CONSTRUCTION TECHNIQUES AND MANAGEMENT (CSE-207) (ELECTIVE-IV)

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COURSE CONTENTS

Construction planning-Construction facilities, Schedules, Layout of Plant utilities, Construction methods: Excavation and handling of Earth and Rock; Production and handling of Aggregates and Concrete , cooling of concrete in dams, Drainage treatment of aquifers/sub-terrain reservoirs; Tunneling, Tunneling in soft rocks- Grouting , chimney formation, etc; Construction control and management-CPM/PERT, Human Factors, Organization.

REFERENCES:

S.no.	Name of the books/author/publisher	Year of publication
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2	Robertwade Brown; Practical Foundation Engineering Handbook, McGraw Hill Publications ,	1995.
3	Joy, P.K.; Total Project Management- The Indian Context, New Delhi, MacMillan India Ltd.,	. 1992.
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CONSTRUCTION PLANNING

LECTURE 1

1.1 Introduction:

Planning is the most important constituent of the construction management. Planning is the mental process for deciding the future line of action. Planning thus helps in deciding what to do, when to do and who will do. At the planning stage of the project, various alternative for the execution of the work are evaluated and the decisions are taken not only about the work as a whole, but for each part of the work like inception of the work and time of completion, materials, labour, machines and equipment required from time to time for the execution of the project. Planning takes into consideration various uncertainties in the execution of the work due to various factors like weather, price fluctuations, non-availability of labour and difficulties in procurement of materials.

1.2 Steps Involved in Planning:

Following steps are involved in planning:

i) Identifying the likely problems to be encountered in the execution of the work and obtaining necessary information useful in the execution of the work.

ii) Ascertaining alternative feasibility of execution of work and selection of optimum plan.

iii) Fixing the time of starting the execution of work.

iv) Deciding the time of delivering the materials at the site.

v) Deciding the quantities and duration of various types of machines and equipment.

vi) Decisions regarding the number of different types of laborers for various works and duration of their employment.

vii) Estimation of financial help if needed.

viii) Estimation of duration of completion of the work.

ix) Evaluation of the effectiveness of plan adopted.

1.3 Objectives of Planning:

The main objective of the planning is to execute the project economically in terms of money and time. Effective planning depends upon the following factors:

i) Proper design of each element of the project.

ii) Proper selection of machinery and equipment for the execution of the project.

iii) Proper arrangement of repair of machinery and equipment near the site of work to keep them ready for work.

iv) Procurement of required materials well in advance.

v) To ensure employment of trained and experienced staff on the project.

vi) To provide welfare schemes for the staff and workers such as medical and recreational facilities.

vii) To arrange constant flow of funds for the completion of the project.

vii) Proper arrangement for communication and feedback.

1.4 Stages of Planning:

Stages of planning are as following:

i) Pre planning: during this stage planning objectives are clearly spelt out, a general framework of the project is to be formulated and cost benefit analysis is carried out.

ii) Detailed planning: planning at this stage includes preparation of detailed drawings, preparation of details design, working out the quantities of materials, breaking the project into different activities.

iii) Monitoring and Control: In this phase, the progress of construction is monitored as per schedule, updating the schedule according to the actual progress of work.

1.5 Planning tasks at different stages of the Project lifecycle

A project success is dependent on the effective management of each stage of the project lifecycle and the project as a whole.

The conceptual stage defines the project's scope and includes the client's needs, the main objectives, and the preferred development strategy. Upon these a project brief is framed from which the design consultant designs and documents the project in the design stage. The design documentation is then used in the tendering stage to assist in selecting a general contractor. In the preconstruction stage, a successful contractor develops a strategy for building the project and then constructs it in accordance with the contract documentation in the construction stage. At the end of the construction stage, the client takes possession of the completed project. This stage is commonly referred to as commissioning.

Of particular importance are the first two stages, which are concerned with defining the project concept and developing its design. This is because the capacity to control project objectives effectively (especially in terms of cost and time) diminishes as the project progresses through its lifecycle. For example, if the client alters the scope of the project at the conceptual stage, the impact on the overall project cost–time is likely to be fairly small since no design or construction have yet begun. But if the changes to the scope occur in the later stages when the work either on the design or construction is under way, the cost–time impact will be considerably greater, particularly in the construction stage.

Conversely, effective co-ordination and management of the conceptual and design stages provide an opportunity for better control of cost and time later in the construction stage.

The importance of effective lifecycle management is obvious. Since planning is one of the essential elements of effective management, it is worth examining specific planning tasks that take place in individual stages of the project lifecycle.

Planning at the conceptual stage

The conceptual stage is characterized by the definition of the project's scope, the development of the preferred strategy, budgeting, and the formulation of a brief.

A project manager will be engaged in two distinct planning tasks:
(i) Strategic planning, and (ii) scheduling.

