

Chapter 3: Project Planning

3.1 Introduction

Planning is a general term that sets a clear road map that should be followed to reach a destination. The term, therefore, has been used at different levels to mean different things. Planning involves the breakdown of the project into definable, measurable, and identifiable tasks/activities, and then establishes the logical interdependences among them. Generally, planning answers three main questions:

- What is to be done?
- How to do it?
- Who does it?

In construction, for example, plans may exist at several levels: corporate strategic plans, pre-tender plans, pre-contract plans, short-term construction plans, and long-term construction plans. These plans are different from each other; however, all these plans involve four main steps:

- Performing breakdown of work items involved in the project into activities.
- Identifying the proper sequence by which the activities should be executed.
- Activities representation.
- Estimating the resources, time, and cost of individual activities.

Detailed planning for tendering purposes and the preparation of construction needs to be conducted through brainstorming sessions among the planning team. The inputs and outputs of the planning process are shown in [Figure 3.1](#).

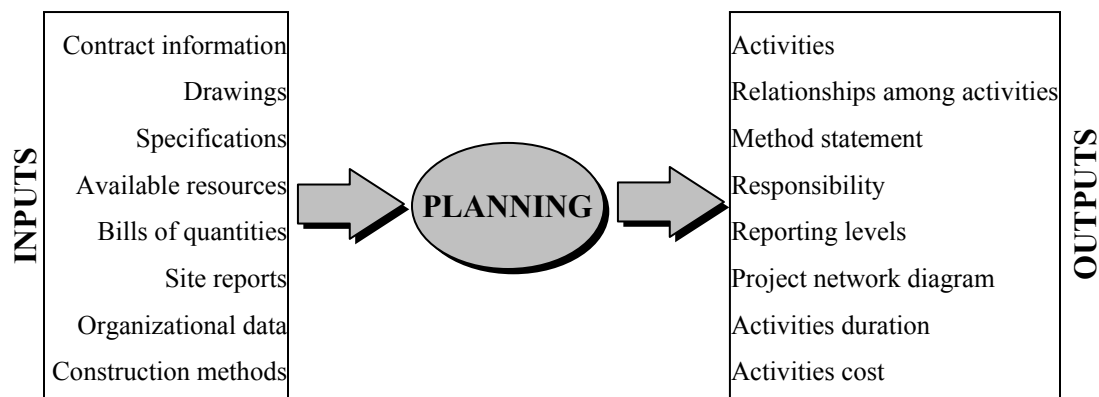


Figure 3.1: Planning inputs and outputs

Planning requires a rigorous effort by the planning team. A planner should know the different categories of work and be familiar with the terminology and knowledge used in general practice. Also, the planning team should seek the opinion of experts including actual construction experience. This helps produce a realistic plan and avoids problems later on site.

3.2 Project Planning Steps

The following steps may be used as a guideline, or checklist to develop a project plan:

1. Define the scope of work, method statement, and sequence of work.
2. Generate the work breakdown structure (WBS) to produce a complete list of activities.
3. Develop the organization breakdown structure (OBS) and link it with work breakdown structure to identify responsibilities.
4. Determine the relationship between activities.
5. Estimate activities time duration, cost expenditure, and resource requirement.
6. Develop the project network.

3.2.1 Work breakdown structure (WBS)

The WBS is described as a hierarchical structure which is designed to logically sub-divide all the work-elements of the project into a graphical presentation. The full scope of work for the project is placed at the top of the diagram, and then sub-divided smaller elements of work at each lower level of the breakdown. At the lowest level of the WBS the elements of work is called a work package. A list of project's activities is developed from the work packages.

Effective use of the WBS will outline the scope of the project and the responsibility for each work package. There is not necessarily a right or wrong structure because what may be an excellent fit for one discipline may be an awkward burden for another.

To visualize the WBS, consider [Figure 3.2](#) which shows a house construction project.

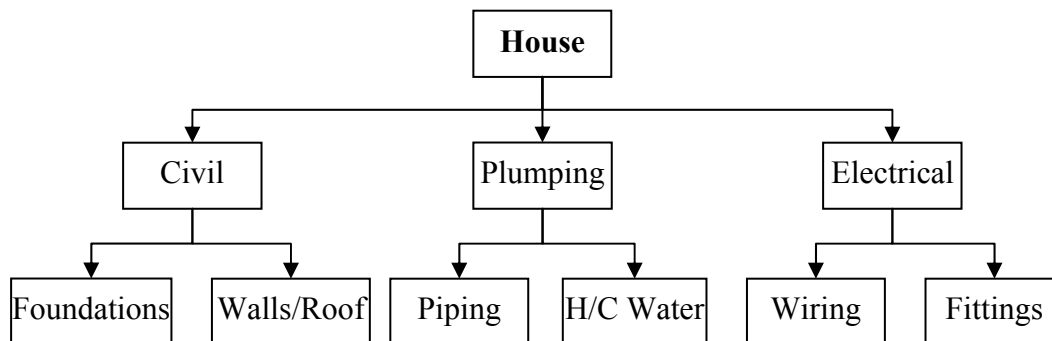


Figure 3.2: WBS and their description

As shown in [Figure 3.2](#), level 1 represents the full scope of work for the house. In level 2, the project is sub-divided into its three main trades, and in level 3 each trade is sub-divided to specific work packages.

[Figure 3.3](#) shows another example for more detailed WBS, in which the project WBS is divided into five levels:

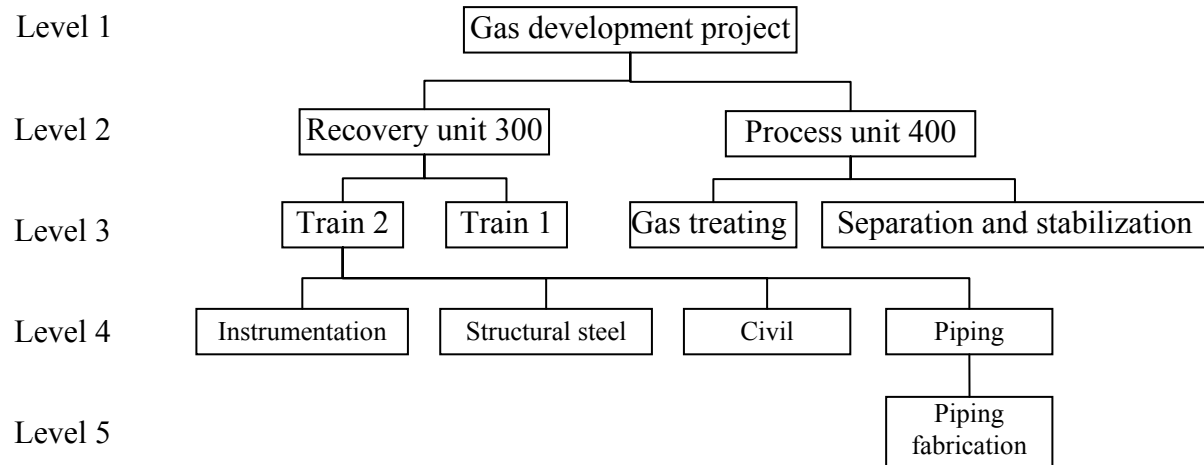


Figure 3.3: Five levels WBS

Level 1: The entire project.

Level 2: Independent areas.

