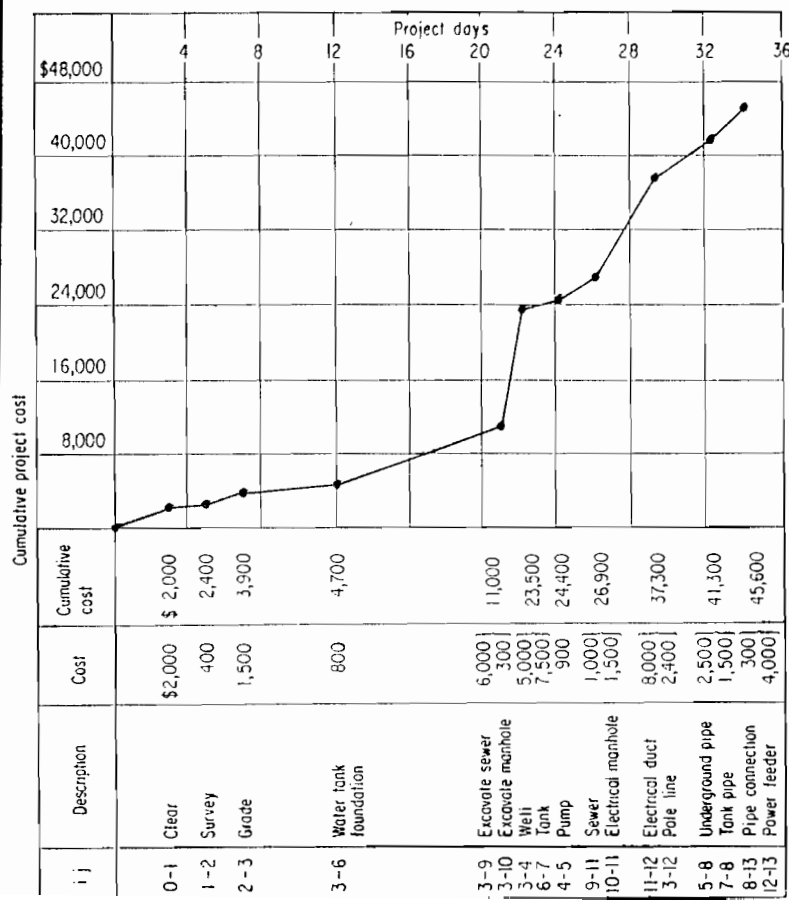


FIG. 14.7 Comparison of early and late cost versus time curves.