Once the overall project strategy has been determined, the project manager starts work on developing an overall project schedule that shows important tasks or activities across all the stages of the lifecycle. The schedule will be a time schedule that will not show a great deal of detail but will show a logical sequence of important activities to be accomplished at each stage. It will also show relationships among activities within and across individual lifecycle stages from which the project manager will attempt to foresee potential co-ordination and integration problems. The degree of detail shown will be governed by the scale of the schedule, which is likely be in months or perhaps even weeks. Of particular importance is the identification of dates for major decisions.

Apart from the overall project schedule, the project manager also develops a detailed schedule for managing the conceptual stage. It will be a medium-term schedule with a time-scale in weeks. It will show a sequence of activities to be undertaken at the conceptual stage, together with the dates for the key decisions and targets. The most important target date will be that for the completion of a brief. The execution of the work at the conceptual stage requires commitment of human resources by specialist consultants. These need to be carefully assessed and built into the schedule.

Planning at the design stage

The aim of the design stage is to design the project and prepare the necessary design and tender documentation. Design is a creative task that is often difficult to fit into a rigid time-frame. It is a time-consuming process that adds substantially to the total development period. It is also a process that is often subjected to a wide range of risks. Nevertheless, every effort is required to

I. Set aside a sufficient time for design and documentation,
II. Allocate the necessary resources to ensure that the work can proceed as planned, and
III. Monitor and control the process to ensure that the work is completed on time.

Planning tasks in the design stage comprise the development of:

- A design management plan
- A medium-term schedule of design activities
- A short-term schedule of weekly design tasks
- A schedule of drawings.

A design management plan is basically a strategic plan formulated for the design stage. It states the main objectives, describes strategies for achieving them, and gives budgets.

Apart from determining the overall strategy, the project manager, together with a project team, prepares a design schedule (a medium-term schedule) showing a sequence of design and documentation activities. This schedule will need to be developed around available resources such as designers, drafts people and computer-aided graphics equipment, and must take into account specific target dates such as that for submitting design documentation to local councils for approval and the date for tendering. Since the design work may involve a number of separate design organizations, a design schedule is vitally important, not just for planning of design activities but also for their co-ordination and integration.

A weekly design schedule will be prepared to show in detail activities and resources needed to accomplish the design work. This schedule will be used to control the everyday design production process.

Another important schedule that will be prepared in the design stage is a schedule of drawings. Since the design process brings together many different design organizations that may produce hundreds of drawings and details, a schedule of drawings will assist in monitoring the production of individual drawings. It will ensure that drawings are produced when required and distributed to the right parties.

Planning in the tendering stage

In the tendering stage, bidding general contractors prepare tender proposals based on tender documentation and other relevant information from which the client selects the winning tenderer. Tendering is a form of competition for work among bidding contractors. Each bidding contractor estimates the cost of construction based on a preferred construction strategy defined in a tender schedule. In developing an appropriate construction strategy, the contractor would need to focus on issues such as:

Type and nature of project to be built

- Site location
- Site conditions
- Contract conditions
- Alternative construction strategies
- An appropriate form of WBS.

A tender schedule is produced in the form of an overall construction program. It is resource-based and is sufficiently detailed to enable the client to establish how the contractor will meet the project objectives.

Planning in the pre-construction and construction stages

After the contract has been awarded to the general contractor, the contractor begins work on developing an overall construction schedule. At first, the contractor reviews a tender schedule and highlights those tasks that may need to be modified as more up-to-date information becomes available, particularly with regard to the design. The contractor also reviews the previously defined WBS and affirms its final structure. The WBS determines the extent of the contractor's scheduling in the pre-construction stage. Large projects constructed over a number of years will require the development of a hierarchy of schedules from the top down, starting with an overall construction schedule that will be supplemented with schedules for each level of the WBS. Smaller projects may require the development of only one overall construction schedule. In developing a construction schedule, the contractor needs to consider a range of issues:

- Off-site activities, for example prefabrication
- Incomplete or missing segments of the design and documentation
- Production of shop drawings
- Lead times and processes for approvals by authorities, consultants and the client
- Lead times for orders of materials and equipment, and their deliveries to the site
- Off-site work of specialist contractors, particularly in the area of building services, such as air-conditioning, lifts, hydraulics and electrical
- Risks associated with on-site and off-site activities that are generally outside the contractor's control
- Lead times for delivery and installation of temporary equipment such as cranes, formwork systems and the like.

Since most construction activities are performed by specialist subcontractors, it is essential for the contractor to seek their input into scheduling. This is particularly important for coordinating and integrating the work of subcontractors and in defining the required level of resources. Similarly, the contractor would need to seek input into scheduling from suppliers of materials and plant/equipment, particularly those whose delivery times are likely to require long lead times. For example, in order to ensure timely delivery of air conditioning plant manufactured overseas, the contractor would want to know how many weeks in advance the contractor would need to place an order with the manufacturer. In the construction stage, the contractor uses the schedules developed in the pre-construction planning to control the production process. These schedules need to be reviewed in line with the progress achieved, and updated at regular intervals.

The contractor manages date-to-date construction activities using short-term schedules. These are prepared each week and show in detail the work to be accomplished by committed resources.