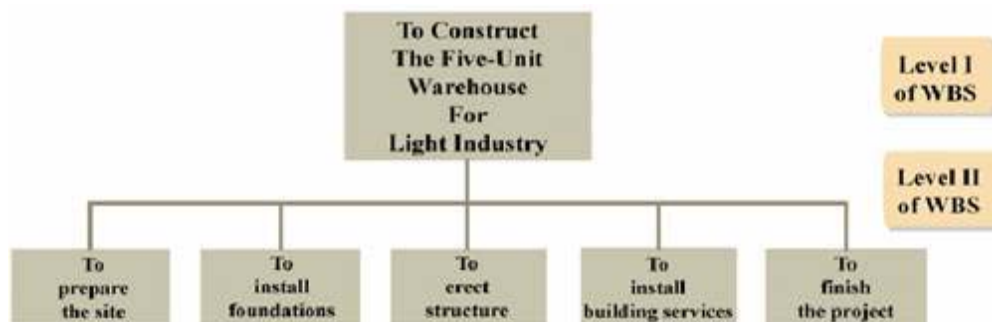
Level 3: Physically identifiable sections fully contained in a level 2 area, reflect construction strategy.

Level 4: Disciplines set up schedule.

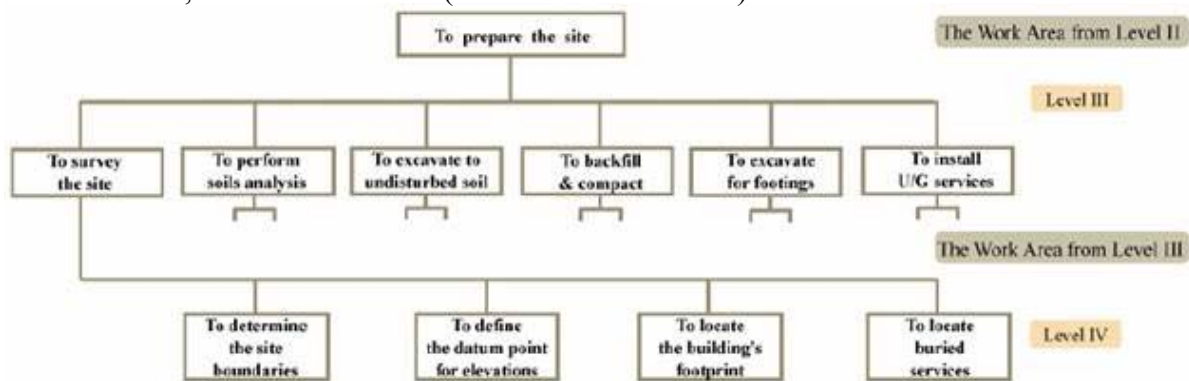
Level 5: Master schedule activities, quantity, duration.

Example 3.1:

The WBS for a warehouse is as follow:



For more details, another two levels (third and fourth levels) can be added as shown below:



Accordingly, a complete WBS for the warehouse project can be shown as follow (Figure 3.4):

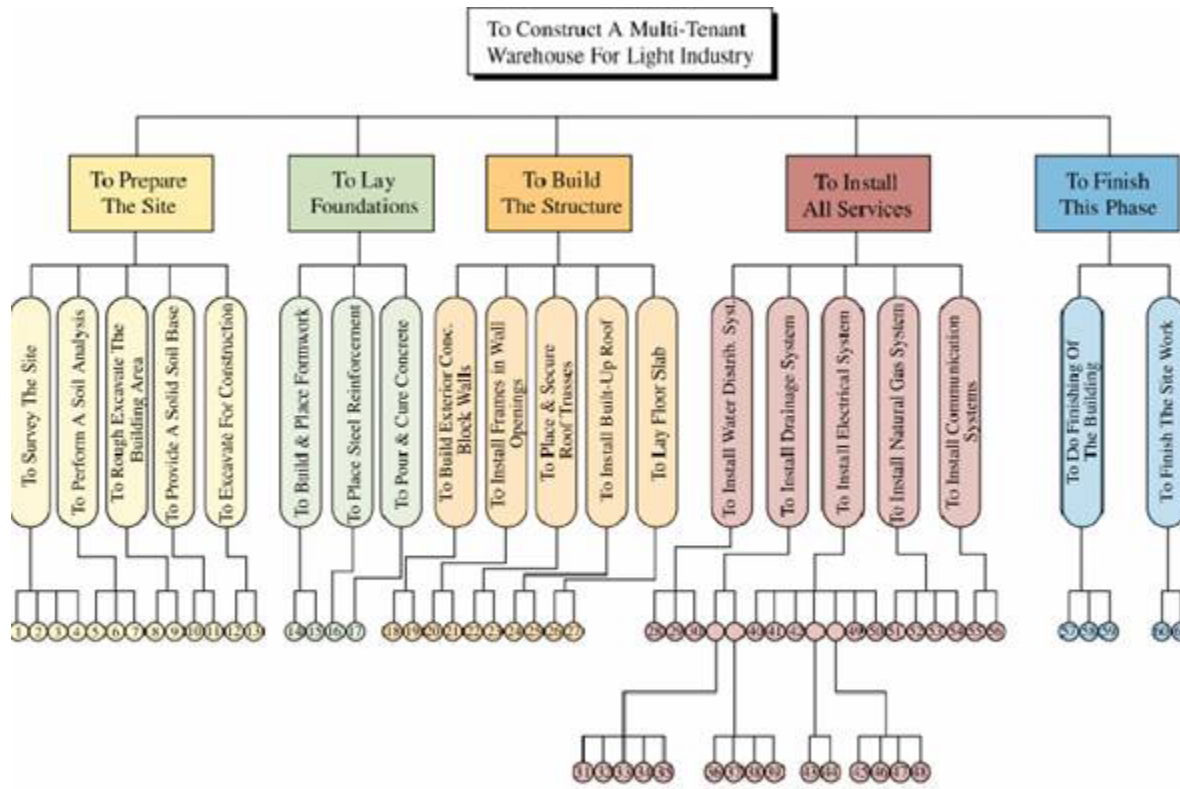


Figure 3.4: Warehouse project WBS

WBS and organizational breakdown structure (OBS)

The WBS elements at various levels can be related to the contractor's organizational breakdown structure (OBS), which defines the different responsibility levels and their appropriate reporting needs as shown in Figure 3.5. The figure, also, shows that work packages are tied to the company unified code of accounts. The unified code of accounts allows cataloging, sorting, and summarizing of all information. As such, the activity of installing columns formwork of area 2, for example, which is the responsibility of the general contractor's formwork foreman, has a unique code that represents all its data.

WBS coding

A project code system provides the framework for project planning and control in which each work package in a WBS is given a unique code that is used in project planning and control. The coding system provides a comprehensive checklist of all items of work that can be found in a specific type of construction. Also, it provides uniformity, transfer & comparison of information among projects. An example of this coding system is the MasterFormat (Figure 3.6) which was developed through a joint effort of 8 industry & professional associations including: Construction Specifications Institute (CSI); and Construction Specifications Canada (CSC).

Figure 3.7 shows an example of the coding system using a standardize system as the MasterFormat. The Master format is divided into 16 divisions as follows:

- 1) General Requirements.
- 2) Site work.
- 3) Concrete.
- 4) Masonry.
- 5) Metals.
- 6) Woods & Plastics.
- 7) Thermal & Moisture Protection.
- 8) Doors & Windows.
- 9) Finishes.
- 10) Specialties.
- 11) Equipment
- 12) Furnishings.
- 13) Special Construction.
- 14) Conveying Systems.
- 15) Mechanical.
- 16) Electrical.

