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BASICS OF CONSTRUCTION MANAGEMENT

Ministry of Agriculture, Forestry and Fisheries
Japan International Cooperation Agency
Japanese Institute of Irrigation and Drainage

BASICS OF CONSTRUCTION MANAGEMENT

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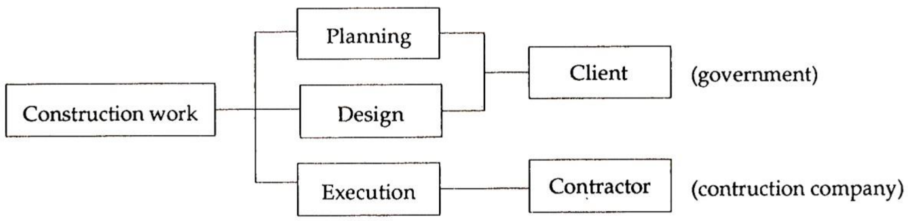
The process of construction work, from awarding the contract through execution, generally comprises the following activities:

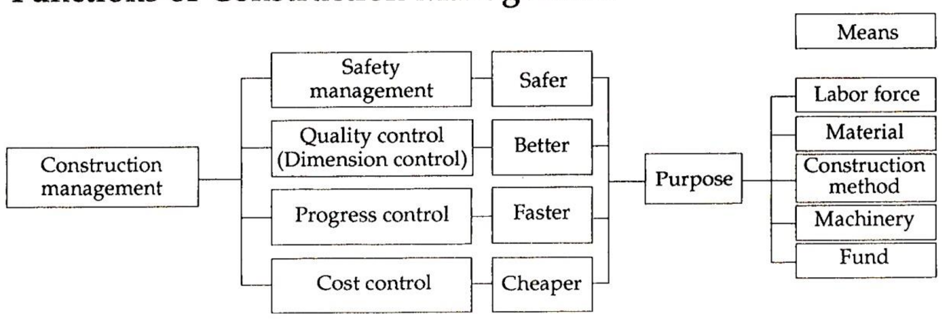


With the increase in size and diversification of construction works and with the increase in complexity and sophistication of construction projects, integration of understanding the project between the owner and contractor, as well as consistency in the planning, design, and execution, are required. In order to accomplish the original purpose of a particular construction project, construction management is playing an increasingly important role.

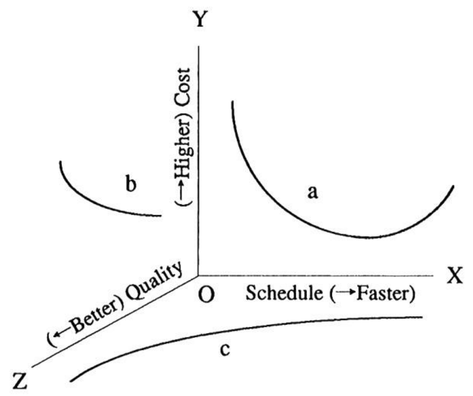
1.1 Construction Management

Construction management involves the selection of labor force, material, construction method, machinery, equipment, funds, and other resources (means of production) which are available for the construction project, and by utilizing these resources, to achieve the primary purposes of safety, quality, schedule and economy of construction work.

1.2 Functions of Construction Management



The quality control, and the cost control require different methods, procedures, organization and system. (Safety control is required to satisfy certain requirements.) At the same time, the control functions are not completely separated from each other. Rather, they are interrelated within a context (framework) of construction management. In any construction project, the following relationships are known to exist among the quality, schedule, and cost.



General Relations among Quality, Schedule, and Cost in Construction Project

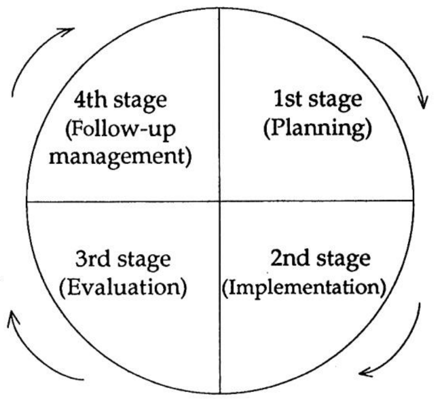
① In the relationship between the schedule and the cost as shown in curve "a", the cost per unit quantity decreases with an increase in progress rate, which increases the quantity to be completed. However, the unit cost increases again beyond a certain point where the work is executed continuously.

② In the relationship between the cost and quality as shown in curve "b", the quality is proportional to the cost.

③ In the relationship between the quality and schedule as shown in curve "c", the quality is proportional to the time spent in construction.

