MIDDLE EAST TECHNICAL UNIVERSITY

CE 332

CONSTRUCTION ENGINEERING AND MANAGEMENT

LECTURE NOTES

DEPARTMENT OF CIVIL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT DIVISION

FEBRUARY 2014

TABLE OF CONTENTS

FOREWORD

These Lecture Notes have been prepared for the use of METU Civil Engineering students taking CE 332 Construction Engineering and Management Course. It brings together the collected chapters on contemporary construction management topics. Some parts of these Lecture Notes have been compiled from the various books and articles about the construction management discipline in order to provide civil engineering students with a complete coverage of the construction management topic.

CHAPTER 1

CONSTRUCTION PROJECT MANAGEMENT AND COMPANY ORGANISATION

1.1 PROJECT MANAGEMENT

DEFINITION OF A PROJECT

Governments invest in schools to provide education services, and bridges to provide transport services, firms invest in shops to provide retail services and houses to provide homes. Investors build factories to produce goods. What all investments have in common-whether directly for profit or not- is that they create something where there was nothing, create new assets to be exploited for private benefit and public good. Thus, construction projects are about “creation of value in society” (Winch, 2002).

Thus, the starting point of a construction project is “further production of a service/product” and its major aim is “creation of value”.

A project may be defined as an investment of resources to produce goods or services, thus it costs money. Projects vary in scale and complexity from small replacement projects to large capital investments.

PMBOK Guide of Project Management Institute defines a project as a temporary endeavor undertaken to create a unique project, product or service. Temporary means that every project has a definite start and an end.

Following are the basic features of a project;

- It should have an objective and it necessitates investment of resources for the determined objective.
- There are constraints with respect to time and cost of the project. A project has a limited duration. The project duration is small when compared with the subsequent working life of the investment.
- Projects are “temporary organizations” with a beginning and an end.
- Every project proceeds through a cycle of activities. There is a list of activities for a project showing the dates for starting and finishing them, which is called a “schedule”.
- A number of parties may come together to form a “project coalition” to ensure the required resource base for the project.
- It requires a “project team” to be set up probably of a multi-disciplinary nature and headed by a project manager.
- Inputs of the project are financial resources in order to cover the costs of investment, and human resources which transform ideas into reality. Thus, construction projects mobilize capital and human resources.

- Each project is unique. Although exactly the same project is to be carried out, as the location, external factors (climate etc.), parties involved, time and budget constraints etc. are different, projects have their unique features which make them unique undertakings.

PHASES OF A CONSTRUCTION PROJECT

Stages of a project can broadly be summarized as follows (Smith, 1996);

1. **Project initiation:** A project is initiated when its "promoter" predicts that there will be a demand for the goods or services that the project may produce. Alternative ideas and schemes are considered to meet the demand, thus the context (scope) of the project is determined.

2. **Feasibility study/appraisal stage:** The project costs and benefits are determined and compared. Appraisal stage is about prediction of demand, estimation of revenues and costs to question whether it is feasible to carry out the project or not. Many projects are cancelled at this stage as they cannot be proved profitable/feasible. If the promoter decides to go on with the project, how best it should be realized and what needs to be done are discussed.

3. **Design:** The main design stage includes deciding on which materials are used, construction methods are utilized etc. to make the project ideas succeed. Decisions made in design determine almost entirely quality and cost, thus, the success of a project.

4. **Project implementation:** Project implementation includes the largest scale of activities, the variety of physical work to implement a project, particularly mobilization of resources, installation of equipment and construction work.

The phases of a construction project may be explained in detail, as given below (Barrie and Paulson, 1990);

1. **Concept and feasibility studies:** Most construction projects begin with the recognition of a need for a new facility. Long before designers start preparing drawings and construction commences, a broad-scale planning is necessary. Elements of this phase cover conceptual analysis, technical and economic feasibility studies and environmental impact analysis.

   Example: A new industrial plant: Location of a new industrial plant should be determined. Where can it be located to provide desirable employment for an adequate supply of skilled workers? What are the costs and customs of the labor force? Depending on its raw materials, will the plant have an access to the most economic forms of transportation, air, water etc.? Does the location provide access to raw materials and to markets? What political and bureaucratic factors may affect the development and operation of the facility? What are the sociological and economic impacts of the plant on the community? What is the environmental impact? What is technical and economic feasibility? In order to find out answers to the above addressed questions, normally, this phase is carried out by the client and/or its consultants.

2. **Engineering and design:** It involves 2 main phases as; preliminary engineering and design and detailed engineering and design. Preliminary engineering and design involves architectural concepts, evaluation of technological process alternatives, size and capacity decisions, comparative economic studies. These steps usually coincide with feasibility studies.

Example: In a high-rise building, preliminary engineering and design determines the number and spacing of stories, general layout of the service and occupied floor spaces, general functional allocations (parking space etc.), and overall design approach. Overall design approach involves decisions such as the choice between steel frame and a reinforced concrete structure. Further refinements cover whether the structure will be precast or cast-in-place concrete.

In infrastructure projects, engineers often need substantial input from geologists, hydrologists, ecologists etc. In designing a dam, preliminary design requires analysis of the watershed's hydrologic characteristics to determine the necessary reservoir storage characteristics, geologic nature of the foundation and abutments. During preliminary engineering and design, the precise location of the dam on its site, geology, size, shape and availability of materials are determined and the choice among structural types such as concrete, earth-fill, earth-rock etc. is made. Further decisions are necessary (concrete structure may be gravity, arch etc.) and serve as departure points for detailed engineering and design.

Once the preliminary engineering and design is complete, there is an extensive review process before detailed work is allowed to proceed.

Detailed engineering and design: Detailed engineering and design involves the process of successively breaking down, analyzing, and designing the structure and its elements so that it complies with recognized standards of safety and performance while presenting the design in the form of a set of explicit drawings and specifications that will tell the constructors exactly how to build the structure in the field.

3. **Procurement/project delivery:** It involves two major types of activities: contracting and subcontracting for services of general and specialty contractors, obtaining materials and equipment required to construct the project. Traditional form of procuring construction services is to solicit competitive bids for a single general contractor after the design phase is over and general contractor handles all subcontracting, plus the procurement of materials and equipment. However, there are other procurement routes today (design-build, professional construction management etc.).

4. **Construction:** It is the process whereby designer's plans and specifications are converted into physical structures and facilities. It involves the organization and coordination of all the resources for the project-labor, equipment, materials, money, technology, time etc.-to complete the project on schedule, within the budget and according to the standards of quality and performance as specified by the designer.

5. **Start-up and implementation:** Most structures and facilities involve a start-up and implementation phase. Both in simple and complex cases, much testing of the components is done while project is underway. As the project nears completion, it is important to ensure that all components function well together as a total system. This phase often involves a warranty period during which the designer and contractors can be called back to correct problems that were immediately evident upon initial testing and to make adjustments to better suit the facility to the owner's needs.

6. **Operation:** Operation is the last stage within the life cycle of a project. During this phase, the constructed facility is used by direct users (in case of a house, users are households), operated for production of goods (e.g. in case of industrial plants, factories) or used by the public (e.g. in case of roads). Sometimes, in Build-Operate-Transfer (BOT) projects, the construction company is given a concession to operate the facility for a given time period.

Figure 1.1 demonstrates the stages within the life cycle of the project.

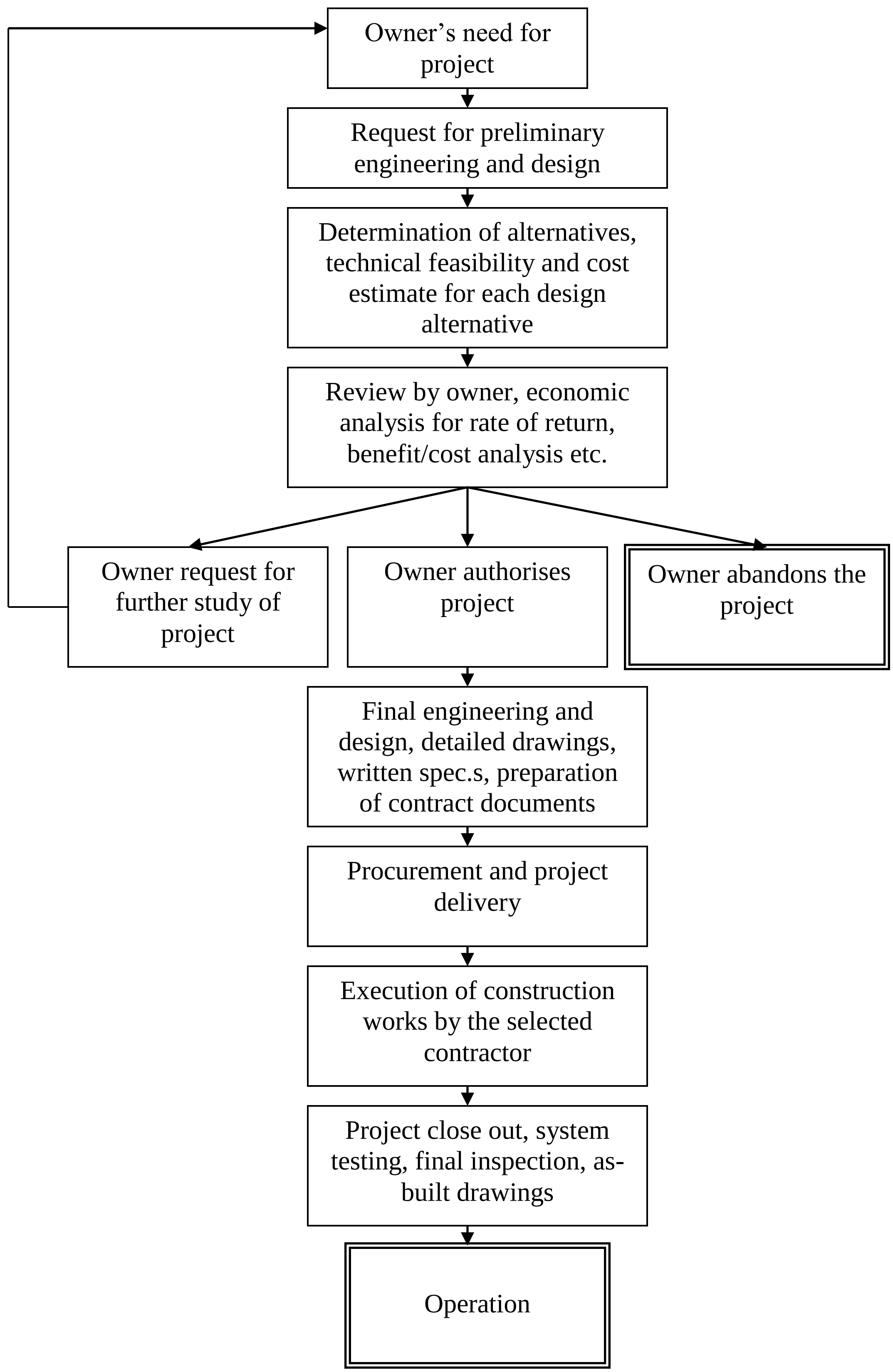


Figure 1.1: Stages of a Construction Project

PARTIES INVOLVED IN A CONSTRUCTION PROJECT

Figure 1.2 demonstrates the basic parties involved in a construction project and contractual relationships in the traditional approach.

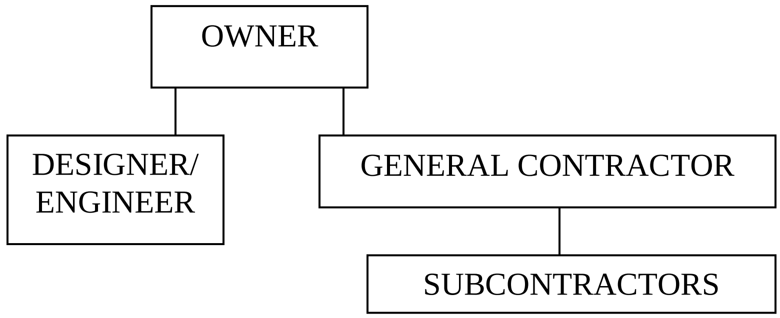


Figure 1.2: Parties involved in a Construction Project according to Traditional Project Delivery System

Responsibilities of these 3 principal parties may further be described as follows:

Owner/client: Owner/client organization is responsible for setting the operational criteria for the completed project such as usage of a building, amount of gas to be transported in a pipeline etc. Any special equipment, material or company standards that are to apply to the project must be defined. They also need to identify their involvement in the project, the review process, required reports, levels of approval etc. Owner should set parameters on total cost, payment of costs, major milestones and project completion date.

Designer/engineer/consultant: Design company is responsible for producing design alternatives, drawings and specifications that meet the needs of the owner. In addition, there may be other duties that may be delegated to the designer by the owner such as on-site inspection, review of shop drawings, etc. Designer should produce a project design that meets all technical codes, standards, environmental and safety regulations. Design budget and schedule should be prepared.

Contractor: Contracting company is responsible for the performance of all work in accordance with the contract documents that have been prepared by the designer including furnishing of all labor, material, equipment, know-how necessary to finish the project. Contractor should prepare an accurate estimate of the project, develop a realistic construction schedule and establish an effective project control system for cost, schedule and quality.

The contractual relationships and types of contract will be discussed in more detail during the "project delivery systems" part of this course.

PROJECT MANAGEMENT

Management may be divided into two different types:

Functional management: it involves the coordination of repeated work of a similar nature by the same people.

Project management: it involves coordination of one time work by a team of people who often have never previously worked together.

Although the basic principles of management apply to both of these types of management, there are distinct differences between the two.

Project management requires a multi-discipline focus to coordinate the overall needs of a project. Project manager should delegate authority and responsibility to others and still retain the focus on the linking process between disciplines. According to the definition of Association of Project Managers, project management is the planning, organization, monitoring and controlling of all aspects of a project and motivation of all involved to achieve project objectives safely and within a defined time, cost and performance.

A project consists of 3 components (Oberlender, 1993);

1. **Scope:** The work to be accomplished - quantity and quality of work
2. **Budget:** Costs
3. **Schedule:** Logical sequencing and timing of the work to be done

When a project is first assigned to a project manager, it is important that all three of these components must be clearly defined. Not only individually defined but each must be linked together since one affects the other significantly.

In order to put together the scope, budget and schedule within a project, project management team has to carry out some basic functions. 5 basic functions of project management and tasks of a project manager (PM) may be summarized as follows;

1. Planning: It is the formulation of a course of action to guide a project to completion. The establishment of milestones and consideration of possible constraints are major parts of planning. There must be an explicit operational plan to guide the entire project throughout its life.

PM's role in planning:

- Develop a plan
- Establish objectives and performance requirements early so everyone involved knows what is required
- Establish clear milestones so everyone knows "what is to be accomplished" and "when it is to be completed"

- Build contingencies into the plan to provide a reserve in the schedule for unforeseen future problems
- Communicate the project plan

2. <u>Organizing</u>: It is the arrangement of resources in a systematic manner to fit the project plan. There must be breakdown of the work to be performed into manageable units that can be defined and measured. The work breakdown structure of a project is a multi-level system that consists of tasks, subtasks and work packages.

PM's role in organizing:

- Develop a work breakdown structure (definition of activities)
- Establish a project organization chart (show who does what)

3. <u>Staffing</u>: It is the selection of individuals who have the expertise to produce the work.

PM's role in staffing:

- Identify the people who are best qualified to work on project, set up the team

4. <u>Directing</u>: It is the guidance of the work required to complete a project. Although each person provides work in his/her area of expertise, the work that is provided by each must be collectively directed in a common effort and in a common direction.

PM's role in directing:

- Serve as an effective leader
- Motivate people
- Obtain resources needed by the project team to accomplish their work to complete the project.

5. <u>Controlling</u>: It is the establishment of a system to measure, report and forecast deviations in the project scope, budget and schedule. The purpose of controlling is to determine and predict deviations in a project so the corrective actions can be taken. Project control requires the continual reporting of information in a timely manner so management can respond during the project rather than afterwards.

PM's role in controlling:

- Maintain a record of planned and actual work accomplished to measure project performance.
- Maintain a regular project cost chart which displays planned and actual expenditures.

All of the above explained 5 functions are necessary for carrying out the following "generic project management tasks" (Winch, 2002);

1. **Defining the project mission:** deciding what the client wants
2. **Mobilizing the resource base:** Forming the project coalition, managing the supply chain
3. **Riding the project life cycle:** managing the budget, managing the schedule, managing quality, managing risk, managing information flow, managing health and safety
4. **Leading the project coalition:** Designing effective project organizations, communicating the project mission (leadership)
5. **Maintaining the resource base**

Also, it can be argued that, the major role of PM is to "set systems" (Kelly et al., 2002). Systems are necessary to realize the management functions for successful completion of the project. Those systems may include;

1. Financial systems that will ensure payments are made according to contract agreements
2. Decision systems that will ensure decisions are communicated at the appropriate time and with the appropriate authority
3. Design change systems that will implement and monitor change
4. Cost and time monitoring systems that will chart real progress against the plan.

As a concluding remark, "construction project management" constitutes a major part of management process within construction companies, however, together with the "temporary organization" during a project, there exist a "permanent organization" that is responsible for the "management of the construction company" which is the subject of the next section.

1.2 COMPANY ORGANIZATION

A firm or business is simply a fairly efficient way of combining the skills and talents of people into an "organization" that can produce the goods and services in sufficient quality to satisfy the desires of the community in which it exists and at the same time, provide sufficient return on the capital invested (Harris and McCaffer, 2001). The choices of "organizational structure" best suited for the company depend on several factors such as the size of the company, its geographical location, type of product/services, etc. As the construction industry is project-based, companies operating in this sector are organized accordingly and there are 2 different management levels:

1. Management at the corporate level (head office functions)
2. Management at the project level (project management functions)

Construction companies may be seen as organizations that are established to transform the inputs into outputs by management of the processes both at the corporate and project management levels. Figure 1.3 demonstrates a construction company as an open system operating within an environment.

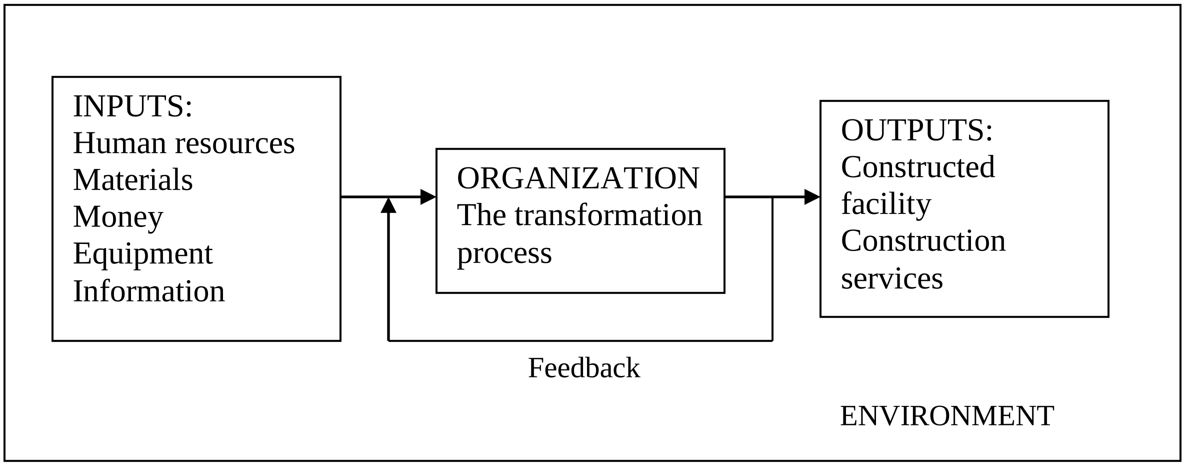


Figure 1.3: Construction Organization as an Open System (adapted from Pilcher, 1992)

Figure 1.4 illustrates the different levels of management in a construction company, although they may merge and overlap. In small firms, the same manager may perform all three roles (general manager, organizational manager and site manager) but in larger firms, the three levels are likely to be separate. The site manager is the top manager of the smaller "task force system". This job involves welding together an effective team as well as dealing with outside influences such as the local labor market, competitors, local authorities, suppliers, etc. Some site managers have considerable autonomy in running their sites whereas others have a narrower role and are expected to leave some of the tasks to more senior managers (contract manager or director) and concentrate their efforts on the day-to-day running of the site.

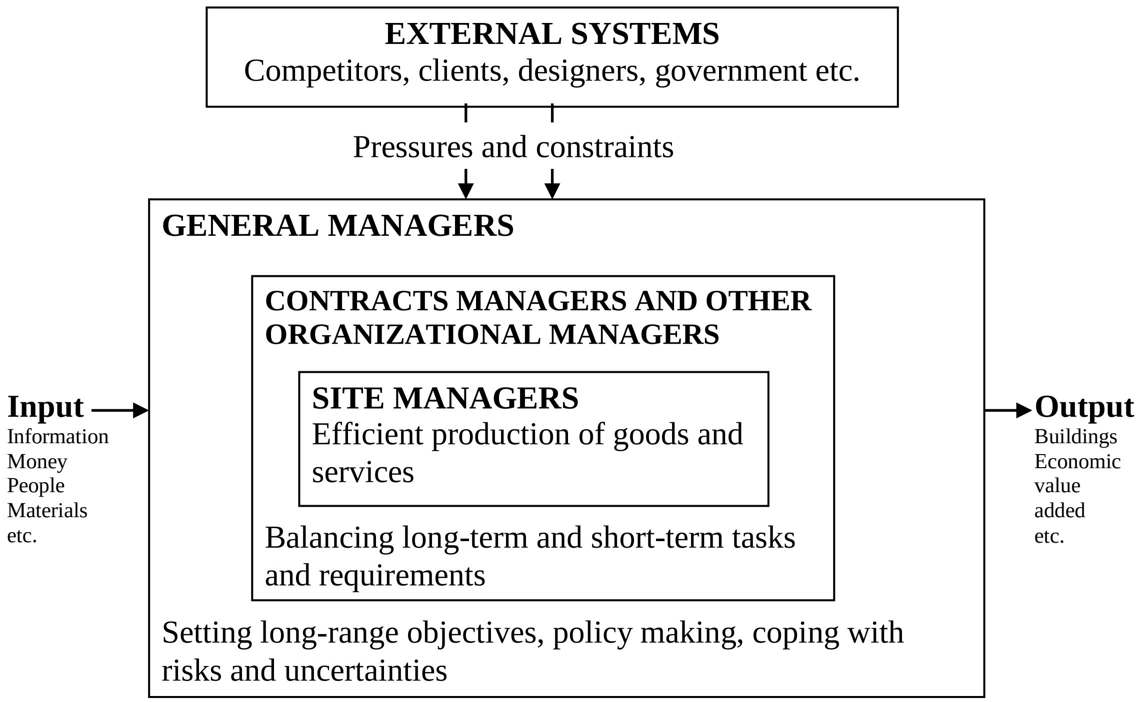


Figure 1.4: Management of a Construction Firm: A Systems View

Some head office functions in a construction company may be listed as follows;

Business development: Business development function is primarily concerned with seeking out new projects in selected markets, identifying new markets and promoting the firm's products and services. Sometimes, market planning and strategic planning of the company operations are also carried out by the business development department.