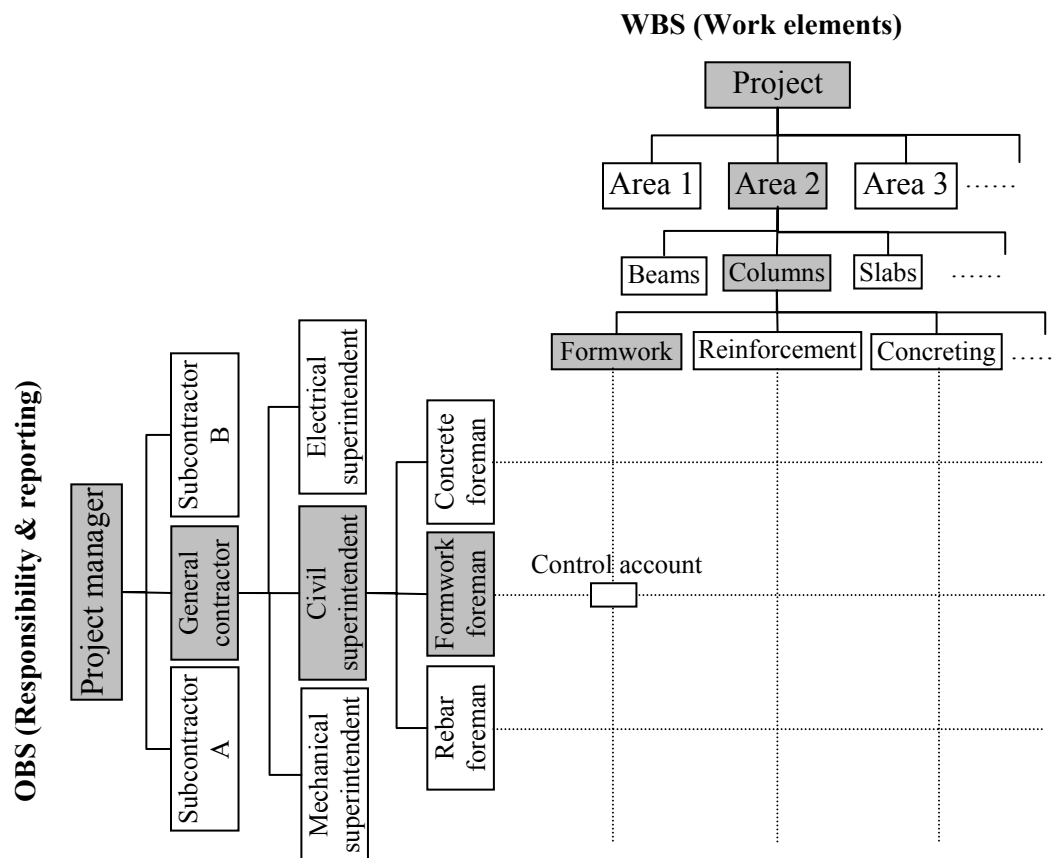


Figure 3.5: WBS linked to the OBS

CSI – Masterformat (Building Construction)

00010 Pre-bid Information
 00100 Instructions to Bidders
 00200 Information available to Bidders
 00300 Bid Forms
 00400 Supplements to Bid Forms
 00500 Agreement Forms
 00600 Bonds and Certificates
 00700 General Conditions
 00800 Supplementary Conditions
 00900 Addenda

Note: The items listed above are not specification sections and are referred to as "Documents" rather than "Sections" in the Master List of Section Titles, Numbers, and Broadscope Section Explanations.

Specifications**Division 1 - General Requirements**

01010 Summary of Work
 01020 Allowances
 01025 Measurement and Payment
 01030 Alternates/Alternatives
 01035 Modification Procedures
 01040 Coordination
 01050 Field engineering
 01060 Regulatory Requirements
 01070 Identification systems
 01090 References
 01100 Special Project Procedures
 01200 Project Meetings
 01300 Submittals
 01400 Quality Control
 01500 Construction Facilities and Temporary Controls
 01600 Material and Equipment
 01650 Facility Startup/Commissioning
 01700 Contract Closeout
 01800 Maintenance

Division 2 - Site Work

02010 Subsurface Investigation
 02050 Demolition
 02100 Site Preparation
 02140 Dewatering

02150 Shoring and Underpinning
 02160 Excavation Support Systems
 02170 Cofferdams
 02200 Earthwork
 02300 Tunneling
 02350 Piles and Caissons
 02450 Railroad Work
 02480 Marine Work
 02500 Paving and Surfacing
 02600 Utility Piping Materials
 02660 Water Distribution
 02680 Fuel and Steam Distribution
 02700 Sewerage and Drainage
 02760 Restoration of Underground Pipe
 02770 Ponds and Reservoirs
 02780 Power and Communications
 02800 Site Improvements
 02900 Landscaping

Division 3 - Concrete

03100 Concrete Framework
 03200 Concrete Reinforcement
 03250 Concrete Accessories
 03300 Cast-In-Place Concrete
 03370 Concrete Curing
 03400 Precast Concrete
 03500 Cementitious Decks and Toppings
 03600 Grout
 03700 Concrete Restoration and Cleaning
 03800 Mass Concrete

Division 4 - Masonry

04100 Mortar and Masonry Grout
 04150 Masonry Accessories
 04200 Unit Masonry
 04400 Stone
 04500 Masonry Restoration and Cleaning
 04550 Refractories
 04600 Corrosion Resistant Masonry
 04700 Simulated Masonry

Division 5 - Metals

05010 Metal Materials
 05030 Metal Coatings

05050 Metal Fastening
 05100 Structural Metal Framing
 05200 Metal Joists
 05300 Metal Decking
 05400 Cold Formed Metal Framing
 05500 Metal Fabrications
 05580 Sheet Metal Fabrications
 05700 Ornamental Metal
 05800 Expansion Control
 05900 Hydraulic Structures

Division 6 - Wood and Plastics

06050 Fasteners and Adhesives
 06100 Rough Carpentry
 06130 Heavy Timber Construction
 06150 Wood and Metal Systems
 06170 Prefabricated Structural wood
 06200 Finish Carpentry
 06300 Wood Treatment
 06400 Architectural Woodwork
 06500 Structural Plastics
 06600 Plastic Fabrications
 06650 Solid Polymer Fabrications

Division 7 - Thermal and Moisture Protection

07100 Waterproofing
 07150 Dampproofing
 07180 Water Repellents
 07190 Vapor Retarders
 07195 Air Barriers
 07200 Insulation
 07240 Exterior Insulation and Finish Systems
 07250 Fireproofing
 07270 Firestopping
 07300 Shingles and Roofing Tiles
 07400 Manufactured Roofing and Siding
 07480 Exterior Wall Assemblies
 07500 Membrane Roofing
 07570 Traffic Coatings
 07600 Flashing and Sheet Metal
 07700 Roof Special Ties and Accessories
 07780 Skylights
 07790 Joint Sealers

