IS 15883-2 (2013): Construction project management - Guidelines, Part 2: Time Management [CED 29: Construction Management including safety in Construction]

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निर्माण परियोजना प्रबंधन — दिशा-निर्देश

भाग 2 समय प्रबंधन

Indian Standard

CONSTRUCTION PROJECT MANAGEMENT — GUIDELINES

PART 2 TIME MANAGEMENT

ICS 03.100.40

B U R E A U O F I N D I A N S T A N D A R D S
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Construction Management (Including Safety in Construction) Sectional Committee, CED 29

FOREWORD

This Indian Standard (Part 2) was adopted by the Bureau of Indian Standards, after the draft finalized by the Construction Management (Including Safety in Construction) Sectional Committee had been adopted by the Civil Engineering Division Council.

A construction project is an endeavour undertaken by a project team on behalf of owner/client to create a built facility suited to the defined functional objectives. From inception to commissioning, the project goes through various distinct stages leading to progressive achievement of project objectives. Each stage involves specific inputs, processes (both technical and managerial) and deliverables. Typically, the life cycle of a project from commencement to completion involves the following stages:

a) *Project appraisal* — Inception, feasibility and strategic planning;
b) *Project development* — Project brief development, planning and design, finalization of proposals, procurement strategy, construction documentation including tender drawings, construction drawings, specifications, cost estimates, bills of quantities, procurement documents;
c) *Planning for construction* — Sequencing of project components, planning tools, resource planning and time cost trade off;
d) *Tender action* — Open competitive bidding/pre-qualification of agencies, issue of tender documents, evaluation of bids, negotiation if required and award of work;
e) *Construction* — Execution, monitoring, control, work acceptance; and
f) *Commissioning and handing over* — Contractual closeout, financial closeout, defect liability commencement, facility handing over.

The distinct features of a construction project include the temporary nature of the project team involved, the evolutionary process of project deliverables during project development stages and the unique output as the built facility. As a result of these features, unless there is efficient and effective project management, a construction project is faced with challenges of uncertainties leading to time over-runs, cost over-runs, changes in project parameters, loss of quality and inability to meet the functional objectives. While technical soundness of a proposal is an important aspect of a construction project, the management aspects, which involve techno-legal, financial and other issues, have also a significant role in the success of a project. Therefore, management functions and technical processes in a construction project need to be integrated towards achieving project objectives. Top management commitment plays an important role in harmoniously achieving these project objectives. In some of the public domain projects, it may be necessary to share relevant information with public at large through appropriate means.

To provide necessary guidance on effective construction project management, a series of standards are being developed as part of IS 15883 'Construction project management — Guidelines'. Part 1 General, of the standard since published, covers general aspects of overall construction project management. The other parts of the standard are under preparation which will cover functions such as scope management, procurement management, cost management, quality management, risk management, communication management, human resources management, safety, health and environment management and integration management.

This standard on time management has been formulated with the aim to provide guidelines for completing the project within the allocated time as many a times, even the viability of a project hinges on the timely completion of the project. This standard is intended to cover aspects on time management as part of construction project management and information regarding the applicable tools and techniques. It gives guidelines on time planning, time monitoring and time control as part of the time management process. Users of this standard are encouraged to employ suitable construction management software as an aid to implement provisions of this standard.

The guidelines may be applicable in general to all construction projects. However, for smaller projects, the applicability of various provisions may be decided appropriately by the parties concerned.

The composition of the Committee responsible for the formulation of this standard is given in Annex D.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

CONSTRUCTION PROJECT MANAGEMENT — GUIDELINES

PART 2 TIME MANAGEMENT

1 SCOPE

1.1 This standard (Part 2) covers guidelines for time management aspects of construction project management.

1.2 The time management aspects regarding project formulation and appraisal up to the stage of preparation of preliminary proposals for financial approval are not covered in this standard. The scope of this standard, therefore, covers the stages subsequent to the stage of approval (when a decision to implement the project including its financing is taken) till commissioning and handing over of the project.

1.3 The provisions of this standard are to be read in conjunction with IS 15883 (Part 1).

2 REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
IS 7272 (Part 1) : 1974	Recommendations for labour output constants for building work: Part 1 North zone
7337 : 2010	Glossary of terms in project management analysis
10400 : 1992	Glossary of terms in inventory control
14580 (Part 1) : 1998	Use of network analysis for project management: Part 1 Management, planning, review, reporting and termination procedures
14580 (Part 2) : 2006	Use of network analysis for project management: Part 2 Use of graphic techniques
15198 : 2002	Glossary of terms in human resource development
15883 (Part 1) : 2009	Construction project management — Guidelines: Part 1 General

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 7337, IS 10400 and IS 15198 shall apply.

4 GENERAL

4.1 Need for Time Management

A project is generally a non-recurring endeavour having a definable start and finish, with a definite mission and has a set of objectives and achievements. A construction project is initiated to create a built facility within a given time period. Time management of the project is necessary because of the following reasons:

a) Project may be required within a defined time period for fulfilling an identified need.
b) Project may be part of a larger project, which cannot be made operational until this project is completed.
c) Availability of resources such as personnel, funds, equipment and facilities have to be matched with the progress of the project.
d) Project is intended to be utilized by the concerned users who have to also organize their infrastructure in a certain time frame. It may be necessary to match the time frame of users with the time frame for completion of project in phases.
e) To provide the required directions and for organization of project functions and to coordinate the activities and responsibilities of various stakeholders.

4.2 Holistic View of Time Management: Time, Cost and Quality Integration

4.2.1 While the goal of these guidelines is to describe time management, the same cannot be viewed in isolation and shall be considered along with other dimensions of construction project management such as cost, quality, safety, scope, etc.

It shall be necessary to draw up an optimum time frame keeping in view the following:

a) Past experience of similar projects.

b) Location and weather conditions.
c) Time and other constraints laid down by the owner and other stakeholders.
d) Availability of resources such as personnel, funds, equipment, etc.
e) Time required for proper execution of various activities without compromising quality and safety.

4.2.1.1 The activities may be grouped under the following stages:

a) Pre-construction stage:
   1) Project development,
   2) Planning for construction, and
   3) Tender action.
b) Construction stage.
c) Commissioning and handing over stage.

4.2.2 It is important to draw a rational and realistic time schedule for the various activities of the project. Working on too short time frame may adversely affect the quality, safety and economy of execution, whereas if the project time frame is larger than the optimum, the cost escalation, overheads, etc, increase the cost besides the delay in intended benefits of the project.

4.3 Organizational Structure for Time Management

During the stages of a construction project, activities may be undertaken in-house by the owner of the project or may be outsourced to the specialized agencies/ consultants/contractors, as follows:

a) *Pre-construction* — This may be carried out in-house and/or through a consultant(s).
b) *Construction* — This is carried out generally through one or more contractors. Each contractor may engage sub-contractors, although the main contractor remains responsible for the overall performance of the contract. The construction work may be supervised in-house or through a Project Management Consultant (PMC)
c) *Commissioning and Handing Over* — While the construction agency or agencies may hand over the project or the concerned component, owner may also be involved in commissioning and subsequent operation of the project.

Appropriate organizational structure is required for meeting the objective of time management under the following units:

a) Organizational structure of owner for,
   1) works to be carried out in-house, for example, planning and operation.
   2) coordination with and supervision of work of consultants, contractors/ construction agencies as per the agreements drawn up with them.
b) Organizational structure of consultants/ PMCs/contractors/construction agencies to fulfil their commitments as per the agreements entered into by them for,
   1) works to be carried out in-house by these units.
   2) works to be carried out by these units through sub-contractors, sub-consultants and supervision thereof.

The organizational structure for the time management process will vary from project to project. It may be necessary to clearly identify the persons or stakeholders who are delegated the functions of time management. On large and medium projects, it may be necessary to have a separate individual or a unit for time management. In small sized projects, this role may be merged with some other functions.

4.4 Methods and Processes for Time Management

Time management essentially involves the following processes:

a) Time planning;
b) Time monitoring; and
c) Time control.

The procedures for above processes involve the following steps:

a) Defining project scope;
b) Activity duration estimating;
c) Activity sequencing with interactivity dependencies;
d) Project schedule development; and
e) Project schedule monitoring and control.

For, network preparation and analysis required under (c) above, which are the basic tools for time management processes, reference shall be made to IS 14580 (Part 1) and IS 14580 (Part 2).

The entire process of time management is dynamic and shall require periodic monitoring, control and updating of the schedule.

The time management process should also take into account the interface at various stages among the different disciplines involved in the project.

Users of this standard are encouraged to employ suitable construction management software as an aid to the provisions of this standard.

5 SCOPE OF TIME MANAGEMENT

5.1 General

5.1.1 The time earmarked for pre-construction, construction and commissioning and handing over activities shall be as per the optimum time frame (*see* **4.2.1**). In order to achieve the optimum time frame,

a) the overall programme shall be available in the shape of (1) Work breakdown structures (WBS), (2) Bar charts, and (3) Network showing various activities and milestones, as considered necessary for the timely completion of the project;
b) all concerned with the project work shall be well aware of the overall programme and their role in it; and
c) a suitable management information system shall be adopted for regular reporting and review of the progress achieved in various activities with respect to the programme laid down and corrective actions required in case of shortfall.

5.1.2 The procedure given below shall be followed for review of progress achieved:

a) Project phases may be divided into suitable performance periods.
b) At the start of each performance period, it shall be confirmed that all concerned are aware of the activities to be performed during that period, and the dates fixed for relevant milestones to be achieved in that period.
c) At the end of each performance period, the persons concerned shall submit performance reports as laid down in the management information system. The progress achieved shall be reviewed with respect to the targets laid down. In case of time variance in certain activities, reasons for the same shall be examined and corrective action taken. Major reason for time variance may be on account of a significant change in the scope or the specifications of the project work.
d) Minor changes in scope of work from time to time, may not individually lead to significant changes in time schedule, but such changes over a period of time may collectively add up and contribute to significant time variance. Therefore, the cumulative impact of all such changes shall be assessed with respect to project schedule and resources required for taking corrective action.
e) During monitoring, importance shall be given to activities on critical path(s) and, those which are close to becoming critical.
f) Where time variance has already occurred, the targets/baselines may have to be revised and intimated to all concerned. Performance shall, thereafter, be monitored against such revised targets. The impact of this change shall be analyzed and the revised time frame drawn up, if necessary in consultation with all affected stakeholders.
g) At the beginning of next performance period, the above cycle shall be started again.

5.2 During Pre-construction Stage

5.2.1 In addition to the procedure stated in **5.1**, during the pre-construction stage, the following shall also be kept in view:

a) A proper and effective co-ordination is ensured among the different groups engaged in pre-construction activities.
b) A person/group is assigned and performs the interface management.
c) Value engineering exercise of the project is carried out.

5.2.2 The time management process shall be applied to various activities of the tender action as described under **5.1.3** of IS15883 (Part 1).

5.2.3 In order to be fruitful, the time planning outputs shall be reviewed jointly with the stakeholders so as to have the concurrence of the concerned with the pre-construction activities.

5.3 During Construction Stage

5.3.1 In order to achieve the optimum time frame, during the review of the progress, the provisions given in **5.1** shall be followed. In addition, during the construction stage, the following shall also be kept in view:

a) A proper and effective co-ordination is ensured among the different disciplines of construction.
b) A person/group is assigned and performs the interface management.
c) During monitoring, the activities historically associated with higher uncertainties are specially looked into.

5.4 During Commissioning and Handing-Over Stage

5.4.1 The scope of work consists of two main activities, that is (a) Commissioning, and (b) Handing-over. It is preferable that the operation and maintenance team is also associated at appropriate stage. It is considered that the time earmarked for these activities has been estimated while determining the time frame for the overall project as indicated in **4.2.1**. A preliminary testing and commissioning plan shall be worked out which shall include all the testing and commissioning activities and their time estimates.

Similarly, sufficient time shall be earmarked for handing-over activity which shall generally include preparation of documents, verification of test results, list of inventories, operation and maintenance manuals and snag list.

5.4.2 Both for planning and progress review of this stage, the procedure described in **5.1** may be followed.

5.4.3 Typically, the items involved at this stage are:

a) *Testing and commissioning*:
   1) Availability of bulk services, that is, water supply, electricity supply, sewerage connection, telephone lines and other project specific requirements.

      These may be available from the service provider or may have been installed specially for the project. In case it is arranged through service provider, necessary approvals/connections for the same will have to be ensured.
   2) A core unit created for management and supervision of testing and commissioning shall be in place.
   3) Trial runs of all services for ensuring satisfactory performance.

b) *Handing-over of project*:
   1) Preparation of a list of any unfinished project activity(ies).
   2) Preparation of a list of all required acceptances and approvals from various authorities.
   3) Preparation of final project completion reports including as built drawings.
   4) Compiling operation and maintenance manual.
   5) Reassignment of resources, including project personnel assembled during construction stages which are now to be transferred/disposed off.

c) Handing-over/taking-over and issuance of completion certificate.