Estimating and tendering: This function is about pricing the work, involving a bill of quantities to which a mark-up/profit margin is added for the final bid. It involves estimating the cost of the work and preparing the tender documents where assistance is required from the planning department in preparing the tender programme and from the purchasing department for obtaining quotations for materials supplies and subcontractors' work. This function is very critical for a construction company, as it is directly related with the ability to get or lose the job.

Head office planning: The functions of the central planning department are usually twofold;

1. to support the estimating department and coordinate the tendering exercise
2. to provide planning and coordinating services to site

Purchasing/procurement: Purchasing function covers obtaining materials quotations and subcontractor procurement for both the tender and contract stages. At the tender stage, responsibility is given so that necessary quotations are at hand when required. Once a tender turns into a contract, the most favorable terms for the contract are tried to be negotiated by the purchasers. Thus, having a central purchasing department provides a central point of responsibility for several contracts and bulk purchasing is possible.

Engineering support: Technical assistance may be given to the site in activities such as formwork design, temporary works design, work study etc.

Health and safety: The task of setting up health and safety assurance procedures for the company and assessing provision in the workplace is carried out by this department.

Quality management: With the introduction of ISO 9000 quality standards into a company, the role of quality management unit is to advise departmental managers in preparing quality assurance procedures and work instructions and then follow up with audits and assessments in order to sustain the expected performance levels.

Finance and accounts: The company accountant is responsible for the bookkeeping function and the payment of all invoices together with providing information on balance sheet, profit-loss accounts etc. Thus, it is the finance department's concern to monitor the overall financial position of the company.

Legal services: This administrative function is related with legal issues such as claims, contracts, rules-regulations etc.

Once a contract is secured, on a large extent the manager on site is independent of the rest of the company, relying on head office functions only when necessary.

As a final remark, the topics covered in this course include mainly the "process of construction project management". However, some head office functions such as estimating, quality management etc. will also be discussed.

1.3 REFERENCES

1. A Guide to the Project Management Body of Knowledge (PMBOK Guide), Third Edition, Project Management Institute, USA.
2. Barrie, D.S, and Paulson, B.C. (1990). Professional Construction Management, McGraw-Hill, USA.
3. Harris, F., and McCaffer, R. (2001). Modern Construction Management, 5th Edition, Blackwell Science, UK.
4. Kelly, J., Morledge,R., and Wilkinson, S. (2002). Best Value In Construction, Blackwell Science, RICS Foundation, UK.
5. Oberlender, G.D. (1993). Project Management for Engineering and Construction, McGraw-Hill, USA.
6. Pilcher, R. (1992). Principles of Construction Management, 3rd Edition, Mc-Graw Hill International Series, UK.
7. Smith, N. J. (1996). Engineering Project Management, Blackwell Science, UK.
8. Winch, G. M. (2002). Managing Construction Projects, Blackwell Publishing, UK.

CHAPTER 2

THE CONSTRUCTION INDUSTRY

2.1 ROLE OF CONSTRUCTION INDUSTRY IN NATIONAL ECONOMY

Construction activity takes place everywhere there is human settlement and one of the main characteristics of civilization is the presence of a built environment. Every day new demand for infrastructure, buildings and utilities appears. Sheltering, one of the primary needs of human beings, is met by construction of residential buildings such as houses or apartment houses. The importance of the sector to society as a whole is immense. Construction, perhaps more than any other industry, is fundamental to the quality of our lives. It provides the drinking water and shelter we need to survive as people and it provides the infrastructure needed for the economy.

The role of construction in national economy and development has been widely studied. Gross domestic product GDP (gayri safi yurt içi hasıla - GSYİH) is the total annual value of all goods and services produced by a country less income from investments abroad. Various development patterns for construction related to GDP have been suggested. The Gross National Product (GNP) is a similar figure, but unlike GDP it includes earnings of domestic companies abroad. The inverse 'U' shape pattern by Ranko Bon (1992) suggests that the share of construction in national output increases in the early stages of development but ultimately will decrease in absolute and relative terms in more advanced industrial countries (Bon 1992, Figure 2.1). An important aspect is that while the proportion for new construction decreases with later stages of development, the share of improvement and maintenance in total construction increases (Bon, 1992).

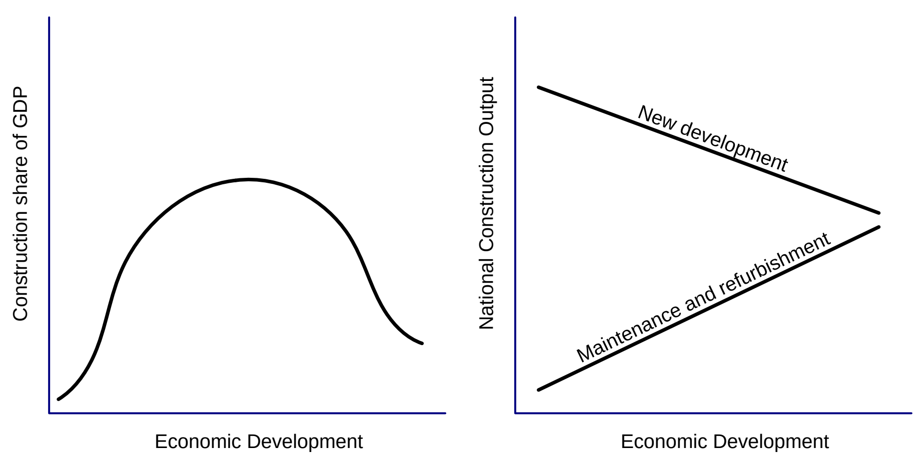


Figure 2.1: Development Patterns of Construction in relation to Economic Development

After rapid expansion in the early stage of economic growth, the rate of growth of construction output tends to slow down in mature economies (Strassmann, 1970; Bon and Crosthwaite, 2000). In many of the richer countries output, in real terms, has more or less stabilized. Stable output combined with a trend towards mechanization/prefabrication has led in some rich countries to stagnant or declining employment in the construction industry. European countries with declining construction employment between 1970 and 1998 include Belgium, Denmark, Finland, France, Italy, Netherlands and Sweden. However, in other high-income countries, employment is still expanding. In Austria, Germany, Ireland, Norway, Portugal, Spain and Turkey construction employment increased between 1970 and 1998, while in Switzerland it remained stable (UN/ECE, various dates). In some developed countries increasing employment follows increasing output, however this is caused by a higher proportion of repair and maintenance activity in the product mix which is very labor-intensive and also very skill-intensive. (International Labor Organization, 2001).

The amount that a country spends on construction is closely related to its income. In 1998, expenditure varied from US$5 per head in Ethiopia to almost US$5,000 in Japan. This means that construction output, by value, is heavily concentrated in the rich, developed world. The high income countries of Europe are responsible for 30% of global output, the United States for 21% and Japan for 20%. China, despite its huge size and rapid economic growth in recent years, lags a long way behind with only 6%. India has 1.7% (International Labor Organization, 2003).

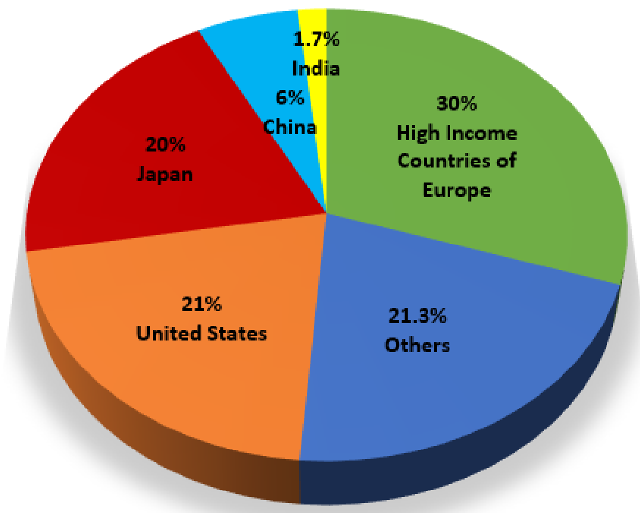


Figure 2.2: Global Construction Output Distribution, 2003

The distribution of construction employment is the reverse of the distribution of output. While three-quarters of output is in the developed countries, three-quarters of employment is in the developing world. Official data suggest there are around 111 million construction workers in the world, some 80 million of them in the low and middle income countries. However, as many construction workers in these countries are informally employed and therefore not counted in official data, the real number may be much higher. The reason for the greater employment-generating potential of construction activity in the developing countries can be traced to differences in technology as shown in Figure 2.3 (International Labor Organization, 2003).

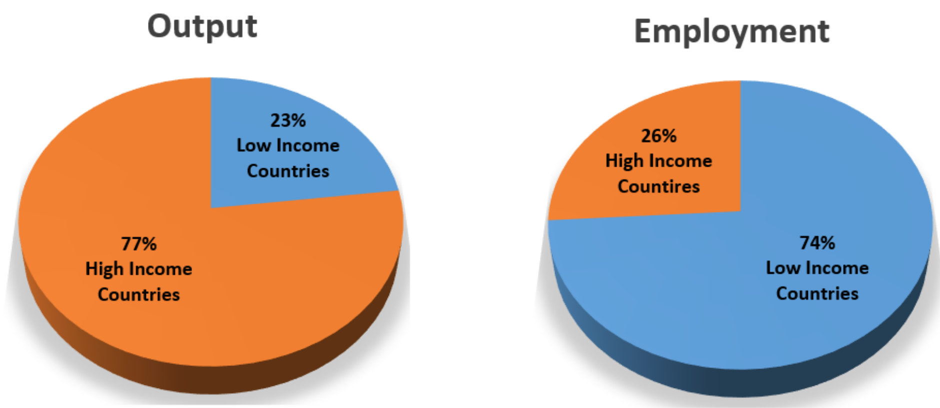


Figure 2.3: Construction Employment (source ILO)

A trend between construction investment and economic growth rate has not been clearly identified, as various studies has contradicting conclusions. Researchers have in some occasions found a positive association between construction activity and economic growth. Given that industrialization is the growth engine, the construction sector, through its relation with numerous other sectors of the economy, would play a determinant role in this development process. In other views, the construction sector does not lead but rather accompany economic growth.

Whatever correlation between construction and general economy does apply, construction is intimately related to the processes of industrialization and urbanization, which are interrelated as well. It is an essential activity in the vast majority of national economies. The global construction spending in 2011 is approximately US $4.6 trillion (World Construction, 2012).

Construction constitutes 10% of the European GDP and consumes nearly 60% of the total investments in Europe amounting to 1,000 billion Euros. It is a major European job-provider, employing around 10 million people (8% of total employment), making it the region's biggest industrial employer. There are in Europe over 200,000 firms associated with this industry most of whom are small and medium-size enterprises (SMEs), and 28% of industrial employments in Europe are construction related. In Europe a considerable proportion of construction activity is attributable to building maintenance. Over the past two decades, the contribution to maintenance has increased from 40% to over 50% of total construction output, which accounts for over 5% of the GDP of many European counties. Narrowly defined, the industry comprises only those enterprises 'adding value' through production or assembly operations on the construction site. A broader definition would include firms and individuals involved in planning, design, the supply of building materials, plant, equipment, transport and other services. Some definitions also include the customer, particularly the professional client or 'property developer'. The recent increase in the number of contractor-financed infrastructure projects might make it sensible to include the financial services sectors as well.

In recent years, global construction sector presented an unsteady outlook. After the rapid growth in 1999, the sector reduced around 3 % in size from 3,6 trillion dollars to 3,4 trillion dollars. This situation continued between 2001 and 2002 where the market dropped to 3 trillion dollars. In 2003, the sector showed increased activity and a better performance was anticipated in the years ahead. In 2007, world construction output reached 4,7 trillion dollars with 5% percent growth. However, global economic crisis in 2008 dropped output of the sector significantly. The construction sector showed signs of recovery in 2010 and output reached 4,6 trillion dollars in 2011 but it was below the levels achieved in 2007. It is predicted that volume of output in the construction sector will grow to 15 trillion dollars worldwide by 2025. (DPT 9. Kalkınma Planı, 2006; WTO, 2007; AECOM, 2012; Global Construction, 2013).

Drawing the boundaries of the construction industry is therefore not easy. Construction can be seen not as a separate industry, but as agents and activities which can be unpackaged and packaged in different ways. The enterprises engaged in construction activity are extremely diverse. They range from self-employed individuals providing a service to private house owners in the local community to multinational firms operating on a global scale (ILO, 2003).

GLOBALIZATION

Traditionally, construction used to be a domestic industry, but this is now far from the case. The construction market is now international. The general trend towards globalization of markets caused by elimination of trade barriers, adoption of international standards, opening of private and public national markets to foreign competition increase the feasibility of exporting construction services to foreign markets. Contractors may be motivated to operate internationally by saturation or instability of home construction demand. Merger and acquisition activity has increased dramatically over the past decade, leading to rapid, international consolidation within the industry. The largest players of the construction industry are operating world-wide, and many Turkish contractors are operating internationally. With new information technologies the distance and spatial boundaries have been blurred to the point where any organization can theoretically participate in a design and construction project in any location. However, the vast majority of enterprises involved in on-site construction are small and local. Despite the existence of an international construction industry, more than 95% of construction activity is still undertaken by firms from within the country, the region or the neighborhood (ILO, 2003). A global main contractor will subcontract large portions of the works when performing international work. In specialized civil engineering and facilities projects, the main contractor will typically subcontract low-skill civil works.

2.2 CONSTRUCTION INDUSTRY CHARACTERISTICS

The construction industry differs in a number of ways from other industrial sectors in terms of structure and mode of operation. The fundamental operating level of construction is the project; it is the main operating process to deliver the end product. Each project is unique – designed once, built once which contrasts to products of manufacturing (designed once – built many times). Construction is not the only industry with a project-based operation; it has however characteristics unique for the construction industry (Harris and McCaffer, 2001; Riley and Clare-Brown, 2001; ILO, 2003):

- Products of construction are *large in scale* and *varied in kind*.
- Construction projects require construction firms to set up temporary organizational structures at dispersed geographical locations, most often at a distance from central management.
- Project teams are highly fragmented, with many disciplines coming together for just a single project.
- Low investment in research and development.
- Low investment in information technology.
- Construction companies have very high turnover compared to their asset base, i.e. very high-budget construction projects can be completed with comparatively small amount of plant and machinery.
- Compared to other sectors, profit in relation to turnover is low.
- The use of hired plant is widespread, and the tendency is growing. Approximately 50-60% of site plant used on projects is hired.
- Cyclical fluctuations in the volume of work.

Clients of the construction industry in the public sector such as central government departments, local authorities and public corporations rely almost exclusively on competitive tendering to justify the awarding of contracts. Clients from private industry tend to follow the same practices and also largely employ competitive tendering procedures. Thus, most construction contracts are awarded after several contractors have submitted a tender and most civil engineering and building contractors derive the major portion of their workload in this way (Harris and McCaffer, 2001).

The construction market is very volatile to the national economic situation. It is also a competitive market, i.e. a market with sellers and buyers that are small and numerous enough to take the market price as given when they decide how much to buy and sell. The construction market has characteristics of a competitive market, e.g. many buyers and sellers, and this creates a supply and demand situation. In times of recession, competition for available construction work intensifies, and contractors will tend to lower the mark-up (profit margin) of their bids to increase chances of winning. If the contractor is really desperate to win they could submit a bid at something less than cost (Harris and McCaffer, 2001). When a contractor obtains such a contract based on a very low cost estimate, they issue claims to attempt to achieve a positive mark-up. This was an often seen situation in the UK, and other places in Europe, in the early 1990’s. Jobs would end without the contractor being fully paid, but with large claim files for conclusion after completion of the works.

As terms of human resources, construction has the following characteristics (Riley and Clare-Brown, 2001; Harris and McCaffer, 2001; ILO, 2003):

- Labor intensive work
- High degree of labor mobility

- Low investment in skills training
- Other industrial sectors and commerce are commonly able to benefit from better prospects in attracting skilled workers either by providing superior working conditions or in being able to pay better wages arising from more intense application of mechanization and advanced technology in general.

The ‘business’ of construction is typically characterized by:

- Public sector is a much more important client than in most other sectors
- Contracts are based on relationships where the project participants constantly oppose each other instead of co-operating and sharing joint objectives.
- Tendency to competition on price alone
- Cash flow dominates behavior (‘cash is king’)
- Reliance on credit and retention

During the 1980s there was an enormous growth in the use of subcontractors by the main contractors. The reason for this development was to enable the contractor take on additional workload without the need for increasing internally the level of employment and capacity required to execute the extra workload, thus ensuring greater flexibility. The trend towards the use of subcontractors has continued through the 1999s (Harris and McCaffer, 2001).

2.3 TURKISH CONSTRUCTION INDUSTRY

Construction sector is one of the leading sectors of the Turkish economy. Its potential to bring foreign exchange to local markets as a result of works carried out abroad and multiplier effect on the economy due to the existence of strong input-output relations with other sectors highlights its importance.

The construction sector creates demand for the products and services of more than 200 sub sectors. This effect is the basic indicator for the construction sector being considered as the locomotive of the economy. It is anticipated that due to its inter-sectoral transactions, the overall effect of construction industry is much higher on the general economy. The overall share of construction sector, together with the contribution of other sectors that supply input to construction, is around 30 %. Today Turkish contractors are working in over 100 countries, realizing around 7000 projects, generating foreign exchange for the Turkish economy, implementing new technologies, joining international partnerships and creating markets to export Turkish goods abroad. Turkish construction industry is also known as one of the leading sectors of economy due its potential for generating employment. It constitutes 6% of GDP and employing approximately 1.8 million people. The share of the construction sector in the Turkish economy reaches 30% when direct and indirect impacts on other sectors are considered. Moreover, the employment rate of the sector reaches %10 (excluding agriculture). Table 2.1 demonstrates relationships between construction sector and gross domestic product (GDP) of Turkey (Turkish Contractors Association, 2012).

Table 2.1: GDP Growth Rate and Construction Sector Growth Rate (TCA, 2012)

Years	GDP Growth Rate (%)	Construction Sector Growth Rate (%)
1999	-3.4	-3.1
2000	6.8	4.9
2001	-5.7	-17.4
2002	6.2	13.9
2003	5.3	7.8
2004	9.4	14.1
2005	8.4	9.3
2006	6.9	18.5
2007	4.7	5.7
2008	0.7	-8.1
2009	-4.7	-16.1
2010	9.2	18.3
2011	8.5	11.3
2012 – 9 months	2.6	1.0

Public construction investments amount to over 30%. The major clients of construction in Turkey are:

- Public sector (kamu kesimi)
- Government budget organizatons (genel bütçeye dahil kurumlar)
- Government and private budget organization (katma bütçeli kurumlar)
- Special administrations (özel idareler)
- Municipalities (belediyeler)
- State economic enterprises (iktisadi devlet teşekkülleri)
- Private sector (özel kesim): individual and enterprises (özel kişi ve teşebbüsler)
- Construction cooperatives (yapi kooperatifleri)

TURKISH CONTRACTORS ASSOCIATION (TCA)

The Turkish Contractors Association (TCA) was founded on 26 January 1952 in Ankara. The main objective of the association is to assist Turkish contractors in all their activities and inform them about developments in the field of contracting at home and abroad. The association deals with problems faced by member and non-member contractors from the contract-award stage to final close-out of the works.

The current membership of the association consists of 154 representatives, which have undertaken about 70% of the domestic projects and 90% of the international projects awarded to date. They are not only involved in construction but are also active in the field of industry and engineering.

The projects completed by the member companies cover a range of works related to all kinds of civil engineering and industrial activities, such as dams, hydropower and thermal power plants, industrial buildings, large scale oil and natural gas pipelines, petrochemical refineries and complexes, motorways, tunnels and bridges, seaports and airports, large-scale housing projects, high-rise and prestige buildings, hotels and tourist resorts.

Table 2.2: Total Project Value and Average Distribution of Works Conducted by TCA Member Firms (TCA, 2012)

Fields of Activity	Project Value (USD 1972-2012)	Share (%)
Road/Bridge/Tunnel	4,132,738,000	15.5%
Housing	3,544,751,871	13.3%
Airport	2,482,426,449	9.3%
Tourism Facilities	2,406,940,986	9.0%
Railroad	2,044,188,354	7.7%
Sport Facilities	1,954,249,748	7.3%
Industrial Plants	1,331,447,530	5.0%
Power Plants	969,849,945	3.6%
Commercial Centers	943,787,858	3.5%
Health Facilities	707,029,126	2.7%
Other	6,092,963,063	22.9%

TCA prepares and submits reports to the relevant public authorities reflecting its members' opinions and observations on matters related to the construction industry. The association also provides technical counsel in the determination of short and long term general policies concerning the construction sector. The TCA is member to the European Union of Developers and House Builders (UEPC) since 1992 and became full member to the European Construction Industry Federation (FIEC) on 25 May 2000 (Turkish Contractors Association, 2012).

TURKISH CONTRACTING IN THE INTERNATIONAL MARKET

Turkish contractors started working internationally during the early 1970's, a period when Turkey faced serious economic and political difficulties. The embargo imposed after the Cyprus crisis in 1974 particularly hurt the economy. The depressed home market coincided with the recession in the world caused by the surge in oil prices. The first country where Turkish contractors offered their services was Libya. Turkish contractors started their Libyan projects by importing the necessary technology from European countries. Later on, the growing Turkish contracting activities extended to other international markets, beginning with the Middle-East countries such as Iraq, Jordan, Saudi Arabia, Kuwait, the United Arab Emirates (UAE), Yemen and Iran. Today, they are working in approximately 100 countries with a business capacity of 242 billion USA Dollars. Turkish contractors have established very good relations with clients, gained first-hand knowledge of the region and its business environment and successfully completed a wide variety of projects employing Turkish labor and using Turkish goods and materials (Turkish Contractors Association, 2012).

Three decades of international work are described in the following paragraphs (Turkish Contractors Association, 2012):

- In the first decade (1972-1979) most of the works were undertaken in North Africa, primarily in Libya (72.53%), followed by Saudi Arabia (15.45%), Iraq (7.25%), Kuwait (4.71%), Greece (0.06%), and Iran (0.01%). The most important activity field in this period was housing (32.1%) followed by seaports (18.1%), industrial plant (15.6%), road/bridge/tunnel construction (11.7%), and urban infrastructure (8.2%), amounting to a total revenue for the period of US$ 1.5 billion.

- In the second decade (1980-1989) the largest share of the total work performed was still in Libya (55.2%), although the importance of this country declined in relative terms. Saudi Arabia (23.4%) and Iraq (11.5%), which were the second and third countries respectively in the first decade, maintained their position while operation in other countries commenced. A new development in this period was the emergence of the former USSR as a market (3.8%). In this decade the share of housing (36.7%) and urban infrastructure (17.2%) increased, followed by road/bridge/tunnel construction (7%) and irrigation (5.4%). The total value of projects undertaken in this period was US$ 11.5 billion.