Figure 3.6: MasterFormat coding system

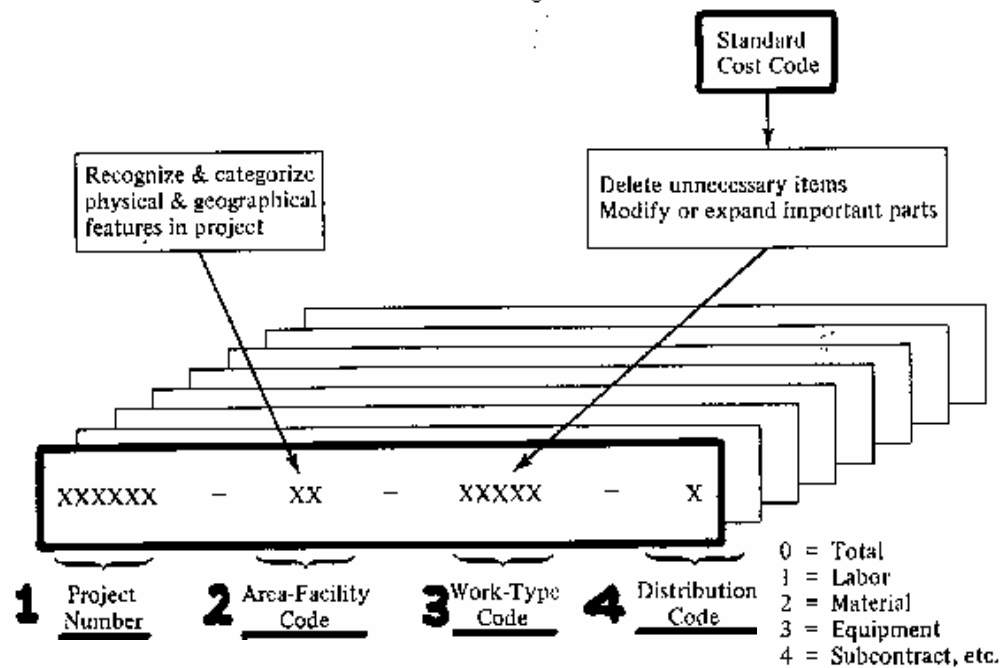


Figure 3.7: An example of an activity coding system

Project activities

The building block (the smallest unit) of a WBS is the activity, which is a unique unit of the project that has a specified duration. An activity is defined as any function or decision in the project that: consumes time, resources, and cost. Activities are classified to three types:

Production activities: activities that involve the use of resources such as labor, equipment, material, or subcontractor. This type of activities can be easily identified by reading the project's drawings and specifications. Examples are: excavation, formwork, reinforcement, concreting, etc. each production activity can have a certain quantity of work, resource needs, costs, and duration.

Procurement activities: activities that specify the time for procuring materials or equipment that are needed for a production activity. Examples are: brick procurement, boiler manufacturing and delivery, etc.

Management activities: activities that are related to management decisions such as approvals, vacations, etc.

An activity can be as small as "steel fixing of first floor columns" or as large as "construct first floor columns". This level of details depends on the purpose of preparing the project plan. In the pre construction stages, less detailed activities can be utilized, however, in the construction stages, detailed activities are required. Accordingly, level of details depends on: planning stage, size of the project, complexity of the work, management expertise.

Example 3.2:

Figure 3.8 shows a double-span bridge. Break the construction works of the bridge into activities. The plan will be used for bidding purposes.

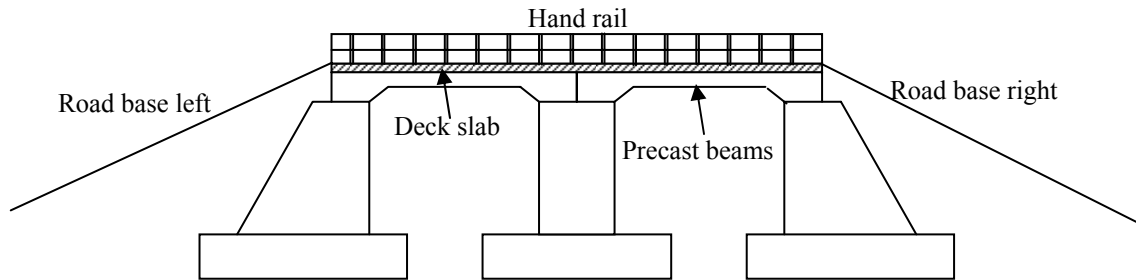


Figure 3.8: Double span bridge

A list of the double-span bridge activities is shown in Table 3.1

Table 3.1: Activities of the double-span bridge

| Activity | Description |
|----------|---------------------------|
| 10 | Set-up site |
| 14 | Procure reinforcement |
| 16 | Procure precast beams |
| 20 | Excavate left abutment |
| 30 | Excavate right abutment |
| 40 | Excavate central pier |
| 50 | Foundation left abutment |
| 60 | Foundation right abutment |
| 70 | Foundation central pier |
| 80 | Construct left abutment |
| 90 | Construct right abutment |
| 100 | Construct central pier |
| 110 | Erect left precast beams |
| 120 | Erect right precast beams |
| 140 | Fill left embankment |
| 150 | Fill right embankment |
| 155 | Construct deck slab |
| 160 | Left road base |
| 170 | Right road base |
| 180 | Road surface |
| 190 | Bridge railing |
| 200 | Clear site |

3.2.2 Activities relationships

In order to identify the relationships among activities, the planning team needs to answer the following questions for each activity in the project:

- Which activities must be finished before the current one can start?
- What activity(ies) may be constructed concurrently with the current one?

- What activity(ies) must follow the current one?

A circle of activity precedences will result in an impossible plan. For example, if activity A precedes activity B, activity B precedes activity C, and activity C precedes activity A, then the project can never be started or completed. Figure 3.9 illustrates the resulting activity network.

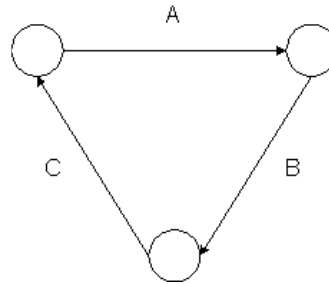


Figure 3.9: Example of a circle of activity precedence

Example 3.3:

Suppose that a site preparation and concrete slab foundation construction project consists of nine different activities:

- A. Site clearing (of brush and minor debris),
- B. Removal of trees,
- C. General excavation,
- D. Grading general area,
- E. Excavation for utility trenches,
- F. Placing formwork and reinforcement for concrete,
- G. Installing sewer lines,
- H. Installing other utilities,
- I. Pouring concrete.

Activities A (site clearing) and B (tree removal) do not have preceding activities since they depend on none of the other activities. We assume that activities C (general excavation) and D (general grading) are preceded by activity A (site clearing). It might also be the case that the planner wished to delay any excavation until trees were removed, so that B (tree removal) would be a precedent activity to C (general excavation) and D (general grading). Activities E (trench excavation) and F (concrete preparation) cannot begin until the completion of general excavation and grading, since they involve subsequent excavation and trench preparation. Activities G (install lines) and H (install utilities) represent installation in the utility trenches and cannot be attempted until the trenches are prepared, so that activity E (trench excavation) is a preceding activity. We also assume that the utilities should not be installed until grading is completed to avoid equipment conflicts, so activity D (general grading) is also preceding activities G (install sewers) and H (install utilities). Finally, activity I (pour concrete) cannot begin until the sewer line is installed and formwork and reinforcement are ready, so activities F and G are preceding. Other utilities may be routed over the slab foundation, so activity H (install utilities) is not necessarily a preceding activity for activity I (pour concrete). The result of our planning is the immediate precedence shown in Table 3.2.

Table 3.2: Precedence relations for Example 3.3

| Activity | Description | Predecessors |
|----------|---|--------------|
| A | Site clearing | --- |
| B | Removal of trees | --- |
| C | General excavation | A |
| D | Grading general area | A |
| E | Excavation for utility trenches | B,C |
| F | Placing formwork and reinforcement for concrete | B,C |
| G | Installing sewer lines | D,E |
| H | Installing other utilities | D,E |
| I | Pouring concrete | F,G |

Example 3.4:

Determine the relationships between activities of the project studied in Example 3.2.