6 TIME MANAGEMENT

6.1 Time Planning

6.1.1 *General*

Time planning or scheduling is conducted to calculate the realistic or workable time schedule of the project considering the project characteristics, complexities and quantum of work to be executed. The step-wise approach to time planning is given in **6.1.2** to **6.1.10**. The typical overall process is given in Fig.1.

6.1.2 *Project Characteristics*

Approach to project time planning depends on the characteristics and complexity of the project; and accordingly for the purpose, the projects may be classified as follows:

a) With respect to the type of work, construction projects may be broadly categorized as:
   1) Building projects;
   2) Infrastructure projects;
   3) Industrial projects; and
   4) Other projects.

b) With respect to project completion time, projects may be categorized as:
   1) Long duration projects (over 5 years);
   2) Medium duration projects (3 to 5 years);
   3) Short duration projects (1 to 3 years) ; and
   4) Special short-term projects (less than 1 year).

c) With respect to project value, projects may be categorized as:
   1) Mega value projects;
   2) Large value projects;
   3) Medium value projects; and
   4) Small value projects.

d) With respect to speed of project execution, projects may be categorized as:
   1) Fast track projects; and
   2) Normal pace projects.

Project characteristics shall be assessed based on the above categorizations, in addition to its location, organizational setup and contract structure. Also, 'Method statement' and 'Design basis' shall be finalized. Accordingly, project time schedules shall be prepared.

6.1.3 *Work Breakdown Structure (WBS)*

6.1.3.1 The project shall be divided into manageable components at a level of detail appropriate for the duration and the complexity of the project. It shall be done with the help of work breakdown structure (WBS) technique that divides the project in an hierarchical order till the desired level of detail is reached. The

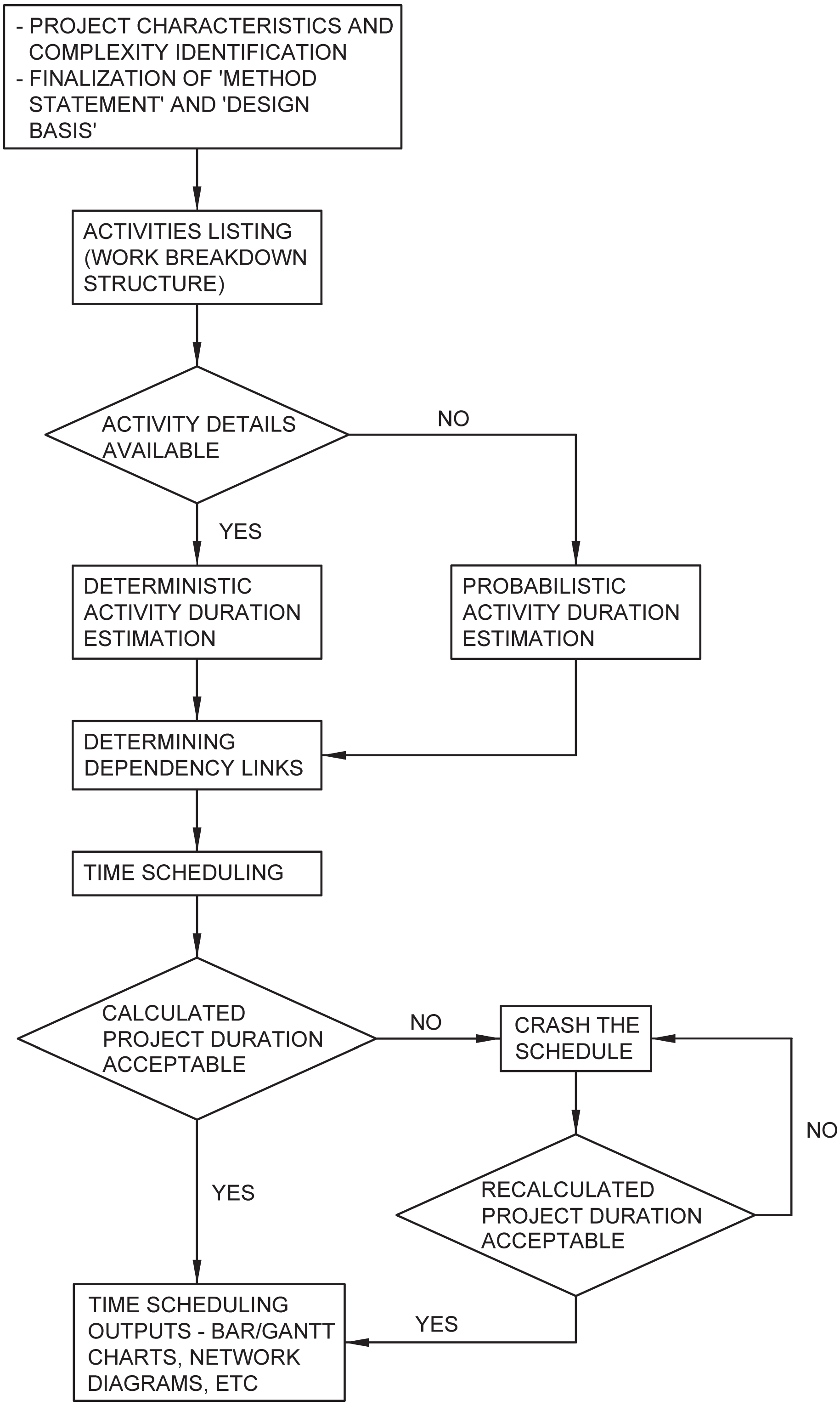


FIG. 1 TYPICAL TIME PLANNING/SCHEDULING PROCESS

project may be divided step-wise in the following sequence:

a) Total project;
b) Sub-projects;
c) Work packages;
d) Tasks; and
e) Minor tasks/activities.

Any of the above WBS components may also be identified as a contractual milestone and can be tracked.

6.1.3.2 WBS shall be prepared with respect to,

a) stages of a project, that is, pre-construction, construction and commissioning and handing over stage.
b) functional or technological disciplines, that is, WBS is based on technological disciplines, for example, in a service intensive building, work of each discipline like civil and plumbing works, electrical works, air-conditioning works, etc, is a sub-project.
c) organizational structure, that is, WBS is prepared as per the reporting structure, for example, works to be monitored by each department or hierarchy level is a sub-project.
d) physical location, that is, WBS based on spatial location, for example, each floor of a building is a sub-project.

6.1.3.3 Preparation of WBS shall take into account the following:

a) Each WBS component shall have a deliverable;
b) All works in the scope of the project shall be included in the WBS; and
c) Each descending level of WBS shall represent more detail.

6.1.3.4 WBS shall be prepared in a tree format or an outline-style and the lowest components in nodes shall be the activities to be considered for project scheduling. The prepared WBS shall be numbered with the help of a coding system which may be alpha-numeric in structure such that each activity is identified by a WBS code which reflects its position in the WBS structure, in the project and any of the classification that it represents.

A standardized WBS code structure shall be implemented in each organization.

6.1.4 *Activity Identification*

6.1.4.1 As given in **6.1.3**, activities shall be identified with the help of WBS technique. List of activities may be short and simple or long and detailed, depending on the size, goals and stage of the project. For example, for project planning at the conceptual stage of a project, activities may be at a broad level and less in number and at the execution stage, activities may be detailed and more in number. Each activity shall have,

a) defined deliverables or scope of work;
b) trackable duration;
c) resources; and
d) cost.

6.1.4.2 *In-house and outsourced activities*

Activities to be executed by the organization managing the project are in-house activities. Activities to be executed by the external agencies or organizations are outsourced activities.

6.1.5 *Productivity Standards*

Productivity standard of each resource for a particular project is the productivity data to be assumed for scheduling that project. It shall be calculated as per the following formula:

Resources' productivity standard (p) = Productivity norms × Production efficiency factor

where

Productivity norms	=	productivity of resources for the minimum unit of scheduling time. For example, if the planning unit for time is a day, output of resources/day is the productivity information required. This should be obtained from published guidelines such as IS 7272 (Part 1) or other authorized publications such as CPWD analysis of rates and MORTH data book or historical data of similar activities archived in the organization. For new type of work when no previous data is available, productivity norms can be estimated through prototype testing or from the experience of the project team. In a situation where multiple resources are required for an activity, productivity of one group of resources should be considered.
Production efficiency factor	=	multiplier used to convert production norms into productivity standards expected under job conditions of the project.

6.1.6 *Resource Availability and Duration Estimating*

6.1.6.1 Activity duration estimation shall be based on the scope of work of each activity and productivity of the resources required for these activities. Duration should be estimated by the project management team members who are conversant with these details. For each activity this information shall be derived from the historical data of the similar activities of previous projects, resources and project work environment and also from the experience of the project team members.

The availability of activity details defines whether the activity duration estimation will be probabilistic or deterministic. For some activities, detailed information may be available at the time of duration estimation. But, for other activities the details shall be finalized progressively.

6.1.6.2 *Deterministic and probabilistic activity duration*

Deterministic activity duration shall be calculated as follows:

$$\text{Duration, } T_E = \frac{q}{p \times n}$$

where

- q = amount of work to be executed in an activity. It may be in suitable unit, for example, cubic metre of concrete casting, kilometre of road laying, etc;
- p = resource productivity standard (*see* **6.1.5**); and
- n = number of identified resource groups that may be deployed on the activity at any time. For example, for excavating a large area, more number of excavators can be deployed, but not so for excavation in a small area.

Contingency planning for activity durations shall include modifying the above calculated activity durations, based on:

a) Activity constraints of time, location, etc;
b) Risks foreseen for the activities; and
c) Study of the project environment and other subjective issues.

Care shall be taken to include appropriate buffer for contingencies, if required.

Probabilistic activity duration shall be calculated as follows:

$$\text{Duration, } T_E = \frac{a + 4\,m + b}{6}$$

where

- a = optimistic duration of the activity,
- m = most likely activity duration, and
- b = pessimistic duration of the activity.

For assuming values of a, m and b following conditions shall apply:

a) a, m and b are positive numbers.
b) $a \leq m \leq b$.

The probabilistic activity duration may be calculated using a triangular distribution. Other form of statistical distribution such as beta distribution may also be used to model construction activity duration.

6.1.7 *Logical Sequencing*

The sequential dependency links between activities may be classified into following four types (*see* Fig. 2):

a) *Finish to start (FS)* — Successor activity to start after the predecessor activity finishes.
b) *Start to start (SS)* — Successor activity to start after the predecessor activity has started and is partially complete. So, for some duration both the activities shall take place simultaneously.
c) *Finish to finish (FF)* — Successor activity to finish only after the predecessor activity has finished. In this situation also for some duration both the activities shall take place simultaneously.
d) *Start to finish (SF)* — There is a relationship between the start of the predecessor activity and the finishing of the successor activity.

Leads and lags define the exact time difference between the two components of any dependency link and shall be identified by the project team members who are aware of the project details. Lead shall indicate the acceleration of the successor activity with respect to the predecessor activity. Lag shall show the delay between the dependency component of a successor activity with respect to that of the predecessor activity.

6.1.8 *Milestones and Time Scheduling*

6.1.8.1 *Milestones*

A milestone defines point of time indicating the start or finish of an important group of activities. Milestone can be any component of the WBS. Project scheduling shall be initiated by identifying project milestones and setting their planned dates as intermediate project targets. At the project execution stage, the assessment of these targets helps the senior level management in assessing the project status and taking strategic decisions for the project.