- In the third decade (1990-1999) the trend changed. The share of the Russian Federation rose to 34.5% while the share of Libya fell drastically to 13.7%, followed by Kazakhstan (7.8%) and Turkmenistan (6.7%). Seen as a whole, the share of the former USSR countries amounted to 58.3%. A development in this period was the great diversification of the countries where work was carried out, with the emergence of markets such as Kazakhstan (7.8%), Turkmenistan (6.7%), Pakistan (6.6%), Uzbekistan (3.9%), Azerbaijan (2.6%), Bulgaria (2.6%), USA (2.5%), and Croatia (2.2%). A drastic fall in the share of Saudi Arabia (3.1%) and the clearance of Iraq from the scene are very significant. Under the classification "others" there are 33 countries accounting for 6.2 % of the work volume. The share of housing decreased (24.9%), followed by road/bridge/tunnel construction (12.7%), industrial facilities (9%) and commercial centers (8.1%). The total value of the projects in this period amounts to US$ 18.2 billion. The Russian Federation accounts for US$ 6.3 billion and US$ 10.6 billion together with the former USSR countries.

In 2001, Turkish contracting firms continued the negotiations for projects totaling to an amount of approximately US$ 1 billion. As a result of these business development activities, several projects have been undertaken in Ireland, India and Morocco. Being a new and potential market, Ireland has an important place in business development activities of the member firms. In Ireland, projects totaling to US$ 100 million varying from power plants to highways and housing are being carried on. Also, a US$ 55 million highway rehabilitation project in India and a US$ 85 million highway construction project in Morocco are few examples of the achievements of Turkish contracting firms in 2001. Romania, the Russian Federation and Iran are also among countries where the member firms have progressed to contract signing stage for various projects.

During the 2000-2012 period, the annual volume of business undertaken abroad increased from 2.6 billion dollars in 2002 to 25.0 billion dollars in 2007. In the following years, under the effects of the global crisis, this figure decreased to 20 billion dollars in 2011. However, in 2012 Turkish international contracting services reached its peak level by 26.6 dollars.

Table 2.3: Turkish International Contracting Services in 2012 (TCA, 2012)

	Number of Project	Project Value (USD)	Share (%)
Turkmenistan	80	4,885,604,764	18.4%
Iraq	114	4,384,036,891	16.5%
Russian Fed.	40	3,640,667,064	13.7%
S. Arabia	27	2,245,458,430	8.4%
Iran	4	1,855,495,000	7.0%
Ethiopia	1	1,699,900,000	6.4%
UAE	5	1,288,870,744	4.8%
Qatar	15	892,285,480	3.4%
Morocco	5	860,986,410	3.2%
Other	150	4,857,068,147	18.3%
	441	26,610,372,930	100.0%

International construction works play an important role through resulting in entrance of foreign currency into Turkish economy in forms of profit transfer of the contracting company. Construction provides a positive support to the country's trade balance through the export of construction materials, machine and equipment (Turkish Contractors Association, 2012).

One of the important advantages of Turkish Construction companies working abroad is the employment of Turkish workers abroad. For political and bureaucratic reasons, employment volume dropped from 200,000 in 1980's to around 50,000 in the following years.

COMPETITIVENESS OF TURKISH CONTRACTORS

Due to instability of construction demand in the domestic market, globalization of services is a widely used strategy by Turkish contractors. Low cost of labor, geographic and cultural proximity, timely delivery of projects and good client relations are the major sources of competitive advantage for Turkish contractors abroad. Other key advantages behind Turkish contractor's success are locally gained experience, intense domestic and international rivalry among contractors. However, to be able to compete successfully in international markets, it is becoming increasingly unavoidable for construction firms to provide a financing package for the client. This seems to be a major weakness for Turkish contractors abroad, i.e. insufficient financial resources.

Every year a list of top 225 contractors are published by the Engineering News Record (ENR). Evaluation parameters cover the annual income and the value of contracts awarded within the year. In years 2008, 2009, 2010, 2011, and 2012, numbers of Turkish contractors included in the list were 23, 31, 33, 31, and 33 respectively. In 2013, there were 38 Turkish contractors among the top 250 international contractors of ENR list. Turkey ranked the second in the World after China in terms of numbers of contractors entered the list.

COMPETITIVENESS OF TURKISH DESIGN ENGINEERING AND CONSULTANCY

Turkish design engineering and consultancy is also operating internationally but has a relatively weak competitive position compared to the contractors. The lag may be explained by the fact that related Turkish government agencies assumed the engineering role themselves for a long period of time. An example is the State Hydraulic Works (Devlet Su İşleri – DSİ) which did their own engineering rather than acquiring engineering services from private firms.

The lag of Turkish engineering has also been attributed to the fact that Turkish firms first started internationalize as subcontractors to foreign firms during the 1970's, which delayed the development of design engineering and consultancy firms. It has been argued that the relative lagging competitive position of Turkish design engineering and consultancy firms is not favorable for long-term competitiveness of Turkish construction as a whole. Weaknesses in engineering services could result in uncompetitive bids in design and build contracts, and furthermore during the design phase of a project it may lessen the opportunity to promote the use of materials and/or contractors from Turkey (Öz, 2001).

2.4 REFERENCES

1. AECOM, retrieved from http://www.aecom.com/deployedfiles/Internet/About/CAM/WorldConstructionReport_2012.pdf
2. Birgönül, T., and Özdoğan, I. (2000). Competitiveness of Turkish Contractors in International Markets, Proceedings of ARCOM 16th Annual Conference, September 6-8 2000, Volume 1.
3. Bon, R. (1992). The future of international construction: Secular patterns of growth and decline, Proceedings of Habitat International, Volume 16.
4. DİE, retrieved from http://www.die.gov.tr/TURKISH/SONIST/BINA/161003tr.htm
5. DPT 9. Kalkınma Planı 2007-2013 (2006). İnşaat, Mühendislik-Mimarlık, Teknik Müşavirlik ve Müteahhitlik Hizmetleri ÖİK Taslak Raporu.
6. Global Construction Perspectives, retrieved from http://www.globalconstruction2025.com/
7. Harris and McCaffer, (2001). Modern Construction Management, 5th Edition, Blackwell Science.
8. International Labor Organization, retrieved from http://www.ilo.org/public/english/dialogue/sector/sectors/constr.htm
9. KLM Press, retrieved from http://www.intlconstruction.com
10. Porter, M. A. (1985). Competitive Advantage, The Free Press, New York, NY.
11. Riley, M. J., and Clare-Brown, D. Comparison of Cultures in Construction and Manufacturing Industries, Journal of Management in Engineering, July 2001.
12. Turkish Contractors Association, retrieved from http://www.tca-uic.org.tr
13. International Labor Organization, retrieved from http://natlex.ilo.ch/public/english/dialogue/sector/techment/tmcit01/tmcitr.pdf
14. Turkish Contractors Association, retrieved from http://www.tmb.org.tr/genel_dokumanlar/ulkeler-firmalar_activities.xls
15. WTO, retrieved from http://www.wto.org/english/tratop_e/serv_e/construction_e/construction_e.htm

CHAPTER 3

PROJECT DELIVERY SYSTEMS AND CONTRACTUAL ARRANGEMENTS

3.1 INTRODUCTION

In this chapter, project delivery systems (sometimes called as procurement methods or contracting methods) commonly used in the construction business will be introduced as well as contract types (sometimes known as payment types). Before a more detailed discussion of these topics, following definitions are given to clarify the terminology of "project delivery systems", "contract types" and "bidding types".

<u>Project Delivery System (PDS):</u> A PDS is a way (a method) of organizing all phases of a construction project by establishing relations *(contractual or non-contractual)* between parties involved in the project. PDS is chosen by the client (or known as the owner) and it determines the responsibilities of different parties involved in the construction process. Client (project owner) may carry out the construction process himself/herself; hire a single contractor or a number of specialty contractors to carry out the construction work. He may assign design to a separate design company or to the contractor. He may organize the construction process himself or hire a professional construction management firm to organize everything. Thus, a number of methods, which are known as PDSs, are used in the construction industry depending on the needs of the client, project characteristics etc. A PDS is also called as a procurement method or contracting method.

<u>Contract Type:</u> Construction contracts may be classified into two major categories on the basis of payment terms: fixed-price contracts and cost-plus contracts. A contractor may be paid in fixed prices (which is also divided into two categories such as lump-sum and unit-price contracts) determined <u>before</u> the construction starts or actual costs realized <u>during</u> the construction plus a fee. Thus, contract type determines how a contractor is paid. There are no strict rules about which contract types may be used in different PDS. For example, in design-build, contract type is usually lump-sum. However, this cannot be generalized as it depends on project characteristics. For example, if necessary, a combination of lump-sum and unit-price payments may be preferred in design-build depending on type of job, predictability of quantities etc.

<u>Bidding Type:</u> It is a way of awarding contracts to different parties by the client. It is also known as "contract award mechanism". There are two methods: <u>competitive bidding</u> or <u>negotiation</u>. In competitive bidding, a number of interested contractors submit bids and client chooses the best option based on predetermined criteria; usually the lowest cost bidder is awarded the contract. In negotiated bidding, client invites a party (or sometimes a number of parties) and evaluations are made based on criteria like experience, managerial capabilities, technical know-how etc. Contract award is based on evaluation of skills rather than price competition. There are no general rules about which type of bidding shall be used in different PDSs as it depends on factors such as client preferences, project type etc. This is also valid for contract types, however, there are certain "common practices" which are widely observed in the construction industry. For example, in negotiated bidding, cost-plus types of contracts are mostly used.

To sum up, there are three decisions that should be made by the client before commencement of the project:

- Which PDS shall be used?
- Which contract type shall be used?
- What kind of bidding shall be used?

In the forthcoming chapters, factors that affect the answers of these questions are discussed in detail.

3.2 PROJECT DELIVERY SYSTEMS

Due to the macro-factors (sustainability issues, technological advances, cost-time limitations, focus on quality etc.) affecting the construction industry, the relationships between the parties involved in a construction project resulted in different ways of project delivery. Each PDS has its advantages and disadvantages. Choosing the right PDS according to the needs of the customer is a crucial task in the early stage of any construction project. The decision that will most affect the relationships and risk allocation on a construction project is the choice of PDS. There is no perfect PDS for every construction project. The best method should be chosen after careful evaluation of the needs of the customer, time and budget constraints, completeness of design, project complexity, the owner's qualifications and experience. Types of PDS are discussed in the forthcoming sections.

3.2.1 Traditional Construction Contracting (Design-Bid-Build or DBB)

In the traditional method of construction contracting, which is also known as Design-Bid-Build (DBB), owner has separate contracts with designer and contractor. He contracts with a designer for the design, and separately contracts with a general contractor for the construction of the project (Figure 3.1). This is the most common method of construction.

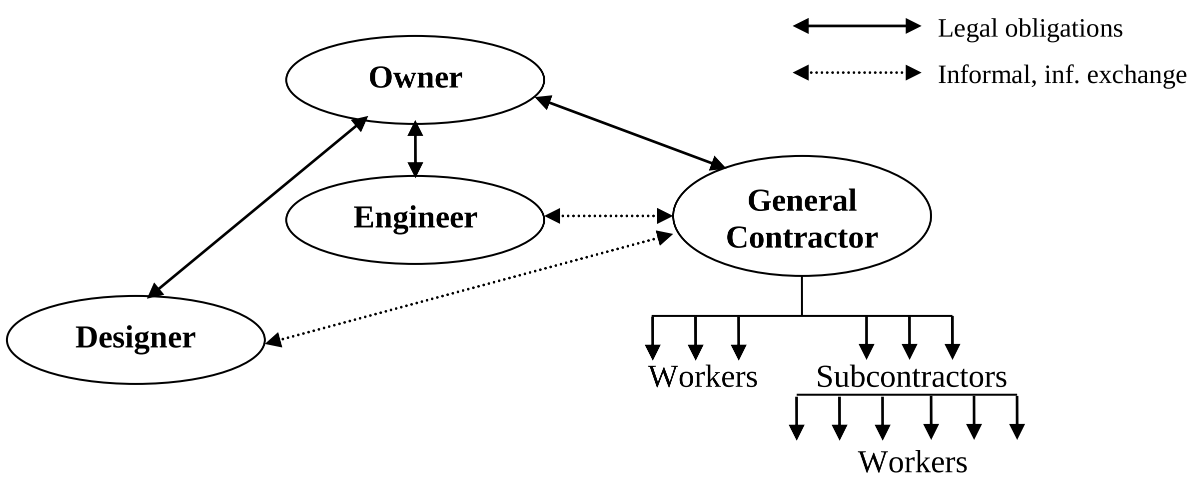


Figure 3.1: Traditional Contracting Method (DBB)

The responsibilities of parties shown in Figure 3.1 are as follows:

Owner	: Feasibility, financing and sometimes controlling the works
Designer	: Technical calculations, drawings, specifications, bill of quantities, cost estimation, preparation of tender documents and sometimes controlling the works
Contractor	: Production (constructing the facility according to design), providing manpower, materials and equipment
Engineering firm	: Controlling the works

In DBB, owner has a dominant role due to separate contractual relationships with both the design entity and the contractor. In this arrangement, the owner warrants to the contractor that the plans and specifications are buildable. If problems arise during the course of construction - or even after substantial completion - the owner becomes the intermediary between the contractor and design firm. The traditional system has several disadvantages. The primary disadvantage is the potential for conflict. The traditional system often hinders communication among the parties which can result in misinterpreted plans and specifications causing delay, cost overruns and legal problems. DBB creates greater potential for time and cost overrun since the design and construction processes are performed independently.

3.2.2 Separate Contracts Method

In this type of system, owner lets contracts to a number of specialty contractors. In other words, owner acts as a general contractor which hires a number of subcontractors to carry out the work (Figure 3.2). The owner should have the necessary organizational skills, knowledge and experience in construction works so that this PDS can be successful.

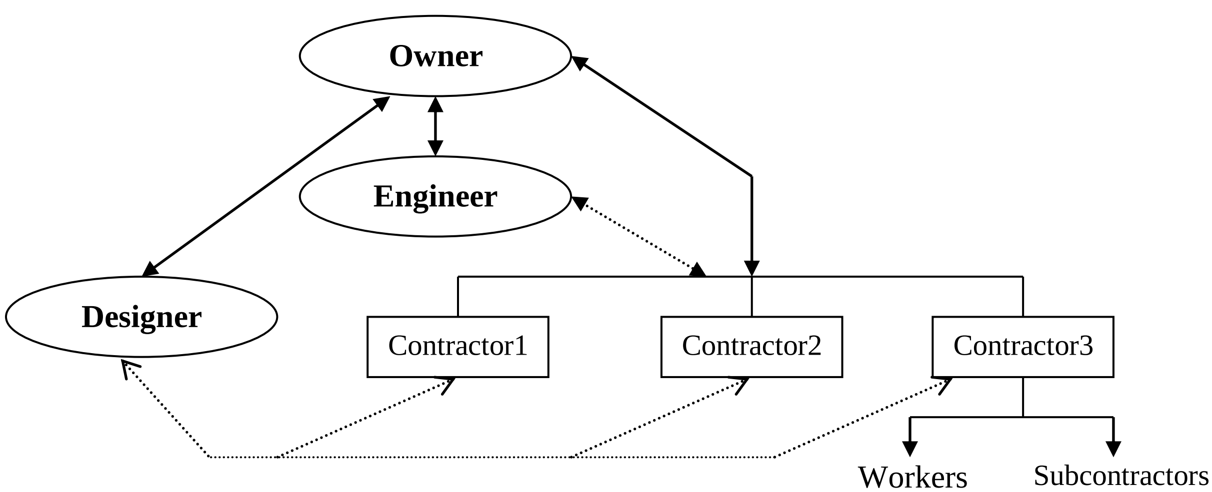


Figure 3.2: Separate Contracts Method

3.2.3 Self-Performance Method (Force Account Method)

In self-performance method, also known as force account method, owner deals with the organization and management of construction works, thus takes the risk of construction works (Figure 3.3). His expected benefit from this is cost minimization by not paying the profit to the general contractor and subcontractors. However, this method requires a permanent construction team in the owner's organization, extensive knowledge and experience in construction works. It is a preferred method if the owner has a continuous construction activity that justifies employing an in-house construction team financially.

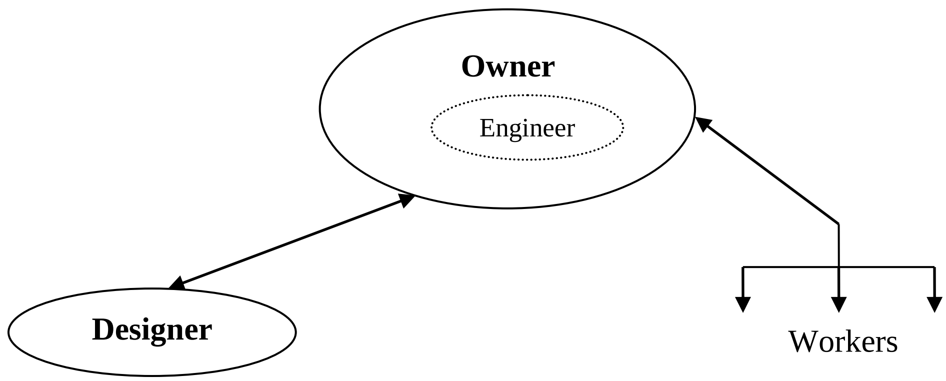


Figure 3.3: Force Account (Self-Performance) Method

3.2.4 Design Build Method (or Turnkey)

In design-build (DB), the owner contracts with a single entity which provides both the design and construction services. Unlike the DBB scenario where the owner assigns the design to the contractor, the DB agency has the responsibility for the design. In this situation, the owner will call upon the DB agency to respond to and correct any design problem that may arise during the course of construction, or following completion of the project. A typical organization chart for DB system is shown in Figure 3.4.

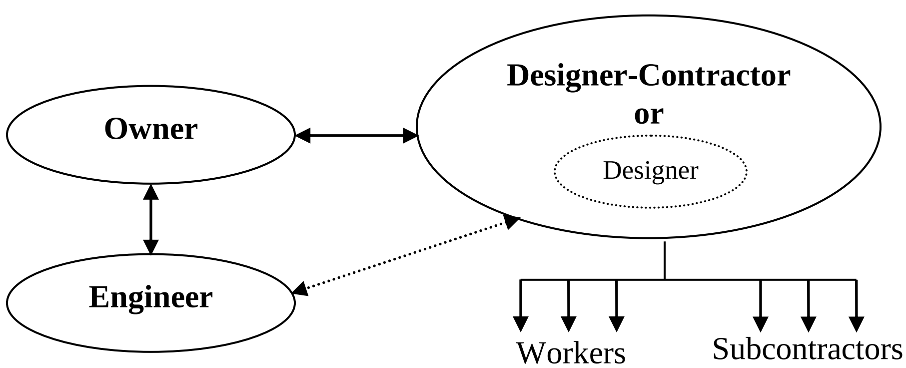


Figure 3.4: Design-Build Method

DB is very popular in recent years, especially for industrial type projects. It gives design firms and contractors the opportunity to work as a team, and to deliver a quality project on time and within budget. Design and construction are overlapped resulting in time savings from the project completion time. For example, once foundation design is completed, the construction may start. Fewer changes will arise during construction since the design evolves with construction. When compared with DBB, DB has significantly less design changes and construction cost overrun. Quality associated with DB is usually claimed to be better than quality performance in DBB. Also, an advantage for the owner is that the owner is in communication with one company for the responsibility of the whole project. In this type of system, the owner is less involved with the project. Supporters of this method claim that the owner enjoys lowest cost in shortest time. Thus, DB can minimize many of the problems which often lead to claims in the DBB process. One of the many advantages of DB is that the general contractor is involved early in coordinating cost issues and structural issues with the architect. The architect and contractor are more motivated to communicate well and work together since they are part of the same team or venture. This decreases the risk of delay and poor constructability.

However, for DB system to be successful, owner should clearly define the scope of the project prior to construction during design brief. The most important task for an owner is to prepare clear performance, technical and quality criteria for the project. These criteria will include objectives for durability, design life, operational criteria, standards of finish and aesthetics, community and environmental standards. The next input from the owner is conditions of contract that appropriately allocate risks and create contractual arrangements that can accommodate a likely range of events and circumstances. In this way, uncertainty and the potential for dispute can be minimized.

Some of the problems associated with DB are;

- Lack of clarity in respect of the specifications in the design brief may lead to disputes as it may be unclear whether the contractor has in fact constructed the product described in the contract or not. The finished product may not turn out to be what was expected.
- It can be difficult for the owner to comparatively assess tender proposals submitted by prospective contractors as proposals may differ significantly.
- The total cost of project is usually not known until the construction phase.
- There is a potential for contractors to affect savings and increase profit within the lump sum contract by under-designing some aspects of the project. This may happen as a result of the design brief which defines performance or quality requirements inadequately.
- From a practical viewpoint, the owner has significantly less control than it would by other delivery methods.

3.2.5 Construction Management (CM)

In Construction Management (CM) method, the owner hires a construction manager (person or company) to develop the necessary relationship between the owner and the general contractor (Figure 3.5). This type of system is used in big construction projects where the owner does not have enough experience about the construction works. The construction manager receives an agreed fee for managing the whole construction process but assumes no financial liability.

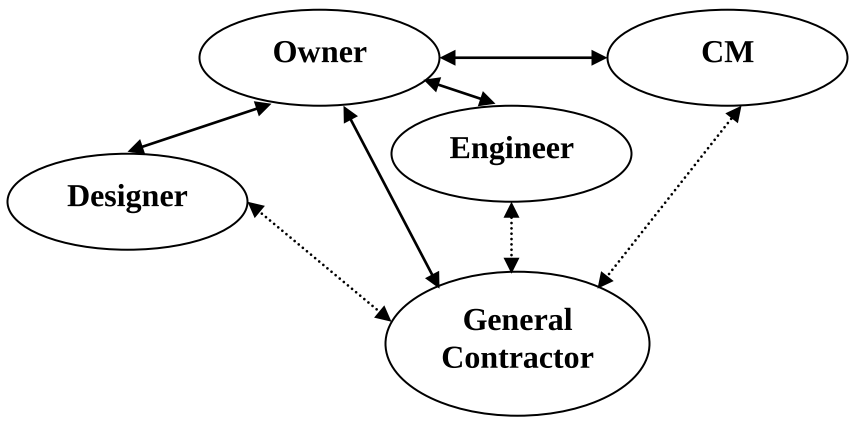


Figure 3.5: Construction Management Method

The construction management approach has the advantage of a single party being responsible for the entire project. Thus, an owner should make all efforts to find the most knowledgeable, experienced manager available. To achieve the best project results under a construction manager, there should be a strong working relationship between the owner and the manager. Although better construction management skills (planning, estimating etc.) and better organization may lead to significant savings, the fee for construction manager may be too high and increase overall cost of the project. Moreover, as construction manager does not guarantee the total cost and quality of work, client may face with the risk of underperformance if the right selection is not made about the construction manager.