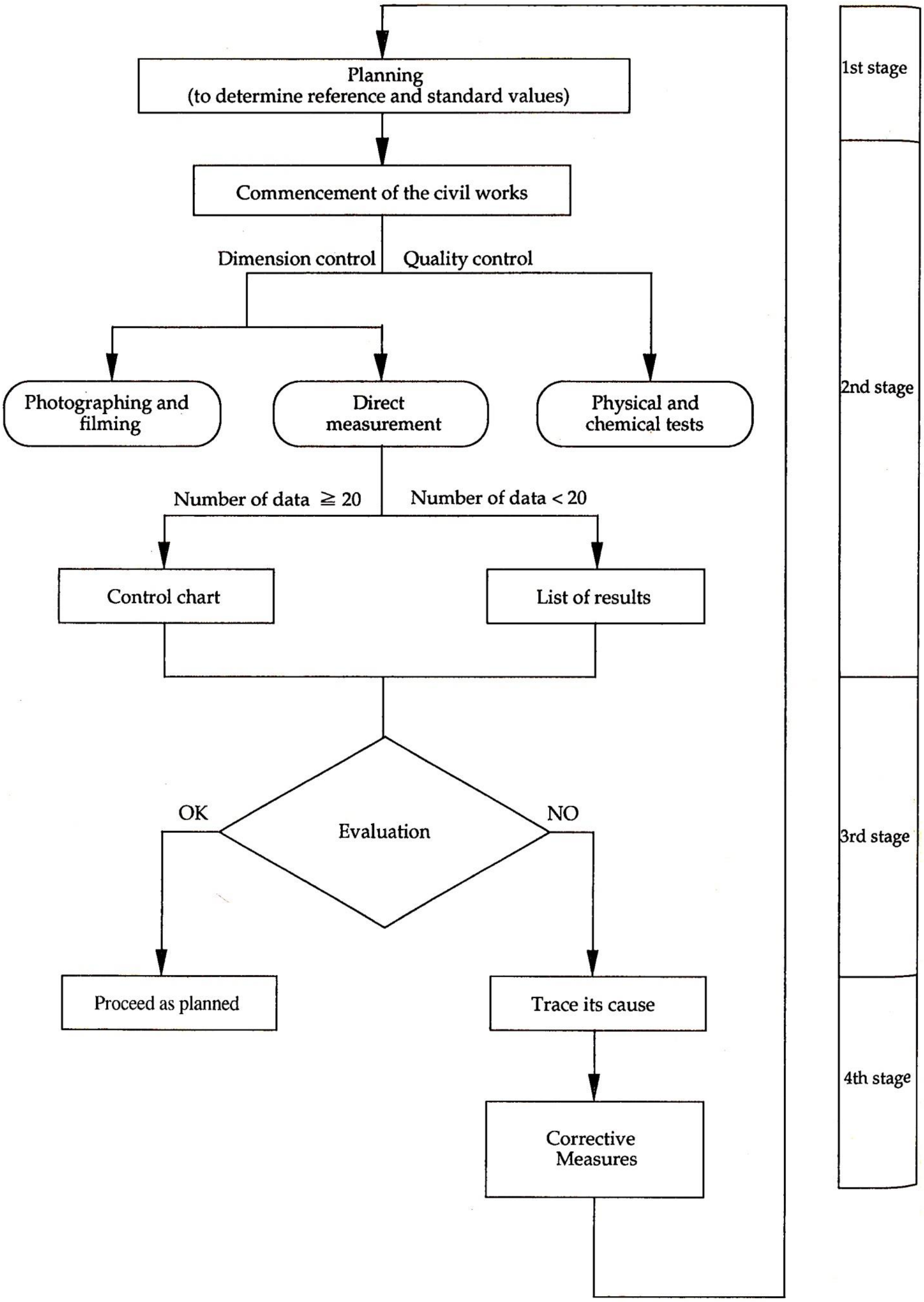
As seen above, both positive and negative relations exist among the quality, schedule, and cost. Thus, the primary purpose of construction management is to prepare the construction plan and execute the project in such a manner as to coordinate (combine appropriately) these three elements so as to minimize the cost, to maximize the quality and to satisfy the schedule.

1.3 Procedures in Construction Management



The construction management proceeds with a repetitive cycle consisting of planning, implementation, evaluation, and follow-up management.

At the planning stage, a plan and standards to execute a project "with good quality, quickly, cheaply, and safely are made". Then, while the work is executed in accordance with the plan and standards, related data is accurately monitored and recorded. The data is compared with the plan, and if any deviation or difference is found, the plan is revised to reflect actual working conditions or the work is improved to eliminate any factor which causes the result to fall short of the plan and standards.



Flow chart of construction management procedures

1.4 Characteristics of Construction Work and Construction Management

Construction management should be carried out by keeping in mind that buildings and structures completed by construction works have the following characteristics which are quite different from those of other products which are manufactured at a factory.

(1) Immobile on land
Once completed, the building or structure cannot be easily repaired or replaced. As a result, careful and strict check is required at various stages of construction management.

(2) Constructed at site
Since the work environment is considerably varied depending on local and environmental conditions, it is difficult to apply statistical techniques to construction management.

(3) Custom-made in nature
As the combination of construction methods varies with project sizes, uniform and standardized construction management is difficult.

(4) Difficult to establish efficient and accurate testing methods

1.5 Construction Planning

1.5.1 Planning

Construction plan is to ensure that the project is safe and establish a sequence of (within the specified time and cost in accordance with drawings and specifications, construction method and procedure) how the work is supervised, inspected, and tested, and it forms a basis of work execution and construction management.

Construction work has different types, sizes, and locations and construction conditions are different from one to another. Also, with the increasing use of equipment and machinery, the project size and nature are becoming larger and complex. To execute these works in systematic and organized ways, the construction plan appropriate for each work needs to be carefully prepared.

Also, public works which may produce traffic blockage, temporary suspension of utility service, noise and vibration (the work in or near public roads, and sanitary work requires temporary suspension of utility service) are often required to specify work period and time, in order to coordinate the work with related authorities.

Therefore, a detailed construction plan suitable for local conditions must be established prior to execution so as to ensure that the work is carried out in accordance with the specified schedule.

Since the construction plan serves as a basis for overall construction work, it must be prepared while keeping in mind (1) to fully investigate and understand the project nature, contract terms, and site conditions, and (2) to achieve purposes of quality assurance, on-time completion, cost minimization, and safety assurance for the project.