The contractor also prepares a range of schedules for control of materials, labour, subcontractors, and plant/equipment.

Planning in the commissioning stage

The commissioning stage is reached when the project under construction is said to be ‘practically complete’. The client takes legal possession of the project although it may not be fully completed. From the legal perspective, the project has reached a defects liability period during which the contractor is required to complete the work under the contract, commission all the services, and repair any defects. It is also during this stage that the client signs up tenants and commences fit out. Clearly, a schedule is needed at the commissioning stage to plan, organize and control such a wide range of activities. It is commonly the responsibility of the project manager to prepare such a schedule. Since it covers a period between two and six months, the schedule will be medium range, with the time-scale in days.

1.6 Types of Plans

Usually following types of plans are prepared:

i) Standing plans: These plans are used repeatedly and include procedures, rules and management’s policies.

ii) Single use plans: These plans are designed to accomplish specific objectives with a relatively short time.

iii) Strategic plan: these plans are concerned with the broad matters, which may vitally affect the development of the organization.

iv) Administrative plan: this plan focuses more on the accomplishment of the objectives of the project and is concerned with factors within the control of the organization.

1.7 Limitations of Planning:

Following limitations are observed in the planning of a project:

i) Planning is expensive.

ii) Planning delays action.

iii) Planning develops a false sense of security.

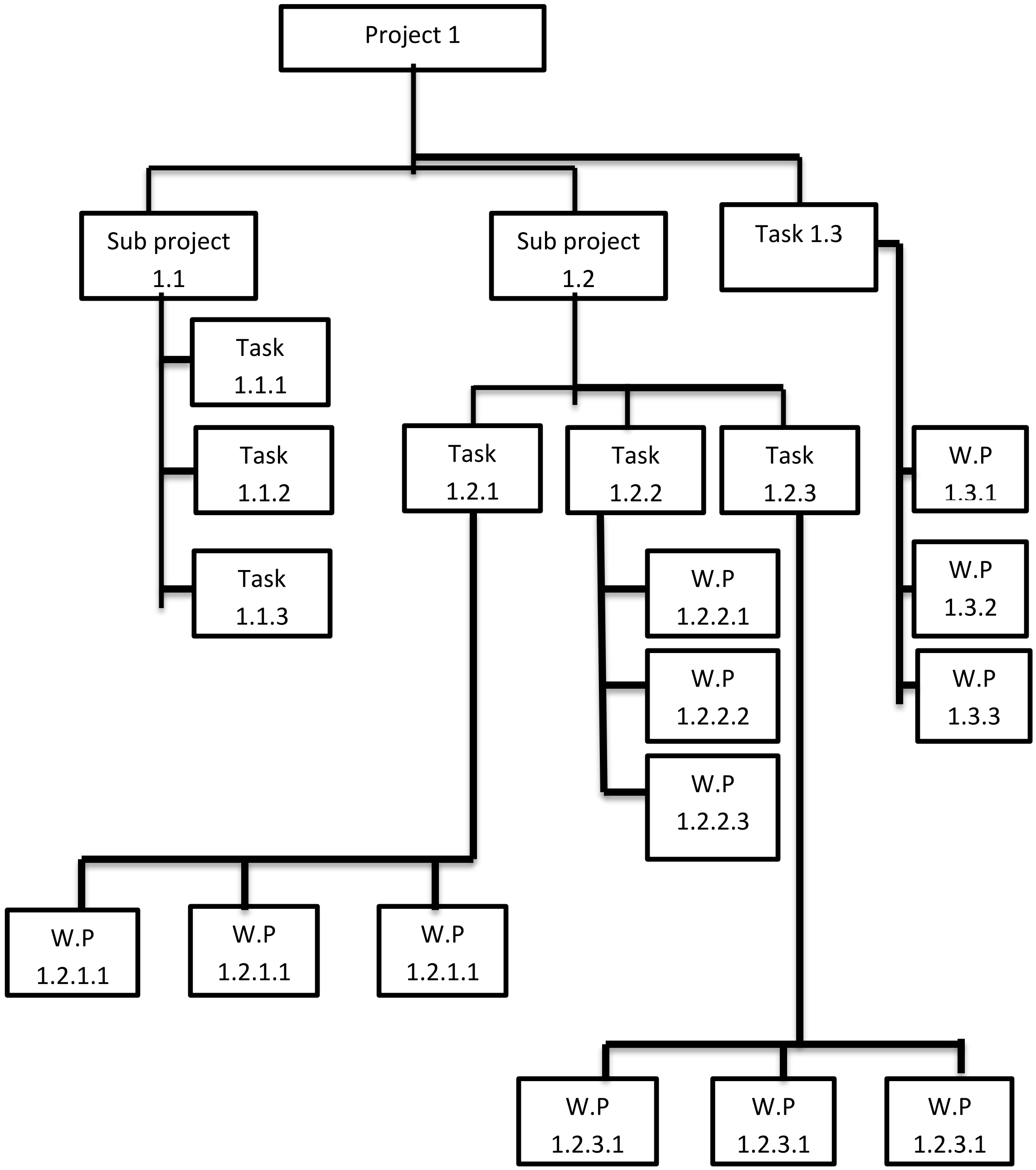
iv) The effectiveness of the plan depends upon the correctness of the assumptions.