6.1.8.2 *Time scheduling*

Time scheduling involves putting the project plan on a calendar, that is, identifying planned start and finish dates for the activities. Precedence diagram method or activity on node method given in **7** of IS 14580 (Part 2)

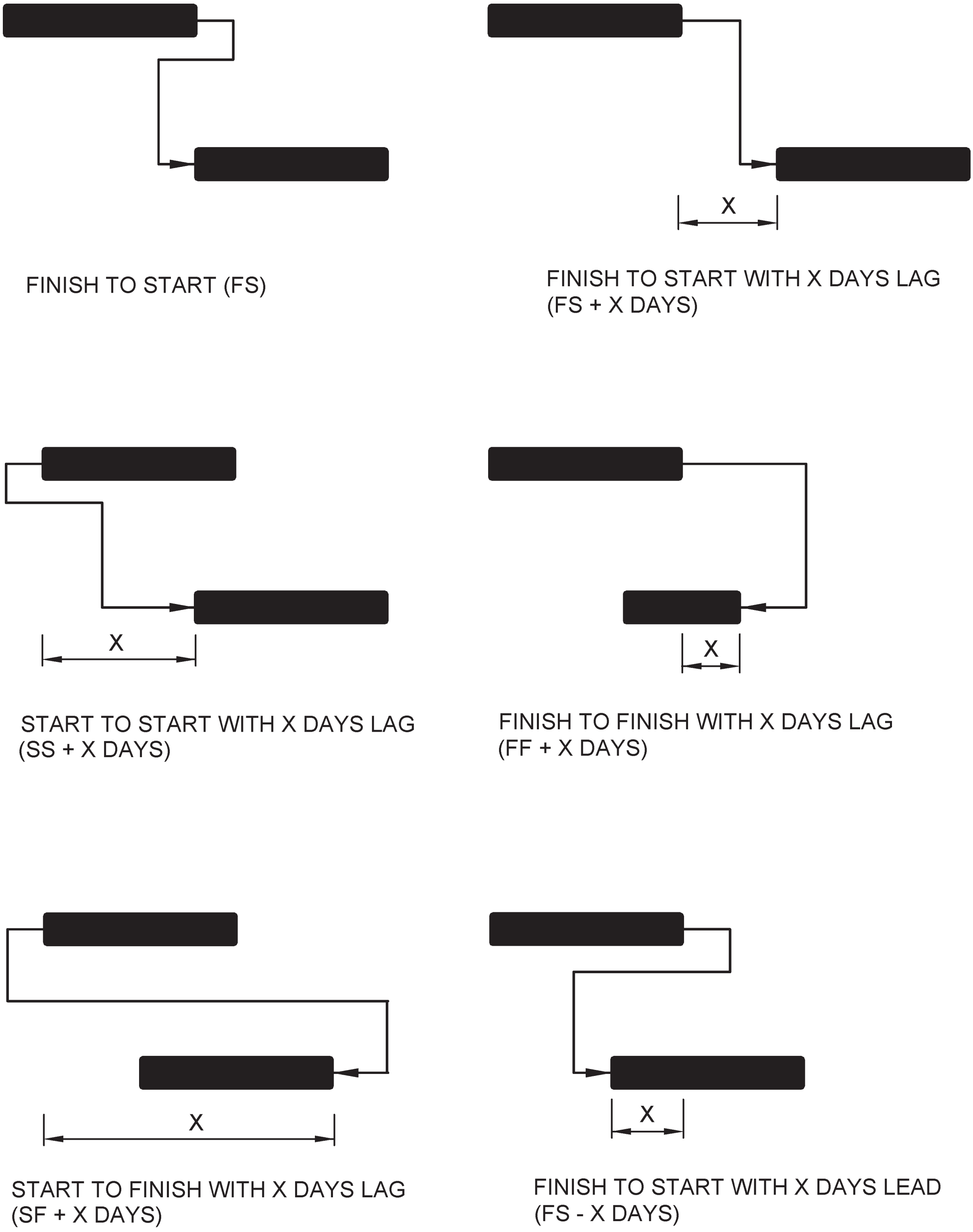


FIG. 2 TYPES OF DEPENDENCY RELATIONSHIP

shall be used for time scheduling. After determining dependency links, the steps given below shall be followed:

a) Preparation of the network diagram based upon established data, and
b) Forward pass and backward pass calculations for the network diagram.

The time scheduling deliverables shall be as given below:

a) Early start and early finish dates of each activity,
b) Late start and late finish dates of each activity,
c) Early and late dates for project milestones,
d) Total float and free float of each activity and project milestones,
e) Critical activities and project critical path, and
f) Calculated project duration.

For automation of time scheduling process and other processes given in subsequent clauses, suitable construction management software may be employed.

6.1.8.3 *Resource scheduling*

Activity duration estimation formula gives the amount of resources required for each activity every day (*see* **6.1.5**), where resources are categorized as manpower resources, material resources and equipment resources. After time scheduling, the calculated resource(s) data shall be superimposed on the time schedule data and resulting resource scheduling deliverables shall be,

a) amount of each type of resource required on each day of every activity, and
b) amount of each type of resource required on each day of the full project duration.

The resource schedule shall be finalized after resource levelling, which shall include,

a) reconciling resource requirement data with resource availability data,
b) optimizing resource requirement schedule for uniform usage of resources,
c) reconciling derived cost schedules with available cash flow, and
d) reconciling resource schedules and time schedules for finishing the project by the optimum finish date.

6.1.8.4 *Project schedule crashing*

The calculated project duration should be acceptable to the management. If the requirement is to complete the project in lesser time, crashing of project schedule shall be conducted (*see* Annex A).

Project schedule crashing shall include following steps:

a) Decreasing estimated activity(ies) duration.
b) Modifying finish-start links to start-start or finish-finish links to have parallel activities.
c) Assessing increased resource requirement per day based on the actions of above two steps and reconciling modified resource schedules and time schedules for finishing the project by the modified optimum finish date.

6.1.9 *Target Setting*

The scheduled early and late dates for the activities and project milestones are the time based targets or baseline to be achieved by the project team. The resource scheduling data shall be the baseline resource requirement. At project execution stage, the actual progress of activities, actual resource usage and their productivity shall be compared with these targets to assess the project status.

6.1.10 *Time Management Deliverables*

Project scheduling data shall be reported in the form of network diagrams and bar charts or Gantt charts.

For each sub-project a separate network diagram or bar chart shall be prepared. To assess the overall project schedule, these individual network diagrams and bar charts shall be linked together to form the master control schedule.

Line of balance (LOB) technique shall be used for scheduling repetitive projects, like similar buildings, very high rise buildings, etc; linear type segmented works like roads, airfields, tunnels, pipelines, etc; and such projects which are linked with each other for sharing resources or because of inter-project flow of information.

For preparation of network diagrams and bar charts, reference shall be made to in IS 14580 (Parts 1 and 2).

6.2 Time Monitoring

6.2.1 *General*

The time monitoring refers to those processes implemented to collect, compile and analyze the status of project progress with respect to its baseline. The objective of time monitoring is to evaluate any deviation from the estimations made during time planning and its impact on project status. Reports generated through time monitoring analysis serves as a decision-making tool which are then input for project time control.

Timely discharge of all contractual obligations by every project-stakeholder is essential for the success of project. Time schedule for each of these obligations which are indicated as distinct activities in the baseline-schedule of time planning shall be monitored. Any variance is appropriately reported for effective contract-administration of the project (*see* Fig. 3 for typical time monitoring process).

6.2.2 *Activity Tracking and Reporting*

Activities identified in the project baseline schedule prepared through time planning shall be tracked by following steps:

a) Compare the current status of activities with respect to their planned status in the baseline schedule.
b) Compilation of deviations in planned sequencing of activities and their impact on overall project schedule.
c) Forecast of project progress based on its past/ current trend.
d) Preparation of a new catch-up plan for future activities to recover delays, if any, to meet the project baseline end date.
e) Monitoring of baseline critical path activities and re-analyzing the current schedule for new critical activities.

Following steps may be adopted for activity tracking:

a) Timeline updating of baseline schedule on periodic basis or whenever there is major deviation in original assumption made for time planning.
b) Performance comparisons while evaluating actual progress against planned progress. Comparisons of rate of performance of activities planned *versus* actual in the form of charts, etc.
c) Project status through time monitoring is summarized into a project status report to depict the overall project health in the form of graphical charts as detailed in **6.2.5**.

The project status report is an important component of management information system (MIS). The report shall contain the following:

a) Progress status of various project activities in terms of planned *versus* achieved.
b) Analysis of past performance and rate of performance.
c) Status of baseline critical activities and forecast of future activities that may become critical.
d) Status of look-ahead programme prepared after the previous iteration of the process of time control.

The information for project status report preparation is compiled from daily progress reporting which shall be bottom-up. This daily reporting shall cover performance including time and resource deployment details of all on-going activities of the project. It shall also include time progress status of critical path activities along with resource deployment/usage details.

For effective daily reporting, effective communication of the baseline plan to all the stakeholders at every WBS level of the project shall be maintained. The communication of the plan shall include,

a) monthly/weekly planned metrics associated with every activities of the project along with the resources to be deployed as per the updated plan.
b) minimum productivity level to be achieved and activity sequence to be followed.
c) the list of critical activities of the project for which the progress metrics along with resource details, which needs to get reported separately in the daily progress report.

6.2.3 *Resource Tracking*

The resource scheduling as per **6.1.8.3** is required to be tracked to monitor actual deployment and deviations, if any with respect to baseline plan of the project. The impact of deviation may be correlated to deviation in rate of performance of activity. The resources to be tracked include the following three components are:

a) *Manpower,* with breakup of skill and trade;
b) *Material*, that are required for the project including the enabling works material; and
c) *Plant and Equipment*, that are to be deployed as per the baseline plan.

The resource tracking process shall determine,

a) the status of deployment of all resources planned *versus* the actual.
b) the variation in resource productivity considered during planning stage and actual achieved.
c) impact of variation in resource productivity and revised requirement of the resources for on-going and future activities.

6.2.4 *Scope Variation Monitoring*

During the course of any construction project, the work scope may change. Changes may be due to variation in scope, instructions from owners, design modifications, unforeseen site conditions, material non-availability, request by the contractor, value engineering exercise, etc. By implementation of a

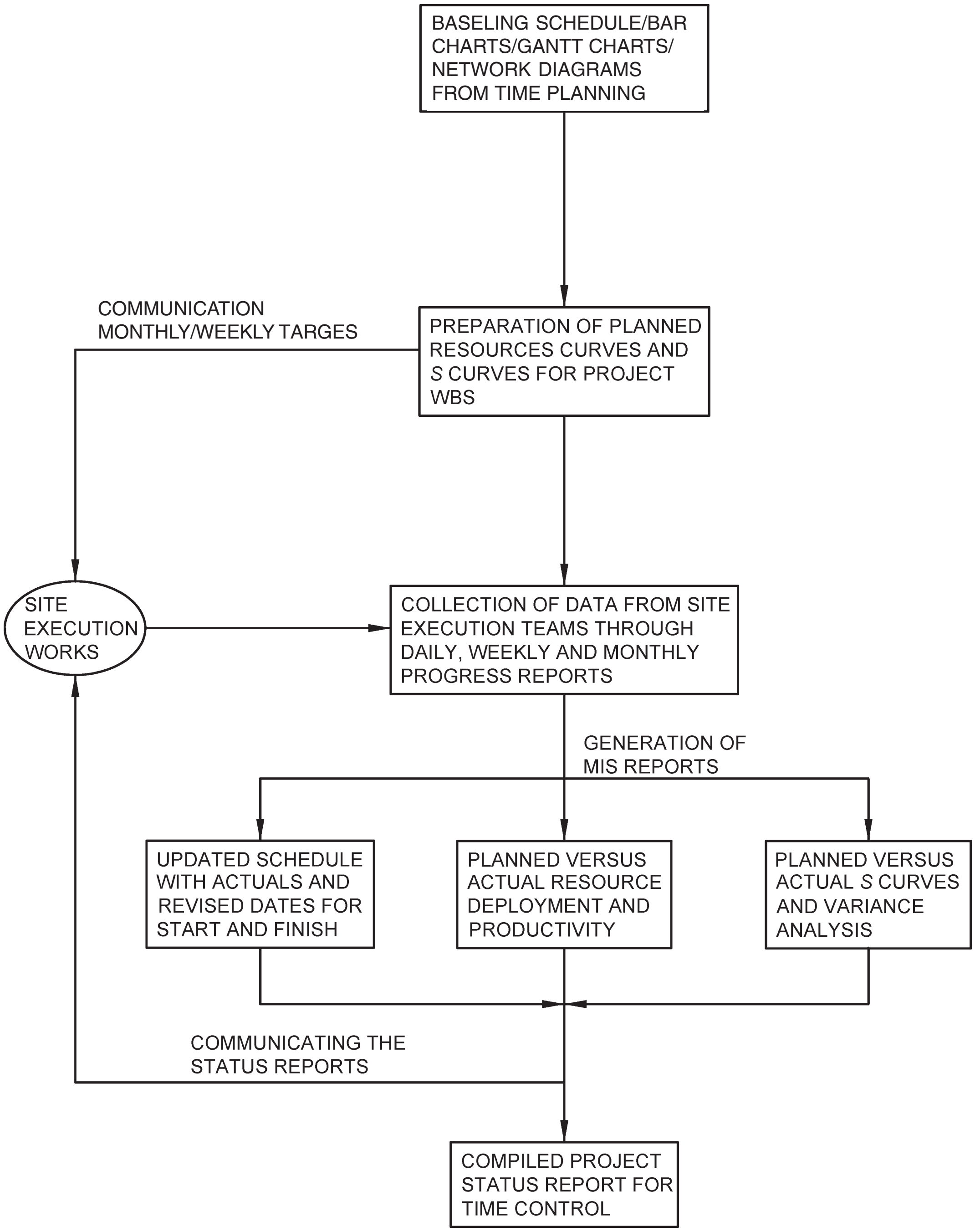


FIG. 3 TYPICAL TIME MONITORING PROCESS

change, the impact on time and cost is to be analyzed and an agreement is to be reached between the owner and the contractor.

The scope variation requires reworking of time planning exercise for the project and preparation of revised baseline schedule along with revised resource plan. The scope variation can alter the critical path of the project and may alter the project timeline.

During implementation of scope variation in project, the time monitoring and time control are to be carried out based on revised baseline schedule.

6.2.5 *Planned* versus *Actual Performance Monitoring*

The time monitoring process shall be summarized in the form of a report preferably in tabular or graphical form. The graphical status report may be prepared at all levels of WBS and each activity of the project may be individually monitored. The graphical report prepared at total project level is a weighted summation of status report of all the sub-activities in the WBS.