Although shapes, dimensions, quantities, and qualities of the project are specified in drawings and specifications, temporary work, construction method and other means of completing the project have equal importance. In this respect, the technical capability and experience of the owner and contractor need to be fully integrated to prepare the construction plan to accomplish the purposes of "high quality", "fast completion", "low cost", and "safe work".

Furthermore, many parts of construction work cannot be checked visually after completion, so that representatives of the client need to be involved in construction management in a supervisory capacity. As a result, both the client and the contractor should have meetings before preparing the construction plan.

1.5.2 Elements of Construction Planning

(1) Project outline

① Project name

② Client

③ Contractor

④ Site location

⑤ Contract amount

⑥ Project period

⑦ Project description

Statement to describe major works

(2) Management organization

① Manpower organization: Chart and diagram to describe organization, component, and discipline of contractor's project team

② Safety management organization: Chart and statement to describe safety management, emergency communication, safety measures and facilities, crime and pollution control measures, safety management meeting, safety patrol, inspection and verification system, and implementation programs.

③ Manpower planning: Estimation of semi-monthly and monthly work force

④ Subcontractors: Name, trade, address, superintendent, and work force of each subcontractor.

(3) Temporary work plan

① Temporary material list: List to specify temporary material's name, standard size, quantity, maker, and vendor.

② Temporary building and structure: Statement and drawing to describe locations and plan of site office, labor's camp, supervisor's residence, material stockyard.

③ Safety facility: Statement and drawing to describe safety and pollution control measures.

④ Leased land and restoration: Statement and drawing to describe land leased by the government and the contractor and methods of restoration.

⑤ Temporary facility plan: Statement and drawing to describe equipment specified in design documents and major temporary facilities (temporary work, scaffold, security fence, access road, and access bridge)

⑥ Others

(4) Construction plan

① Bill of quantity

② Execution plan: Statement and drawing to describe the construction sequence and method of major works, and other related activities (such as construction method for works adjacent to housing, railway, and road, works involving underground structure, important temporary work, and works relating to noise, vibration, waste discharge and other pollution control measures for surrounding community).

③ Construction machinery utilization plan: List to describe the name, type, specification, quantity, and use of construction machinery.

④ Major materials: List to describe the name, standard dimension, quantity, maker, and delivery date of major materials.

(5) Construction management

① Work-task control: Diagram to show the construction schedule according to work task, and statement to describe the method of controlling their progress.

② Quality control: Statement to describe the concept, policy, and method of contractor on quality control.

③ Production control: Statement to describe production control items in accordance with specified standards and the method of production control.

Chapter 2 Roles of Construction Management

Items related to construction management referred to in various types of documents are described as follows:

2.1 Construction Contract and Construction Management

2.1.1 Article 1, Standard Form of Contract

The client and the Contractor shall perform the Agreement on project described in the Standard Form of Contract in accordance with provisions hereof and contract drawings, specifications, explanation of project for contract, and responses to questions on the explanation.

2.1.2 Article 1-6, General Specifications for Construction Work "Construction Management"

The construction management shall be performed in accordance with the Specifications, Contract Drawings, and/or Special Specifications.

2.1.3 Special Specifications for Construction Project

The construction management shall be performed in accordance with the accompanying "Construction Management Standard for Civil Works" established by the Agricultural Structure Improvement Bureau of the Ministry of Agriculture, Forestry, and Fisheries.

2.1.4 "Performance of Construction Management" in the Construction Management Standard for Civil Works

(1) The Contractor shall appoint the Project Manager responsible for management of the Project and notify the Superintendent of the appointment. The Project Manager shall be responsible for construction management of the Project and shall perform faithful management in accordance with the Standard.

(2) The construction management shall be performed in accordance with methods and procedure set forth in Appendix I "Dimension Control by Direct Management", Appendix II "Dimension Control through Photographs and Films", and Appendix III "Quality Control". Any matters which are not provided for in the Standard and/or the Special Specifications shall be dealt with in accordance with instructions of the superintendent.

(3) The construction management shall be performed promptly in accordance with the progress of work, and the results shall be reported to the Supervisor for verification.

(4) Control charts, tables and/or construction management report shall be prepared and submitted to the Supervisor at the time of the Completion Inspection or Interim Inspection.

(5) All costs and expenses related to the Construction Management shall be borne by the Contractor.

As stipulated above, the construction management is a part of the contractual obligations which the contractor has in accordance with the Civil Work Management Standard. In other words, the construction management is an integral part of the contract, and only when requirements for the construction management are satisfied can the project be inspected for final completion.

Cost and expenses required for the construction management are included as engineering fees of general temporary construction cost. Generally, they are allowed for the following four items in the form of a fixed percentage of each work.

① Costs and expenses required for quality control related tests

② Costs and expenses required for survey and photographing for the purpose of dimension control

③ Costs and expenses required for preparation of documents for progress control

④ Other costs and expenses required for preparation of documents for technical control

2.2 Client and Contractor during the Construction

As civil works often encounters unforeseeable conditions in aspects of topography, geology and ground water, the contractor is required to consult with the client for instruction. Also, as the quality of civil works cannot be fully inspected after completion, it needs to be inspected and checked as the work progresses. For these purposes, the client (the supervisor as an agent) supervises the contractor's work.

The construction project progresses as a combination of different types of work which are executed in stages. As a result, if a certain work is found defective or inadequate and needs to be corrected, subsequent or related works also need to be corrected, requiring a large amount of time and cost.

To prevent defective or inadequate work from being performed, the construction contract provides obligations which the owner and the contractor must perform. In addition, both of them must work together to monitor and understand any unusual or unforeseeable conditions promptly and accurately so as to complete the project without any defect or unnecessary cost and time.