1.8 Work Breakdown Structure (WBS)

Work Breakdown Structure (WBS) is a ‘deliverable-focused hierarchical grouping of project. It defines the total work scope of project’. Deliverables are tangible, measurable parts of the project. Non-deliverable items of work such as the designing, resources procurement and financing of project etc. are not included in the WBS. The project work can be broken down into manageable parts arranged in a hierarchical order into levels of sub-project, tasks, work packages (WP) and activities.

1.9 Classification of Project Work Breakdown Levels

Level	Description	Main Criteria
1	Sub-project level	An independent, deliverable end product requiring processing of multitasks having large volume of work.
2	Task Level	An identifiable and deliverable major work containing one or more work packages
3	Work package level	A sizeable, identifiable, measure, cost-able and controllable work package of activities.
4	Activity level	Identifiable lower level job, operation or process, which consumes time and possibly resources



Typical Work Breakdown Structure Configuration (fig 1)

LECTURE 2

2.0 The concept of scheduling

Scheduling involves answering the questions, such as ‘When can the work be carried out?’ ‘How long will it take?’ and ‘What level of resources will be needed?’ Scheduling is concerned with sequencing and timing. Since time is money, it is also concerned with cost.

Scheduling is performed using appropriate operational planning tools such as a bar chart or the critical path method. Scheduling is a modeling task that assists in developing a desired solution for a problem and tests its validity. Through modeling, the physical size of a problem (say the development of an overall construction schedule for a large project) is scaled down to a smaller number of representative activities that are then scheduled by an appropriate scheduling tool. The solution is checked and validated for accuracy. The derived schedule is used to plan, organize and control construction of the project.

To check time progress, individual parts of the job are tracked to determine if they are completed within the specified time limits. Such information is then analyzed to determine where the problems are.

The most common form of a model in scheduling is a graphic chart or network generated either by hand or by computer. The form and shape of a chart varies from technique to technique. For example, a sheet of paper lined with columns and rows represents a bar chart format, while charts generated by the critical path method are rather more complex and are commonly referred to as networks.

2.1 Use of scheduling

Following are the uses of scheduling:

i) The quantity of work involved, labor material, equipment and money required at each stage of work can be determined by scheduling.

ii) The actual progress of work can be checked from time to time by scheduling.

iii) The project can be carried out in a systematic manner by the use of scheduling.

2.2 Advantages of Scheduling

For any important construction work the planning and scheduling is indispensable. Following are the advantages of scheduling:

By studying the schedule of the work, alternate methods of execution can be examined and the most economical method can be selected.

i. It gives clear picture of quantity and type of materials, man power and equipment required at different stages of execution of work and duration of supply of material.
ii. As the time of starting of each activity is known, the arrangement of adequate resources as manpower, material, money and equipment etc. can be done in advance.
iii. The resource utilization can be optimized and the available resources can be directed to various activities to the best advantage.
iv. The actual progress of each activity can be monitored with reference to the planned program. If there is any delay in any activity the remedial measures can be taken to speed it up before it can cause difficulty in the other related activities.
v. As the interrelationship of various activities at different stages is known, their priorities can be fixed to the best advantage.
vi. The effect of any change such as modification in original plan or weather conditions can be properly evaluated and the program of construction can be suitably amended.
vii. viii) Total time of completion of work can be known from scheduling.
viii. The most important advantage of scheduling is that work may be executed in a most efficient way without wastage of time and any input, resulting in maximum possible economy.

2.3 Types of schedules

- Time schedule
- Resource schedule
- Target schedule.

Time schedule

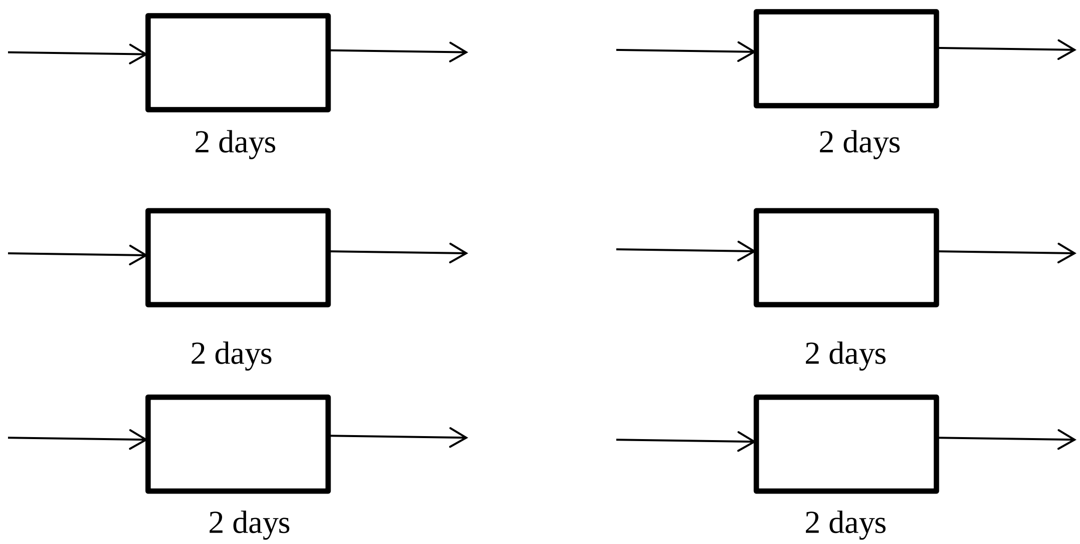
Sometimes a schedule may be prepared to show a logical sequence of activities with only notional information about duration of activities. The main aim would be to see the logic of the production process and its approximate duration. Schedules produced for this purpose are referred to as 'time schedules'.