3.2.6 Build Operate Transfer (BOT) and its Variations

The BOT structure was developed specifically as a way of involving the private sector in the provision of new infrastructure. Due to lack of governmental funds to finance basic infrastructure projects such as hydropower plants, tolled motorways, tolled crossings (Bridges, tunnels, channels) etc., a private company is given the right to first develop and then to operate these facilities. Thus, it is usually implemented in developing countries where the government does not have sufficient financing to carry out infrastructure projects. In BOT, usually, a consortium of firms (contractors, designers, financial institutions, operator firms etc.) is established to finance, construct and operate the facility for a concession period awarded by the government. Ownership of the facility is transferred to the government at the end of the concession period, which will be of such length as to allow the builders and financiers to recover their outlays with a return. In some cases, government guarantees a certain amount of demand to generate agreed minimum revenue for the organization to recover the investment costs. Although it is an innovative PDS specifically developed to finance infrastructure projects needed in developing countries, its success is not guaranteed. It may be sometimes difficult for the government to find a company that may be financially strong enough to cover the project budget. The project must be feasible so that it may attract potential investors. Thus, government should give some guarantees to increase feasibility of projects such as demand guarantee etc. The legal background of the BOT system has to be very strong so that responsibilities of parties and risk allocation schemes can be clearly defined. Another complication about this system is that the government has limited control over a facility during the operation period by the company, which can be a very strategic project for the country. Finally, due to the high number of parties involved, significant uncertainties about future revenues and cost, and legal complications, BOT projects are risky undertakings. BOOT (Build Own Operate Transfer) and BOO (Build Own Operate) are variations of the BOT system which are developed to increase applicability of BOT formula.

3.3 CONTRACT TYPES

There are two general classifications of contracts used in the construction industry based on the way in which a contractor is paid for: fixed price contracts and cost-plus contracts. In fixed price contracts, contractors agree to construct the facility on a fixed price basis where either the overall price (lump sum contract) or unit prices (unit price contract) are fixed.

In **lump-sum (götürü usul)** pricing, a contractor's fee for services is established as a total contract amount. A price is agreed upon by the client (owner) and the contractor for the whole project. The risks due to market fluctuations belong to the contractor. So, it is a nice system for the client (owner) who knows exactly how much the job will cost (unless there is an unforeseen event) and will get his job completed in the minimum time. However in this system, a complete control must be kept on the job since the contractor may use poor material and unqualified labor. The owner may be in an adversary position with the contractor especially if the scope of work is not clearly defined. For the contractor, the advantage of lump sum pricing is that it gives him a set target to shoot for. The disadvantage lies in the fact that a lump sum contract allows no flexibility for adjustments thus, a risk premium is required to financially cover the cost of unforeseen job conditions. Poor cost estimating may result in disastrous situations for the contractor.

The **unit pricing** method (birim fiyat) establishes payments based on the amount of production or quantity of works completed at a fixed price. It is a steady and guaranteed system for the contractor who is covered against any fluctuations in the market. In Turkey, in unit price contracts, costs can be calculated by multiplying quantities with unit prices which are published every year by the Ministry of Environment and Urban Planning. Sometimes, rather than the unit prices published by Ministry of Environment and Urban Planning, unit prices offered by the contractor are used. In case of offered unit-prices, the contractor should accurately estimate the unit price of production and complete the job successfully to ensure profitability.

A combination of lump-sum and unit-price contracts is also possible. In mega projects where quantities associated with some part of work are determined, whereas some quantities cannot be clarified due to uncertainties (about geological conditions, poor scope definition etc.), a combination of lump-sum and unit-price can be used. Although a lump-sum price is determined, for the unclear part of work, contractor may be paid in unit-prices.

In **cost-plus-fee (maliyet artı kar)** pricing (often called simply "cost-plus"), payments for services are based on the contractor's actual expenses plus a predetermined fee, which is usually a percentage of the expenses. Here the contractor has the advantage that if he carefully records all his costs, he is almost certain of a profit. On the other hand, the enormous amount of paperwork involved can be very time-consuming, and if any expenses are not recorded, the costs of those expenses as well as the profits may be lost. The success of a cost-plus contract relies heavily on the good faith of the contractor. Client should control that the contractor claims the "real costs" and does not exaggerate the costs with the aim of earning more money. Cost-plus-fee contracts are mostly used in negotiated bidding. Most widely used forms of cost-plus contracts are "cost-plus fixed-fee" and the "cost-plus-percentage fee" contracts. A cost-plus contract provides a formula for determining the fair price of the work as it is done and often sets a guaranteed maximum price (GMP) for the project. As a result, both the contractor and the project owner are protected. In this type of contract, only major changes in the scope of work or the original intent of the contract results in adjustment of the GMP. Finally, although quality of the work is claimed to be higher in cost-plus contracts, it is also known that cost-plus may not be the most economical solution for the client.

3.4 CONTRACT STRATEGY

A **contract** is a document or set of documents that expresses the expectations and responsibilities of the parties involved in a project and protects each party's rights regarding the project. Although it is legally binding, the real essence of any contract is that it is an expression of trust between the parties. The construction contracts documents—the contract with attachments—defines the agreement made between the owner and the constructor for project construction. This is a two-party agreement, in whatever form, accurately documents a "meeting of minds" of the parties. The contract should be in clear, concise language, clearly defines responsibilities of the parties without overlaps or voids, and aims at achieving a quality project.

A contract is necessary because each party has its own expectations, which sometimes conflict with the expectations of the other party. A contractor expects a reasonable profit, satisfactory working conditions, fair treatment and timely payment. The project owner expects quality work at a reasonable cost, timely completion and fair treatment. Both sets of expectations are based on the desire for profit. Seen from this perspective, the contract becomes the ground on which each party tries to establish conditions in which it can maximize its profit. For his part, the contractor wants a contract that allows him maximum opportunities for doing a quality job at the lowest reasonable cost and for the highest reasonable fee. The project owner, on the other hand, wants the contract to ensure that he gets quality work but for the lowest reasonable fixed price or fee, and here is where the potential for conflict arises. The contract recognizes that the conflict exists but also expresses each side's willingness to compromise for mutual benefit and to trust the other's fairness. It defines the business relationship and provides guidelines for dealing with the unforeseen events that plague every project and threaten one or both parties' profits.

Gaining an advantage begins with thoroughly understanding what the contract says and then organizing and implementing the construction efforts accordingly (ASCE, 1988). Despite its legal terminology, a construction contract essentially states six simple things:

- Who is responsible for what?
- How work is to be done.
- When it is to be done.
- What the finished product must be.
- Who gets paid what, and when, and
- What happens when something goes wrong?

Unfortunately, it is the nature of the construction process for these simple things to become enormously complicated. Thus, contract documents must be precisely worded and thoroughly detailed.

The term "contract documents" includes the contract for construction between the owner and constructor, together with other documents referenced by and made a part of the owner/constructor agreement. These documents, taken together, define the responsibilities of each party during the construction phase. Contract documents generally include:

- Definition of the parties.
- Identification of applicable law.
- Addenda (if any) issued before bid submittal.
- Contractor's bid.
- Notice of award.
- Effective date of the contract.
- Definition of uncommon terms.
- Scope of work.
- Plans and specifications for facilities to be constructed.
- Contractual milestone dates/completion dates.
- Assignment of authority and responsibility between parties.

- Risks and liabilities assumed by each party.
- Terms and methods of payment.
- Insurance and bonds.
- Contract change-order procedure.
- Settlement of disputes.
- Contract termination conditions.
- Indemnifications.
- Warranties/guarantees.

The basic definitions of various terms discussed in a contract are listed below:

Construction **plans** are drawings that show the location, dimensions, and details of the work to be performed. Taken together with the specifications, they should provide a complete description of the facility to be constructed. Types of contract drawings include site drawings and detailed working drawings. Contract drawings are usually organized and numbered according to specialty, such as structural, electrical, and mechanical.

Construction technical **specifications** provide the detailed requirements for the materials, equipment, and workmanship to be incorporated into the project. Contract drawings and specifications complement each other and must be used together.

Shop drawings are drawings, charts, and other data prepared by a contractor or supplier which describe the detailed characteristics of equipment or show how specific structural elements or items of equipment are to be fabricated and installed. Thus they complement but do not replace the contract drawings.

Subcontracts are contracts between a prime contractor and secondary contractors or suppliers. Subcontracts are widely used in building construction for the installation of electrical, plumbing, and heating and ventilating systems.

A **claim** is a request by the contractor for a time extension or for additional payment based on the occurrence of an event beyond the contractor's control that has not been covered by the contract. Most claims fit into one of the following categories; injury or damage claims, delay or disruption claims, change in conditions claims, change in scope claims, time extension claims, termination claims and payment delay claims.

Disputes are disagreements between the contractor and owner over some aspect of contract performance.

In general, one will have a good basic understanding of the project contract if the following questions (MCAA, 1984) can be readily answered:

1. Who are the parties in the contract?
2. Who gives orders, in what circumstances?
3. Who pays who and how is the payment method?

4. What kind of job is it? (Government, institutional, public, commercial, industrial, etc.)
5. Are designers, subcontractors, suppliers, etc. involved in the project and what are their duties about the project?
6. What permits and inspections are required by the Government? (Codes, standards, etc.)
7. Are there any subcontractors and what are their duties?
8. What are the specific details of construction? (Special tool or equipment requirements, potential coordination problems, feasibility of design)
9. What is the project schedule? Are there any penalty fees if the project is delayed?
10. What are the important administrative details? (Procedures for billing, approving change orders and its estimates, accepting work, back charges, getting compensation for delays, filing claims, etc.)
11. Who determines the project schedule and how can the schedule be modified if there changes out of the original scope?
12. What is the procedure for changes? (Who has the authority to approve change orders? How are changes to be billed? When are changes to be billed? When will payments be made?)
13. What happens if something goes wrong? (Who is liable for losses due to accidents, delays, changes? How will the amounts of claims be calculated?)

Substantial efforts by professional and industry associations have advanced the cause of standardization of contract content, form, and language with a large body of information. For example, as a standard form of contract, FIDIC Conditions of Contract prepared by International Federation of Consulting Engineers, is widely used in international construction projects.

3.5 CONSTRUCTION WORKS GENERAL SPECIFICATION FOR PUBLIC PROJECTS

General Specification for Construction Works describes the fundamentals that will be applied in execution of all kinds of public construction works. This specification becomes automatically part of the contract when the client makes an agreement with the contractor according to Public Bidding Law (2002).

3.6 REFERENCES AND BIBLIOGRAPHY

1. ASCE (1988). Manuals and Reports on Engineering Practice No. 73. ‘Quality in the Construction Project’. First Edition.
2. Bayındırlık İşleri Genel Şartnamesi, 29. 8 .1984 Tarih, 84 /8520 Sayılı Bakanlar Kurulu Kararı, Başbakanlık Basımevi -1984, Ankara.
3. Bosch J.C.V., P.E. (1997). Comparing Project Delivery Systems, A Report Submitted To Construction Industry Institute.
4. COBRA (2001) Conference Papers, retrieved from www.Rics-Foundation.Org

5. Genesis (2003). Selecting the Right Project Delivery System, retrieved from www.Genesisplanners.Com
6. Gould, F. (1997). Managing the Construction Process. Prentice Hall. Upper Saddle River, NJ.
7. Hanna, A.S. (2001). CEE 498 Class Notes, Integrated Project Estimating and Scheduling. University of Wisconsin, Madison.
8. Harris, F. and McCaffer, R. (2001). Modern Construction Management, 5th Edition, Blackwell Science, UK.
9. HK Highways Department Project Delivery System (2003), Volume 1, Selection of Project Delivery Options.
10. Humphreys, K. and Wellman, P. (1987). Basic Cost Engineering. Second Edition. Marcel Dekker Inc. New York, NY.
11. Ibbs C.W., Young H. K., Tzeyu N., and Odabasi, A. M. (2003). Project Delivery Systems And Project Change: Quantitative Analysis, ASCE Journal Of Construction Engineering And Management, Vol. 129, No. 4, July/August 2003, pp. 382-387.
12. MCAA Project Managers Manual (1984). Mechanical Contractors Association of America, Inc. Bethesda, MD.
13. Mcwhorter, V.S., and Hanson, M. E. (2000). Twenty-First Century Project Delivery Systems. Proceedings of North American Tunneling 2000 Conference.
14. Mincks, W., and Johnston, H. (1998). Construction Jobsite Management. Delmar Publishers.
15. Newcombe, R. (1999). Procurement as a Learning Process. Journal of Construction Procurement, 5(2), 211-220.
16. Nunnally S.W. (1993). Construction Methods and Management. Third Edition. Regents /Prentice Hall, Englewood Cliffs, NJ 07632.
17. Parsons Brinkerhoff Network, March (2000). Alternative Project Delivery Systems.
18. Robertson P.A., and Associates, P.A. (1997). Newsletter. Project Delivery System: Methods and Risks.
19. Russell, J.R. (2001). CEE 498 Notes. Construction Project Management. University of Wisconsin, Madison.
20. Tennant, T.R. (1998). 'Advanced Project Delivery Systems: Design-Build And Design Delegation Insurance Issues, Presented At The American Bar Association Forum On The Construction Industry And Section Of Public Contract Law By Terry R. Tennant On October 16-17, 1998 At The Fairmont Hotel, Chicago, IL.

CHAPTER 4

CONSTRUCTION COST ESTIMATING

4.1 INTRODUCTION

Cost estimating is an attempt to forecast the actual cost of a project. Cost estimates play an important role for determination of the bid amount as well as development of the project budget. Inaccurate cost estimates may lead to lost opportunities, lower than expected returns, and unsuccessful projects. Estimating in general requires detailed study of the bidding documents including construction drawings and specifications, a quantity takeoff, and determination of costs. There are numerous estimating methods that could be used depending on the project type, delivery method, and details of the drawings available. This chapter presents only general aspects of construction estimating rather than a very detailed discussion of estimating methods.

TYPES OF ESTIMATES

There are several classifications about the cost estimates depending on their accuracy level, or methods being used to determine the estimated cost. In general cost estimates could be classified into two groups; preliminary cost estimates and detailed cost estimates. Preliminary cost estimates also sometimes named as conceptual cost estimates are usually prepared before drawings and specifications are available and detailed cost estimates are prepared after construction drawings and specifications are available. According to cost estimate definitions of Construction Cost Institute (CII SD-6) preliminary cost estimates are expected to have an accuracy range of ±10% to ±50% depending on the level of information and estimating method being used. Detailed cost estimates on the other hand, are expected to have an accuracy of ±1 to ±10% depending on the type of project.

4.2 PRELIMINARY ESTIMATES

Preliminary cost estimates are usually performed at the early stages of the projects with very limited information since drawing and specifications are not available. One of the main reasons for having preliminary estimates is to decide about feasibility of a project. If a project is determined as feasible based on the preliminary estimate than detailed design, bidding, and construction stages could be initiated, therefore early estimates play a crucial role on committing resources for further development of a project. Preliminary estimates could also be used for evaluation of different project alternatives and also for development of an initial project budget.

Preliminary cost estimates are not expected to be very accurate since detailed drawings are not available and there are several uncertainties present about project cost at the early stages of a project. However, a quick and reasonably accurate estimate is needed based on the information available, especially when a feasibility decision is to be made.

Numerous techniques could be used for preliminary cost estimating. In general data of past projects are used to develop preliminary cost estimates. A very simple method to determine a preliminary cost estimate is to use average unit cost of similar projects such as 250 $/ m^2$ for building construction, or 100 million $/km. for metro construction. Cost estimates determined by average unit cost method are not expected to be accurate since these estimates are very general, and are based on very limited project information. Modeling techniques such as regression analysis method could be used to improve accuracy of preliminary cost estimates.

4.3 DETAILED ESTIMATES

Detailed estimating requires determination of the quantities and all of the costs to complete the project. The costs to complete the project can be grouped into four categories; material, labor, equipment and machinery, and overhead costs. A profit is added to the total cost estimate for determination of the bidding price. Material costs include cost of all the bulk materials such as concrete, steel, lumber, cables, as well as cost of the mechanical and electrical items such as elevators, boilers and transformers. Labor costs are the cost of the workers that will participate in the project such as; carpenters, electricians, welders and helpers. Equipment and machinery costs include expenses for the construction equipment and machinery such as cranes, trucks and excavators. Overhead costs are the expenses that cannot be related to a specific construction activity but rather general project expenses such as; office expenses, mobilization and camp expenses, bond and insurance expenses.

QUANTITY TAKEOFF

The first step of detailed estimation is investigation of the bidding documents for preparation of quantity takeoff. A quantity takeoff is a detailed calculation of quantities for each work item that is going to be performed to complete the project. Quantity takeoff is an important step of estimating and bidding and a complete set of bid documents including drawings, specifications and conditions of contract are needed for preparation of quantity takeoff accurately. Although the bid documents for a unit-price project usually provide contractors with estimated quantities of each bid item, these are approximate quantities and contractors should perform their own quantity takeoff not only to check bid quantities but also to provide more detailed quantities for accurate pricing of the project.

Quantity takeoff process is mainly calculation of volumes, areas and counting of elements, but it requires an organized approach to every drawing and construction item to ensure that not a single work item is missed. To accomplish this effectively the project must be divided into smaller work packages and each work package must be utilized with the correct units. During quantity takeoff a common unit of measure should be used for each item included. For example; for excavation and backfill m3, for formwork m2, for concrete m3, for structural steel tons are used as a unit of measure.

At the end of this chapter quantity take-off for basic building activities are illustrated with two examples. It is important for the quantity surveyor to visualize the drawings properly and adjust calculated quantities for waste. As an example, when ordering concrete some concrete may be spilled when transported from the mixer by a bucket and this waste amount should be considered during takeoff.

MATERIAL COSTS

Once the approximate quantities of material that will be used for the project are determined the contractor would request quotations (prices) from material suppliers and manufacturers for all materials required. Although sometimes prices of manufacturers may be available as a list, it is more desirable to obtain written quotations that include specifications of the material, transportation details, time required for delivery, materials included in the price, taxes, guarantees and terms of payment. When material costs quoted by different manufacturers are being compared they must be brought to common basis; for example, delivered to site including all expenses.

LABOR COSTS

Labor costs are generally classified into two groups; direct labor costs, and indirect labor costs. Direct labor contributes physical completion of a construction task for completion of a permanent facility. Examples for direct labor are; carpenter, electrician, concrete finisher, welder. Indirect labor supports the completion of the project but cannot be identified as directly working for a specific task. Examples for indirect labor are; project manager, planning engineer, and timekeeper.

In order to estimate direct labor costs accurately the estimator must make a detailed quantity takeoff, analyze job conditions and project schedule carefully, and also maintain a comprehensive library of actual worker hours and labor costs from past projects. One of the methods that is being used commonly for estimating direct labor costs is to use average worker hours per unit quantity. For example using historical records it could be estimated that to produce $1m^2$ of formwork 0.75 carpenter and 0.75 laborer hours is needed. Once the average work hours per unit is determined for a task this could be multiplied by the total quantities calculated to determine total worker hours, and the total worker hours are multiplied by the hourly wages of the workers including taxes and social security expenses to calculate labor cost. If major deviations from average job conditions are expected average worker hours should be adjusted to reflect these deviations.

Indirect labor costs could be estimated after staffing requirements for the project is determined. Once the decision about the size of the indirect project staff is made using project schedule the periods that the staff will be needed for the project could be determined. These durations are multiplied by the gross salaries to determine the indirect labor costs.

EQUIPMENT AND MACHINERY COSTS

Determination of the equipment and machinery that will be used for the project and durations that the equipment and machinery will be used are needed for estimation of equipment and machinery costs. In order to estimate equipment and machinery expenses accurately, early management decision must be made concerning the machinery sizes and types and also whether existing machinery will be used or additional machinery will be rented or purchased. Estimation of equipment and machinery expenses will be discussed in Chapter 8.

OVERHEAD COSTS

Overhead costs are expenses that cannot be related to any specific item of work. If the costs can be related to an item of work they should be included under the material, labor, or equipment costs. The overhead costs are usually estimated as a percentage of total project cost. In calculation of unit prices of Ministry of Environment and Urban Planning the overhead expenses and profit is taken as % 25 of the cost.

The overhead costs are generally divided into two groups; general overhead costs and project overhead costs. General overhead expenses cannot be related to a specific project but often referred as general or administrative costs. Examples for general overhead expenses are head office expenses, salaries of personnel at the head office, and company legal expenses. Project overhead costs are expenses that are related to a specific project but that cannot be related to a specific item of work. Some examples for project overhead cost are salaries of indirect site personnel, mobilization costs, site office expenses, project travel expenses, cost of bonds, project insurance expenses. Since most of the project overhead costs depend on the project duration a project schedule is necessary for calculation of project overhead expenses.

4.4 BIDDING STRATEGY

One of the critical decisions for bidding is determining the amount of profit that will be added to the detailed cost estimate. If profit amount is too high, than the company may not be awarded the contract but on the other hand, if profit amount is too low there may be a risk of a loss at the end of the project instead of a profit. The profit amount depends on several parameters including market conditions, the workload of the contractor, the number of companies bidding for the project and contractor's business strategy. A risk premium called contingency may also be included in the bid amount. The contingency is generally used to cover the uncertainties and risks involved for the bid project.