Summarizing the status of various activities of the project into a single index for the total project requires a common measurement parameter for all the activities. This common parameter may be any of the following:

a) Earned value or budgetary cost of the activity (*see* Annex B for earned value management technique).
b) Manhour estimate for execution.
c) A pre-agreed weightage based on the criticality/importance of the activity (*see* Annex C for a sample report based on weightage).
d) A combination of the above.

Once the common parameter, project metric to be used in the project is decided, all the status report of the project activities shall refer uniformly to the planned and achieved quantum of this project metrics by the activity.

The following procedure for graphical report preparation may be adopted:

a) Time planning process facilitates assigning of quantum of project metric to each activity in the WBS.
b) The assignment of project metric to activities for status reporting may be restricted to Level 3 or Level 4 in WBS or as appropriate for the project [for levels of network/schedule, *see* **5.2.2** of IS 14580 (Part 2)].
c) Against each activity up to Level 3 or Level 4 as decided in the baseline schedule, the quantum of project metrics is worked out. The time planning process determines the distribution of the metrics on the project timeline.
d) The summation of all the project metric in total WBS will give the project summary which can be graphically represented against project time scale. The summary can be individually obtained at every level of WBS, that is, Level 1, Level 2, Level 3, etc.
e) The project metric on Y-axis and Timeline on X-axis may be used for graphical representation. The points to be plotted may be a cumulative project metric value or absolute value bar histogram. The timescale for metrics distribution and graphical representation may be month, week or even days depending on the nature of project and level of monitoring required for the project (*see* Fig. 4).

The identification and monitoring procedure standardization shall be as follows:

a) As the project progresses, the actual performance of the summary activities at the required level shall be again plotted along with its baseline plan value (*see* Fig. 5).
b) The horizontal offset between the baseline and actual curve shall determine the deviation in project timeline at summary level and vertical offset determines the percent progress deviation.
c) The reasons for deviation may be ascertained by drilling down to lower levels in WBS of the project. This analysis shall become input for time control and decision-making for mitigation.
d) The time control procedure in **6.3** shall determine revised plan and activities metrics for future activities.
e) The project metrics distribution shall be reworked for future activities of the project and plotted in dotted line as a forecast curve. If the actual progress is behind the baseline and, if it is possible for the backlog to be recovered either before or by the baseline completion time, this is deemed as ‘catching up’, and the distribution plotted for this is called the catch-up curve (*see* Fig. 6).
f) Graphical representation as illustrated in this section depicts pictorially the status of an updated schedule of the project. This is a tool for time monitoring and this graphical report becomes an input for time control.
g) The data from time monitoring may also be analyzed and reported as tabular or narrative form.

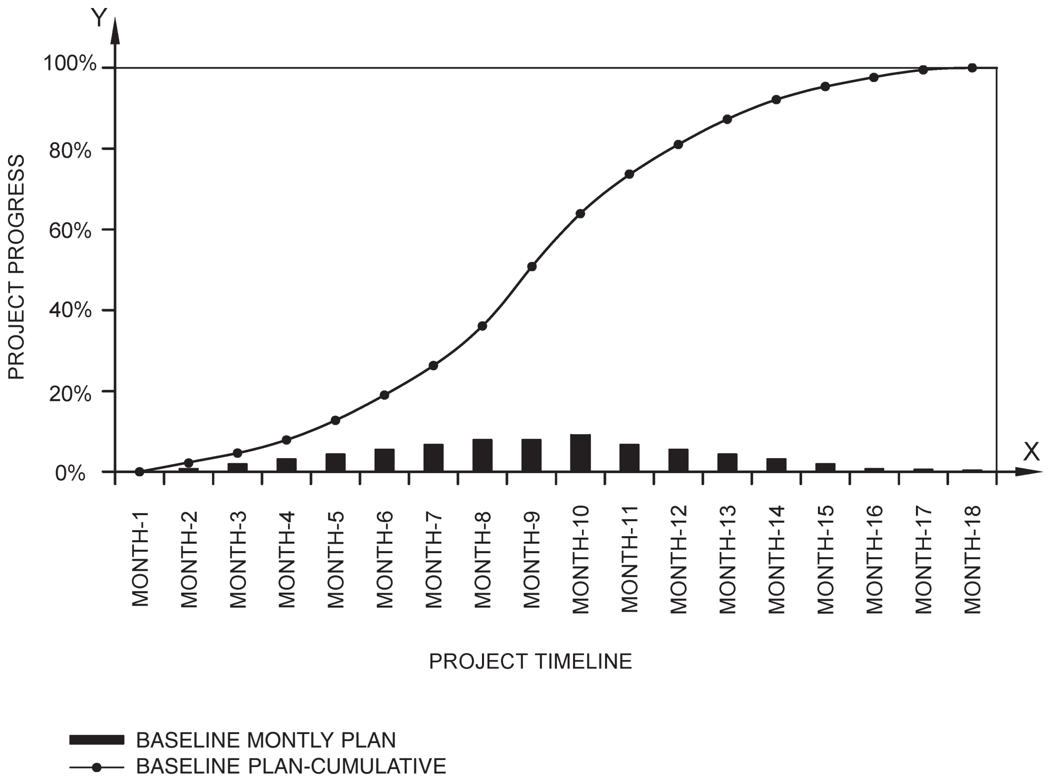


FIG. 4 BASELINE PLAN

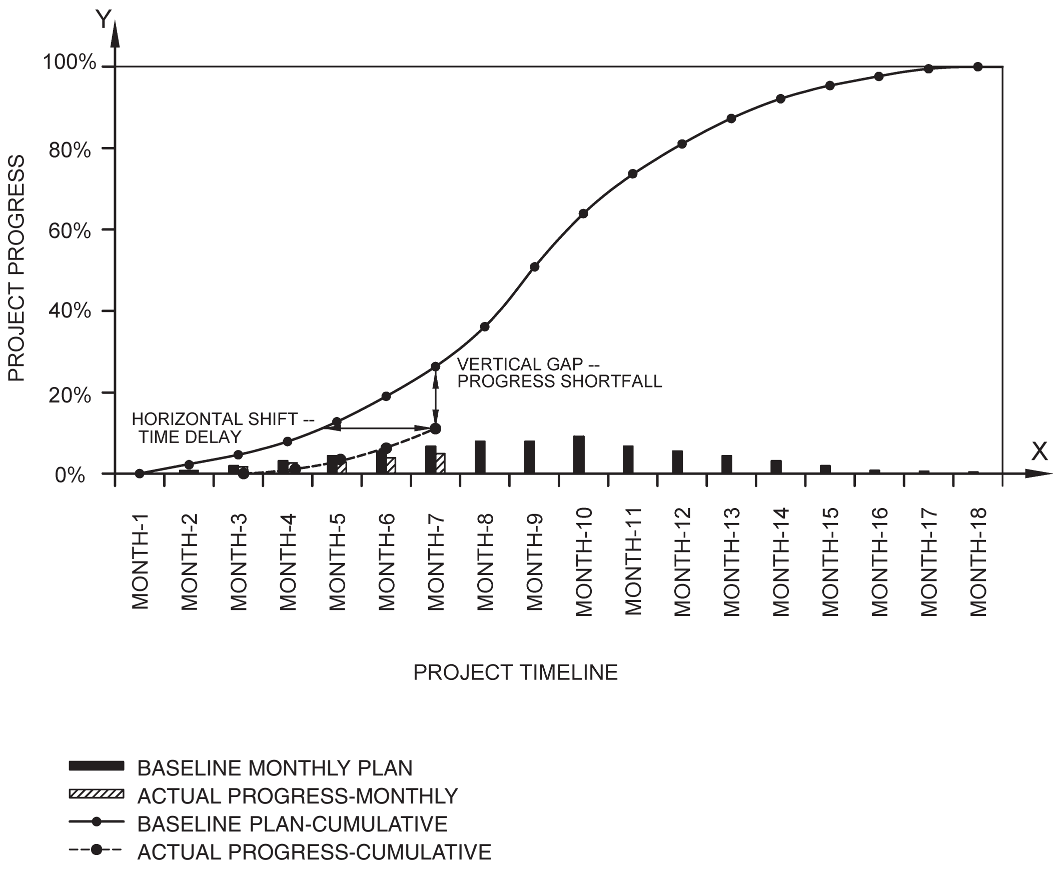


FIG. 5 BASELINE *VERSUS* ACTUAL PROGRESS

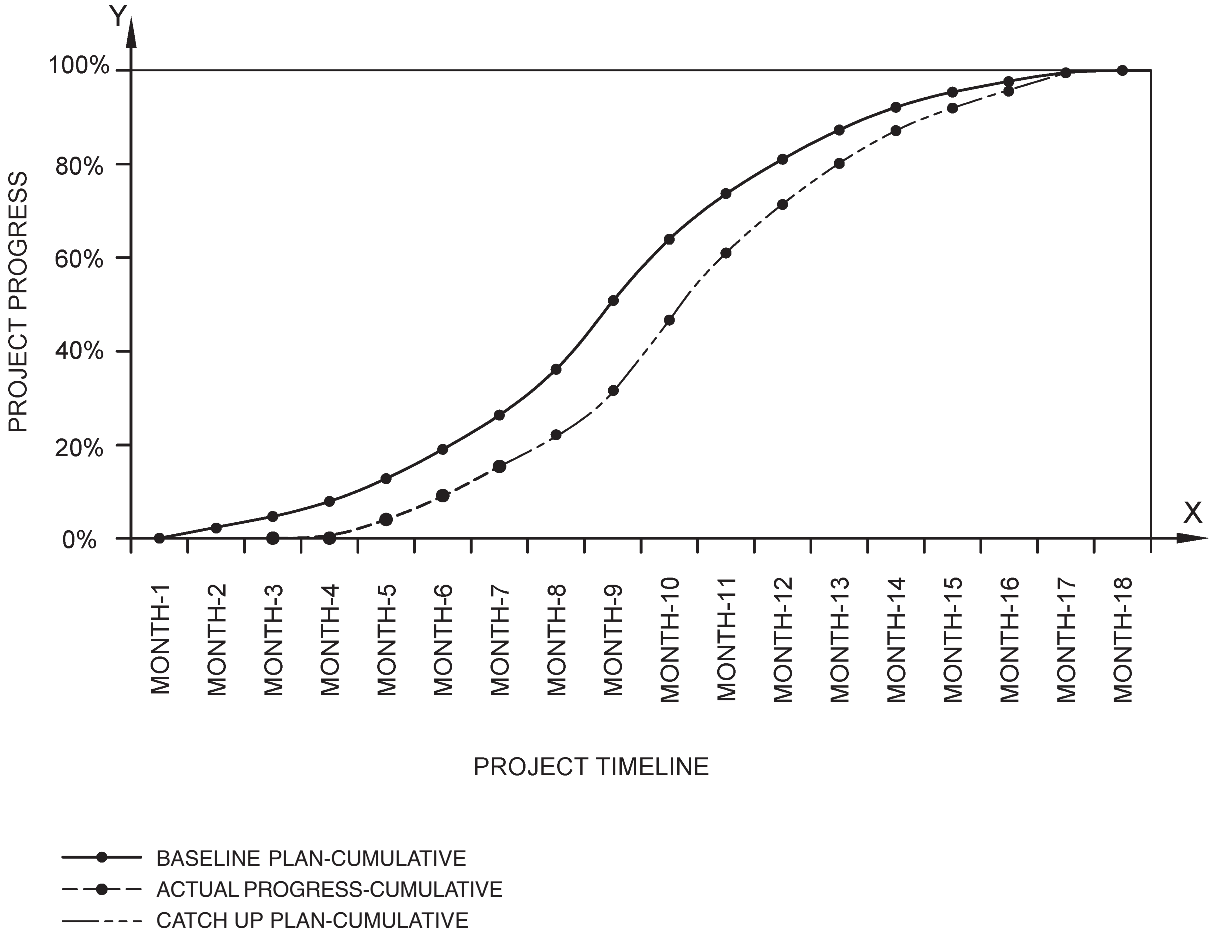


FIG. 6 CATCH-UP PLAN

6.2.6 *Delay Identification*

The time monitoring process helps in identification of any delay in activities and assessment of its impact, if any, on the overall project time line. The possible causes of delays in project activity may be,

a) deviation in resource deployed from baseline plan.
b) deviation in assumed productivity level of resources deployed.
c) deviations in assumed sequencing and workflow of activity in the baseline.
d) any unforeseen factors.

The aforesaid causes may result in,

a) alteration in project's critical path.
b) extension in project duration.
c) alteration in intermediate milestones leading to interface clashes.

The updated baseline schedule can be filtered to identify all those activities which have exceeded or likely to exceed the planned finish time. These identified activities under delay are analyzed through root-cause analysis and mitigated in time control process.

The project metric parameters used for project report preparation are also useful for delay identification.

6.2.7 *Reporting for Time Control*

The status of the project activities in terms of project metrics actually earned shall be periodically compiled from execution site. The project status report as described in **6.2.5** shall be prepared in time monitoring process. The project status report shall be in the form of narrative, table or graphical charts which will form input report for time control.