2.3 Laws and Regulations Related to the Execution of Civil Works

The following provisions of the Public Accounts Act, the Budget Settlement and Accounting Ordinance, and Public Contract Administration Regulations are binding up the client and the contractor for their performance of civil work projects.

2.3.1 Client's Responsibility

(1) Article 29.8 of
the Public Accounts Act. .... Preparation of the contract document
Article 100 of the Budget Settlement
and Accounting Ordinance .... Items covered in the contract document

(2) Article 29.11 of
the Public Accounts Act .... Ensuring of contract performance (supervision and inspection)
Article 101.3 of
the Budget Settlement and
Accounting Ordinance .... Method and procedure for supervision
Article 101.4 - 9 .... Method and procedure for inspection

(3) Article 17.1 - 3 of
the Public Contract Administration
Regulations .... General duties of public work superintendent

① Any officer appointed by the contractor administrator as the superintendent for any construction, manufacturing or other type of contract (hereinafter referred to as the "Contract") or any officer instructed by the head of a government department or agency or his agent to supervise the Contract (hereinafter collectively referred to as the "Supervisor") shall, when considered necessary, prepare detailed design drawings and/or full-scale drawings required for performing the

Contract in accordance with specifications and design documents thereof, or shall evaluate the contract documents prepared by the contracting party for approval.

② The Supervisor shall, when deemed necessary, attend the execution of the Contract, supervise the progress and quality thereof by means of material and other testing and inspection during the construction and/or manufacturing, and issue instructions to the contracting party.

③ When performing supervisory work as specified in the preceding two paragraphs, the Superintendent shall not unjustly disturb the contracting party's work or disclose any trade secret or confidential matter of the contracting party, which has become known to him in the course of performing his supervisory work, to the third party.

(4) Article 18 of the Public Contract Administration Regulations .... Report by Superintendent

The Supervisor shall keep close communications with the Contract Administrator and report to him on the supervisory work at his request or at certain intervals.

(5) Article 19.1 - 4 of the Public Contract Administration Regulations .... General duties of public contract inspector

① Any officer appointed by the Contract Administrator as an inspector for the Contract or any officer instructed by the head of a government department or agency or his agent (hereinafter collectively referred to as the "Inspector") shall, for the purpose of validating the delivery of the Contract, inspect the delivery in accordance with the contract document, specifications, design documents and other related documents, and when considered necessary, shall request the attendance of the responsible Supervisor during the inspection.

② The Inspector shall, for the purpose of validating the completion of the delivery under any contract other than the Contract, inspect contents and quantities of the delivery in accordance with the contract document and other related documents.

③ The Inspector shall, for the purpose of performing his duties under the preceding two paragraphs and when deemed necessary, inspect the delivery by means of a breaking or overhauling test.

④ In the event that the delivery is found not to comply with requirements for a particular contract a result of the inspection conducted pursuant to any of the above paragraphs, the Inspector shall submit an inspection report stating the fact and possible corrective measures to the responsible Contract Administrator.

(6) Article 2 of
Public Work Contract .... Securing of work site
Article 3 .... Coordination among related works
Article 9 .... Supervisor
Article11 .... Request for safety and other measures to the contractor and subcontractors
Article 15 .... Obligation to modify the work not complying with design documents, breaking test, and others
Article 17 .... Modification, suspension of work
Article 19 .... Reduction of construction period at the request of the Client
Article 20 .... Variation in contract value due to wage and other price changes
Article 30 .... Defect
Article 37, 39, and 40 .... Others

(7) Articles 1 - 17 of Manuals for Supervision of Construction Project.

2.3.2 Contractor's Responsibility

(1) Article 4 of
Construction Contract .... Submission of construction schedule
Article 10 .... Acting contractor at the site and chief engineer
Article 12 .... Quality and inspection of construction materials
Article 13 .... Attendance of the Supervisor and maintenance of work record
Article 16 .... Change in contract terms and conditions
Article 18 .... Extension of contract period at the request of the contractor
Article 20 .... Others

2.3.3 Others

(1) Constructor's Act

(Principle of Construction Contract)

Article 18 Each party of the construction contract shall conclude the fair contract in accordance with an agreement made on an equitable basis, and shall perform it faithfully.

(Contents of Construction Contract)

Article 19 Each party of the construction contract shall, at the time of signing the contract in accordance with the principle stipulated in the foregoing article, prepare and sign the statement containing the following items and issue it to the other party.

Article 19.8 Time and method of inspection by the Client to verify the completion of a whole or part of the project, and time of delivery thereof

In the event that either party of the construction contract desires to change any of the items listed in the foregoing subparagraphs and pertaining to contents of the construction contract, the party shall prepare and sign the statement specifying such change and issue to the other party.

* Special Notes on Contracting

The Technical standard for Civil Work Inspection is a basis of inspection conducted by the Ministry of Agriculture, Forestry, and Fisheries. It should be noted, however, that the standard is not included in the contract document and particular care shall be taken in this respect.

Dimensions and other standard values referred to in the contract document are specified in the respective control standard and general/ special specifications. However, this does not necessarily means that the compliance with the contract document is not sufficient for the passing of the completion inspection, since the Technical Standard for Civil Work Inspection states that the civil work is deemed to pass the inspection "when all of the measured values satisfy the standard values specified in Appendix Tables and a mean value of five measurements (X5) satisfies the acceptable value." Thus, satisfying the standard values constitutes a partial fulfillment of requirements for passing. Therefore, at the explanation of project at the site and other meeting, it shall be clearly explained that the completion inspection standard adopted the mean value of five measurements (∂) as the acceptable value, which consists of 0.13% of the defect factor (P^0), 5% of the producer risk factor (ß), and 10% of the consumer risk factor (P^1) against the standard values.