A time schedule is prepared on the assumption that its activities will be given all the required resources when needed. In other words, time scheduling assumes that resources are unlimited and available when needed. This is an unrealistic assumption, however, since resources may simply be unavailable when needed or available in limited quantity, size and type or technical specification.

Furthermore, the assumption of unlimited resources will lead to inefficient allocation of resources and the likelihood of higher cost. This is illustrated in the following example.

Let's focus on just three concurrent activities X, Y and Z in a schedule in fig 1(a). Assume that the three activities X, Y and Z take two days each to complete. Let's assume further that each of the three activities requires access to a crane for two days. Under the assumption of unlimited resources, a project manager could order three cranes, one for each activity. The three activities X, Y and Z would then be completed in two days.

Figure 1 Example of time and resource schedules



1(a) 1 (b)

Time schedules are useful in developing an overall strategy within a broadly defined time-frame. But since they assume that resources are readily available when needed, they may not create a realistic plan of the actual production process. More realistic planning can be achieved using resource schedules.

Resource schedule

When resources are limited in availability, technical specification, cost or some other means, those resources that are actually available then drive the scheduling task. For example, a very large high-rise project may require a crew of 2000 workers to be employed at the peak of activities. With such a large number of people working on the site, part of the project manager's task will be to ensure that the site provides the required volume of site amenities, the necessary safety equipment for the workers, and that the workers can be moved efficiently through the structure to their work stations. It may well be that the site is too confined to provide the necessary volume of amenities for so many workers.

The site may also be too confined to accommodate a sufficient number of personnel hoists that would ensure speedy distribution of workers to their stations. The project manager may respond by limiting the number of workers engaged on the site (say 1200 maximum) to match available resources. The project manager will then schedule the work around the maximum number of 1200 workers. This approach ensures that resources are used efficiently, but the project will take longer to complete. A schedule based on the available or committed resources (in this case based on the maximum of 1200 workers) is referred to as a 'resource schedule'.

In resource schedules the work to be accomplished is assigned to available or committed resources. When the volume of resources is insufficient to carry out the work that has been scheduled, the project manager would need to either inject more resources or reschedule the work to free over-committed resources. Injecting additional resources is likely to incur extra cost while keeping to the same schedule. Rescheduling the work around committed resources will most likely extend the project period and possibly even its cost. In organizing resources in the planning stage, the project manager has the opportunity to seek an optimum relationship between the cost and time of the project. But once the project is under way with committed resources, it is not possible for the project manager to keep the cost and time at optimum when the committed resources are insufficient to carry out the scheduled volume of work. The project manager then has either to inject more resources or to reschedule the work. Neither scenario is desirable since this is likely to increase the project cost and extend its duration.

Let's go back to the problem in Figure 1 and assume that only one crane is available for the scheduled work involving activities X, Y and Z. Clearly, these activities cannot be performed concurrently as scheduled. The project manager would need to allocate the only available crane to one activity at a time in some order of priority. Let's assume that the order is X, Y and Z. The completion of all three activities, X, Y and Z, will now take six days as illustrated in Figure 1(b). In both (a) and (b), the total volume of work will be the same: six crane days. But the completion times and costs will be different. The difference in completion times is clearly apparent, but why would the costs be different? Since time is money, the former case would incur lower overhead costs due to a shorter schedule, but the cost of assembling and dismantling the cranes would be higher than in the latter case

An important observation here is that time schedules are likely to provide an overly optimistic assessment of the project period. For example, a contractor who has won a tender on the basis of a time schedule runs a serious risk of either delaying the contract due to having insufficient resources at certain times, or spending money on additional resources that must be injected to keep the project on schedule, or both. Clearly, control of time and cost are more likely to be achieved using resource-based scheduling.

Target schedule

Adding specific targets, such as starting or finishing dates, to activities in a resource schedule results in the creation of a 'target schedule'. The term 'target date' implies that a specific activity or task must be accomplished by that date. Target dates are commonly imposed by a contract. A schedule that is resource-based and contains target dates is a realistic scheduling tool.