6.3 Time Control

6.3.1 *General*

Time control, is a sub-function of the construction project time management process that allows both reactive and proactive measures for project schedule adherence. This sub-function shall continue through the life of the construction project. A construction project schedule shall be prepared initially during the time planning sub-functions and then time monitoring and time control functions shall be performed periodically during the life of the project. The interval between time monitoring and time control functions depends, amongst other factors, on the nature, complexity and the contractual requirements of the construction project (*see* Fig.7 for typical time control process).

Project schedule adherence and the current status of a construction project, as represented by the time monitoring, shall forms the basis for time control.

The tools and techniques commonly employed in time control are:

a) *Progress reporting*, which includes field data and reports on the actual start and finish dates of activities that have started including the remaining duration of unfinished activities and likely start data of the activities not yet started.
b) *Variance analysis*, which includes comparison of the planning data with actual performance to identify any delays or variations in the project schedule.
c) *Performance measurement*, which includes quantifying and assessing the severity of delays, if any, and other deviations, if any, by measuring project schedule performance compared against the project plan. Based on this assessment the corrective or proactive actions are determined. Some common performance measurement tools used in practice are,
    1) schedule comparison bar charts,
    2) reports and graphs produced by scheduling software (*see* Annex C for *S*-curve), and
    3) schedule variance and schedule performance index produced through an earned value analysis (*see* Annex B).

6.3.2 *Evaluation of Impact of Scope Variation*

Success of a construction project is in part dependent on the scope definition, scope management and scope control. After the initial definition of the scope, its management and control is dependent on the change management process. Changes made to the scope of the project may impact the schedule of the project.

6.3.2.1 *Revising baseline*

The time control process, once completed, provides the necessary information and inputs which leads to revising the baseline schedule. After the changes in scope are identified and approved and delays have been identified and quantified the baseline shall be revised. Before revising the baseline, the original schedule baseline shall be saved to store historical scheduling data.

6.3.3 *Delay Analysis*

Delay analysis, looks at every delay in the schedule at the activity level to determine where, when and why the delay occurred and identifying the stakeholder responsible for the same. The cost implications of any delay shall be calculated. The time responsibility and cost implications may be determined by variance analysis and trend analysis using weighted concept (*S*-curve) given in Annex C and earned value management technique given in Annex B.

6.3.4 *Schedule Specific Risk Analysis*

During the time planning and time control sub-functions, it is important to analyze schedule risks, specially on construction projects with high uncertainty in the underlying scheduling data. Both qualitative and quantitative processes are involved in the schedule risk analysis process. After the risk identification step is complete, the qualitative process shall be undertaken. The qualitative process shall involve subjective's experience based input on common likelihood factor and common impact factor. The product of these two provides an identification of the risk associated with various risk factors. After the qualitative process, the baseline schedule may normally be utilized to perform a quantitative analysis of schedule risks. Programme evaluation and review technique (PERT) and monte carlo simulation technique commonly used, may be utilized to perform schedule risk analysis. At the completion of the qualitative and quantitative processes, decision makers shall have a plan to monitor and control project risks associated with the project schedule.

6.3.5 *Mitigation Measures*

Once the delay has been identified and delay analysis carried out, measures shall be put in place to mitigate the impact of the delay. Based on the information and data available, several measures may be considered to mitigate this delay.

One of the foremost measures may be to address the issues identified in delay analysis and take necessary action thereby ensuring that the programme does not

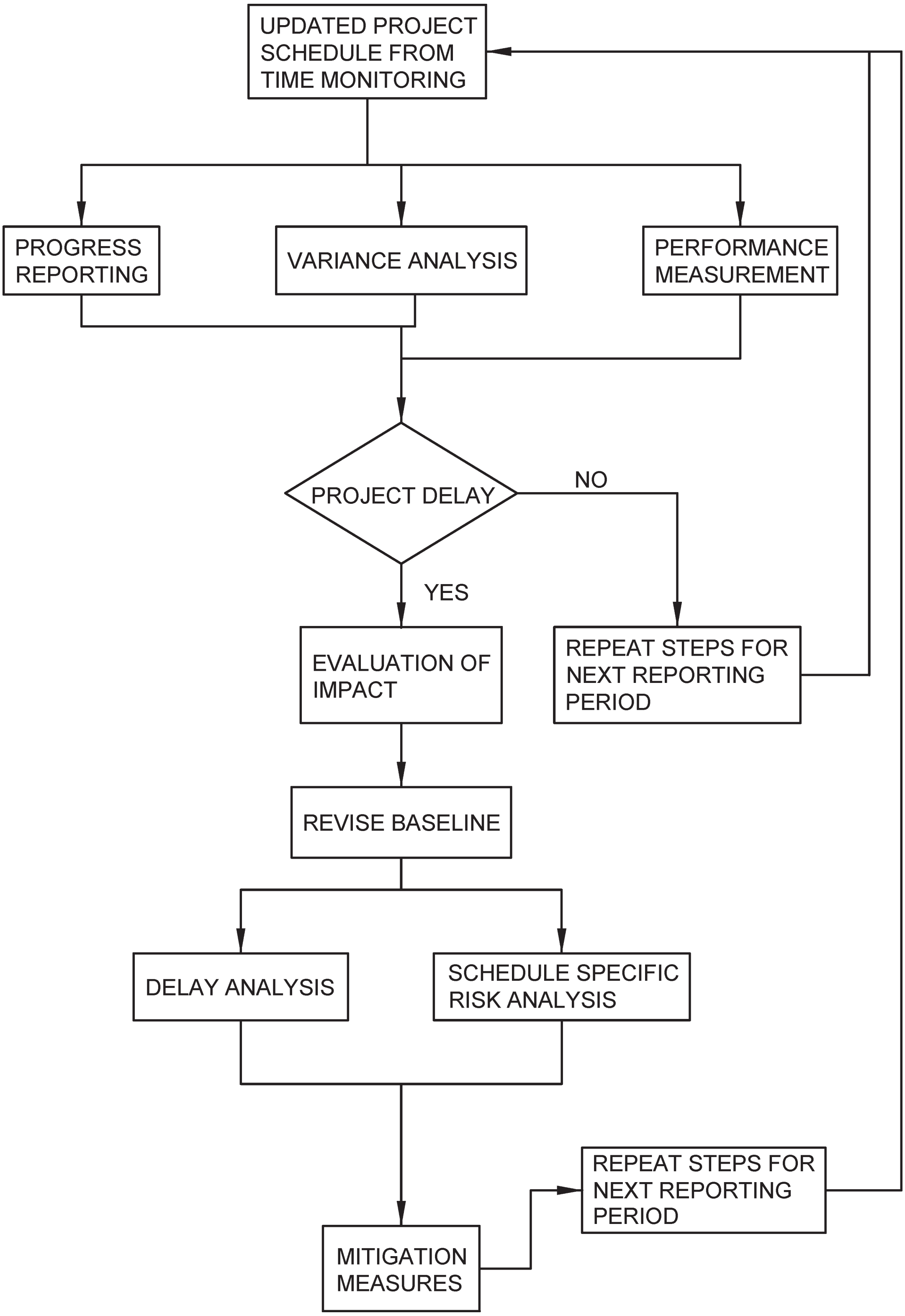


FIG. 7 TYPICAL FLOW CHART FOR TIME CONTROL

slip any further on account of these issues remaining unaddressed. Among others, these measures may include providing incentives to expedite the progress of works. Another measure may be to highlight to the contractor the liquidated damages and other contractual issues to make him aware of his contractual obligations and thus expedite the progress.

The next step shall be to identify and take measures whereby the delays encountered may be recovered and project is brought back on track. These measures result in accelerating the originally foreseen rate of progress of works, and are called acceleration measures.

6.3.5.1 *Acceleration measures*

Acceleration measures (or schedule compression measures) is an important tool for meeting schedule deadlines and project completion targets. Also termed as time-cost trade-off process (*see* Annex A), acceleration measures are formulated on the simple concept of buying time in the most cost effective and optimum fashion. A number of algorithmic techniques based on heuristics like modified Siemens method (*see* Annex A) are available for determining the optimum acceleration measures for a construction project.

6.3.5.1.1 *Additional resource mobilization*

The most common and simple form of acceleration measures adopted on construction projects is the deployment of additional resources. Extra labour, additional incentives, additional or longer shifts, multi-skilled labour crews are common methodologies adopted by construction project managers. Deployment of additional equipment on equipment-intensive activities is another common acceleration measure. A rule-of-thumb to be adopted in such decisions is that generally additional resource mobilization on critical activities is more effective than such deployments on non-critical activities. However, over-crowding and site-congestion which may result in lower production rate shall be avoided. It shall be necessary to match the supervisory and administrative resources.

6.3.5.1.2 *Change of construction technology including materials*

Adoption of efficient construction methods and/or more equipment intensive construction technologies to accelerate the schedule are commonly used strategies on construction projects. This may be identified and adopted during the control phase of the project through various types of analysis including constructability analysis.

6.3.5.1.3 *Change of design*

Change in design to accelerate the schedule is another commonly used strategy on construction projects. This strategy may be undertaken during the control phase of the project through value engineering and constructability analysis.

6.3.5.2 All these measures may have contractual implications which shall be looked into.

ANNEX A

(*Clauses* 6.1.8.4 *and* 6.3.5.1)

TIME-COST TRADEOFF

A-1 GENERAL

Time-cost tradeoff (also known as schedule crashing or schedule compression) is a process to reduce the project duration with a minimum increase in the project direct cost, by buying time along the critical path(s) where it can be obtained at the least cost. It is a procedure by which the project duration is reduced to threshold value normally assigned by the project owner. It is an important part of the time management process as project managers are often asked to meet an externally dictated shortened project schedule.

A-2 METHODS

A number of heuristics/algorithms are available in the literature for time-cost tradeoff. One of the commonly adopted/adapted time-cost tradeoff algorithms is called the Siemen's approximation method (SAM)[1)] of time cost tradeoff. The central principle on which SAM and in fact other similar algorithms are based is the time-cost slope of project activities. This is shown in Fig. 8. While estimating the duration of a construction activity the scheduler provides the estimate under a most likely scenario. This translates to the normal point on the time cost curve shown in Fig. 8. The direct cost associated with this point is called normal cost (C_N) and the duration estimate associated with this point is called normal time (T_N). In an effort to reduce the duration of the project activity a project manager will normally deploy more

[1)] Siemens, N., (1971) "A simple CPM time-cost tradeoff algorithm" Management Science, vol 17: B354-B363.

resources for the activity, for example, add more equipment, deploy additional labour, add labour work shifts, etc. All this translates to additional direct costs. So in general it is clear that as direct cost is increased the activity duration reduces. To simplify the calculations a linear time-cost relationship is assumed as shown in the figure below. Realistically there is a limit to the deployment of additional resources for a given activity beyond which additional deployment of resources may not result in any reduction in duration in fact activity duration may start increasing due to site congestion. This limiting point is shown as the crash point on the time-cost curve. The cost associated with this point is called crash cost (C_C) and the duration associated with this point is called crash time (T_C).

Figure 8 is then used to calculate the cost slope of the activity, which is the amount of money needed to reduce the duration of the activity under consideration by one day. For the cost slope calculations an estimate of the crash cost (C_C), normal cost (C_N), normal time (T_N) and crash time (T_C) are needed. These may be obtained from the historical databases or from experts. The equation used to calculate cost slope of an activity is provided below:

$$\text{Cost slope} = \frac{C_C - C_N}{T_N - T_C}$$

The cost slope equation given above is essential to perform the time cost tradeoff exercise on a given project network. The assumption used for the calculation is that there exists a linear relationship between time and cost of an activity. This is an approximation. Numerous enhancements such as piecewise linear approximation, non-linear relationship, etc are available in literature.