Table 3.3: Solution of Example 3.4

| Activity | Description | Predecessors |
|----------|---------------------------|---------------|
| 10 | Set-up site | --- |
| 14 | Procure RFT | --- |
| 16 | Procure P.C. Beams | --- |
| 20 | Excavate left abutment | 10 |
| 30 | Excavate right abutment | 10 |
| 40 | Excavate central pier | 10 |
| 50 | Foundation left abutment | 14, 20 |
| 60 | Foundation right abutment | 14, 30 |
| 70 | Foundation central pier | 14, 40 |
| 80 | Construct left abutment | 50 |
| 90 | Construct right abutment | 60 |
| 100 | Construct central pier | 70 |
| 110 | Erect left P.C. Beams | 16, 80, 100 |
| 120 | Erect right P.C. Beams | 16, 90, 100 |
| 140 | Fill left embankment | 80 |
| 150 | Fill right embankment | 90 |
| 155 | Construct deck slab | 110, 120 |
| 160 | Left road base | 140 |
| 170 | Right road base | 150 |
| 180 | Road surface | 155, 160, 170 |
| 190 | Bridge railing | 155 |
| 200 | Clear site | 180, 190 |

Logical relationship considering resource constraints

For efficient use of resources or in case of constrained resources, it might be beneficial to consider the resources when determining the logical relationship among the activities that use the same resources. For example, consider the case of construction a simple project consists of three units and each unit has three sequential activities (logical relationship). Table 3.4 shows the logical relationship among these activities assuming unconstrained (resources are available with

any quantities) and constrained resources (only one resource unit is available form each resource type).

Table 3.4: Logical relationships considering constrained and unconstrained resources

| Activity | description | Predecessors (unconstrained resources) | Predecessors (constrained resources) |
|----------|-------------------|---|---|
| A1 | Excavate unit 1 | - | - |
| B1 | Concreting unit 1 | A1 | A1 |
| C1 | Brickwork unit 1 | B1 | B1 |
| A2 | Excavate unit 2 | - | A1 |
| B2 | Concreting unit 2 | A2 | B1, A2 |
| C2 | Brickwork unit 2 | B2 | C1, B2 |
| A3 | Excavate unit 3 | - | A2 |
| B3 | Concreting unit 3 | A3 | B2, A3 |
| C3 | Brickwork unit 3 | B3 | C2, B3 |

Overlap or lag

Overlap between activities (negative lag) is defined as how much a particular activity must be completed before a succeeding activity may start. The absence of overlap means that the first activity must finish before the second may start. A negative overlap (lag) means a delay is required between the two activities (Figure 3.10)

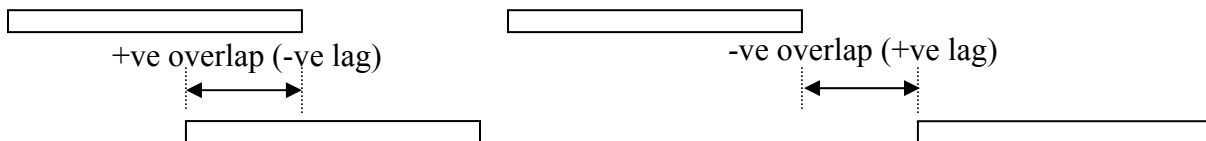


Figure 3.10: Overlap among activities

Example 3.5:

This case study is for a small 3 houses project. The main segments of a single house, the responsibilities, and the logical relationship are identified as follows:

- 11 work packages are involved: A and B (civil work, substructure), C, D, E, and F (civil work, superstructure), G (electrical, interior), H (electrical, exterior), I (mechanical, HVAC), J (mechanical, elevator), and K (mechanical, plumbing).
- Substructure is supervised by Ahmed (activity A), and Ali (activity B).
- Superstructure is supervised by Hossam (activities C and F) and Mona (activities D and E).
- All electrical work is supervised by George.
- HVAC and plumbing are supervised by Adam; elevator work is supervised by Samy.
- Activities E and F follow activity B.
- Activity C precedes activity G.
- Activity I follows the completion of activity E.
- The predecessors to activity K are activities H and I.

- Activity D follows activity A and precedes activity H.
- Activity J is preceded by activities F and G.

1. Create a WBS and OBS chart.

Solution: From the available information, the relationship table, the network diagrams, and the WBS linked to an OBS are formed as shown below (Table 3.5 and Figure 3.11).

Table 3.5: Logical relationships of Example 3.5

| Activity | Predecessors |
|----------|--------------|
| Start | - |
| A | Start |
| B | Start |
| C | Start |
| D | A |
| E | B |
| F | B |
| G | C |
| H | D |
| I | E |
| J | F, G |
| K | H, I |
| Finish | J, K |

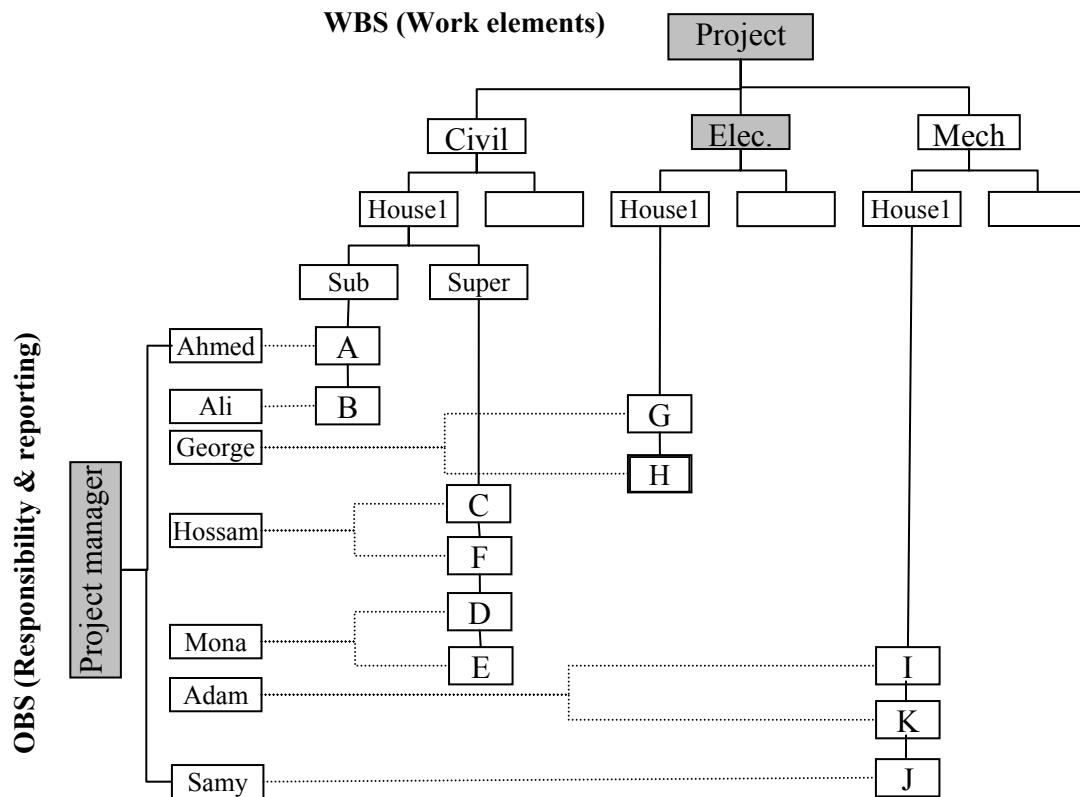


Figure 3.11: WBS and OBS of Example 3.5

Types of activities relationships

Four types of relationships among activities can be defined as described and illustrated below (Figure 3.12). Typically, relationships are defined from the predecessor to the successor activity.

- a) Finish to start (FS). The successor activity can begin only when the current activity completes.
- b) Finish to finish (FF). The finish of the successor activity depends on the finish of the current activity.
- c) Start to start (SS). The start of the successor activity depends on the start of the current activity.
- d) Start to finish (SF). The successor activity cannot finish until the current activity starts.