Schedules can be further classified into following groups:

1. Construction schedule
2. Material schedule
3. Labor schedule
4. Equipment schedule
5. Financial schedule
6. Control schedule
7. Organizational schedule
8. Summary schedule

LECTURE 3

3.0 Methods of scheduling

Scheduling can be done by different methods depending on the size of the project. Usually following methods are employed:

1. Bar charts or Gantt charts

2. Milestone charts

3. Network analysis

3.1 Bar charts

Bar chart is a graphical representation of completion of various activities of a project. Simple projects can be scheduled directly in the bar chart format by experienced personal. This technique was introduced by HENRY GANTT in 1919.

A bar chart consists of two coordinate axis. The activities are represented on *y*- axis and time required to complete the activity on *x*-axis. Each bar chart represents one specific activity of the project. The beginning and end of the bar chart represents the start and the finish time of the activity. The length of the bar shows the time required to complete that activity.

3.1.1 Symbols used in bar charts

In a bar chart usually following symbols are used:

1. The planned programmer is shown by a thick line.

2. The actual progress of work obtained is shown by a hatched line.

3. The planned start and finish are shown by small vertical lines.

4. Float represents flexibility range within which the start and finish times of an activity can fluctuate without affecting the total duration of the project. In bar charts it is represented by dotted horizontal line,

5. The dependency of one activity on another activity is shown by dotted vertical line. *Figure 3.1* shows the symbols used in a bar chart.

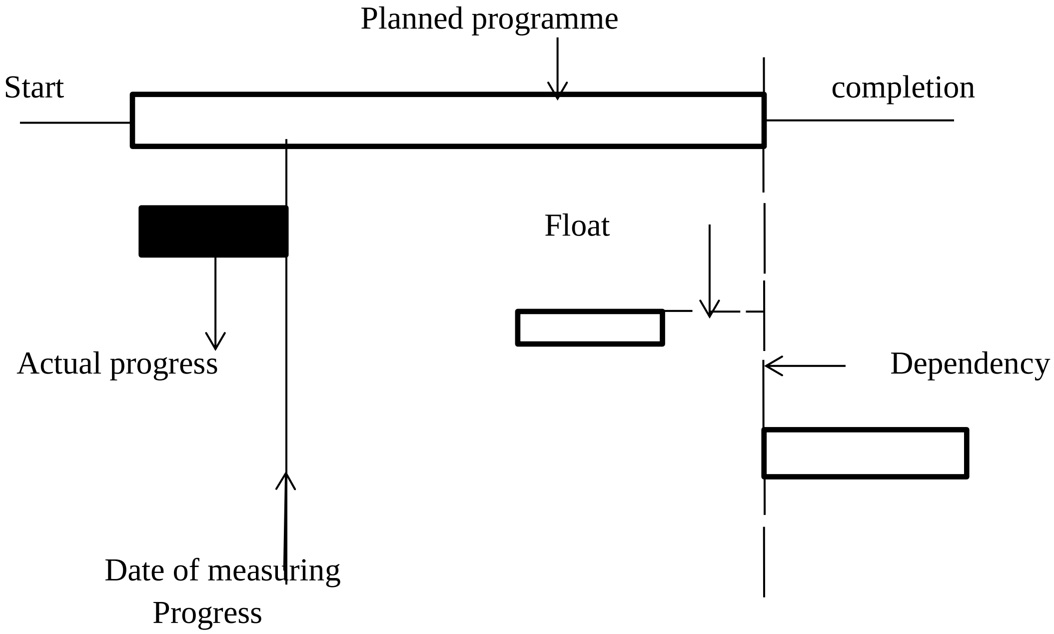


Fig 3.1 Symbols used in a bar chart

3.1.2 Limitations of bar charts

Though bar chart is simple to construct and understand and widely used for scheduling, yet it has a number of limitations as follows:

1. It can be used only for small projects.

2. It is difficult to depict or show complicated interdependencies of various activities of project. This is a serious limitation of the bar chart.

3. Bar chart doesn’t indicate the actual progress of work as it only represents the time which has elapsed. Thus the progress of work cannot be monitored scientifically.

4. From bar chart it is not possible to know the maximum or peak progress necessary for its completion. It gives the impression that the Rate of progress of any activity is uniform.

5. Delays in the work are not detected till the allotted time is over and work remains incomplete.

6. It doesn’t indicate the critical activities of the project.

7. It gives some idea of the physical progress of the project only and the financial aspects involved are not known whether the cost of the project is within the estimated cost or it has escalated.

8. In case of the variation from the planning programme it is difficult to find out the alternative course of action to be adopted to complete the work in time.

3.1.3 Milestone charts

It is a modification of the original bar charts, in milestone charts there are certain key events in every activity which are to be carried out for the completion of the activity. These key events are known as milestones and are represented by a circle or square. These events can be easily identified over the main bar representing the activity. If an activity is represented by a very long bar, the details will be lacking in it. *Fig 3.2* shows a milestone chart.