4.5 EXAMPLES

Example-1: Section views, normal floor column and ceiling plans of a building project are given in Figures 4.1 to 4.5. Determine the quantities of following items:

1) Formwork for slab D302, beam K302 (between S2 and S3), and column S2 (between +3.70 to +6.50).
2) Support for ceiling formwork for Bedroom 1 and Bedroom 2 (including K301, K313, K312, K308, K314, K305 and, K315 but, excluding roof extensions)
3) Reinforcement for column S2 between +3.70 to +6.50, excluding reinforcement extensions from previous floor (For Φ8 rebars unit weight is 0.395 kg/m and for Φ16 rebars unit weight is 1.578 kg/m)
4) Concrete (C20) for slab D302, beam K302, and column S2 (between +3.70 to +6.50).
5) Exterior walls between +3.70 to +6.50 (masonry block-Gazbeton)
6) Interior walls for the normal floor. (Lintel length is 1.3 m.)
7) Interior plastering for the bedrooms and bathrooms (1.2 cm thickness).
8) Scaffolding for interior plastering of ceiling for the gallery opening.
9) Exterior plastering of wall in A1-D1 direction (between +3.70 to +6.38, excluding roof extensions)
10) Scaffolding for exterior plastering for the wall in A1-D1 direction between – 0.80 to +6.38 (Assume that the site in A1-D1 direction has been graded to -0.80 level)
11) Interior painting for the bedrooms
12) Flooring for the bedrooms (hardwood parquet 3 cm. thickness, thickness of the door frame is 3 cm, cornice 10 cm)
13) Baseboard for the flooring in the bedrooms (10 cm.)
14) Polishing of parquet and baseboard for the bedrooms
15) Window frames for the bedrooms and bathrooms (pine with no cornices)
16) Heat insulation of roof (glass wool, including roof extensions)

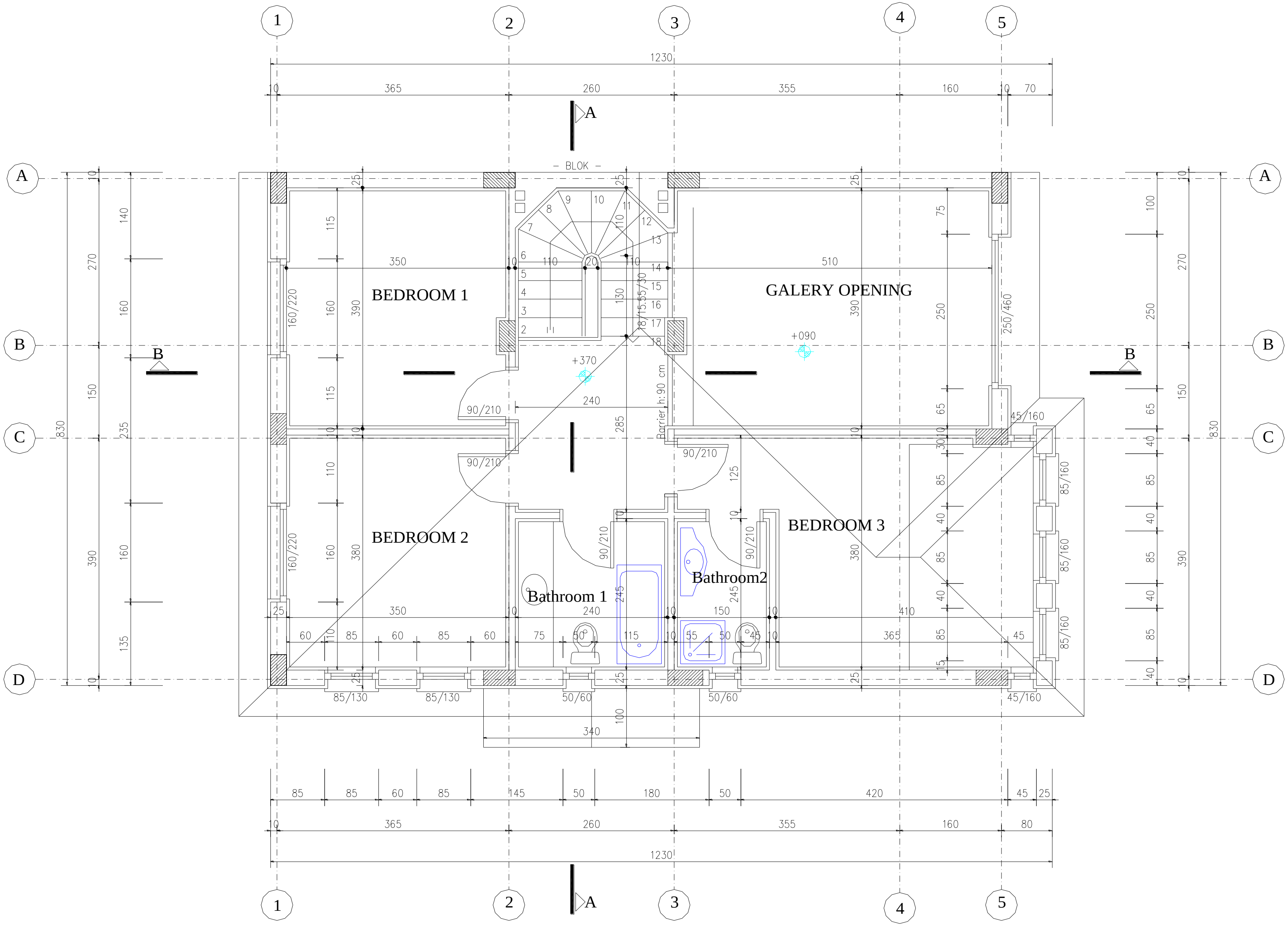


Figure 4.1: Normal Floor Plan

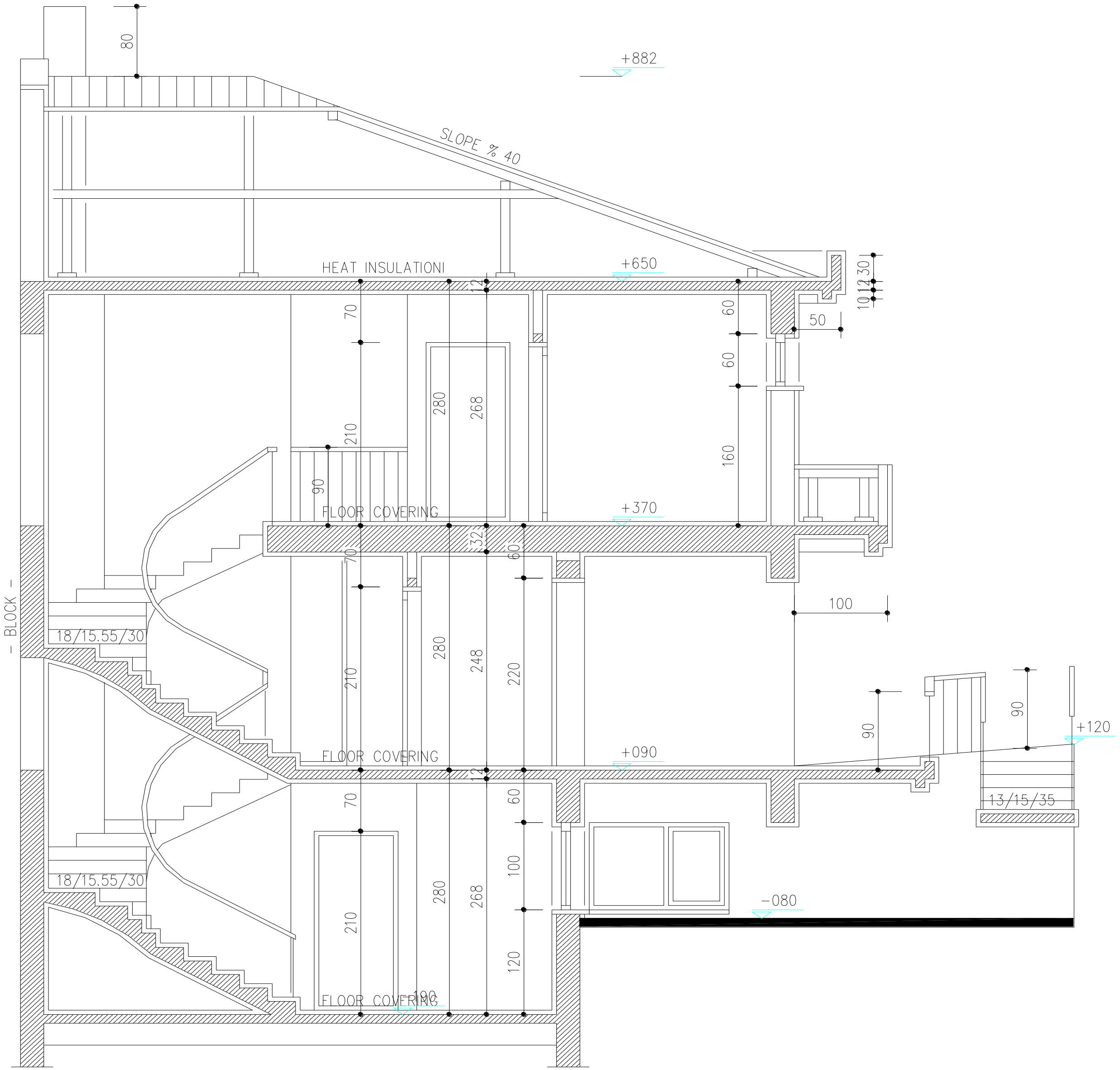


Figure 4.2: Section A-A

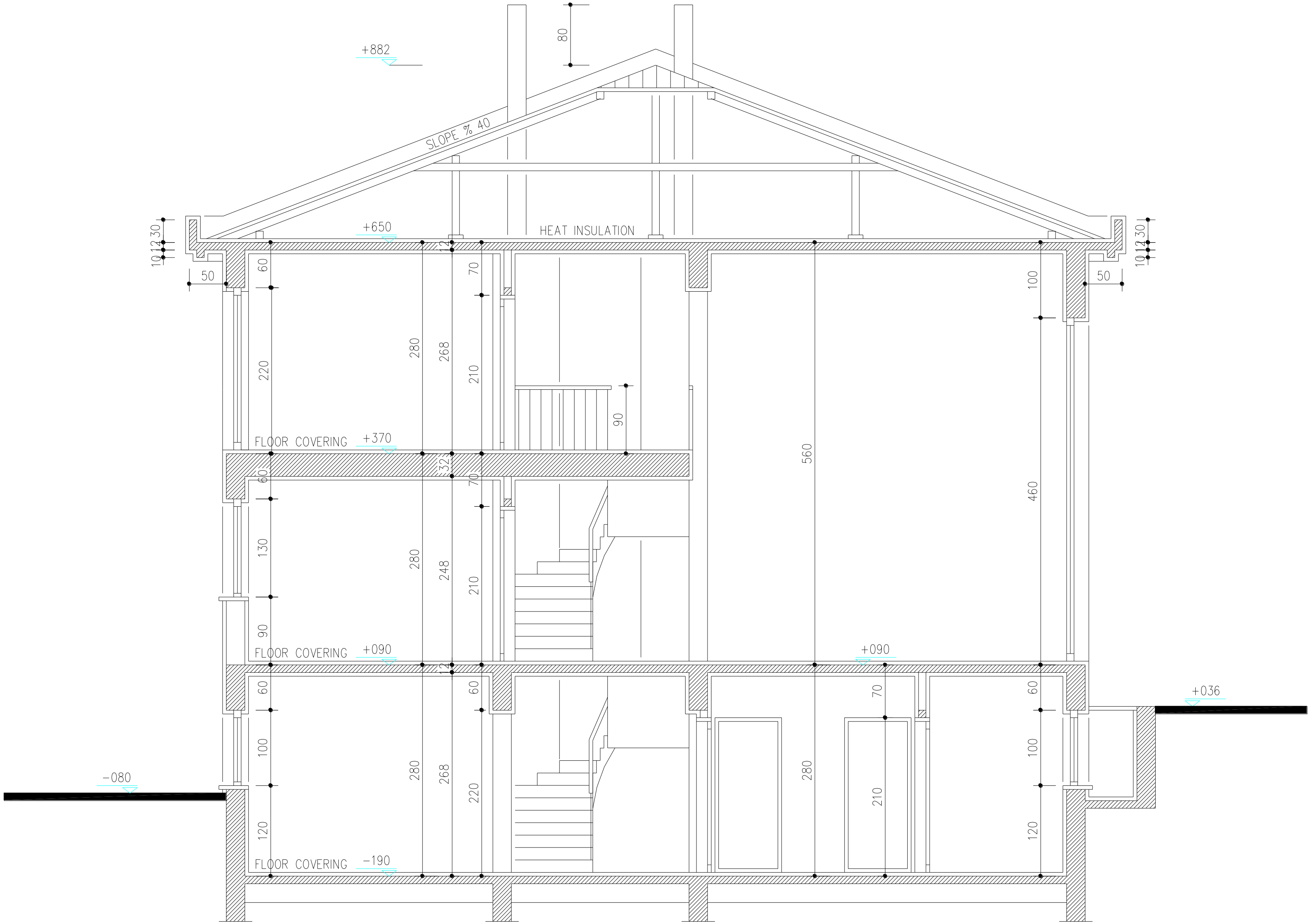


Figure 4.3: Section B-B

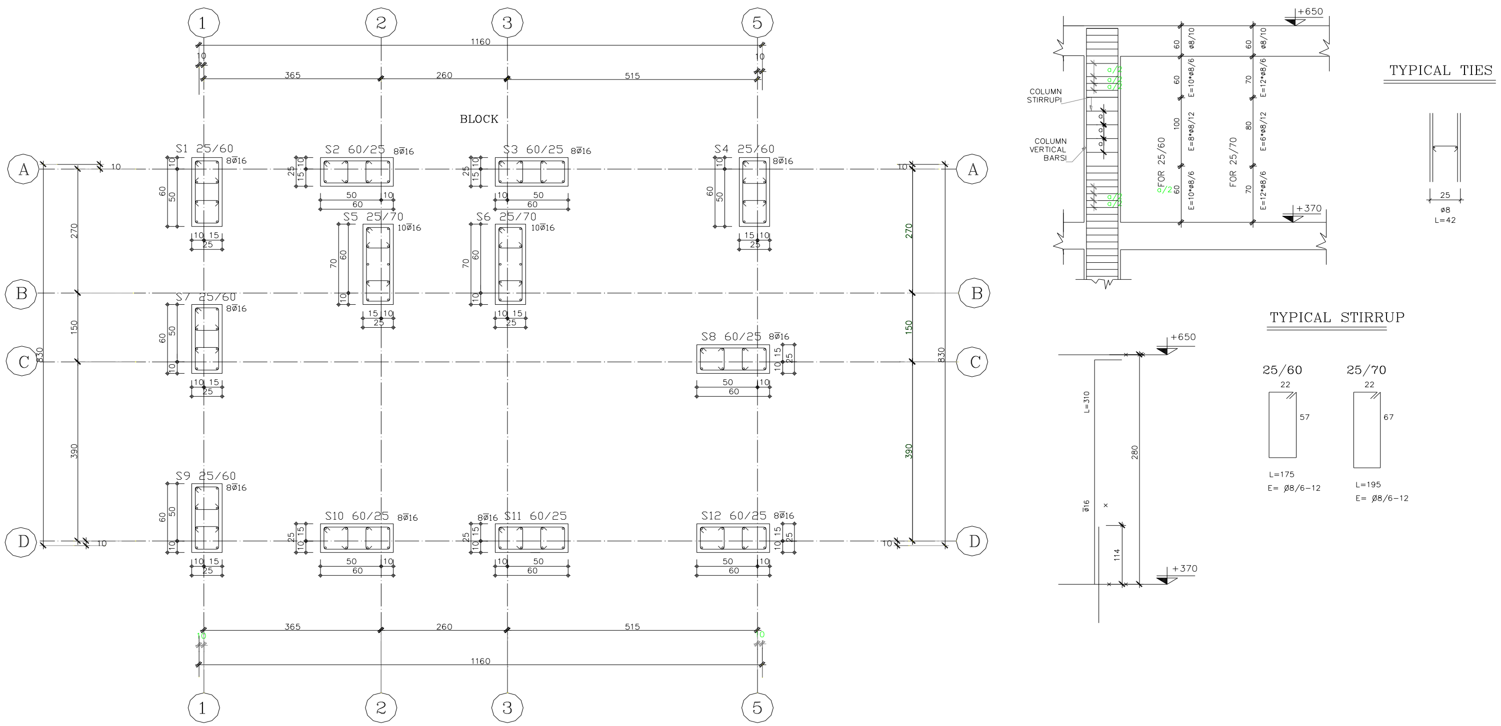


Figure 4.4: Normal Floor Column Plan

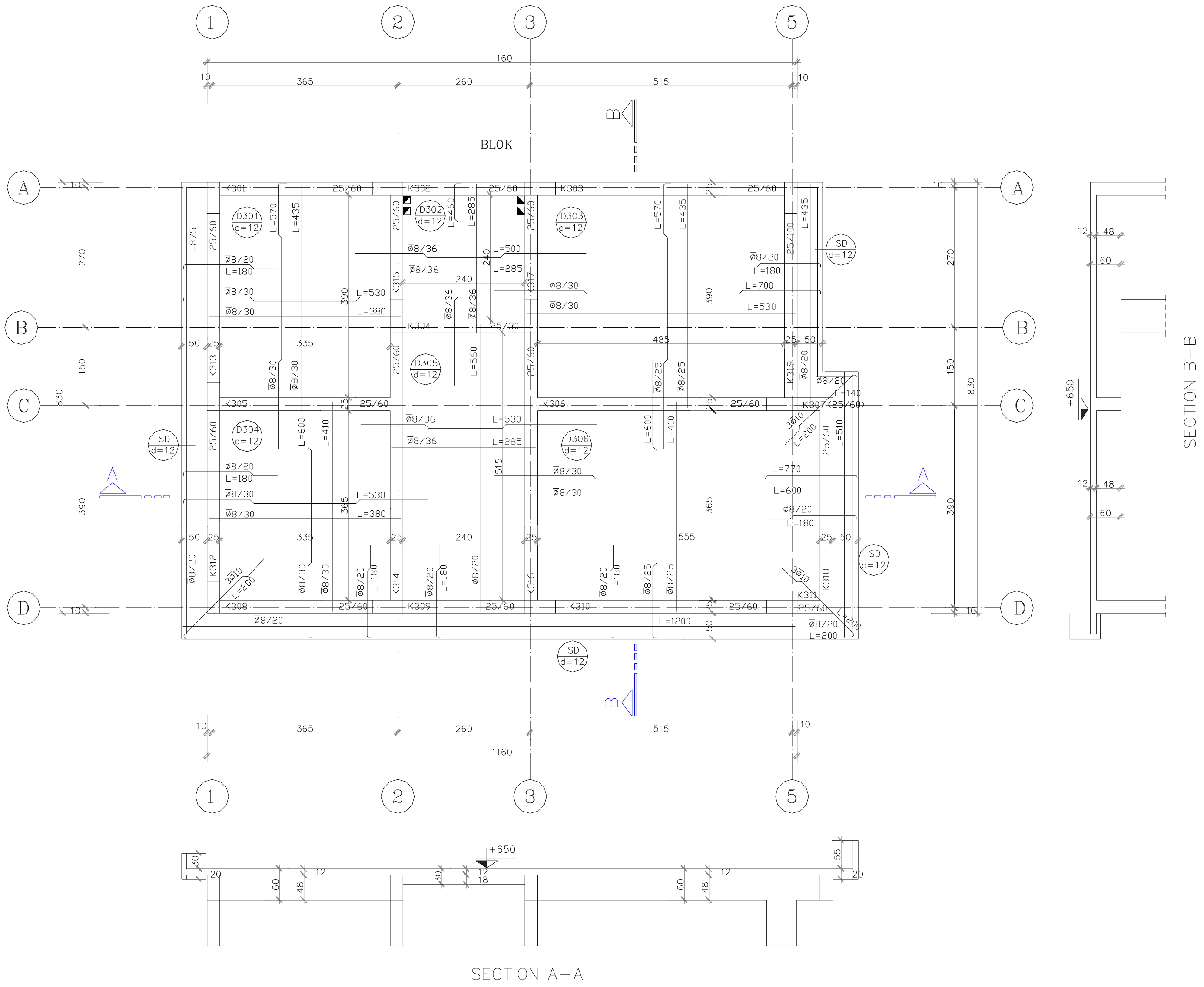


Figure 4.5: Normal Floor Ceiling Plan

NO	TYPE OF JOB	Location	Width(m)	Length(m)	Height(m)	Void	Qty.	Cum Qty.	Unit
1a	Formwork for Slab D302	D302	2.40	2.40			5.76	5.76	m^2
1b	Formwork for Beam K302	K302 (outer face)		2.40	0.60		1.44		m^2
		K302 (inner face)		2.40	0.48		1.152		m^2
		K302 (bottom)	0.25	2.40			0.60		m^2
	Total							3.192	m^2
1c	Formwork for Column S2	S2 (sides)		(2*0.25)	2.20		1.10		m^2
		S2 (outer face)		0.60	2.80		1.68		m^2
		S2 (inner face)		0.60	2.68		1.608		m^2
		K315		0.25	0.48	0.12	-0.12		m^2
	Total							4.268	m^2
2	Support for Ceiling Formwork for Bedrooms 1 & 2	A1-A2-D1-D2	8.30	3.85	2.68			85.639	m^3
3	Reinforcement of Column S2	S2	number	length	mass(kg/m)				
	Φ8	Stirrup	34	1.75	0.395		23.503		Kg
	Φ16	Vertical Bars	8	3.10	1.578		39.134		Kg
	Φ8	Ties	68	0.42	0.395		11.281		Kg
	Total (Φ8)							34.784	Kg
	Total (Φ16)							39.134	Kg
			Width(m)	Length(m)	Height(m)				
4a	Concrete for Slab D302	D302	2.40	2.40	0.12			0.691	m^3
4b	Concrete for Beam K302	K302	0.25	2.40	0.60			0.36	m^3
4c	Concrete for Column S2	S2	0.25	0.60	2.80			0.42	m^3
5	Exterior Walls	D1-D2	0.25	3.50	2.20		1.925		m^3
	(+3.70 to +6.50)	Window	0.25	0.85	1.30	0.2763	-0.27625		m^3
		Window	0.25	0.85	1.30	0.2763	-0.27625		m^3
		Column S10	0.25	0.50	2.20	0.275	-0.275	1.0975	m^3
		D2-D3	0.25	2.40	2.20		1.32		m^3
		Window	0.25	0.50	0.60	0.075	-0.075	1.245	m^3
		D3-D5	0.25	(1.50+4.45)	2.20		3.2725		m^3
		Column S11	0.25	0.50	2.20	0.275	-0.275		m^3
		Column S12	0.25	0.60	2.20	0.33	-0.33		m^3
		Window	0.25	0.50	0.60	0.075	-0.075		m^3
		Window	0.25	0.45	1.60	0.18	-0.18	2.4125	m^3
		A1-A5	0.25	11.60	2.20		6.38		m^3
		Column S1	0.25	0.25	2.20	0.1375	-0.1375		m^3
		Column S2	0.25	0.60	2.20	0.33	-0.33		m^3
		Column S3	0.25	0.60	2.20	0.33	-0.33		m^3
		Column S4	0.25	0.25	2.20	0.1375	-0.1375	5.445	m^3
		A1-D1	0.25	8.30	2.20		4.565		m^3
		Column S1	0.25	0.60	2.20	0.33	-0.33		m^3
		Column S7	0.25	0.60	2.20	0.33	-0.33		m^3
		Column S9	0.25	0.60	2.20	0.33	-0.33		m^3
		Window	0.25	1.60	2.20	0.88	-0.88		m^3
		Window	0.25	1.60	2.20	0.88	-0.88	1.815	m^3
		A5-C5	0.25	3.90	1.80		1.755		m^3