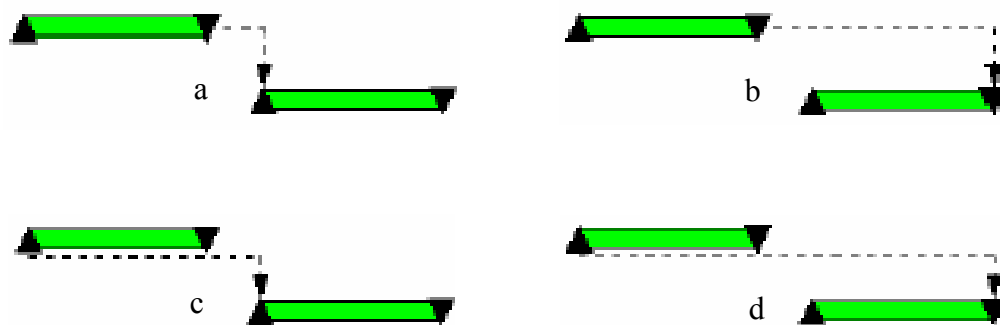


Figure 3.12: Types of relationships

3.2.3 Drawing the project network

A network is a graphical representation of the project activities and their relationships. A project network is a set of arrows and nodes. Before drawing the network, it is necessary to ensure that the project has a unified starting and ending point. The need for this start activity arises when there is more than one activity in the project that has no predecessors and the end activity is needed when there is more than one activity that has no successors. Also, networks should be continuous (i.e., each activity except the first and the last has both preceding and succeeding activities).

There are two ways that are commonly used to draw a network diagram for a project:

1. Activity on Arrow (AOA) representation.
2. Activity on Node (AON) representation

3.2.3.1 Activity on arrow network (AOA)

In this method, the arrows represent activities while the nodes represent the start and the end of an activity (usually named as events) (Figure 3.13). The length of the arrow connecting the nodes

has no significance and may be straight, curved, or bent. When one activity depends upon another, both appear on the diagram as two arrows having a common node.

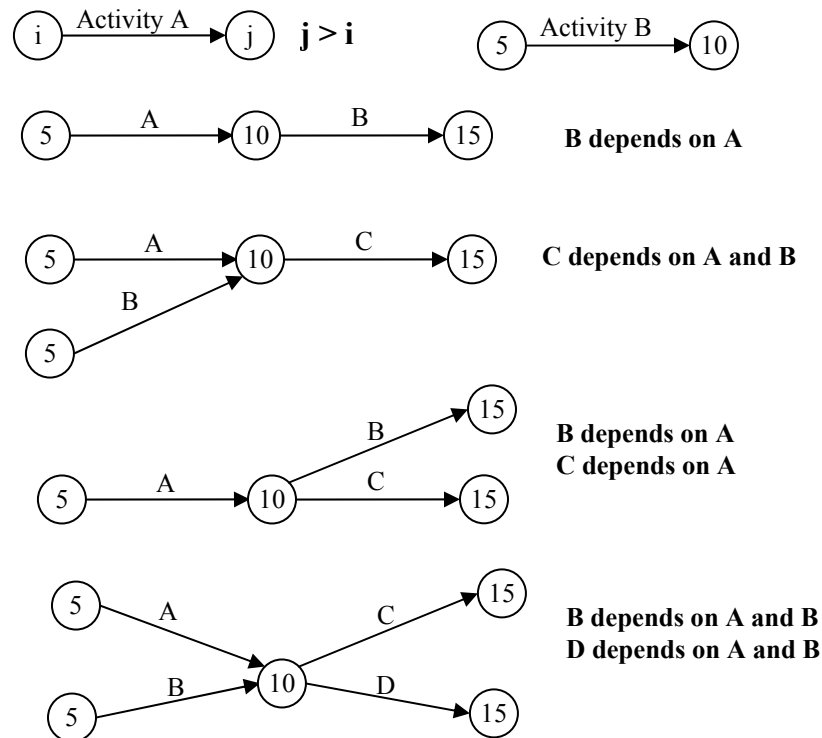


Figure 3.13: Basic patterns of AOA diagrams

The following are some rules that need to be followed when constructing an AOA network diagram:

- Each activity must have a unique $i - j$ numbers, where i (the number at the tail of the arrow) is smaller than j (the number at the head of the arrow).
- It is recommended to have a gap between numbers (i.e., 5, 10, 15, etc.). This will allow for accommodation of missed activities.
- Avoid back arrows.

In some situations, when more than one arrow leave the same node and arrive at another node, dummy activities must be used. The dummy activity is an activity with zero duration, consumes no resources, drawn as dashed lines, and used to adjust the network diagram. A dummy activity is also used when one activity depends upon two preceding activities and another activity depends only upon one of these two preceding activities as shown in [Figure 3.14](#).

3.2.3.2 Activity on node network (AON)

This method is also called the precedence diagram method. In this method, the nodes represent activities and the arrows represent logical relationships among the activities. If the arrow starts from the end side of an activity (activity A) and ends at the start side of another activity (activity

B), then A is a predecessor of B (Figure 3.15). AON representation allows the overlap or lag representation on the relationship arrows connecting activities.