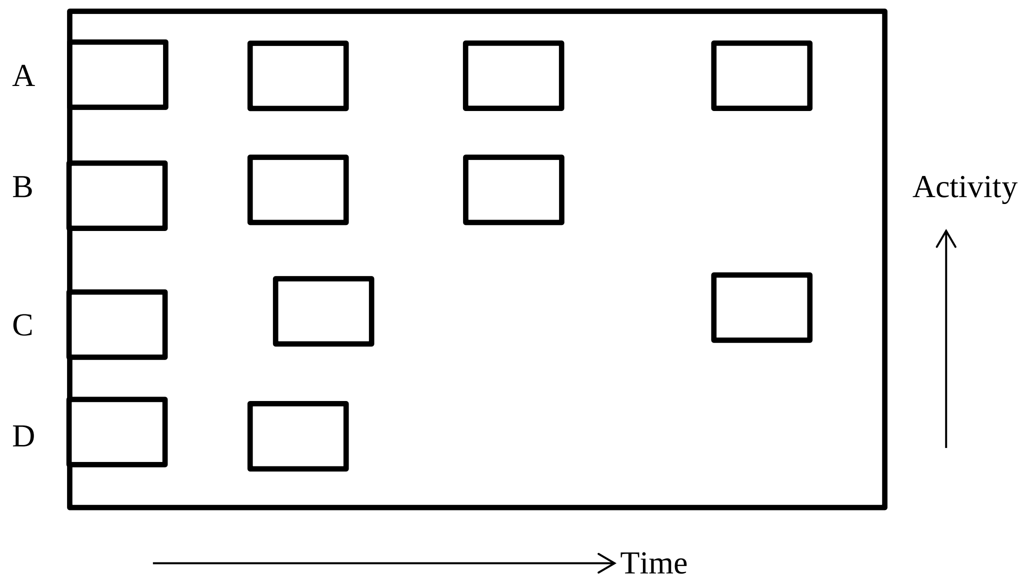


Fig 3.2 Milestone chart

3.1.4 Limitations of milestone chart

Milestone charts have following disadvantages:

1. The interdependencies between the milestones are not possible.

2. The relationship between two specific milestones with an activity only is revealed by the milestone chart, but the relation between milestones contained in different activities is not indicated.

Note: Network analysis will be discussed in detail separately in coming lectures

LECTURE 4

4.0 AGGREGATE PRODUCTION

This lecture discusses the total process of aggregate production from extraction through processing. Processing influences mineral, quality and integrity, aggregate physical properties and in particular gradation (size control). Establishing a stable production process may reduce variability of the product.

4.1 EXTRACTION

With the exception of slag and other manufactured aggregate most materials for aggregate production come from bedrock or unconsolidated deposits. The vast majority of materials used in the mineral aggregate industry are obtained from surface-mined stone quarries or from sand and gravel pits. How materials are extracted influences their quality.

4.1.1 STRIPPING

As a first step, a producer is required to designate a detailed stripping procedure for each and every deposit that is mined. This phase often is overlooked, yet has a great influence on the quality and variability of the product. Inadequate removal of overburden from the mineral deposit often may be the source of excessive variation in material and may even have a deleterious effect on nearby vegetation and other aspects of the mine.

For example, excessive knobs and depressions on the surface of a stone deposit may necessitate the use of smaller equipment or special techniques to clean the stone. Inexperienced equipment operators may easily corrupt good stripping practices (which are somewhat of an art and site specific). Spillage over the working face and other sloppy practices can also affect the cleaning process.

4.1.2 DRILLING AND BLASTING

Quarry operators commonly design fragmentation shots for safety, economy, ease of use at the primary crusher, and even public relations, but they often forget about quality.

The shot layout is required to be properly engineered, documented, and adhered to for maximum consistency. Varying the shot pattern may mean changes in product size throughout the operation. Smaller shot rock, resulting in less crushing in the secondary and tertiary stages, may mean less improvement through crushing. Therefore, the mineral quality and/or changes in physical properties of the product may be affected.

Hole detonation-sequencing and blast intensity also are required to be properly engineered. Size changes resulting from inattention to detail can have the same effects as mentioned above. Also, an erratic blast that throws the shot rock over a large area tends to cause variation in size gradation that is delivered to the primary crusher. Any deviation from previously established shot patterns, sequencing, and intensity should be carefully thought out as to the effect on product quality. Production changes are required to be documented in the Producer's Quality Control Plan.

4.1.3 SHOT ROCK OR GRAVEL BANK

A constant problem of gravel pit and quarry operators is the difficulty in maintaining uniform load-out from either the shot rock pile or the gravel bank. Even the best shot has some variation from side to side and from front to back. Only experienced and well-trained equipment operators may accomplish the mixing from around the shot for the most uniform feed to the processing plant.