NO	TYPE OF JOB	Location	Width(m)	Length(m)	Height(m)	Void	Qty.	Cum. Qty.	Unit
5	Exterior Walls	Window	0.25	2.50	1.8	1.125	-1.125		m³
	Continued	Column S4	0.25	0.35	1.8	0.1575	-0.1575	0.4725	m³
		C5-D5	0.25	(4.15–0.25*)	2.2		2.145		m³
		*The portion of 0.25m is already included in D3-D5 Section.							
		C5 Extension	0.25	0.45	2.2		0.2475		m³
		Window	0.25	0.45	1.6	0.18	-0.18		m³
		Window	0.25	0.85	1.6	0.34	-0.34		m³
		Window	0.25	0.85	1.6	0.34	-0.34		m³
		Window	0.25	0.85	1.6	0.34	-0.34	1.1925	m³
	Total							13.68	m³
6	Internal Wall	A2-C2		3.90	2.20		8.58		m²
	(Normal Floor)	Column S5		0.70	2.20	1.54	-1.54		m²
		Door		0.90	2.10	1.89	-1.89		m²
		Lintel		1.30	0.10	0.13	-0.13	5.02	m²
		C2-D2		3.80	2.20		8.36		m²
		Door		0.90	2.10	1.89	-1.89		m²
		Lintel		1.30	0.10	0.13	-0.13	6.34	m²
		C3-D3		3.80	2.20		8.36		m²
		Door		0.90	2.10	1.89	-1.89		m²
		Lintel		1.30	0.10	0.13	-0.13	6.34	m²
		C1-C2		3.60	2.20		7.92	7.92	m²
		C3-C5		(5.10–0.35)	2.20		10.45	10.45	
		2--3 (BR 1)		2.40	2.68		6.432		m²
		Door		0.90	2.10	1.89	-1.89		m²
		Lintel		1.30	0.25	0.325	-0.325	4.217	m²
		3--4 (BR 2 a)		1.50	2.68		4.02		m²
		Door		0.90	2.10	1.89	-1.89		m²
		Lintel		1.30	0.25	0.325	-0.325	1.805	m²
		C--D (BR 2 b)		(3.80–1.25)	2.68		6.834	6.834	m²
	Total							48.926	m²
7a	Interior Plastering of Bedroom 1	A1-A2		3.50	2.68		9.38		m²
		C1-C2		3.50	2.68		9.38		m²
		A1-C1		3.90	2.68		10.452		m²
		Window		1.60	2.20	3.52	-3.52		m²
		A2-C2		3.90	2.68		10.452		m²
		S5 Extension		(2*0.15)	2.20		0.66		m²
		Door		0.90	2.10	1.89	-1.89		m²
	Interior Plastering of Ceiling	A1-A2-C1-C2	3.90	3.50			13.65		m²
		Column S5	0.15	0.70		0.105	-0.105		m²
	Total							48.459	m²
7b	Interior Plastering of Bedroom 2	C1-C2		3.50	2.68		9.38		m²
		D1-D2		3.50	2.68		9.38		m²
		Window		(2*0.85)	1.30	2.21	-2.21		
		C1-D1		3.80	2.68		10.184		m²
		Window		1.60	2.20	3.52	-3.52		
		C2-D2		3.80	2.68		10.184		m²
		Door		0.90	2.10	1.89	-1.89		
	Interior Plastering of Ceiling	C1-C2-D1-D2	3.80	3.50			13.30		m²
	Total							44.808	m²

NO	TYPE OF JOB	Location	Width(m)	Length(m)	Height(m)	Void	Qty.	Cum. Qty.	Unit
7c	Interior Plastering of Bathroom 1	C2-C3		2.40	2.68		6.432		m^2
		Door		0.90	2.10	1.89	-1.89		m^2
		D2-D3		2.40	2.68		6.432		m^2
		Window		0.50	0.60	0.30	-0.30		m^2
		C2-D2		2.45	2.68		6.566		m^2
		C3-D3		2.45	2.68		6.566		m^2
	Interior Plastering of Ceiling	C2-C3-D2-D3	2.45	2.40			5.88		m^2
	Total							29.686	m^2
7d	Interior Plastering of Bedroom 3	C3-C5		5.70	2.68		15.276		m^2
		S8 Extension		(2*0.15)	2.20		0.66		
		Window		0.45	1.60	0.72	-0.72		m^2
		D3-D5		4.10	2.68		10.988		m^2
				1.60	2.68		4.288		m^2
		Window		0.45	1.60	0.72	-0.72		m^2
		Door		0.90	2.10	1.89	-1.89		m^2
		C3-D3		1.25	2.68		3.35		m^2
				(3.80 – 1.25)	2.68		6.834		m^2
		Door		0.90	2.10	1.89	-1.89		m^2
		C5-D5		3.80	2.68		10.184		m^2
		Window		(3*0.85)	1.60	4.08	-4.08		m^2
	Interior Plastering of Ceiling	C3-C5-D3-D5	4.10	3.80			15.58		m^2
			1.60	1.25			2.00		
		Column S8	0.15	0.60		0.09	-0.09		
	Total							59.77	m^2
7e	Interior Plastering of Bathroom 2	C3-C4		1.50	2.68		4.02		m^2
		Door		0.90	2.10	1.89	-1.89		m^2
		D3-D4		1.50	2.68		4.02		m^2
		Window		0.50	0.60	0.30	-0.30		m^2
		C3-D3		2.45	2.68		6.566		m^2
		C4-D4		2.45	2.68		6.566		m^2
	Interior Plastering of Ceiling		1.50	2.45			3.675		m^2
	Total							22.657	m^2
8	Scaffolding for Gallery Opening	A3-A5-C3-C5	3.90	5.00	(5.48-1.50*)		77.61		m^3
			*1.50m is reserved for worker on scaffolding.						
		Column S6	0.15	0.70	(5.48-1.50*)	0.418	-0.418		m^3
		K316 & K317	0.15	(3.90-0.70)	0.48	0.2304	-0.230		m^3
	Total							76.962	m^3
9	Exterior Plastering of the Wall A1-D1 for Normal Floor	A1-D1		8.30	2.68		22.244		m^2
		Window		1.60	2.20	3.52	-3.52		m^2
		Window		1.60	2.20	3.52	-3.52		m^2
	Total							15.204	m^2
10	Scaffolding for Exterior Plastering for the Wall A1-D1 (-0.8 to +6.38)	A1-D1		8.30	7.18			59.594	m^2

NO	TYPE OF JOB	Location	Width(m)	Length(m)	Height(m)	Void	Qty.	Cum. Qty.	Unit
11a	Painting of Bedroom 1	Same as Plastering						48.603	m^2
11b	Painting of Bedroom 2	Same as Plastering						44.808	m^2
11a	Painting of Bedroom 3	Same as Plastering						55.558	m^2
12	Flooring for Bedroom 1	A1-A2-C1-C2	3.90	3.50			13.65		m^2
		Door	0.10	0.84			0.084		m^2
		Column S5	0.15	0.70		0.109	-0.109	13.625	m^2
	Flooring for Bedroom 2	C1-C2-D1-D2	3.80	3.50			13.30		m^2
		Door	0.10	0.84			0.084	13.384	m^2
	Flooring for Bedroom 3	C3-C5-D3-D5	4.10	3.80			15.58		m^2
			1.60	1.25			2.00		m^2
		Door	0.10	0.84			0.084		m^2
		Column S8	0.15	0.60		0.09	-0.09	17.574	m^2
	Total							44.583	m^2
13	Baseboard for Bedroom 1	A1-A2-C1-C2		14.80			14.80		m
		Door				1.04	-1.04		m
		Column S5		2*0.15			0.30	14.06	m
	Baseboard for Bedroom 2	C1-C2-D1-D2		14.60			14.60		m
		Door				1.04	-1.04	13.56	m
	Baseboard for Bedroom 3	C3-C5-D3-D5		19.00			19.00		m
		Door				1.04	-1.04		m
		Door				1.04	-1.04	16.92	m
	Total							44.54	m
14	Polishing Parquet						44.583		m^2
	Baseboard		0.10	44.54			4.454		m^2
								49.037	m^2
15	Window Frames Bedroom 1	A1-C1	1.60	2.20			3.52	3.52	m^2
	Bedroom 2	A1-C1	1.60	2.20			3.52		m^2
		D1-D2	2*0.85	1.30			2.21	5.73	m^2
	Bathroom 1	D2-D3	0.50	0.60			0.30	0.30	m^2
	Bathroom 2	D3-D4	0.50	0.60			0.30	0.30	m^2
	Bedroom 3	D5	0.45	1.60			0.72		m^2
		C5-D5	3*0.85	1.60			4.08	4.80	m^2
	Total							14.65	m^2
16	Heat Insulation	A1-A5-C1-C5	12.60	3.40			42.84		m^2
		C1-C5-D1-D5	13.30	5.15			68.495		m^2
	Total							111.335	m^2

Example-2: For the quantities calculated in Example-1 determine the cost of the following items using 2006 unit prices of Ministry of Environment and Urban Planning (including overhead expenses and profit).

a) Formwork for column S2 (between +3.70 to +6.50).
b) Reinforcement for column S2 between +3.70 to +6.50, excluding reinforcement extensions from previous floor.
c) Concrete (C20) for column S2 (between +3.70 to +6.50).

a) Cost of formwork for column S2:
In 2013 unit prices of Ministry of Environment and Urban Planning cost of 1 m^2 formwork (pos. no: 21.011) (including overhead expenses and profit) is: 19.59 TL per m^2.
Cost of formwork for column S2 is: 19.59 x 4.268 = 83.61 TL

b) Cost of reinforcement for column S2:
In 2013 unit prices of Ministry of Environment and Urban Planning cost of 1 ton of reinforcement (including overhead expenses and profit) for Φ8 – Φ12 (pos. no:23.014) is 1,727.34 TL per ton and, for Φ14 – Φ28 (pos. no:23.015) is 1,702.65 TL per ton.
Cost of rebar for column S2 between +3.70 to +6.50 is: 0.0348 x 1,727.34 + 0.0391 x 1,702.65 = 126.69 TL

c) Cost of concrete for column S2:
In 2013 unit prices of Ministry of Environment and Urban Planning cost of 1 m^3 C20 concrete (pos. no:16.050/04/1) (including overhead expenses and profit) is 109.35 TL per m^3.
Cost of concrete for column S2 between +3.70 to +6.50 is: 0.42 x 109.35 TL = 45.93 TL

Example-3: Typical plan and sections views of a building footing and foundation wall are given in Figure 4.6.

a) Determine the volume of excavation for the site which has been graded to elevation +17.9 m.
b) Determine the amount of formwork required to pour footings, walls and slab.
c) Determine the total labor and material cost of formwork. To complete 1m^2 of formwork 0.75 carpenter and 0.75 laborer hours is needed. Hourly wage for the carpenter is 4 TL/hour and hourly wage for the laborer is 3 TL/hour. Material cost of 1 m^2 of formwork is 8 TL.

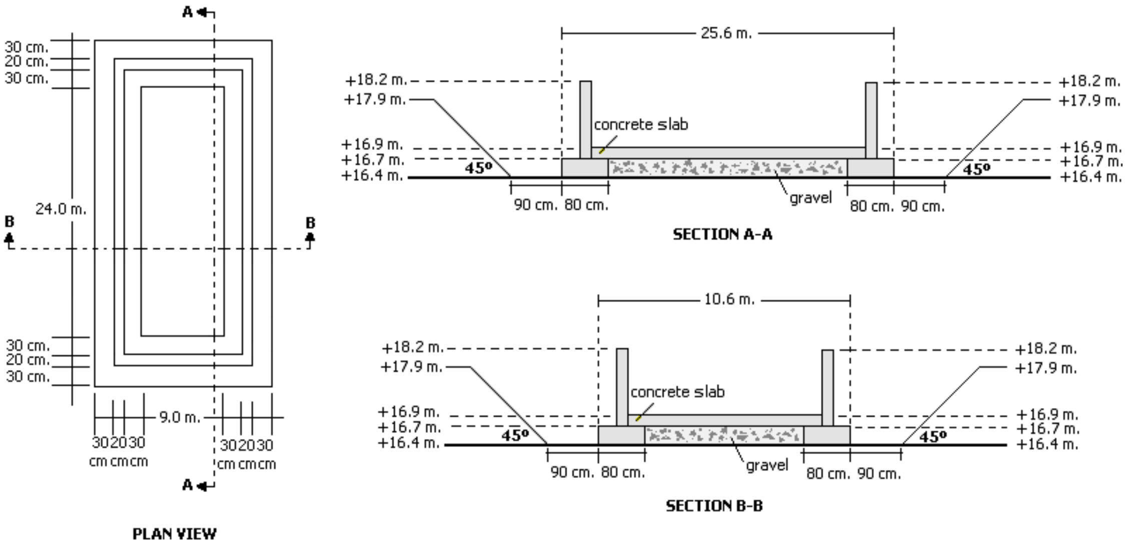


Figure 4.6: Plan and section views for the footing and walls

a) Excavation calculations:
The excavation is in a form of shape called prismoid. The volume of prismoid is calculated by the formula:

Volume = h/6 x (ABASE + 4 x AMID + ATOP)

h = 17.9 – 16.4 =1.5 m.
ABASE = (25.6 + 2 x 0.9) x (10.6 + 2 x 0.9) = 339.76 m^2
AMID = (25.6 + 2 x 0.9 + 2 x 0.75) x (10.6 + 2 x 0.9 + 2 x 0.75) = 401.71 m^2
ATOP = (25.6 + 2 x 0.9 + 2 x 1.5) x (10.6 + 2 x 0.9 + 2 x 1.5) = 468.16 m^2
Volume of excavation = 1.5/6 x (339.76 + 4 x 401.71 + 468.16) = 603.69 m^3

b) Formwork quantity calculations:
Footings outer strip: 2 (25.6 + 10.6) x 0.3 = 21.7 m^2
Footings inner strip: 2 (24 + 9) x 0.3 = 19.8 m^2
Walls outer strip: 2 (25 + 10) x (18.2 – 16.7) = 105 m^2
Walls inner strip: 2 (24.6 + 9.6) x (18.2 – 16.7) = 102.6 m^2
No formwork is needed for the slab.
Total formwork needed: 21.7 + 19.8 + 105 + 102.6 = 249.1 m^2

Note that the calculations are made assuming that first walls are poured than slab is poured. If slab is poured first total amount of formwork needed will be also 249.1 m^2.

c) Formwork cost calculations:

Labor cost = 249.1 x (0.75 x 4 + 0.75 x 3) = 1307.78 TL
Material cost = 249.1 x 8 = 1992.80 TL
Cost of formwork = 1307.78 + 1992.80 = 3300.58 TL

4.6 REFERENCES

1. Akçalı, Ü. (2002). 2002 Yılı İnşaat Birim Fiyat Analizleri, Şafak Matbaacılık, Ankara
2. Dagostino, F.R., and Feigenbaum, L. (2003). Estimating in Building Construction, Prentice Hall, Upper Saddle River, New Jersey.
3. Oswald, P.F. (2001). Construction Cost Analysis and Estimating, Prentice Hall, Upper Saddle River, New Jersey.

CHAPTER 5

CONSTRUCTION PROJECT PLANNING

One way of describing management from managers' duties point of view can be as "efforts made to achieve organizational goals by using technical knowledge to perform planning and control duties, and by using human relations abilities to perform duties of organizing and directing people". There is not an agreed single definition of management among management scientists, but above definition has received acceptance among the so called classical viewers. According to this definition, planning is considered as a duty of managers.

PLANNING

Everyone, whether good or bad, short-term or long-term, important or unimportant, consciously or unconsciously, makes plans. Construction managers do make plans also like everyone else.

Then, the definition of planning is:

"Planning is a decision making process performed in advance of action which endeavors to design a desired future and effective ways of bringing it about" (Ackoff, 1970).

"Trying to anticipate what will happen and devising ways of achieving the set of objectives and targets" (Fryer, 1992).

Both definitions emphasize that in planning there are goals (objectives) that are desired (or instructed or specified) to be realized in future, and that planning is a process during which efforts and decisions are made to achieve the goals at the desired time in the desired way.

The main objectives of a construction project are:

- to complete the construction within the specified time (duration),
- to complete it within the budget, (with a profit),

- to complete it in compliance with technical and administrative specifications.

Before going into the discussion of construction project planning, a few points will be highlighted about planning in general.

5.1 CONSTRUCTION PROJECT PLANNING

Construction project consists of several work items (tasks / jobs) to be completed at certain times during the execution of the project. These work items are to be done in a sequence. Some items cannot be started before some other items are not completed. An example for this would be to say “plastering of walls cannot be done before the walls are made”. Some items may be carried out at the same time. Depending upon the number of work items, their sizes and scope, completion of a project will take a certain time, which is called “project duration”. While carrying out work items, manpower and materials will be needed according to the nature of the work. Sometimes quite skilled people will be required. Construction managers will have to plan their work in order to be able to complete the project in time, within the budget and by complying with the specifications and standards. To plan for a construction project, the following four questions should be taken into account.

1. *What* should be done? (activities=work items)
2. *How* should the activities be performed? (methods)
3. *Who* should perform each activity and with what means? (resources)
4. *When* should activities be performed? (sequence and timing)

PURPOSE OF PLANNING (WHY PLAN?)

Generally speaking, the purpose of planning is to assist the manager to fulfill his primary function, namely, direction and control. Direction can be subdivided into execution (or action planning) and coordination. Execution concerns the directing of the parties under the supervision of the construction company in the implementation of the projects components (work items). Execution should be understood to mean that early decisions – the plans – become either direct assignment, or at least guide-lines for site management to make operational decisions later on. The essential elements of how, when and who are thus prepared for the execution of the construction project.

The second planning function is to coordinate and communicate with the many parties involved into the realization of a construction project, i.e. owner, designer, licensing authorities, subcontractors and suppliers, and numerous specialists and functionaries on site and in home office. The construction technology being inherently interdependent provides few or no "buffers", and requires many diverse parties to work in close liaison with each other in terms of time and / or space. Maintaining coordinated production becomes thus a key function of construction management.

The third function of the planning is to facilitate project control which encompasses control and forecasting. If planning establishes targets and the course to reach them, control is the process that ensures the course of action is maintained and desired targets are reached. Control involves measuring and evaluating performance and the taking of corrective action when performance diverges from plans. To be effective, a control system must be modeled closely after planning system.

PLANNING PROCESS (HOW TO PLAN?)

Process of planning comprises five phases (as shown in Figure 5.1):

- planning the planning process
- information gathering
- preparation of plans
- information diffusion
- evaluation of planning process

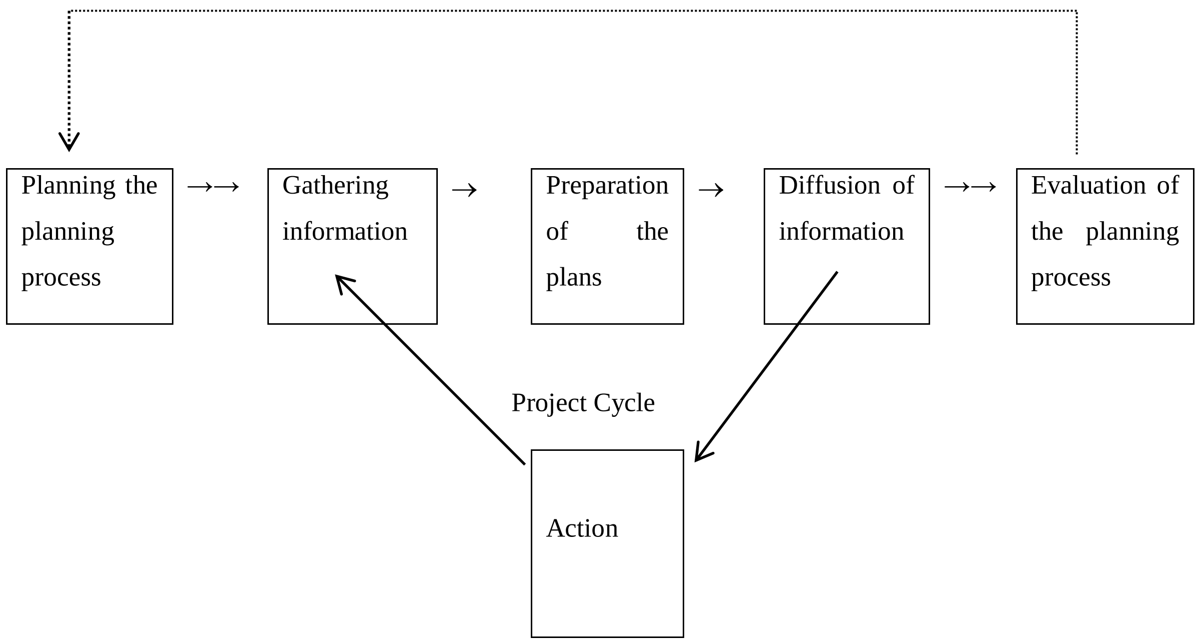


Figure 5.1: The Planning Process (——— Continuous, ⋯⋯⋯ Intermittent)

Planning the planning process

In the big size construction companies where planning is a standard procedure, a procedure manual spells out the detailed planning steps of who does what, when and how. Each project ought to be analyzed beforehand and throughout its duration in respect of the features that make it unique environmentally, technologically and organizationally. The results become the basis for laying out the planning process.

Decisions made at this stage include:

- effort and timing for each planning stage,
- updating frequency,
- planning horizons and level of detail,
- degree of planning and control centralization.

The planner further decides on

- the selection of the information to be gathered,
- the method of distribution,
- on the scheduling techniques to be used.

Information gathering

The next phase, information gathering, may require considerable resources. The source material required for planning a typical construction project includes:

- Contract documents
- Drawings and specifications
- Site and environmental conditions (investigate the site)
- Construction technology
- Internal and external resources (e.g. availability and cost)
    - self-resources
    - list of possible subcontractors and suppliers
- Productivity of labor and equipment
- Goals and constrains dictated by top management, the client, and various external authorities regarding quality control, finance and law.

After construction has started, information regarding progress on site is also collected for control and forecasting purposes, with emphasis on resources consumed and goals achieved.

Preparation of plans

In the third stage, working out the plans, decisions are made based on the evaluation of the collected information using techniques adapted to resource planning and scheduling (e.g. site layout, temporary facilities, flow diagrams and process charts, Gantt, Line of Balance (LOB), Critical Path Method (CPM) and Program Evaluation and Review

Technique (PERT)) and their respective cost implications (e.g. cash flow, break-even and risk analysis).

1. Decide the level of detail for the project schedule
2. Decide the preliminary work breakdown structure (Activities=What?)
3. Decide construction methods and resources (Methods=How? and resources=Who?)
4. Decide project completion constraints
5. Divide project into milestones (Timing=When?)
6. Prepare milestone schedule (Master Time Plan)
7. Develop the detailed work breakdown
8. Collect scheduling information from subcontractors
9. Decide activities sequence and duration (CPM, When?)
10. Perform scheduling calculations (obtain construction schedules)

Information diffusion

The preparation of the plans is followed by information dissemination according to users' needs. Information overload can be as harmful as a shortage. The planner must take a realistic, and to a certain degree psychological assessment, of what information is required by whom and in what format. After each planning iteration during the project's cycle, needs must be reassessed to adjust to the constant changes in the staffing of key recipients of information and particularly in consequent changes in the plans. If a drastic change in the execution of the project is called for, or if the response time must be very short, the medium and format of the information distribution must be adapted accordingly. Under these circumstances, the planner not only makes the decisions concerning information distribution but often has to take an active role in its assimilation.