Steps used in the SAM algorithm are broadly as listed below:

a) Perform CPM calculations for the project network under consideration. Calculate the project normal duration (P_N).
b) Identify in consultation with the project stakeholders the required reduction in the project duration to establish the reduced project duration (P_R), where $P_N > P_R$.
c) From the project network identify all project paths. For each identified project path

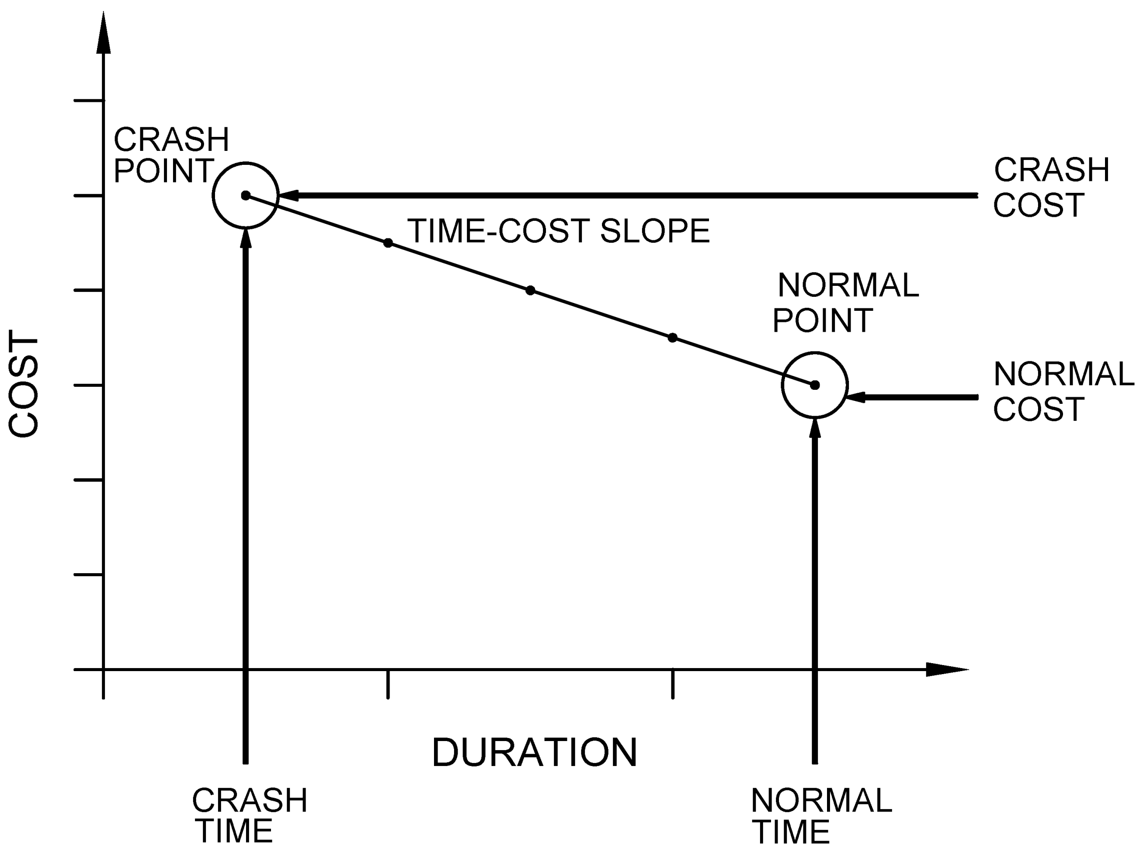


FIG. 8 TIME-COST CURVE

calculate its length by adding normal time of all activities on the path.

d) Compare each paths expected length with P_R. Select all the paths from the original list whose expected lengths are greater than the reduced project duration P_R. These are paths that require shortening.

e) Identify all activities present in at least one of the selected paths requiring shortening noting for each activity its cost slope and time reduction available.

f) Determine the effective cost slope of each identified activity where effective cost slope is defined as the cost slope of the given activity divided by the number of inadequately shortened paths which contain that activity.

g) For the path(s) with the highest time reduction required, select the activity with the lowest effective cost slope. Break ties by:

   1) giving preference to the activity which lies on the greatest number of inadequately shortened paths.

   2) giving preference to the activity which permits the greatest amount of shortening.

   3) choose an activity at random.

h) Shorten the selected activity as much as possible, which will be equal to the minimum of the following:

   1) the unallocated time remaining for the selected activity or

   2) the smallest demand of those inadequately shortened paths containing the activity

      i) Continue the process till all the path needing shortening are below the desired threshold, that is, P_R. Once this condition is met the shortening process can be stopped. A strategy for project duration reduction is now available along with the increased cost.

Some scheduling software implement the time-cost tradeoff procedure using proprietary algorithms.

ANNEX B

[*Clauses* 6.2.5 (a), 6.3.1(c)(3) *and* 6.3.3]

EARNED VALUE MANAGEMENT (EVM) TECHNIQUE

B-1 GENERAL

Earned value management (EVM) technique is used to track the progress and status of a project and forecast the likely future performance of the project. The EVM technique integrates the scope, schedule and cost of a project. It answers a lot of questions to the stakeholders in a project related to the performance of the project. EVM technique can be used to evaluate past performance of the project, current performance of the project and predict the future performance of the project by use of statistical techniques. Good planning coupled with effective use of the EVM technique reduces a large amount of uncertainties arising out of schedule and cost overruns. There are following three basic elements of EVM, which are taken into account on a regular basis:

a) Planned value (PV),
b) Actual cost (AC), and
c) Earned value (EV).

B-1.1 Planned Value (PV)

This is also referred to as budgeted cost of work scheduled (BCWS). Planned value (PV) or BCWS is the total cost of the work scheduled/planned as of a reporting date. It may be calculated as:

PV or BCWS = Hourly rate × Total hours planned or scheduled

NOTE — Hourly rate is the rate at which effort will be valued.

B-1.2 Actual Cost (AC)

This is also referred to as actual cost of work performed (ACWP). Actual cost (AC) or ACWP is the total cost taken to complete the work as of a reporting date. This may be calculated as:

AC or ACWP = Hourly rate × Total hours spent

B-1.3 Earned Value (EV)

This is also referred to as budgeted cost of work performed (BCWP). Earned value (EV) or BCWP is the total cost of the work completed/performed as of a reporting date. It may be calculated as follows:

EV or BCWP = Baseline cost × Percent complete of actual work

B-1.4 All these three elements can be derived from work breakdown structure by associating the costs to each of the tasks. For a big project it will be a tedious task to calculate these elements manually. Scheduling softwares are used to calculate these three elements.

B-1.5 Cost Variance (CV)

Cost variance (CV) is very important factor to measure project performance. Cost variance (CV) indicates how much over or under budget the project is. It may be calculated as follows:

CV = Earned value (EV) – Actual cost (AC)

or

CV = BCWP – ACWP

The formula mentioned above gives the variance in terms of cost which will indicate how less or more cost has been to complete the work as of date. Positive cost variance indicates the project is under budget and negative cost variance indicates the project is over budget (*see* Fig. 9).

B-1.5.1 *Cost Variance Percent (CV Percent)*

It indicates how much over or under budget the project is in terms of percentage. It may be calculated as follows:

$$\text{CV percent} = \frac{\text{Cost variance (CV)}}{\text{Earned value (EV)}}$$

or

$$\text{CV percent} = \frac{\text{CV}}{\text{BCWP}}$$

The above formula gives the variance in terms of percentage which will indicate how much less or more money has been used to complete the work as planned in terms of percentage. Positive variance percent indicates percent under budget and negative variance percent indicates percent over budget.

B-1.6 Cost Performance Indicator (CPI)

Cost performance indicator is an index showing the

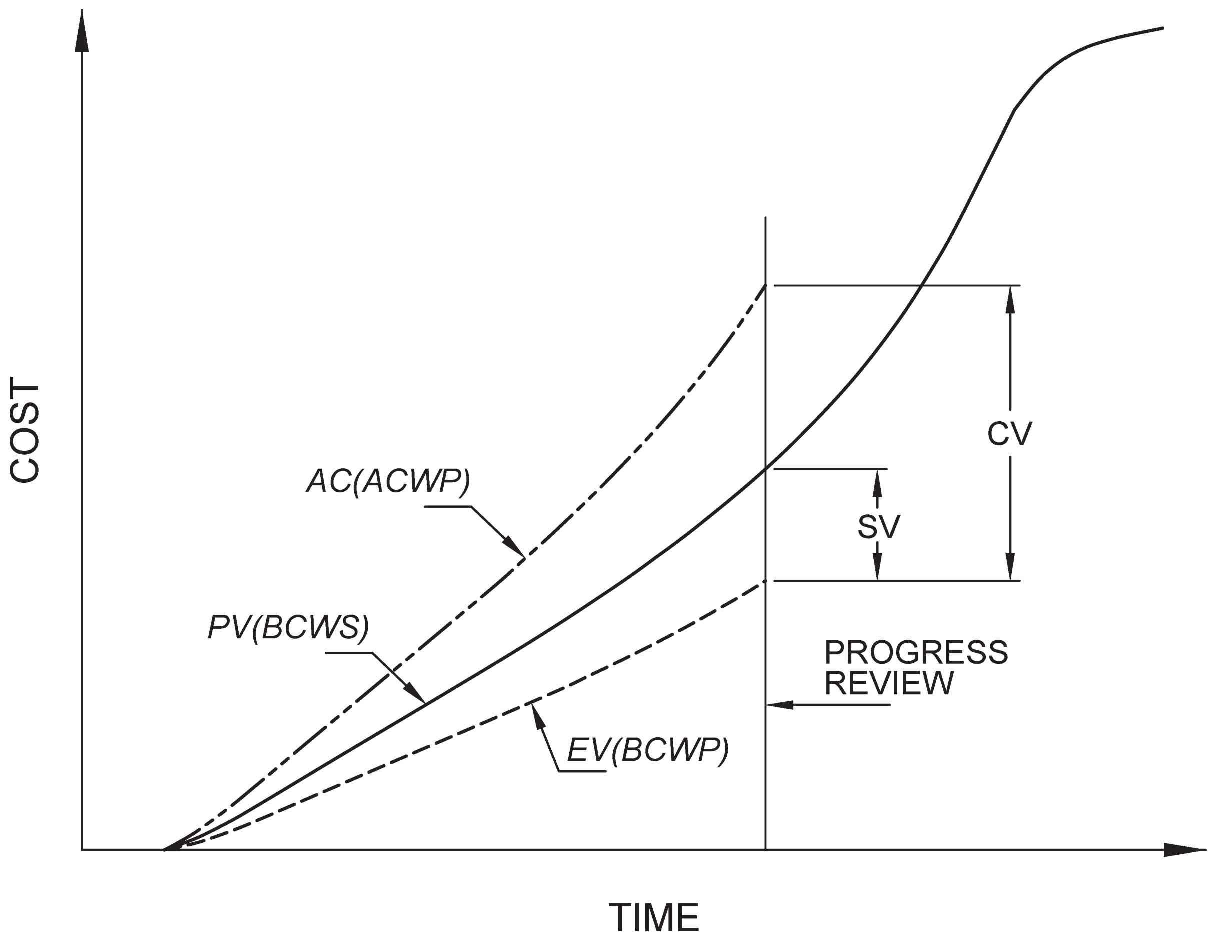


FIG. 9 EVM GRAPH

efficiency of the utilization of the resources on the project. It may be calculated as follows:

$$CPI = \frac{\text{Earned value (EV)}}{\text{Actual cost (AC)}}$$

or

$$CPI = \frac{BCWP}{ACWP}$$

The formula mentioned above gives the efficiency of the utilization of the resources allocated to the project. CPI value above 1 indicates efficiency in utilizing the resources allocated to the project is good and that below 1 indicates efficiency in utilizing the resources allocated to the project is not good (*see* Fig. 10).

B-1.6.1 *To Complete Cost Performance Indicator (TCPI)*

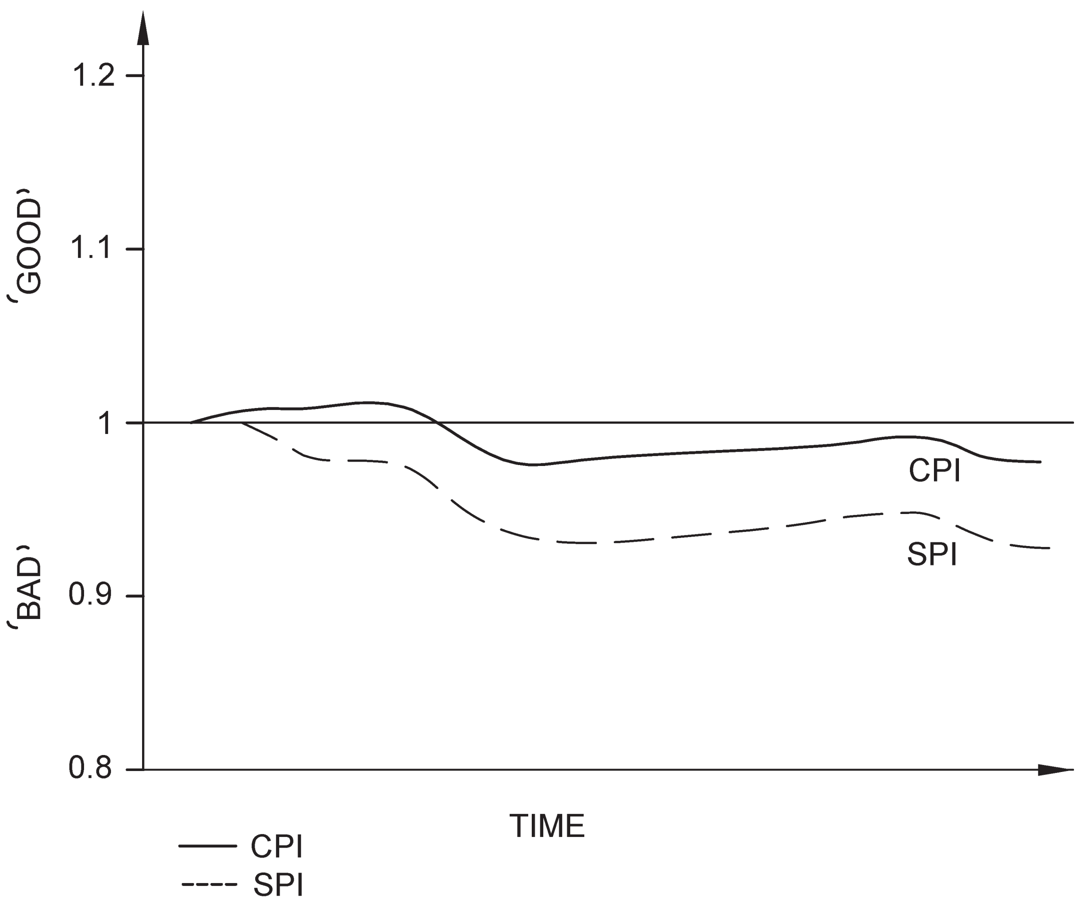
It is an index showing the efficiency at which the resources on the project should be utilized for the rest of the project. This can be calculated as follows:

$$TCPI = \frac{\text{Total budget} - EV}{\text{Total budget} - AC}$$

or

$$TCPI = \frac{\text{Total budget} - BCWP}{\text{Total budget} - ACWP}$$

The formula mentioned above gives the efficiency at which the project team should be utilized for the rest of the project. TCPI value above 1 indicates utilization



$$CPI = \frac{BCWP}{ACWP}$$

$$SPI = \frac{BCWP}{BCWS}$$

FIG. 10 SPI AND CPI GRAPH

of the project team for the rest of the project can be lenient and that below 1 indicates utilization of the project team for the rest of the project should be stringent.