Subsurface sampling and testing are required to inform gravel-pit managers where the size of the material changes. In many cases, for example, material from both above and below ground water level is required to be blended in a prescribed manner to maintain uniform feed to the plant. Changes in equipment, if done without thought as to how to maintain uniform sizing, also may have the same effect. Any change in equipment is required to be evaluated for effect. These changes are incorporated into an agenda to the Producer's Quality Control Plan.

Geologic variability in the deposit may sometimes affect sizing but more often causes a change in mineral integrity and physical properties. If a large variation exists, some products at later stages in the process may require separation.

Moisture variation in shot rock may also cause significant problems during processing. Shot-rock moisture is required to be monitored because significant changes in moisture almost always require changes in downstream processing.

4.2 CRUSHING

The first step of processing begins after the extraction from quarry or pit. Many of these steps also are common to recycled materials, clay, and other manufactured aggregates. The first stage in most operations is the reduction and sizing by crushing. Some operations, however, provide a step prior to crushing called scalping.

4.2.1 SCALPING

Scalping most often is used to divert fines at a jaw primary crusher in order to improve crusher efficiency. In this way the very coarse portion is crushed and then recombined with the portion of crusher-run material before further processing. This first step may, however, be an excellent time to improve a deleterious problem. If a deleterious or fines problem exists in the finer fraction of crusher-run material (namely, clay, shale, finely weathered material, etc.) the fall-through of the scalping operation may be totally or partially diverted and wasted, or may be made into a product of lesser quality. In any case, only acceptable amounts, if any, should be returned back into the higher quality product. Consideration of process variables in this early stage may be very important.

4.2.2 PRIMARY CRUSHING

In stone quarries or in very "boney" gravel pits, large material usually is reduced in size by either a jaw or a gyratory crusher. Both types are compression crushers. Although economical, they have the tendency to create thin, elongated particles. Particle shapes sometimes may be a problem for Producers of hot mix asphalt. In some operations impact crushers are used for primary crushing, but they may have a slightly higher cost per ton. Impact crushers may upgrade poor-quality aggregate and increase separation, such as removal of rebar from concrete in recycling operations.

After primary crushing/reduction the resulting aggregate generally is placed in a large "surge" pile where the aggregate may be fed into the secondary operation whenever convenient.

Care is always taken when building up and loading out surge piles, as this step may be a major source of segregation of material going to the secondary plant. Variation at this point may affect both mineral quality and gradation. Drawing from an inverted cone over a load-out tunnel works well after material has been deposited and left undisturbed to form the walls of the draw-down cone. If the need ever arises to consume the entire pile, care is taken to thoroughly mix the older material a little at a time with fresh product to make the surge as uniform as possible as the aggregate is being pushed into the tunnel. If the operation relies on end loaders to feed the secondary plant from the surge pile, the same care is taken to mix coarse with fine material from the outside to the inside of the pile.

4.2.3 SECONDARY AND TERTIARY CRUSHING

Secondary and tertiary crushing, if necessary, are the final steps in reducing the material to a desired product size. Historically, cone and roll crushers were the most common choice crushers, but in recent year’s impact crusher are more widely used. These crushers also are sometimes used as primary crushers for fine-grained gravel deposits. The cone crusher (a compression type) simply crushes the aggregate between the oscillating cone and the crusher wall (Figure 5-9). Clearance settings on this equipment are required to be checked and maintained as part of standard operating procedure.

As with other compression crushers, the cone crusher yields a somewhat elongated and slivery particle shape. This may be minimized, however, by "choke" feeding the crusher. This technique will also make the shape and size more uniform. One way to choke feed is with a surge hopper and a controlled belt-feed to the cone crusher. Automatic level controls measure the head of the material over the top of the cone.

A roller crusher is another compression type crusher that simply breaks the material by pinching the aggregates. These types of crushers are often found in gravel operations. Roller crushers have constant maintenance problems and are prone to excessive wear. The rollers are required to be checked frequently to insure proper clearance and uniformity across each roller. Rebuilding and re-milling the roller is a standard operating procedure.

4.2.4 IMPACT CRUSHING

Impact crushers may be used as primary, secondary, or tertiary crushers. Despite having a somewhat higher operating cost than other crushers, they tend to produce a more uniform particle shape. Impact crushers usually will benefit the aggregate better than compression crushers, and they may generate more fines. Common types are the horizontal shaft, vertical shaft, and hammer mill impactors. The horizontal shaft single or double rotor may aggressively handle large and odd-shaped material. Large horizontal impactors sometimes are used as primary crushers. Fracturing occurs at the same time by rock against rotor, rock against breaker bar, and rock on rock**.**

The vertical shaft impactor is operated in rock against anvil, or rock against rock (through the installation of a rock shelf) modes. The Producer is required to decide carefully the mode best suited to the raw material. The hammer mill impactor provides excellent reduction and beneficiation through the impacting and shearing action of the hammers and grates; however, a large amount of fines is produced. This type of crusher is sometimes used in the manufacture of agricultural ground limestone.

Note: For any queries / clarifications, contact

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