Chapter 3 Progress Control

3.1 Purpose of Progress Control

A principal purpose of progress control is to plan the work schedule and control its execution within a specified construction period. Since the quality and cost of construction are primarily governed by the progress rate of work, the progress control for component works is a key activity in the construction management.

From the client's point of view, the progress control is to control the construction process to ensure that the project is executed in accordance with adequate progress rate to meet a specified schedule while achieving sufficient qualities and accuracies. Also, the progress control provides an important basis of controlling the construction budget and of assessing any damage or loss due to natural disaster and force major. On the other hand, the progress control from the contractor's point of view is a means of managing the project to maximize the productivity while minimizing the cost.

3.2 Progress Control Procedure

The procedure for the progress control is basically the same as that for ordinary construction management, and is comprised of planning, implementation, evaluation and follow-up.

Major activities involved in the progress control are to record the progress of the work per the construction schedule on a daily, weekly, and/or monthly basis and to compare the planned and actual progress to determine the progress rate and to keep the actual progress on schedule. If the actual progress has significantly deviated from the planned progress, the construction plan is not appropriate or the work system has a problem. Thus, the construction plan and the work system need to be reviewed to identify the problem and to devise corrective measures. Once the construction plan is revised, the progress control cycle of implementation - evaluation - follow-up is repeated.

3.2.1 Planning Stage

At the planning stage, the work schedule and sequence for each component task are determined in accordance with a basic construction plan including construction methods and sequences which are appropriate for site conditions.

Then, based on individual work schedules and sequences, the construction schedule is prepared.

In the process, the resource scheduling concerning the use of labor force, material, and equipment should be carefully considered.

In addition to the overall construction schedule, it is important for the smooth progression of the project to prepare construction schedules for critical work components for intensive progress control.

3.2.2 Implementation Stage

At the implementation stage, mobilization of labor force, material, equipment and other resources are arranged in accordance with work schedules and sequences specified in the construction schedule. Then, the construction work instructions are issued as required.

3.2.3 Evaluation Stage

At the evaluation stage, the progress of the work is recorded and the actual progress is compared with that planned to determine the progress rate. Also, the progress report is made to the supervisor whenever required.

3.2.4 Follow-up Stage

At the follow-up stage, if the actual progress significantly deviates from that planned or is not stable, corrective measures are taken to improve the work efficiency. If necessary, the construction schedule and/or other components of the construction plan are revised.

3.3 Construction Schedule

In the progress control, activity and resource scheduling are prepared in the form of charts and graphs, which form a basis of the implementation, evaluation, and follow-up activities.

The construction schedule is sometimes prepared for the overall schedule and partial (detailed) schedule. The overall construction schedule combines major activity schedules in an optimal sequence to satisfy the overall construction period. This is used to monitor the progress of the entire project and to evaluate the critical component of the project (the activity which takes the longest period from start to completion). On the other hand, the partial construction schedule is a detailed schedule for an important portion of the entire schedule and is designed to ensure the smooth progress of the entire schedule through the intensive control of the portion.

The following types of chart and graph are generally used for construction scheduling.

(1) Chart schedule (Gannett chart, bar chart)

(2) Graph schedule (banana curve)

(3) Network construction schedule (PERT, CPM)

Their advantages and disadvantages are summarized as follows:

① Bar chart

Advantages .... Since the number of days is shown on the horizontal axis, the duration of each activity can be easily identified. Also, the general work flow is shown from right to left to permit general relationship between activities to be identified.

② Graph schedule

Advantages .... Since the progress is shown in total value of contract completed, the progress rate can be clearly depicted.

Disadvantages .... It is difficult to identify the work sequence, the number of days required for each work, and the critical work. To overcome the disadvantage, this is generally used in combination with the chart schedule.

③ Network construction schedule

Advantages .... The work sequence, the number of days required for each work, the progress rate, and the critical work can be easily identified.

Disadvantages .... If the project consists of a large number of activities, sophisticated techniques and complicated calculations are required to determine activity, cost, and resource schedules.

Therefore, either of the above types should be selected in consideration of work and site conditions, together with any modification thereof, to develop the most appropriate scheduling.

3.4 Methods of Preparing Construction Schedule

Various charts and graphs or construction scheduling, used as a basis for progress control, are called the construction schedule. Traditionally, the bar chart has been most frequently used. Recently, however, the construction schedule using the network method has been gradually adopted. Because of many advantages, it is desirable to use the network scheduling method as much as the size and the nature of the project permit.

3.4.1 Bar Chart Scheduling

The bar chart for construction scheduling is constructed in accordance with the following steps:

(1) List all works (portions) consisting of the entire project in rows from top to bottom.

(2) Calibrate the horizontal axis of the chart to show the construction period.

(3) Determine the number of days required for each work (portion).
The duration of each work (portion) is plotted on the chart to determine the best practicable combination of the works to complete the entire project. In this process, each activity (work) is allocated according to the duration and period by using either of the following three methods.

① Forward method
In this method, the date to start the earliest activity (work portion), such as temporary works, is determined.

Then, the duration is determined by dividing the quantity of each activity by the mean daily work quantity (as estimated from labor force and equipment available).

The same procedure is repeated for subsequent activities (work portions), and those which can start simultaneously are arranged concurrently. Finally, the overall schedule is examined if the project is completed within a specified construction period.

If all activities, including internal inspection and site clearance, are completed within the specified period, the construction schedule is accepted.