B-1.7 Schedule Variance (*SV*)

Schedule variance indicates how much ahead or behind schedule the project is. It may be calculated as follows:

$$\text{Schedule variance (SV)} = \text{Earned value (EV)} - \text{Planned value (PV)}$$

or

$$\text{Schedule variance (SV)} = \text{BCWP} - \text{BCWS}$$

The formula mentioned above gives the variance in terms of cost which will indicate how much cost of the work is yet to be completed as per schedule or how much cost of work has been completed over and above the scheduled cost. Positive schedule variance indicates project work being ahead of schedule and negative schedule variance indicates work being behind the schedule (*see* Fig. 9).

B-1.7.1 *Schedule Variance Percent (SV Percent)*

It indicates how much ahead or behind schedule the project is in terms of percentage. It can be calculated as follows:

$$\text{SV percent} = \frac{\text{Schedule variance (SV)}}{\text{Earned value (EV)}}$$

or

$$\text{SV percent} = \frac{\text{SV}}{\text{BCWP}}$$

The formula mentioned above gives the variance in terms of percentage which indicates how much percentage of work is yet to be completed as per schedule or how much percentage of work has been completed over and above the scheduled cost. Positive variance percent indicates percent ahead of schedule and negative variance percent indicates percent behind of schedule.

B-1.8 Schedule Performance Indicator (SPI)

Schedule performance indicator is an index showing the efficiency of the time utilized on the project. Schedule performance indicator can be calculated using the following formula:

$$\text{SPI} = \frac{\text{Earned value (EV)}}{\text{Planned value (PV)}}$$

or

$$\text{SPI} = \frac{\text{BCWP}}{\text{BCWS}}$$

The formula mentioned above gives the efficiency of the project team in utilizing the time allocated for the project. SPI value above 1 indicates project team is very efficient in utilizing the time allocated to the project and that below 1 indicates project team is less efficient in utilizing the time allocated to the project (*see* Fig. 10).

B-1.8.1 *To Complete Schedule Performance Indicator (TSPI)*

It is an index showing the efficiency at which the remaining time on the project should be utilized. This can be calculated using the following formula:

$$\text{TSPI} = \frac{\text{Total budget} - \text{EV}}{\text{Total budget} - \text{PV}}$$

or

$$\text{TSPI} = \frac{\text{Total budget} - \text{BCWP}}{\text{Total budget} - \text{BCWS}}$$

The formula mentioned above gives the efficiency at which the project team should utilize the remaining time allocated for the project. TSPI value above 1 indicates project team can be lenient in utilizing the remaining time allocated to the project and that below 1 indicates project team needs to work harder in utilizing the remaining time allocated to the project.

B-1.9 Budget at Completion (BAC)

Budget at completion (BAC) is the total budget allocated to the project. It is generally plotted over time, like periods of reporting (monthly, weekly, etc). It is used to compute the estimate at completion (EAC) (*see* **B-1.11**). BAC is also used to compute the TCPI and TSPI (*see* Fig. 11). It is calculated as follows:

$$\text{BAC} = \text{Baselined effort hours} \times \text{Hourly rate}$$

B-1.10 Estimate to Complete (ETC)

Estimate to complete (ETC) is the estimated cost required to complete the rest of the project. It is calculated and applied when the past estimating assumptions become invalid and a need for fresh estimates arises. ETC is used to compute the estimation at completion (EAC).

B-1.11 Estimate at Completion (EAC)

Estimate at completion (EAC) is the estimated cost of the project at the end of the project (*see* Fig. 11). There are three methods to calculate EAC, as follows:

a) *Variances are typical* — This method is used when the variances at the current stage are typical and are not expected to occur in the future. In this method, EAC is calculated as AC + (BAC – EV).

b) *Past estimating assumptions are not valid* — This method is used when the past estimating assumptions are not valid and fresh estimates are applied to the project. In this method, EAC is calculated as AC + ETC.

c) *Variances will be present in the future* — This method is used when the assumption is that the current variances will be continued to be present in future. In this method, EAC is calculated as AC + (BAC – EV) / CPI.

B-1.12 Variance at Completion (VAC)

Variance at completion (VAC) is the variance on the total budget at the end of the project. This is the difference between what the project was originally expected (baseline) to cost, *versus* what it is now expected to cost. It is calculated as follows (*see* Fig. 11):

$$\text{VAC} = \text{BAC} - \text{EAC}$$

B-1.13 Percent Completed Planned

The percent completed planned is the percentage of work which was planned to be completed by the reporting date. This is calculated using the following formula:

$$\text{Percent completed planned} = \frac{\text{PV}}{\text{BAC}}$$

B-1.14 Percent Completed Actual

The percent completed actual is the percentage of work which was actually completed by the reporting date. This is calculated using the following formula:

$$\text{Percent completed actual} = \frac{\text{AC}}{\text{EAC}}$$

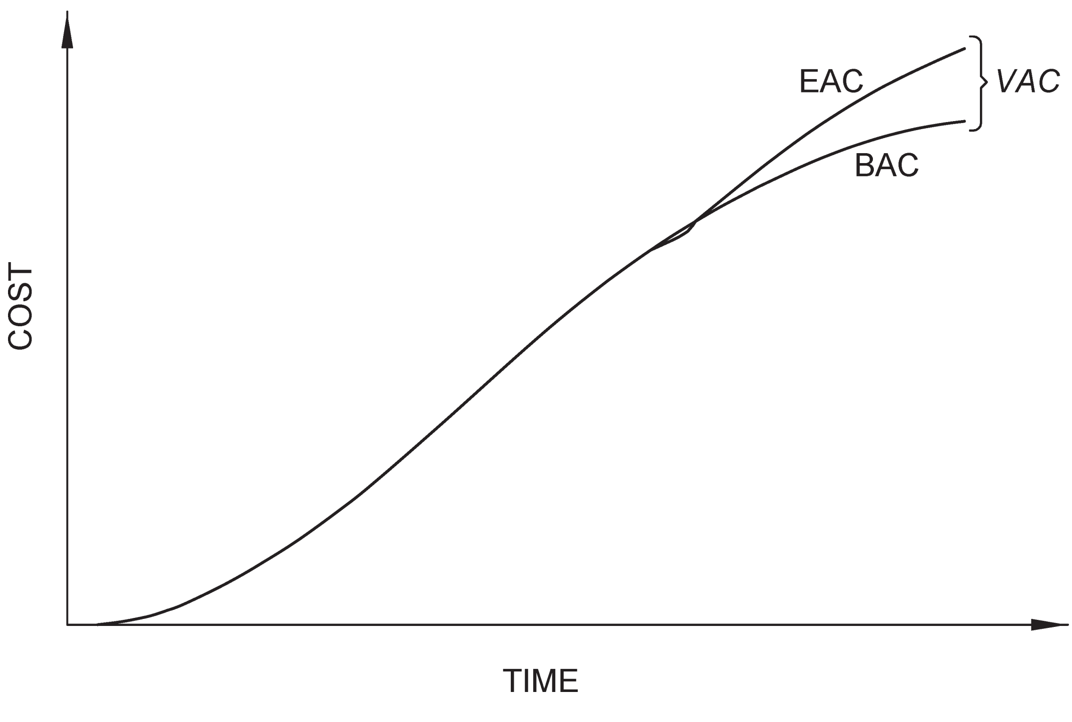


FIG. 11 VAC GRAPH

ANNEX C

[*Clauses* 6.2.5 (c), 6.3.1(c)(2) *and* 6.3.3]

SAMPLE TIME MONITORING BASED ON WEIGHTAGE CONCEPT (*S*-CURVE)

C-1 GENERAL

To summarize the status of various activities of a construction project a single common measurement parameter, namely, project metric, is required. One of the simple solutions for this is by assigning a pre-agreed percent weightage for all the activities of the project. The weightages of all activities are summed up and plotted as a cumulative planned curve which is usually in the shape of English alphabet 'S'. This *S*-curve plotted for planned and actual metric may be used as an efficient tool for time monitoring.

S-curve can be prepared at all levels of WBS and each work element of the project can be individually monitored and status summary prepared. The *S*-curve prepared at total project level is a weighted summation of all the sub-activities in the work breakdown structure.

S-curve is a useful MIS tool for time monitoring which depicts pictorially the status of an updated schedule of the project, the tool is useful for decision-making during the time control.

C-2 PROCEDURE FOR *S*-CURVE PREPARATION

For allocation of weightages to various works packages within a project, the following three criteria are to be considered:

a) Criticality/importance of work package,
b) Tentative tendering cost, and
c) Level of effort required.

Within the works package weightages are further distributed to each progress phase of work totalling up to 100 percent, that is,

a) Design : X percent (say 5 percent)
b) Procurement : Y percent (say 40 percent)
c) Construction : Z percent (say 50 percent)
d) Testing and Commissioning : T percent (balance 5 percent)

The distribution is standardized across all the work packages in a project.

The weightages are further distributed within the above four phases across activities on vertical scale. Following distribution criteria are to be considered:

a) Level of efforts/skill level of tradesman required for implementation.
b) Based on sub-critical path within a works package driven by its own intermediate completion milestone.
c) For procurement activities, lead time for delivery and availability in the market.

Weightages are assigned (total 100 percent distributed on horizontal scale) to different work phases of each activity.

Table 1 to Table 4 give a sample distribution of weightages to different phases across vertical and horizontal scales for a work package.

Against each activity in Tables 1 to 4 BOQ unit is chosen as a progress representative. The baseline schedule from time planning process determines the distribution of the metrics on the project timeline.

Table 1 Typical Example for Design

(*Clause* C-2)

Sl No.	Phase Design	Percent Weightage ×	Scope	Submissions 35 percent	Conditional Approval 55 percent	Final Approval 10 percent
VERTICAL ↓	Activity 1	X 1		Stages in Horizontal Scale →		
	Activity 2	X 2				
	Activity 3	X 3				
	Total	**X**				

Table 2 Typical Example for Procurement
(*Clause* C-2)

Sl No.	Phase	Percent Weightage	Scope	Raw Material at Vendor Premises/PO Release	Manufacturing	Testing During Manufacturing	Dispatch of Material	Delivery to Site
	Procurement	**Y**		**10 per cent**	**35 percent**	**15 percent**	**20 percent**	**20 percent**
VERTICAL	Activity 1	Y 1			Stages in Horizontal Scale →			
	Activity 2	Y 2						
	Activity 3	Y 3						
	Total	**Y**						

Table 3 Typical Example for Construction
(*Clause* C-2)

Sl No.	Phase	Percent Weightage	Scope	Preparatory Works	Installation	Checking/Inspection
	Construction	**Z**		**15 percent**	**80 percent**	**5 percent**
VERTICAL	Activity 1	T 1			Stages in Horizontal Scale →	
	Activity 2	T 2				
	Activity 3	T 3				
	Total	**Z**				

Table 4 Typical Example for Testing and Commissioning
(*Clause* C-2)

Sl No.	Phase	Percent Weightage	Scope	Pre-commissioning	Commissioning	Performance	System Integration
	T & C	**T**		**30 percent**	**40 percent**	**10 percent**	**20 percent**
VERTICAL	Equipment 1	T 1		Stages in Horizontal Scale →			
	Equipment 2	T 2					
	Equipment 3	T 3					
	Total	**Z**					

The baseline *S*-curve for a project is prepared from its baseline schedule by distributing the progress metrics along each activity duration and summarized from bottom up in the work breakdown structure.

The metrics identification and distribution can be done upto Level 3 or below of the baseline schedule depending on the complexity level of works package within a project.

A sample distribution of metrics based weightages across the project duration is shown in Table 5.

The weightage distribution at different WBS levels is plotted across time scale in the form of a curve. The monthly values are plotted as bars and cumulative values points at the end of each month are joined smoothly to form *S* shaped curve for time monitoring (*see* Fig. 12).