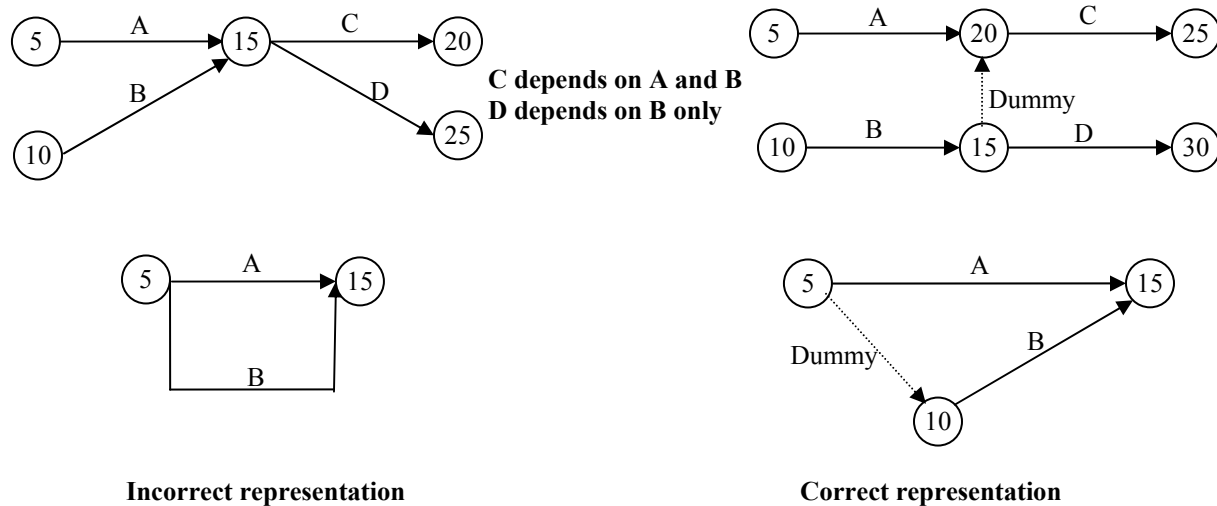


Figure 3.14: Use of dummy activity

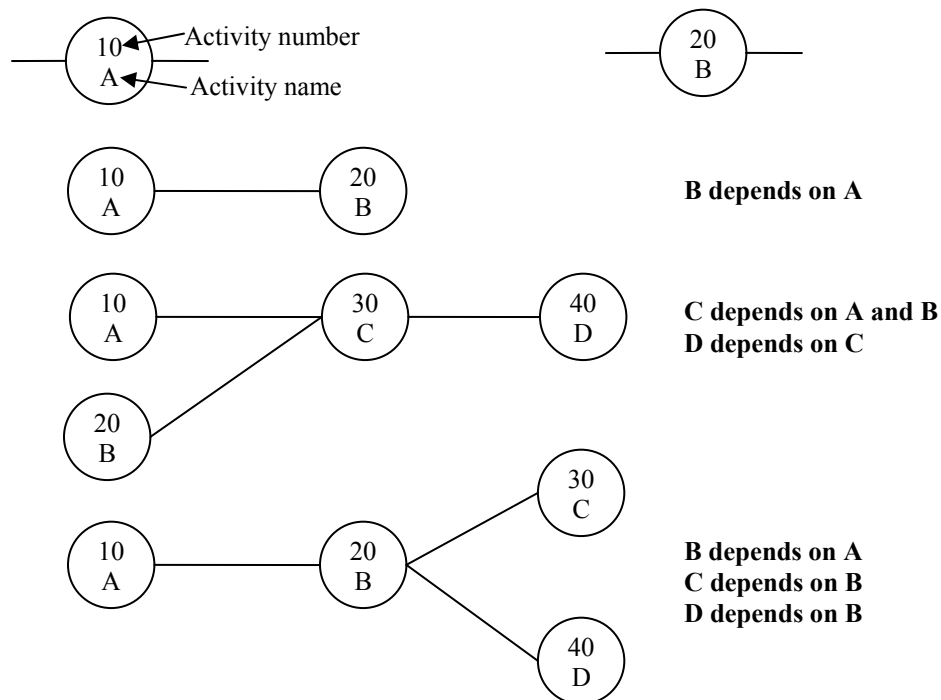


Figure 3.15: Basic patterns of AON diagrams

Comparison between AOA and AON

While both networks can be used to represent a project network, there are some differences between them:

- There is no need for the use of dummy activities in AON representation.
- AON are more easily to draw and to read.
- In AOA, an activity can only start when all its predecessors have finished.
- AON allows for overlap/lag representation.
- AON allows for the representation of the four types of relationships while AOA allows only for the finish to start relationship.

Example 3.6:

Construct an AOA and AON networks for the activities listed in Table 3.6.

Table 3.6 Data for Example 3.6

| Activity | Predecessors |
|----------|--------------|
| A | - |
| B | - |
| C | A, B |
| D | C |
| E | C |
| F | D |
| G | D, E |

Forming an AOA network for this set of activities might begin by drawing activities A, B and C as shown in Figure 3.16 (a). At this point, we note that two activities (A and B) lie between the same two event nodes; for clarity, we insert a dummy activity X and continue to place other activities as in Figure 3.16 (b). Placing activity G in the figure presents a problem, however, since we wish both activity D and activity E to be predecessors. Inserting an additional dummy activity Y along with activity G completes the activity network, as shown in Figure 3.16 (c).

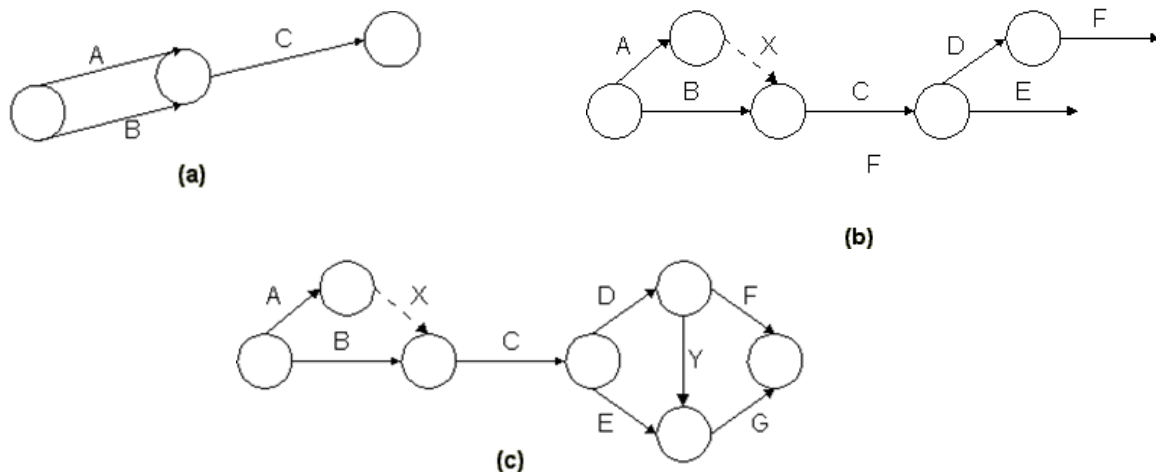


Figure 3.16: AOA Network for Example 3.6

To understand the drawing of the AON, some ordering for the activities may be necessary. This is done by placing the activities in a sequence step order. A sequence step may be defined as the earliest logical position in the network that an activity can occupy while maintaining the logical relationships. In this example, as there are two activities (activities A and B) has no predecessor, then a start activity is added to have one unified start activity (Start) for the project. Also, a finish activity (Finish) is added as there are two activities without successors (activities F and G).

Considering the data given in Table 3.6, sequence step 1 is assigned to the Start activity. Then, we take all activities on the list one by one and look at their immediate predecessors and then assign a sequence step that equals the highest sequence step of all immediate predecessors plus one as given in Table 3.7. After all sequence step numbers have been assigned, the AON diagram can be drawn.

Table 3.7: Determining the sequence steps

| Activity | Predecessors | Sequence step (SS) |
|----------|--------------|------------------------------|
| Start | - | SS(Start)=1 |
| A | Start | 2=SS(Start)+1 |
| B | Start | 2=SS(Start)+1 |
| C | A, B | 3=Highest of [SS(B), SS(A)] |
| D | C | 4=SS(C)+1 |
| E | C | 4=SS(C)+1 |
| F | D | 5=SS(D)+1 |
| G | D, E | 5=Highest of [SS(D), SS(E)] |
| Finish | F, G | 6= Highest of [SS(F), SS(G)] |

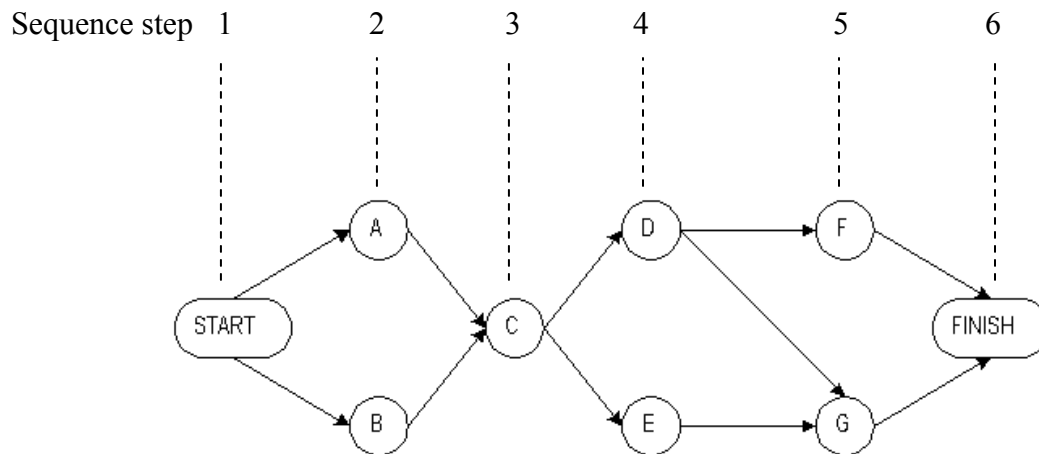


Figure 3.17: An AON Network

AON representation is shown in Figure 3.17, including project start and finish nodes. Note that dummy activities are not required for expressing precedence relationships in activity-on-node networks.