If not, the daily standard productivity for each activity (work portion) needs to be reviewed by reassessing the number and performance of equipment, work hours, and the number of workers. Then, the above procedure is repeated until the most rational and economical construction schedule within the completion period is obtained.

② Reverse method

In this method, the procedure is reversed; the duration of each activity (work portion) is determined in accordance with the same procedure applied in 1) above, but starting from the planned completion date.

This method is used when the project has passed the mid-point and the remaining schedule is to be examined.

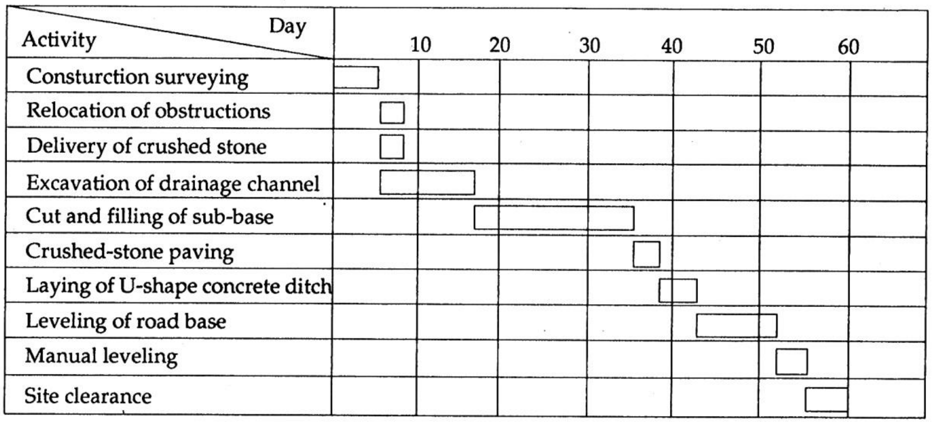
③ Priority method

In this method, the starting or completion date is first set for a certain activity (work portion) which is considered to be important in connection with weather and other environmental conditions (e.g., winter, flooding season) or various agreements with local community and government authority (e.g., environmental control, excavation of cultural properties). Then, the duration of other activities is determined by forward and reverse methods to construct the entire schedule.

This is used when the interim completion period is specified or the construction period includes the end of the year or the flooding season.

Generally, the construction schedule is planned according to activities specified by the owner in design documents. It should be noted, however, that the construction schedule according to work classification, such as earth work, concrete work, and asphalt work, is sometimes more suitable.

Example of Bar Chart Scheduling



3.4.2 Graph Schedule

The progress of each activity (work portion) is plotted on a graph with the completion period on the horizontal axis and the corresponding cost (or % of the total construction cost) on the vertical axis, so as to form a graph.

This curve may be made in a straight line for the sake of simplification.

Then, the construction period is divided by calendar month, and the quantity of work (or cost %) completed in each activity (work portion) is added up for each month to obtain a planned progress curve for the entire project.

Generally, the rate of progress is relatively low in early and later stages of the project in comparison to middle stages, because nonproductive works, such as temporary works, preparation works, finishing works, and site clearance, are required. As a result, the overall progress curve takes an "S" shape.

Since the planned graph schedule is prepared on the basis of mean rates of progress for labor force and equipment, it is relatively flexible in absorbing a certain deviation. Generally, the actual graph schedule does not agree with the one planned because of variations in site and other conditions.

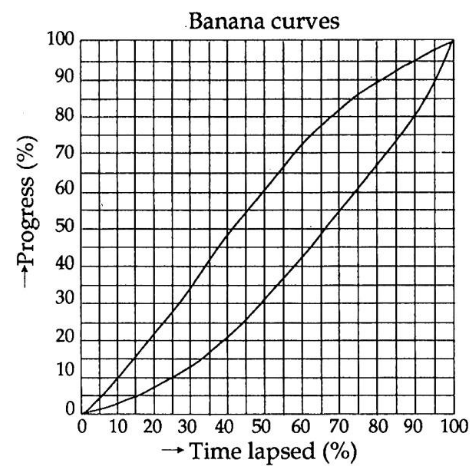
However, it should be kept in mind that there is a recoverable range for the deviation of the actual progress from the one planned, and thus it is very important to maintain the deviation within such a range all the time.

It is safe to say that, if the graph schedule is controlled within the recoverable range of deviation, the project will satisfy requirements for the construction period, quality, and economy. In other words, the graph schedule indicates a safety range within which the rate of progress can be recovered without rush work or other extraordinary expediting measures.

The safety range is defined by two straight lines, one of which connects a point of 20% progress in the contract period and value, and another connecting a point of 0% progress in both the contract period and value as a lower limit and that of 80% progress in the contract period and 100% progress in the contract value.

The banana curves were developed from the study of statistical relationships between the time and progress, based on progress curves for 45 road projects in the California Public Highway Jurisdiction in the US, and it is widely used as the progress control curve for road works.

The banana curves contain 80% of the rates of progress for the sampled project in each of 10 equal divisions of the construction period, i.e., excluding those in the fastest and slowest 10% ranges. The curves serve as the upper and lower control limits. The name comes from their banana-like shape.



For instance, an allowable safety range for the rate of progress, as read from the banana curves, is 13-35% when 30% time has lapsed. Thus, if the actual rate of progress is less than 13%, the project is significantly delayed and appropriate measures are needed.

As the graph schedule is expected to serve as a means of checking the progress curve, it does not need to very accurate. The banana curves are widely used as the graph schedule for construction projects, because they mostly agree with a range of deviation for allowable limit lines which are statistically determined from actual project records, and are applicable to unavoidable delays in the early and later stages of project.