Table 5 Typical Example Showing Sample Distribution of Metrics Based Weightages Across Project Duration

(*Clauses* C-2 *and* C-2.1)

Phases on Vertical Axis	Sl No.	Scope		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18
	Design	100%	Monthly	0.5%	8%	15%	20%	20%	20%	16%											
			Comu.	1%	9%	24%	44%	64%	84%	100%											
	Procure-ment	100%	Monthly		0%	2%	9%	18%	20%	16%	12%	8%	8%	7%							
			Comu.		0%	2%	11%	29%	49%	65%	77%	85%	93%	100%							
	Const-ruction	100%	Monthly				0%	2%	7%	9%	12%	15%	18%	18%	8%	6%	3%	2%			
			Comu.				0%	2%	9%	18%	30%	45%	63%	81%	89%	95%	98%	100%			
	T & C	100%	Monthly												0%	12%	18%	22%	20%	16%	12%
			Comu.												0%	12%	30%	52%	72%	88%	100%

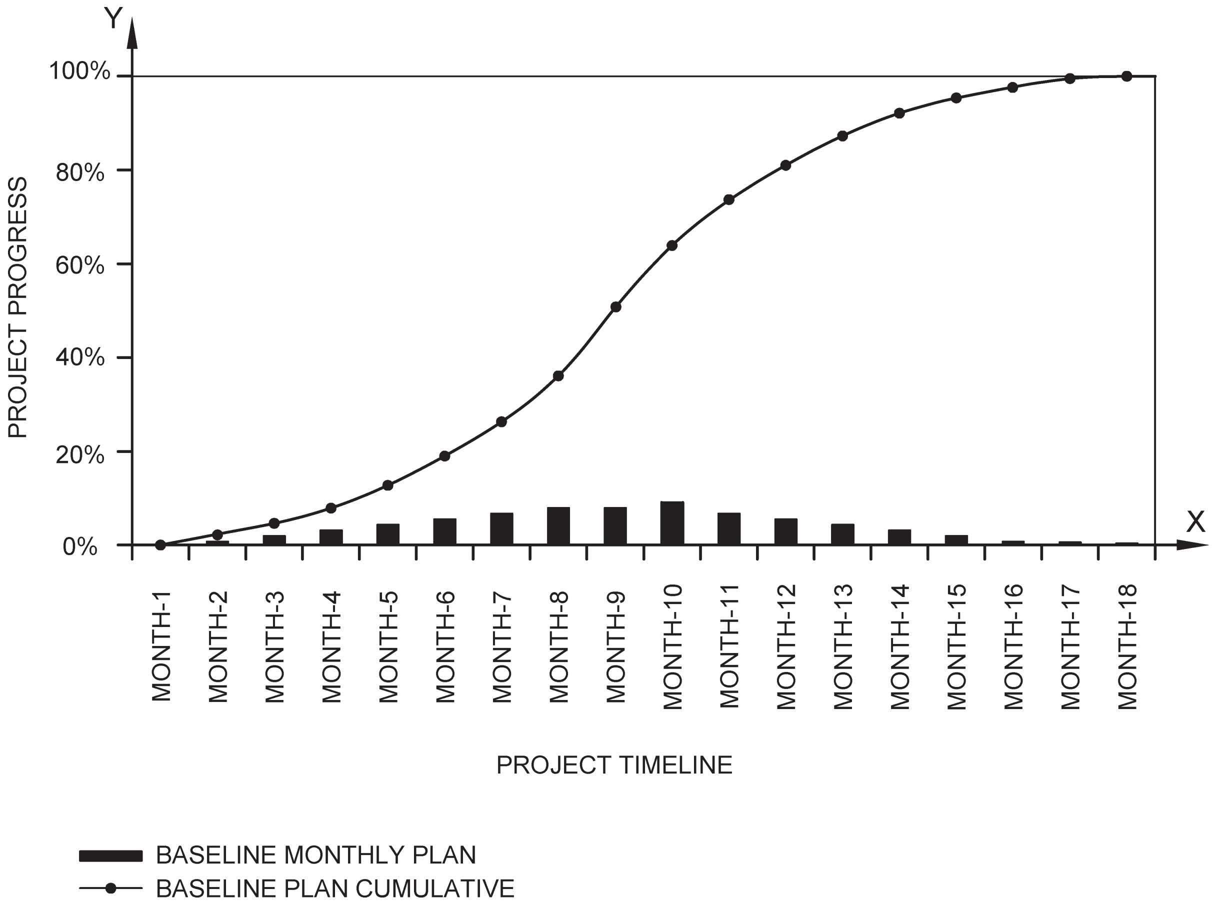


FIG. 12 BASELINE PLAN

The timescale for metrics distribution and curve plotting can be month, week or even days depending on the nature of project and level of monitoring required for the project.

C-2.1 Identification and Monitoring Procedure Standardization

As the project progresses, the actual performance of works packages and its activities are tracked against its planned value as given in Table 5 and a new actual *S*-curve is plotted along with its baseline *S*-curve (*see* Fig. 13).

The reasons for deviation can be ascertained by drilling down to lower levels in WBS of the project. This analysis becomes input for time control and decision-making for mitigation.

The time control procedure in **6.3** determines revised plan and activities metrics for future activities. The weightage distribution is reworked for future activities of the project and plotted in dotted line as a forecast curve. If the actual progress is behind the baseline and if it is possible for the backlog to be recovered either before or by the baseline completion time this is deemed as 'catching up', and the distribution plotted for this is called the catch-up curve (*see* Fig. 14).

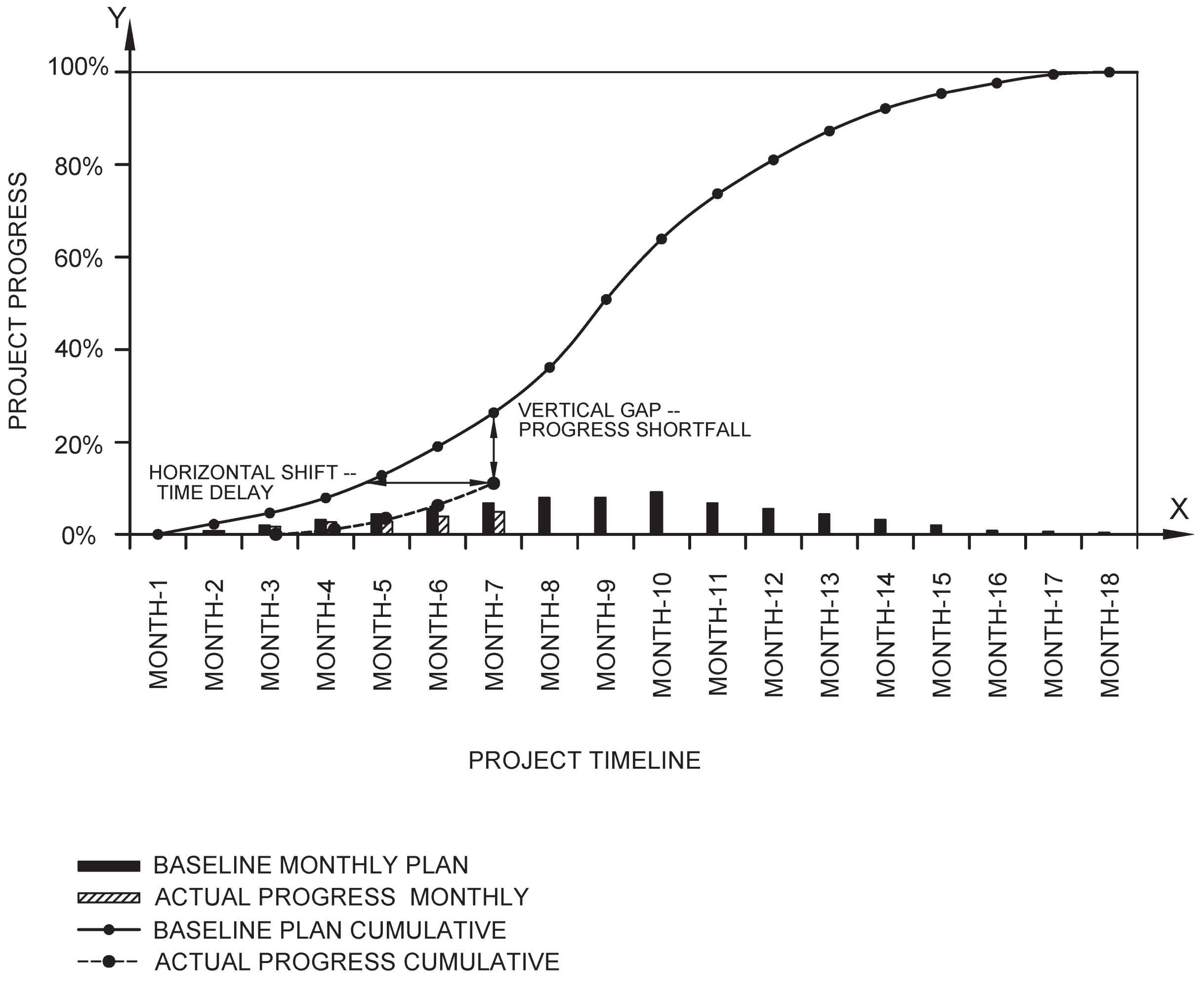


FIG. 13 BASELINE *VERSUS* ACTUAL PROGRESS

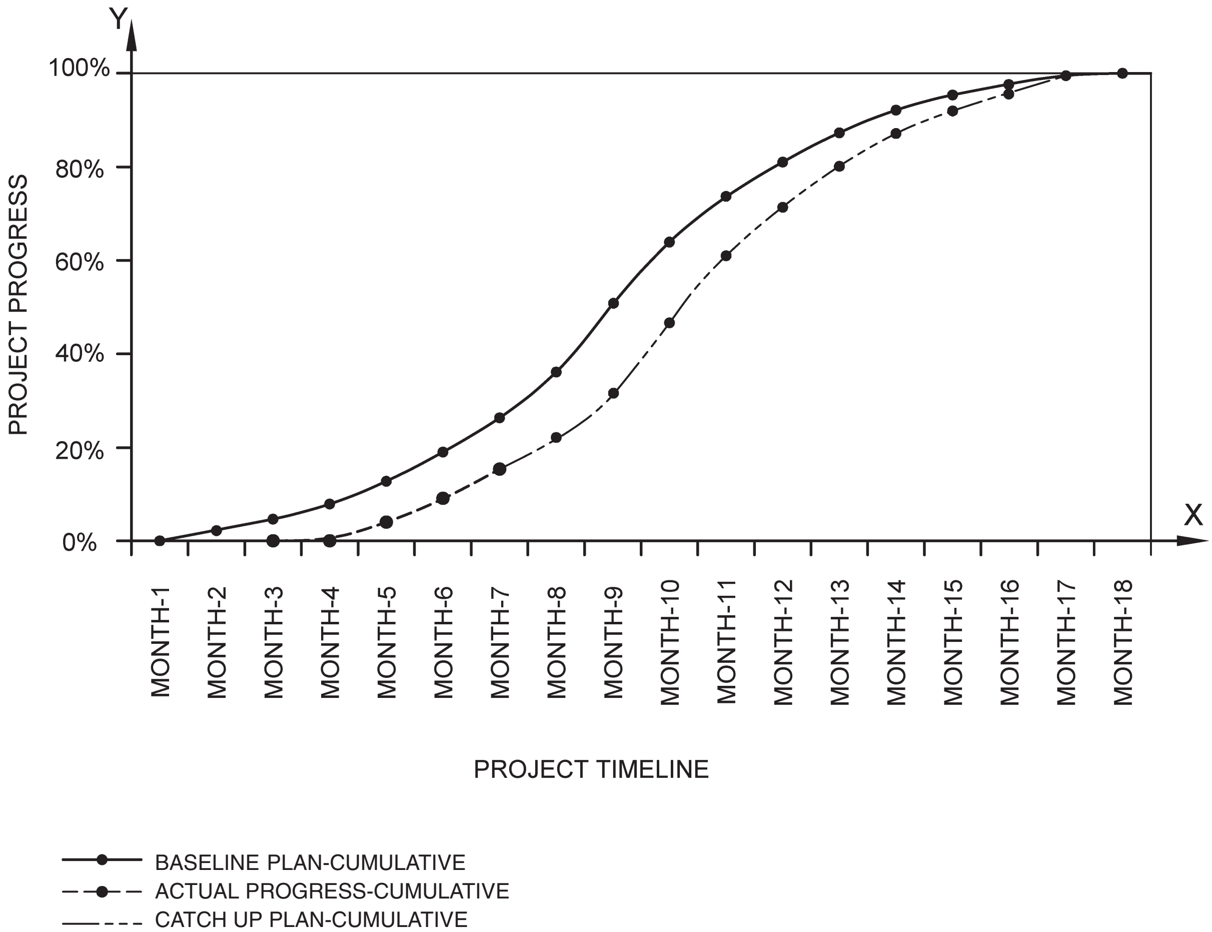


FIG. 14 CATCH-UP PLAN

ANNEX D
(*Foreword*)

COMMITTEE COMPOSITION

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