Example 3.7:

Draw the AOA and AON networks for the project given in Example 3.5.

Solution

The AOA is given in Figure 3.18 and the AON is given in Figure 3.19 as shown below.

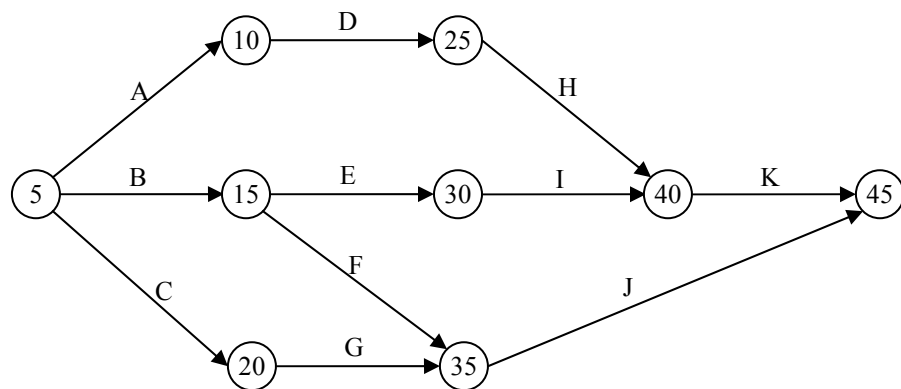


Figure 3.18: AOA network

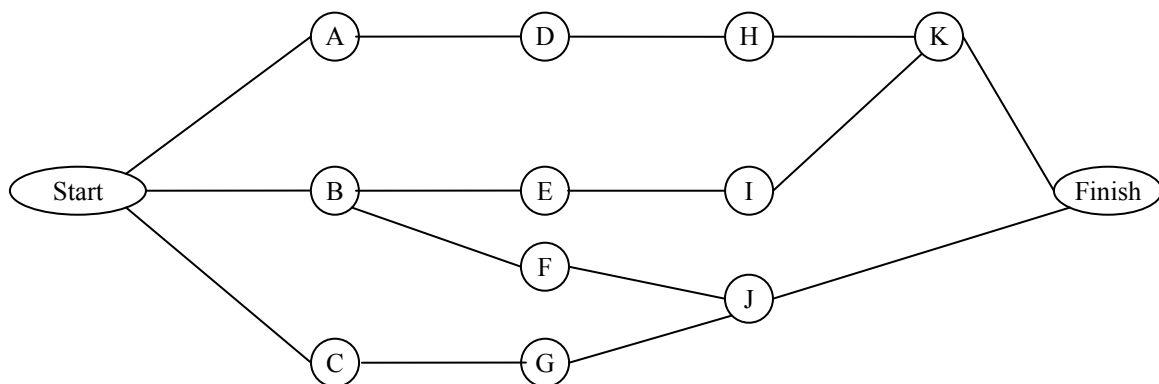


Figure 3.19: AON network

3.3 Estimating Activity Duration and Direct Cost

Having defined the work activities, each activity has associated time duration. These durations are used in preparing a schedule. For example, suppose that the durations shown in Table 3.8 were estimated for a project. The entire set of activities would then require at least 3 days, since the activities follow one another directly and require a total of $1.0 + 0.5 + 0.5 + 1.0 = 3$ days.

Table 3.8: Durations and predecessors for a four-activity project

| Activity | Predecessor | Duration (Days) |
|-------------------|-------------------|-----------------|
| Excavate trench | --- | 1.0 |
| Place formwork | Excavate trench | 0.5 |
| Place reinforcing | Place formwork | 0.5 |
| Pour concrete | Place reinforcing | 1.0 |

All scheduling procedures rely upon estimates of the durations of the various project activities as well as the definitions of the predecessor relationships among activities. A straightforward approach to the estimation of activity durations is to keep historical records of particular activities and rely on the average durations from this experience in making new duration estimates. Since the scope of activities is unlikely to be identical between different projects, unit productivity rates are typically employed for this purpose. The duration of an activity may be estimated as:

$$\text{Activity duration} = \text{quantity of work} / \text{number of crews} \times \text{resource output}$$

Typically, the quantity of work is determined from engineering drawings of a specific project. The number of crews working is decided by the planner. In many cases, the number or amount of resources applied to particular activities may be modified in light of the resulting project plan and schedule. Some estimate of the expected work productivity must be provided. Historical records in a firm can also provide data for estimation of productivities.

Having defined an activity duration, it means that the planner have already defined the number of resources that will be employed in a particular activity. Knowing activity duration and resources employed, it is simple to estimate the activity direct cost. Then, the three elements of an activity: duration, cost, and resources form what is called construction method. Some activities can be performed using different construction methods. Where, its method will have its own resources, cost and duration.

Example 3.8:

If the daily production rate for a crew that works in an activity is 175 units/day and the total crew cost per day is LE 1800. The material needed for daily work is 4.5 units at LE 100/unit.

- Calculate the time and cost it takes the crew to finish 1400 units
- Calculate the total unit cost. Consider an eight hour work day.

Solution

- a. Duration (units of time) = Quantity / Production per unit of time x number of crews
 $= 1400 / 175 \times 1 = 8 \text{ days}$
 Cost (labor cost) = Duration (units of time) x crew cost per unit of time
 $= 8 \text{ days} \times \text{LE } 1800 / \text{day} = \text{LE } 14400$
 Total direct cost = Le 14400 + 4.5 units of material x LE 100 / day x 8 days = LE 18000
- b. Unit cost = total cost / quantity
 $= \text{LE } 18000 / 1400 = \text{LE } 12.86 / \text{unit}$

Sometimes the productivity of a specific crew expressed in man-hours/unit not units/day. For example, if the productivity is said to be 0.5 Man-hour/cubic meters, this means how long it will take one labor to construct one unit. This way applied to any crew formation and work hours.

Example 3.9:

What is the duration in days to install 6000 square feet of walls shuttering if:

- a. Crew of 2 carpenters is used with output of 200 square feet/day
 b. Productivity is measured as 0.008 man-hour/square feet. Number of carpenters = 3, and number of working hours/day = 8 hours

Solution

- a. Duration = $6000 / 200 = 3 \text{ days}$
 b. Total man-hours needed = $6000 \times 0.008 = 48 \text{ man-hours}$ (if one man used)
 Duration = $48 / 8 = 6 \text{ days}$ (if one man used)
 Duration using 3 men = $6 / 3 = 2 \text{ days}$

Example 3.10: (use of several resources)

The construction of a reinforced concrete wall involves placing 660 m³ concrete, fixing 50 tone of steel, and 790 m² of formwork. The following information belongs to the jobs involved in this activity:

- A 6 man concrete crew can place 16 m³ of concrete/day.
- A steel-fixer and assistant can fix 0.5 ton of reinforcement/day.
- A carpenter and assistant can fix and remove 16 m² of shuttering/day.

Calculate the duration of the activity considering the steel-fixer as the critical resource.

Solution

- using one steel-fixer: duration = $50 / 0.5 = 100 \text{ days}$
- using one carpenter: duration = $790 / 16 = 49.4 \text{ days}$
- using one concreting crew: duration = $660 / 16 = 41.25 \text{ days}$.

Then, for a balanced mix of resources, use 2 steel-fixer crews, one carpenter crew, and one concreting crew. Accordingly, the activity duration = $50 / 0.5 \times 2 = 50 \text{ days}$.