Any planned progress curve is considered appropriate if it is within the middle range of allowable limits for these control curves.

3.4.3 Construction Scheduling by Network Method

The network method is useful in identifying an activity or work portion which is critical to the construction period and cannot be easily found by the bar chart method. Also, the network method is useful for understanding relationships between works. Although its revision due to variation in the construction plan is time consuming, the results can be obtained in a definite form if the basic principle is understood. The network method is particularly useful for the complex project consisting of a large number of activities. In any case, it is important to apply the method in a consistent manner up to the completion of the project.

(1) General description of network

Generally, the network is developed by breaking a project down into its component works and by organizing them into an interrelated diagram.

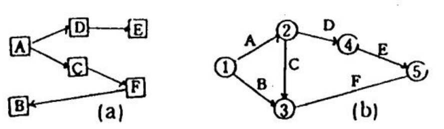


Fig. 3-4-1 Project graph and Arrow diagram

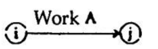


Fig. 3-4-2
Expression of work

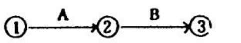


Fig. 3-4-3
Preceding of work

The network is divided into the project graph in which each work is contained in a box and is connected to preceding and subsequent works (Fig. 3.4.1 (a)), and the arrow diagram in which each work is expressed in a line with an arrow (arc) and is defined by circles at both ends (node). (Fig. 3.4.1 (b)) At present, the arrow diagram is mostly used.

The network is designed to show the necessary sequence of works. On the basis of the sequence established, the construction schedule is developed.

(2) Arrow diagram

As described above, the arrow diagram indicates each work in a line with an arrow and circles at both ends as starting and ending points. The line is called the job or activity, and the circle is called the node or event. Each circle is numbered, starting from the beginning of the line to the end. For instance, when job A is expressed by ⓘ-->ⓙ , the job can be indicated as (i,j). (See Fig. 3.4.2) It is assumed that each job progresses in the direction of the arrow. A course of activity from node i to node j without passing the same node twice is called the path.

General rules for constructing the arrow diagram are as follows.

① Preceding and following jobs

In Fig. 3.4.3, A is the predecessor of B (B cannot be started until A is completed), and B is the successor of A. (B can be started after A is completed.)

② Concurrent jobs and merge node

In Fig. 3.4.4, D cannot be started until A, B, and C are all completed. In this case, A, B, and C are concurrent jobs, and node ④ is the merge node.

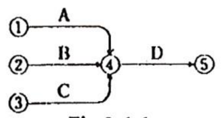


Fig.3-4-4
Concurrent jobs and merge node

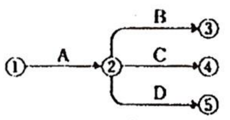


Fig.3-4-5
Burst node

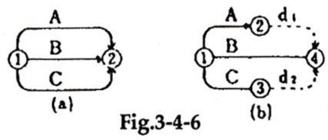


Fig.3-4-6
Dummy (case 1)

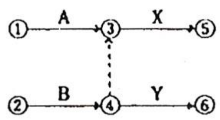


Fig.3-4-7
Dummy (case 2)

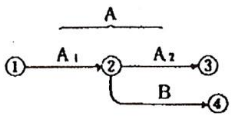


Fig.3-4-8
Division of jobs

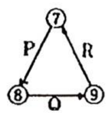


Fig.3-4-9
Cycle

③ Burst node

In Fig.3.4.5, B, C, and D can be started after A is completed. In this case, node ② is called the burst node.

④ Dummy (case 1)

Only one arrow can connect two nodes. As Fig. 3.4.6 (a) violates this rule, dummies d_1 and d_2 which have durations of zero are inserted to have Fig. 3.4.6 (b).

⑤ Dummy (case 2)

In Fig. 3.4.7, A and B are the predecessors of X and Y, respectively. These relationships can be clearly indicated by inserting the dummy.

⑥ Division of jobs

Fig. 3.4.8 indicates the relationship in which B can be started after a certain portion of A has been completed. A_1 denotes the first half of A and A_2 the last half.

⑦ Job group

If a group of jobs in an identical pattern appears in more than one place, it can be replaced with a job group for convenience.

⑧ Source and sink node

A diagram should have a source and a sink node for the convenience of readers. The source means a node which does not have a preceding node, and the sink node means a node without a following node.

⑨ Cycle

In Fig. 3.4.9, P precedes Q, which precedes R, and which precedes P. This is called the cycle and no progress is made. The cycle must be avoided.

⑩ Node No.

Node No. must be an integral number without duplication. The numbering should preferably be made with the arrowhead being larger than the other end.

Table 3.4.1 Summary of Job Relationships (in case of Fig.3.4.1)

Job	Preceding Job	Following Job
A	-	C, D
B	-	F
C	A	F
D	A	E
E	D	-
F	B, C	-

However, when serial node Nos. are assigned to order all jobs (i,j) in $i < j$ for PERT calculation, topological ordering needs to be done to renumber the nodes.

(3) Construction of network

Before constructing the network, a job list should be prepared to understand the order of sequence accurately. The job list contains all jobs and their predecessors and successors as shown in Table 3.4.1. In the table, columns for jobs preceding the first job and for jobs following the last job are marked off.

On the basis of the job list, the network is constructed in order of sequence, starting from the first job and proceeding to the last one.

Chapter 4 Dimension Control

4.1 Outline of Dimension Control

4.1.1 Objective

The dimension control is designed to determine if a project is completed in compliance with the contract requirements intended by the owner, and to identify any unsatisfactory part for improvement.

4.1.2 Outline of Dimension Control Technique

The dimension control can be roughly classified into the following types:

- Dimension control
  - Dimension control by direct measurement
  - Dimension control by photographic record

The dimension control is an activity to determine if a project satisfies contract requirements and the intentions of the owner. It is conducted by the following means:

(1) Dimension control by direct measurement
This is conducted in accordance with the construction management standard. Measured values are compared with design values and recorded on control charts, dimension lists, or structural drawings. This way, deviation from control standard values is depicted.

(2) Dimension control by photographic record
After the completion of a project, dimensions and quantities of the works which cannot be visually checked are photographed for verification.

- Dimension control by photographic record
  - Dimensions (quantities)..Photographing of shapes, dimensions, quantities, and other
  - Progress............................Photographing of construction method, equipment, spreading depth, and slope tamping depth.

Basically, the dimension control is conducted by the above two methods. Then, corrective measures for any deviation from control standard values should be devised as final control measures. The comparison should be made with control standard values specified in the Construction Management Standard for Civil Works, and any deviation should be corrected upon instructions of the superintendent.

4.1.3 Dimension Control Planning

The dimension control is not a measurement of the works in accordance with the progress of a project. Instead, as soon as the construction plan is established, the dimension control plan should be prepared in accordance with the control standards. In the dimension control plan, control points, dimensional measurement points, locations and frequencies of photographs, and types of control charts should be clearly specified. When implementing the plan, a check system should be established to examine if the control activities are conducted in accordance with the plan.

The dimension control plan should be prepared with due care in accordance with the following requirements:

(1) Photography locations should be selected at dimension control points.
(2) Least practicable points should be selected with due consideration to the intent of the construction management standard.
(3) Control charts should be prepared according to specific purposes; for those to verify quantities, development or other drawings may be used; and for those requiring allowance for standard values, as-built drawings, progress schedules, and histogram should be prepared to maximize the availability of data.
(4) Selected dimensions should be after completion (measuring points, variable points).
(5) One example of a dimension control chart is shown below.

Work		Dimension control			Photograph		Photograph of progress	Remarks
		Item	Measuring point and position	Control method	Item	Measuring point and position		
1. Common work	General						Whole view before and after the commence-ment (one each)	
							Progress Dragline excavation Sheet pile driving Embankment filling Block manufacturing at factory	3 times each
							Temporary works Temporary building Temporary road Temporary cofferdam Temporary channel Scaffold	Twice each

Work		Dimension control			Photograph		Photograph of progress	Remarks
		Item	Measuring point and position	Control method	Item	Measuring point and position		
1. Common work	General						Quality control Concrete compressive strength test - Slump - Air content - Reinforcement label	At each test
	Excavation	Reference elevation	No. 20, No. 20+50 No. 22, No. 22+50. No. 23,	Dimension list	Width	No. 20 No. 21 No. 22 No. 23		
		Width	Ditto	Ditto	Depth	Ditto		
		Length of slope	Ditto	Ditto	Length of slope	Ditto		
		Total length	No. 20 ~ No. 23	Ditto	Grade of slope	Ditto		
					Side ditch for discharge	Ditto		
	Filling	Reference elevation	No. 20, No. 20+50 No. 21, No. 21+50 No. 22, No. 22+50 No. 23	Dimension list				

4.1.4 Dimension Control

(1) Selection of measuring points

Measuring points and parts indicated in dimensions on design drawings should be selected as control points in accordance with the construction management standard.

(2) Measuring items

Control reference values are specifically established at the construction management stage for the purpose of ensuring "standard values", and are indicated for dimension control by direct measurement.

4.2 Preparation of Control Charts

As mentioned earlier, the dimension control is conducted to secure "allowance" for standard values and to verify quantities of work completed. This provides essential data to determine if a project is acceptable to the owner. Therefore, the dimension control chart should be prepared in due consideration to this purpose and on the basis of an appropriate control system.

Control system
- Using the control chart.......................... Control values are 20 points or greater
- Using the dimension list........................ Control values are less than 20 points
- Indicating on the structural drawing.. Control values are for each point or unit
- Not requiring the record........................ Particular part of grade of slope

The control charts and other documents for the dimension control should be prepared with reference to Appendix "Important Points in Dimension Control by Direct Measurement".

4.3 Dimension Control by Photographic Record

4.3.1 Objective

Photographing construction works not only serves as a progress record, but also serves as a basis of verifying quantities of work portions which cannot be checked after completion or from the outside. Also, it provides important information on construction methods, equipment, temporary work methods, and safety management at each construction stage.

4.3.2 Types of Photographs

Dimension control by photographing
- Photographing of progress
  - Photograph of overview (the site before the commencement, the project at completion)
  - Photograph of progress (construction process)
  - Photograph of quality control (measurement, inspection, and test)
- Photographing of material inspection .... Photograph of material inspection process
- Photographing of as-built project .... Work portion for which dimensions and quantities cannot be measured after the completion
- Other...........................
  - Photograph of part in which drawing does not agree with site
  - Photograph of temporary works
  - Photograph of safety facilities
  - Photograph of overload
  - Photograph of public compensation and other

4.3.3 Photographing Plan

Before commencing a project, a photographing plan should preferably be established as a part of the dimension control plan in consultation with the superintendent, so as to ensure that photographs which best describe the project can be taken.

Photographing should be done in accordance with the Appendix "Important Points in Dimension Control by Photographing" and with due consideration to the construction plan and site conditions, while keeping in mind the purpose (verification of dimension and quantity, or recording of progress).