The evaluation of factors made during this phase includes:

- Functionaries receiving information (e.g. project manager, purchasing agent)

- Scope of information (e.g. by entire projects or by area, comprehensive or selective)
- Subjects (e.g. cost, procurement status)
- Content (e.g. guidelines and goals, results and status, variances and reasons, analysis and calculations, assumptions and explanations, and remedy suggestions)
- Level of detail (e.g. broad brush, very detailed)
- Distribution frequency (e.g. weekly, monthly)
- Format (e.g. textual, tabular, symbolic, graphical, pictorial)
- Medium (e.g. visual – paper screen, auditory – take, telephone, direct meeting)
- Accompanying activities (e.g. consulting, advising, training, negotiations, involving and promoting)

OUTPUT OF THE PLANNING PROCESS

As a result of the planning process, a complete schedule of the project is obtained. The major benefits that may be expected from the planning process and the project plan can be summarized as follows (Oberlender, 1993);

1. Finish the project on time
2. Continuous (uninterrupted) flow of work
3. Reduced amount of rework (least amount of changes)
4. Minimize confusion and misunderstandings
5. Increased knowledge of status of project by everyone
6. Meaningful and timely reports to management
7. Knowledge of scheduled times of key parts of the project
8. Knowledge of distribution of costs of the project
9. Responsibility/authority of people are defined
10. Clear understanding of who does what, when and how much
11. Integration of all work to ensure a quality project for the owner
12. You run the project instead of project running you

5.2 PROJECT SCHEDULING

BAR CHARTS/GANTT CHARTS

A bar chart graphically describes a project consisting of a well-defined collection of tasks or activities, the completion of which marks its end. An activity is a task or closely related group of tasks whose performance contributes to completion of the overall project. A typical activity noted in a bar char for a building project could be “Excavation foundation”.

A bar chart is generally organized so that all activities are listed in a column at the left side of the diagram. A horizontal time scale extends to the right of the list, with a line corresponding to each activity in the list. A bar representing the progress of each activity is drawn between its corresponding scheduled start and finish times along its horizontal line. A simple bar chart is shown in Figure 5.2.

Bar charts are the easiest to understand and the most widely used form of planning tools. Even when the network analysis is used, the initial work schedule is presented usually in bar chart form.

NETWORK ANALYSIS SYSTEMS: They provide a comprehensive method for project planning, scheduling and controlling. Network analysis is a general title for the technique of defining and coordinating work by a graphical diagram that shows work activities and the interdependencies of activities. Two techniques are widely used for scheduling, namely as critical path method (CPM), which is deterministic; and program evaluation and review technique (PERT), which is probabilistic.

CRITICAL PATH METHOD (CPM)

The CPM was developed in 1956 by the DuPont Company, with Remington Rand as consultants, as a deterministic approach to scheduling. The CPM method is commonly used in the engineering and construction industry. In order for a project to be scheduled by CPM the followings have to be known:

Work breakdown structure of the project, so that each activity of the project is determined,

- Predictions about the activity durations,
- Logical relations between the activities

For project management the CPM is the most commonly used network analysis technique. The concept is simple, the computations only require basic arithmetic, and a large number of computer programs are available to automate the work required of CPM scheduling. There are two basic methods of constructing CPM diagrams: the arrow diagram (activity on arrow) and the precedence diagram (activity on node). Although both methods achieve the same results, most project managers prefer the precedence diagram because it does not require the use of dummy activities.

PLANNED TIME SCHEDULE / WORK SCHEDULE (GANNT CHART)

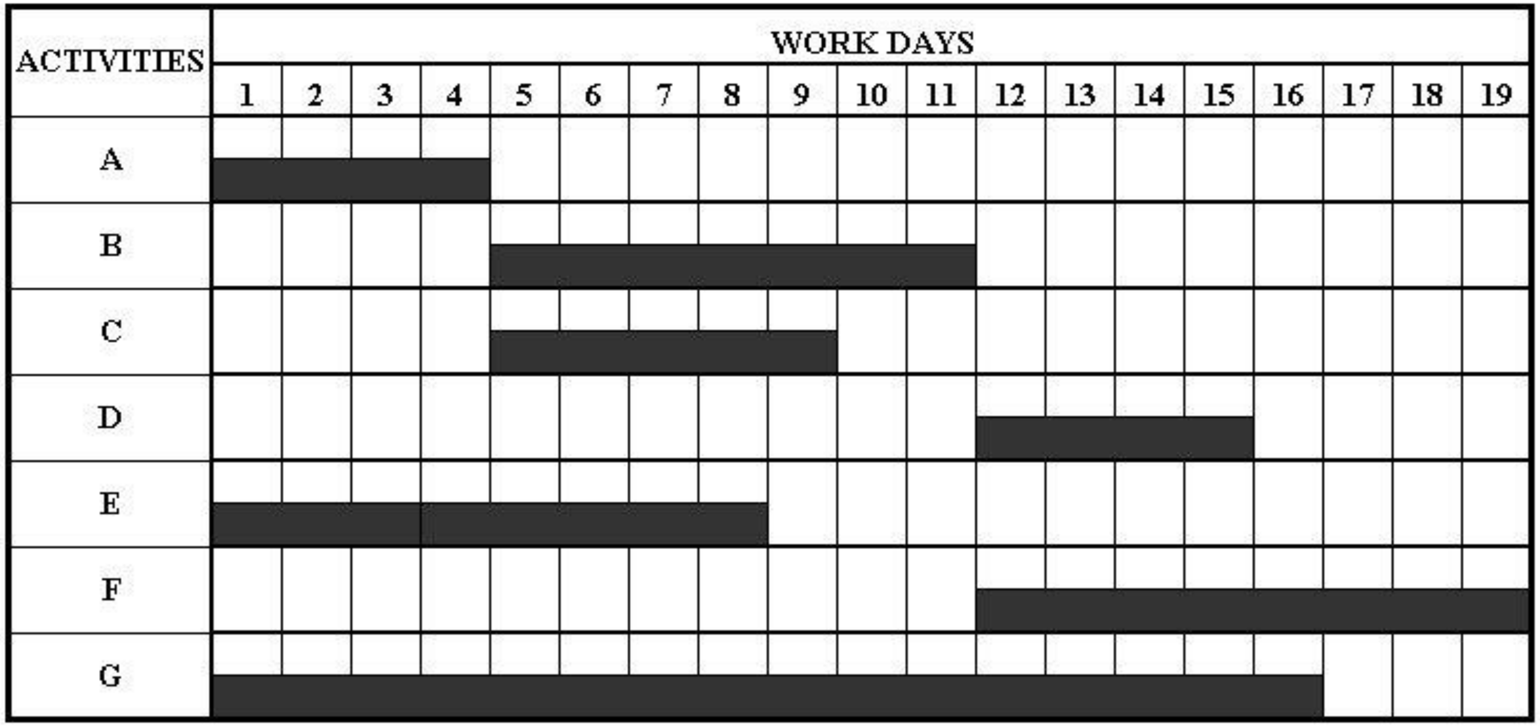
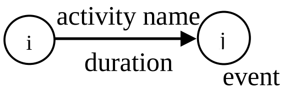


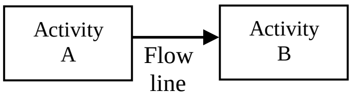
Figure 5.2: A Simple Bar Chart

DEFINITIONS RELATED TO CPM

Activity : The performance of a task required to complete the project, such as, design of foundations, review of design, procure steel contracts, or form concrete columns. An activity requires time, cost, or both time and cost.



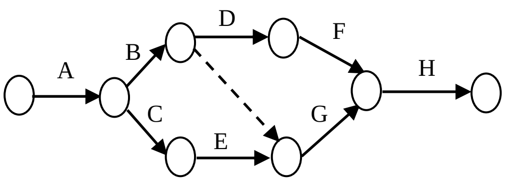
Arrow Diagram



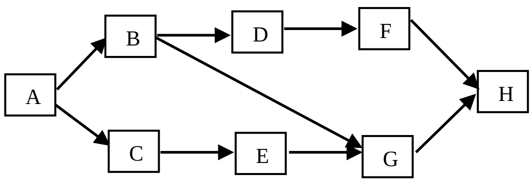
Precedence Diagram

Event : A notation to show the starting and ending points of an activity. It is an instant in time horizon.

Network : A diagram to represent the relationship of activities to complete the project. The network may be drawn as either an "arrow diagram" or a "precedence diagram".



Arrow Diagram



Precedence Diagram

Duration (D) : The estimated time required to perform an activity. The time should indicate all resources that are assigned to the activity.

Early Start (ES) : The earliest time an activity can be started.

Early Finish (EF) : The earliest time an activity can be finished and is equal to the early start plus the duration

$$EF = ES + D$$

Late Finish (LF) : The latest time an activity can be finished.

Late Start (LS) : The latest time an activity can be started without delaying the completion date of the project.

Total Float (TF) : The amount of time an activity may be delayed without delaying the completion date of the project.

$$TF=LET_j-EET_i-D$$

where the subscript *i* represents the preceding event and the subscript *j* represents the following event.

Free Float (FF) : The amount of time an activity may be delayed without delaying the early start time of the immediately following activity.

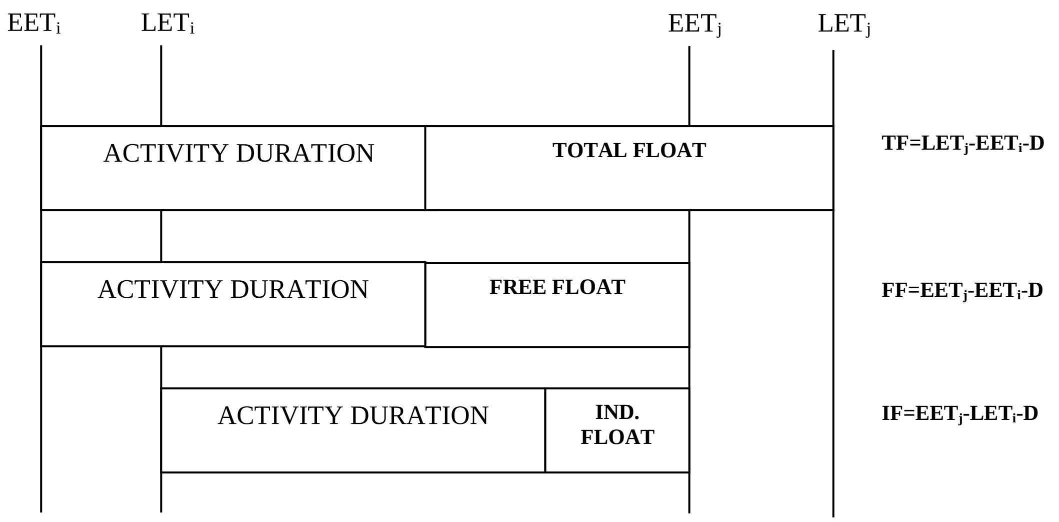
$$FF=EET_j-EET_i-D$$

where the subscript *i* represents the preceding event and the subscript *j* represents the following event.

Independent Float (IF) : The amount of time an activity may be delayed without delaying any other activity.

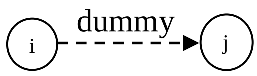
$$IF=EET_j-LET_i-D$$

where the subscript *i* represents the preceding event and the subscript *j* represents the following event.



Critical Path : A series of interconnected activities through the network diagram, with each activity having zero, free and total float time. The critical path determines the minimum time to complete the project.

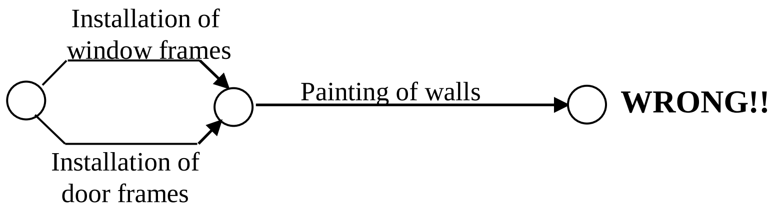
Dummy Activity : An activity (represented by a dotted line on the arrow network diagram) that indicates that any activity following the dummy cannot be started until the activity or activities preceding the dummy are completed. The dummy does not require any time and resource.

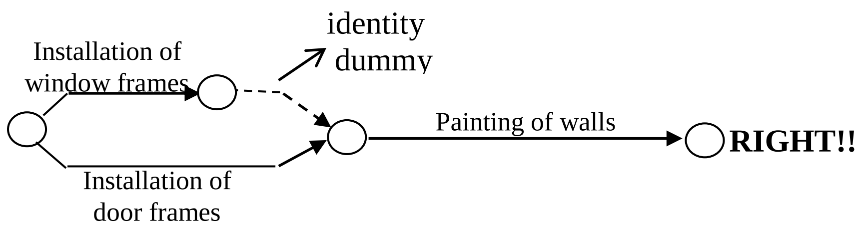


Classified as identity dummy and logic dummy.

<u>Identity dummy</u>: used to identify activities when two or more parallel independent activities have the same start and finish events.

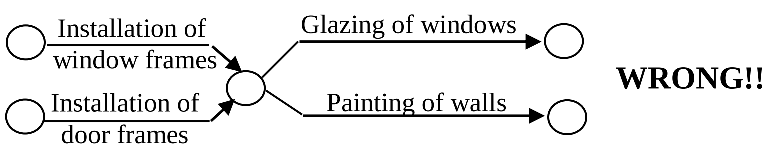
Example:

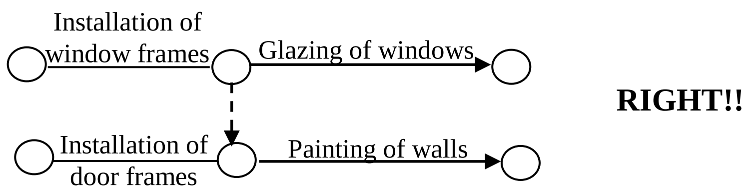




<u>Logic dummy:</u> used to prevent the error in logic arising from chains of wholly or partly independent activities having a common event.

Example:





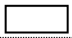
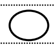
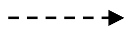
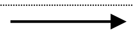
NETWORK CONSTRUCTION

Network diagramming techniques:

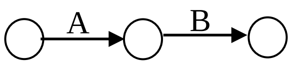
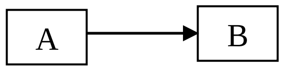
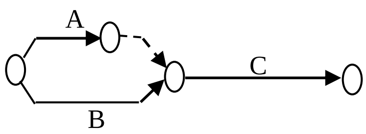
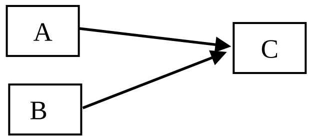
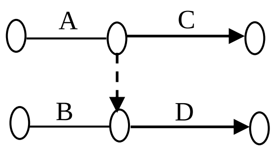
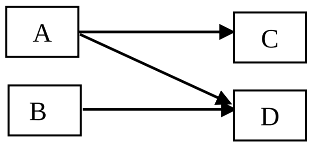
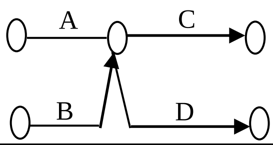
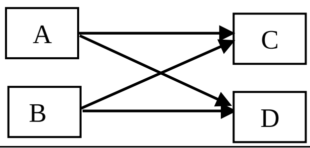
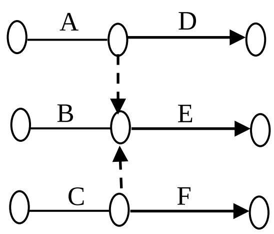
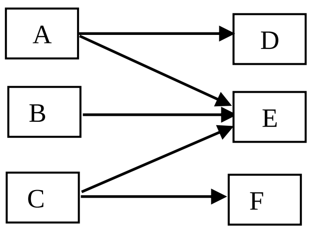
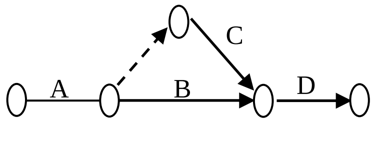
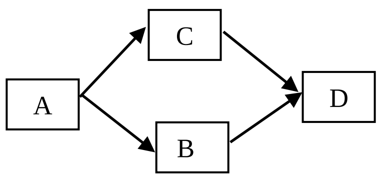
Activity on Arrow (AoA)

Activity on Node (AoN)

Summary of Denotations:

	A-o-A denotation	A-o-N denotation
Activity		
Event		none
Dummy		none
Flow line	none	

Examples about network construction:

Explanations	A-o-A	A-o-N
B depends on A		
C depends on A&B; A&B starts at the same time		
C depends on A; D depends on A&B		
C depends on A&B; D depends on A&B		
D depends on A; E depends on A,B&C; F depends on C		
B depends on A; C depends on A; B and C starts at the same time; D depends on B&C		

CPM CALCULATIONS

The major aims of calculation of activity times are to find the critical path, total project time and floats of activities. As a result of forward pass and backward passes, the activities are classified as critical and non-critical; free and total floats of the activities are determined.

Forward Pass: In forward pass calculations, early start and early finish of each activity are calculated. The largest early finish of all preceding activities defines the early start of all following activities. The calculations start from the first event to the last.

Backward Pass: In backward pass calculations, late start and late finish of each activity are calculated. The smallest late start of all following activities defines the late finish of all preceding activities. These calculations cannot be performed without ending the forward pass calculations. This pass starts from the last event to the first.

Example 5.1:

In the following table you are given a set of activities, their durations and relationships between them.

Activity	**Duration (days)**	**Dependence**
A	4	-
B	7	A
C	5	A
D	4	B
E	8	-
F	8	B,C,E
G	16	-

You are required to;

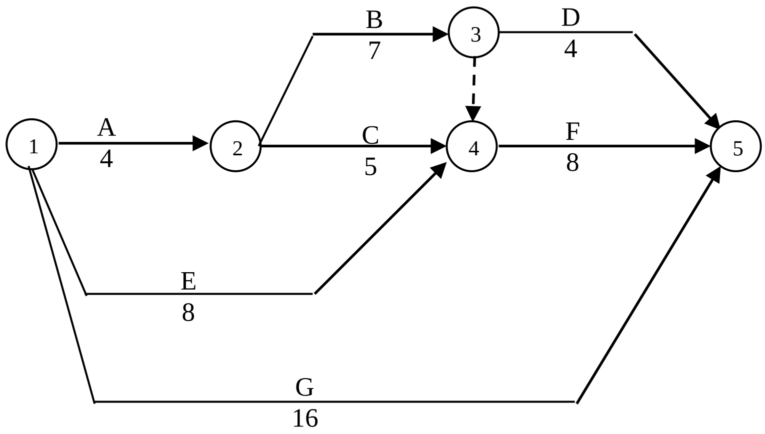
a) Draw A-o-A

b) Draw A-o-N

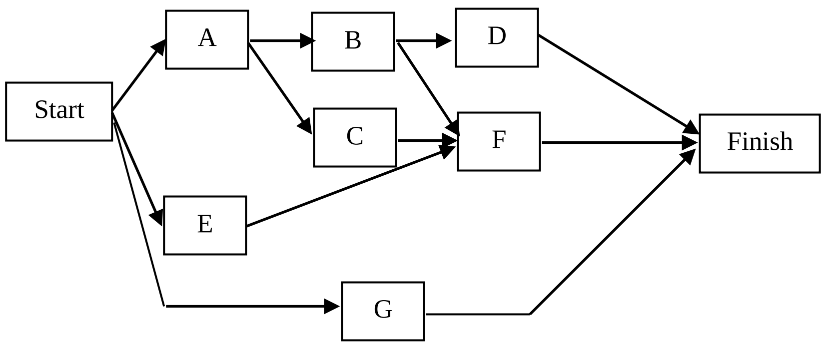
c) Carry out CPM calculations on both of the diagrams to find the project duration and critical path.

Solution:

a) A-o-A diagram

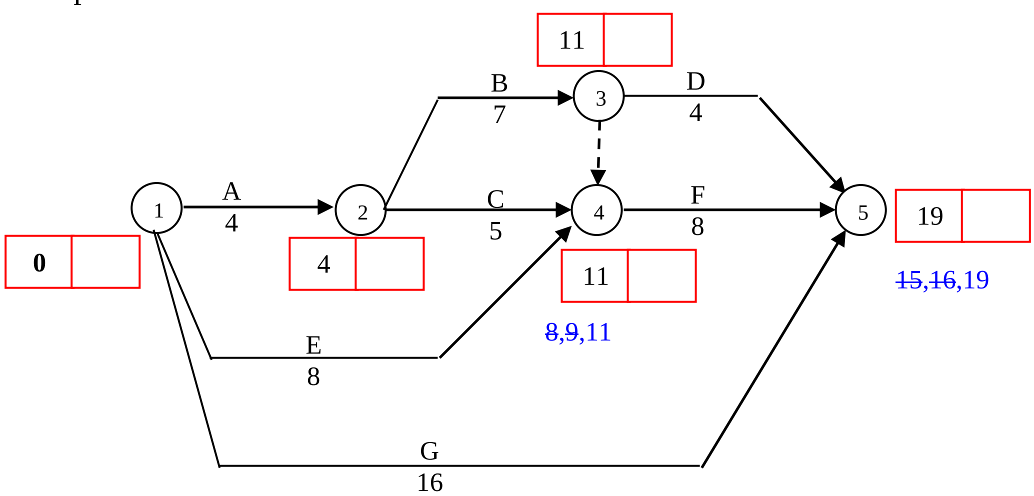


b) A-o-N diagram

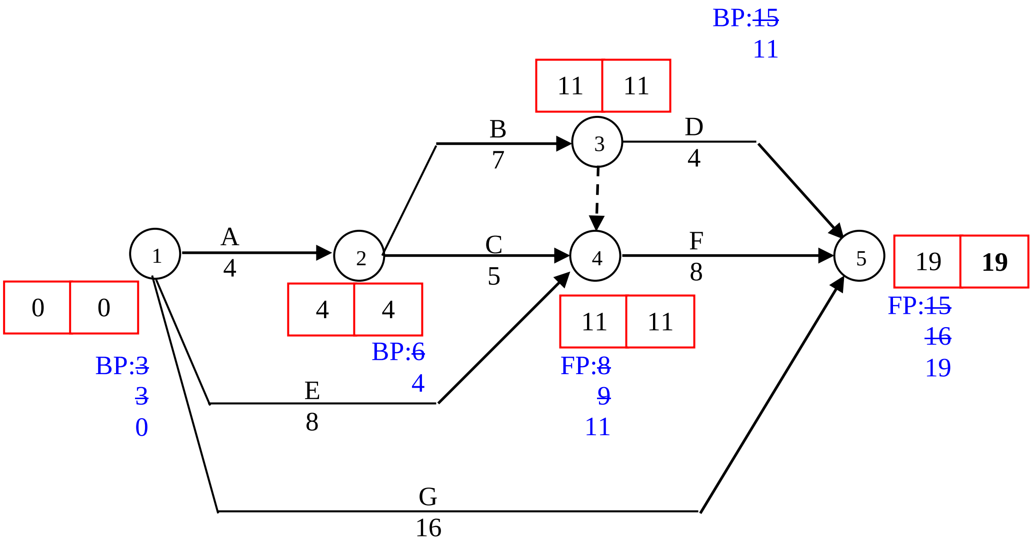


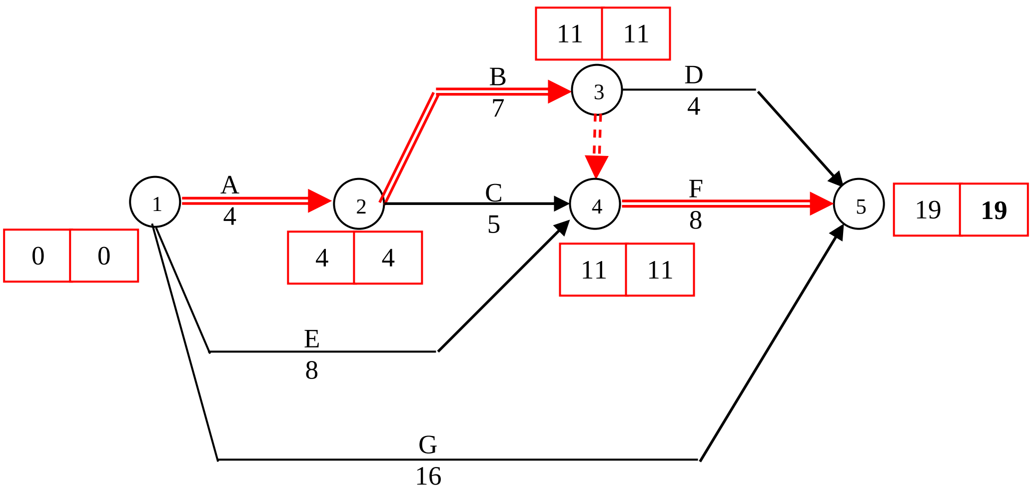
c) CPM calculations on A-o-A

Forward pass calculations:



Backward pass calculations:





Critical Path: A-B-F (indicated as double line on the network)

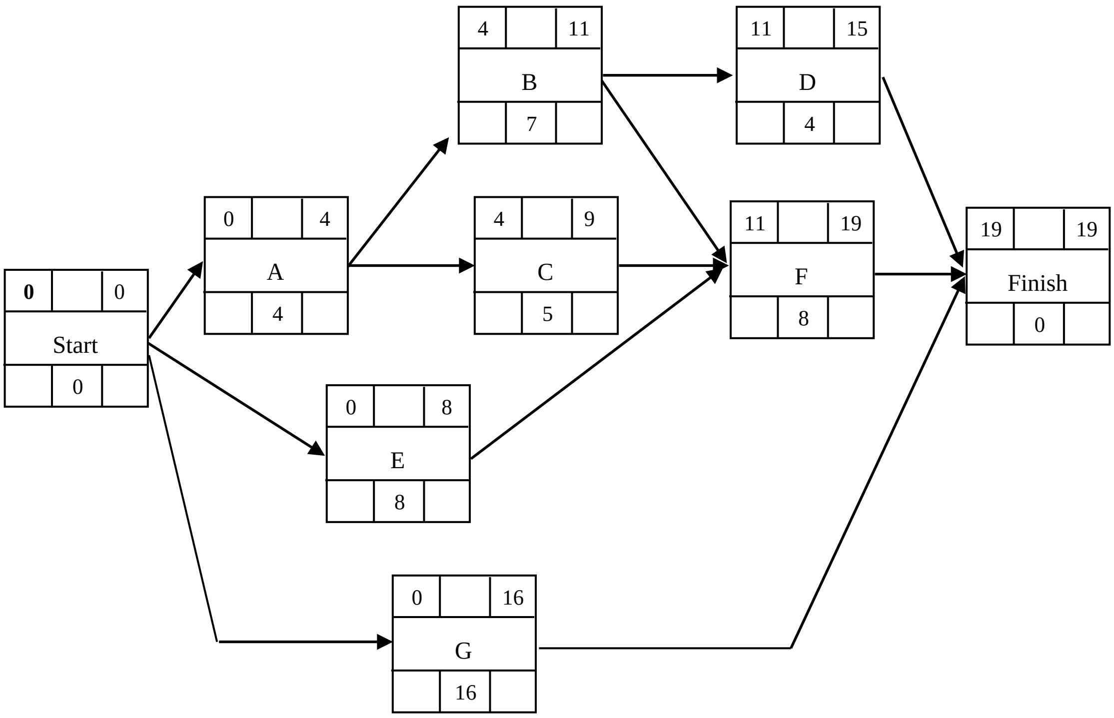
Project Duration: 19 days

CPM calculations on A-o-N

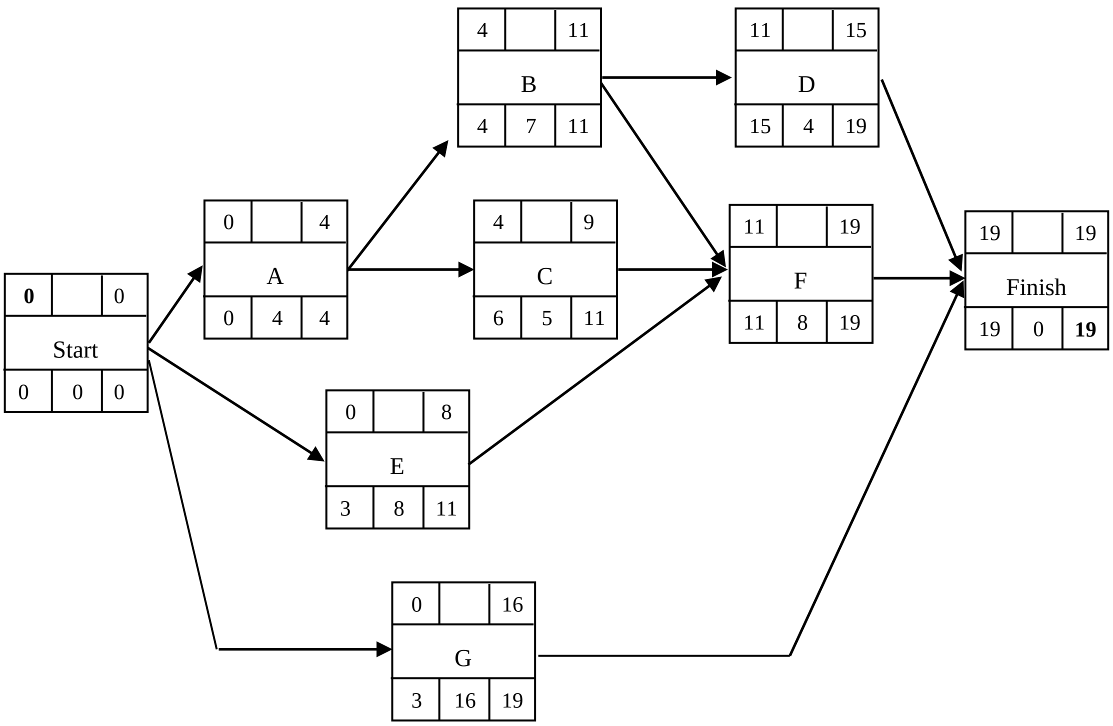
Legend:

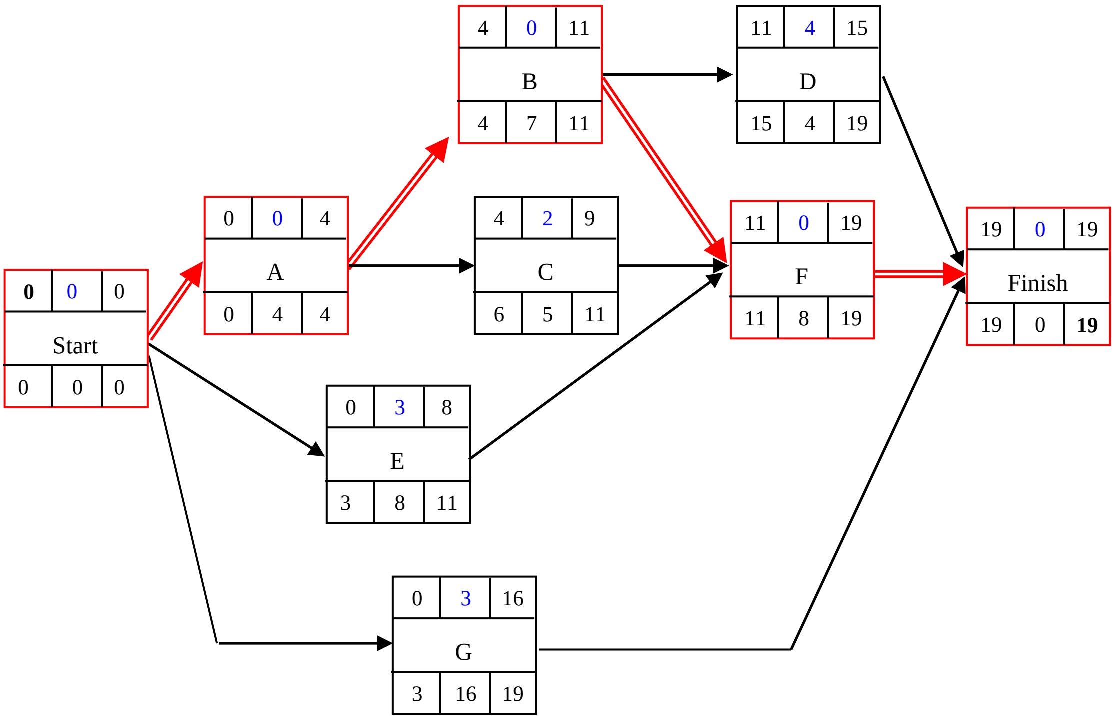
ES	TF	EF
	Act. name	
LS	dur	LF

Forward Pass:



Backward Pass:

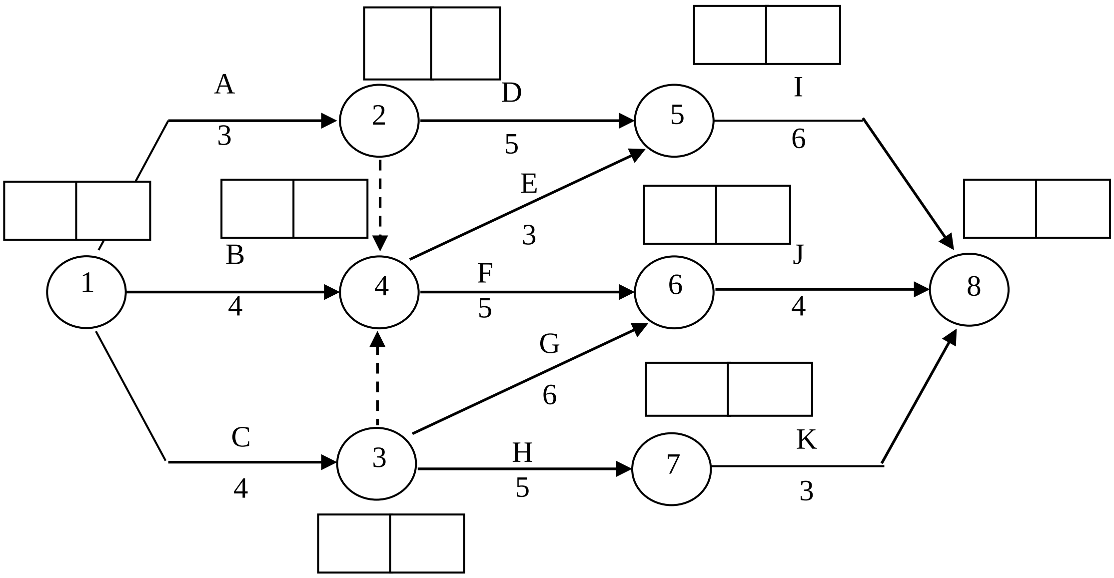




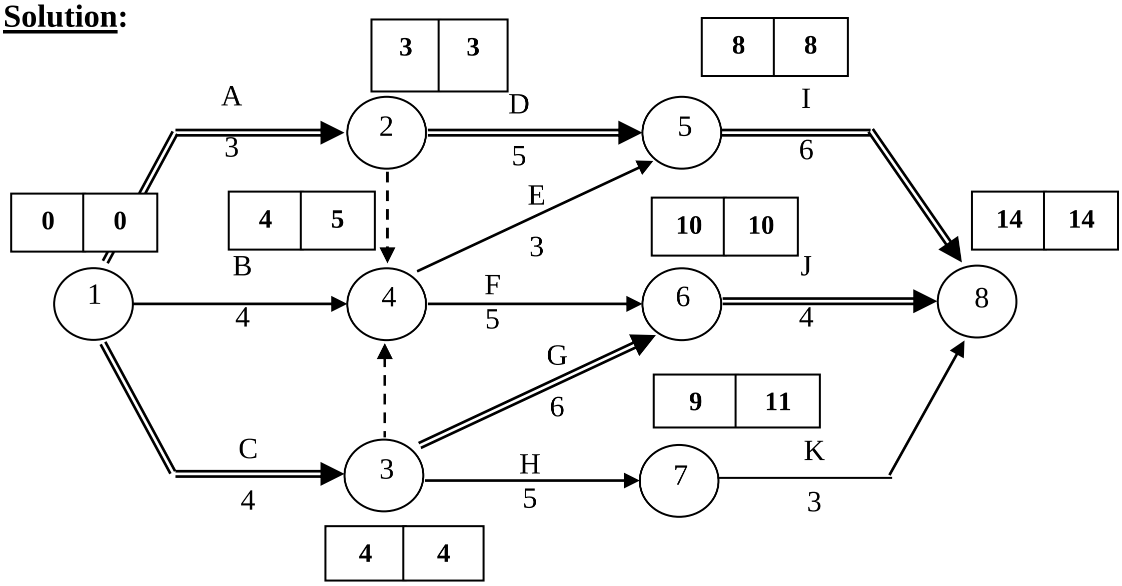
Activity	Duration	EST	EFT	LST	LFT	TF
A	4	0	4	0	4	0*
B	7	4	11	4	11	0*
C	5	4	9	6	11	2
D	4	11	15	15	19	4
E	8	0	8	3	11	3
F	8	11	19	11	19	0*
G	16	0	16	3	19	3

Example 5.2:

Carry out CPM calculations for the given A-o-A network below to find project duration (days) and the critical path(s).



Solution:



Project Duration: 14 days

Critical Paths: A – D – I   C – G – J (indicated as double line on the network)

Activity	Duration (days)	EST	EFT	LST	LFT	TF	Critical
A	3	0	3	0	3	0*	Yes
B	4	0	4	1	5	1	No
C	4	0	4	0	4	0*	Yes
D	5	3	8	3	8	0*	Yes
E	3	4	7	5	8	1	No
F	5	4	9	5	10	1	No
G	6	4	10	4	10	0*	Yes
H	5	4	9	6	11	2	No
I	6	8	14	8	14	0*	Yes
J	4	10	14	10	14	0*	Yes
K	3	9	12	11	14	2	No

Example 5.3:

A contractor is responsible to complete the excavation and basic construction works (except the finish works) of a 2 story building. There is one excavator and 1 team for each activity (R/C works, formwork, plastering, wall construction, floor covering etc.) Following are the activities and estimated durations of these activities:

Abbreviation	**Activity Description**	**Duration (days)**
EXC	Excavation	5
$FORM_F$	Formwork for foundation	6
MECH	Installation of mechanical & electrical conduits and pipes	8
R/C_F	R/C works (reinforcement and concrete casting) for the foundation	5
INSU	Water insulation of foundation	2
$FORM_1$	Formwork for 1st floor	8
R/C_1	R/C works for 1st floor	6
$FORM_2$	Formwork for 2nd floor	8
R/C_2	R/C works for 2nd floor	6
$WALL_1$	Wall construction in 1st floor	10
$WALL_2$	Wall construction in 2nd floor	10
$PLAS_1$	Plastering in 1st floor	8
$PLAS_2$	Plastering in 2nd floor	8
$FRAM_1$	Installation of window/door frames in the 1st floor	2
$FRAM_2$	Installation of window/door frames in the 2nd floor	2
$FLOOR_1$	Floor covering in the 1st floor	10
$FLOOR_2$	Floor covering in the 2nd floor	10
CLEAN	Cleaning, mobilizing	1

Required:

1. Draw the A-o-A and A-o-N diagrams
2. Perform the CPM calculations on both of the network diagrams; find the total project time and critical path.

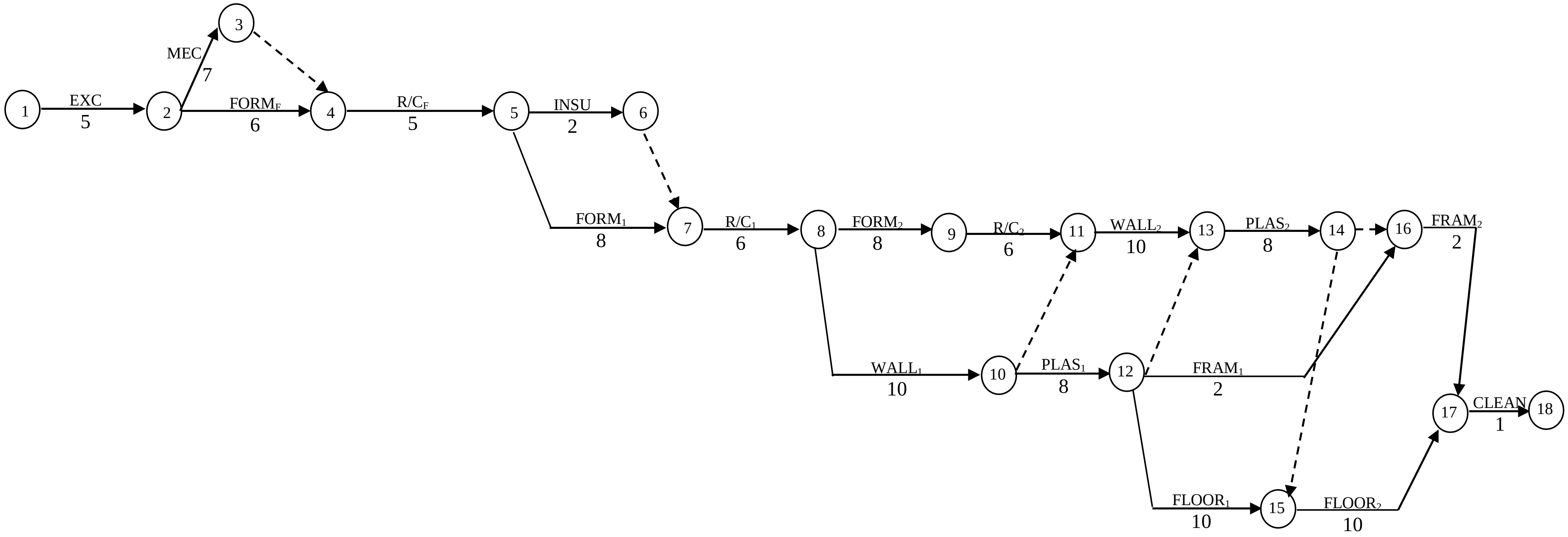
PART1: Following is the A-o-A diagram.

CP: EXC-MECH-R/C_F-$FORM_1$-R/C_1-$FORM_2$-R/C_2-$WALL_2$-$PLAS_2$-$FLOOR_2$-CLEAN

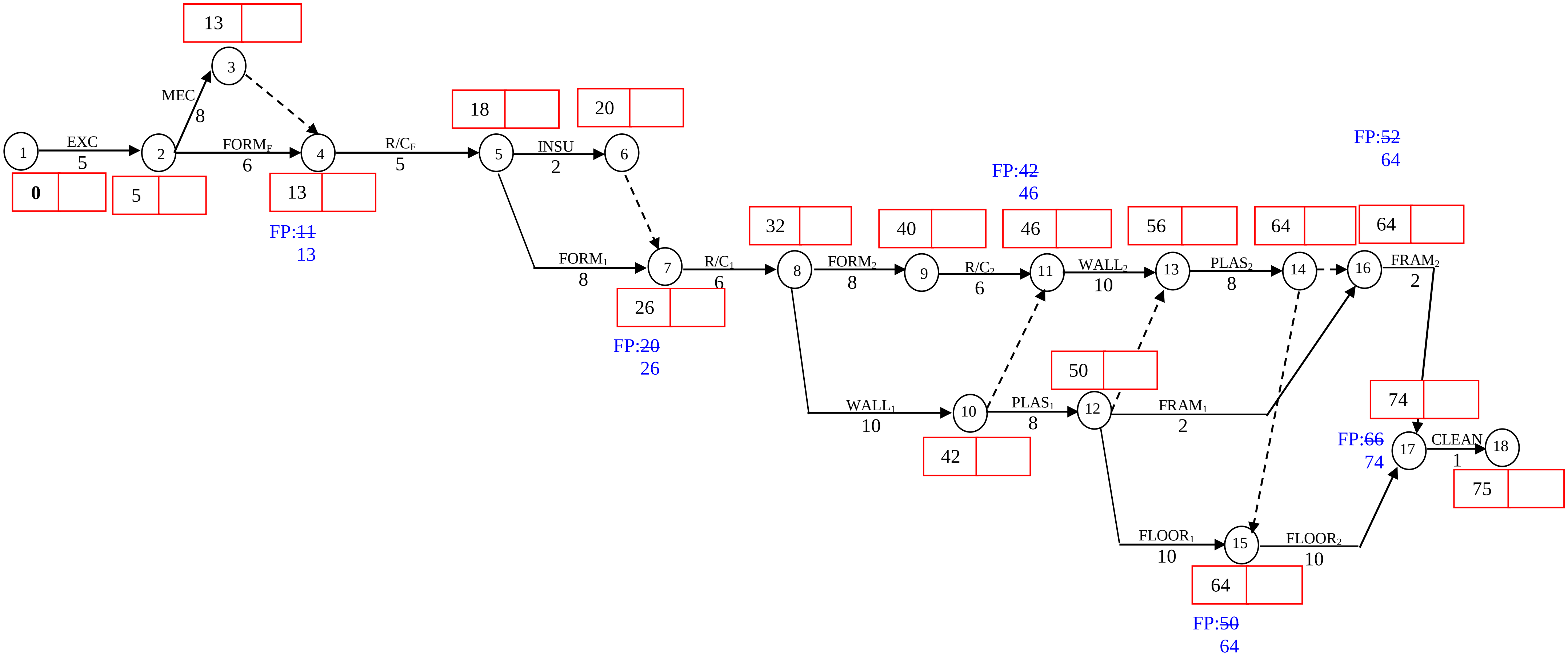
Total Project Time: 75 days.

Activity	Duration (days)	EST	LST	EFT	LFT	TF	Critical
EXC	5	0	0	5	5	0*	Yes
$FORM_F$	6	5	7	11	13	2	No
MECH	8	5	5	13	13	0*	Yes
R/C_F	5	13	13	18	18	0*	Yes
INSU	2	18	24	20	26	6	No
$FORM_1$	8	18	18	26	26	0*	Yes
R/C_1	6	26	26	32	32	0*	Yes
$FORM_2$	8	32	32	40	40	0*	Yes
R/C_2	6	40	40	46	46	0*	Yes
$WALL_1$	10	32	36	42	46	4	No
$WALL_2$	10	46	46	56	56	0*	Yes
$PLAS_1$	8	42	46	50	54	4	No
$PLAS_2$	8	56	56	64	64	0*	Yes
$FRAM_1$	2	50	70	52	72	20	No
$FRAM_2$	2	64	72	66	74	8	No
$FLOOR_1$	10	50	54	60	64	4	No
$FLOOR_2$	10	64	64	74	74	0*	Yes
CLEAN	1	74	74	75	75	0*	Yes

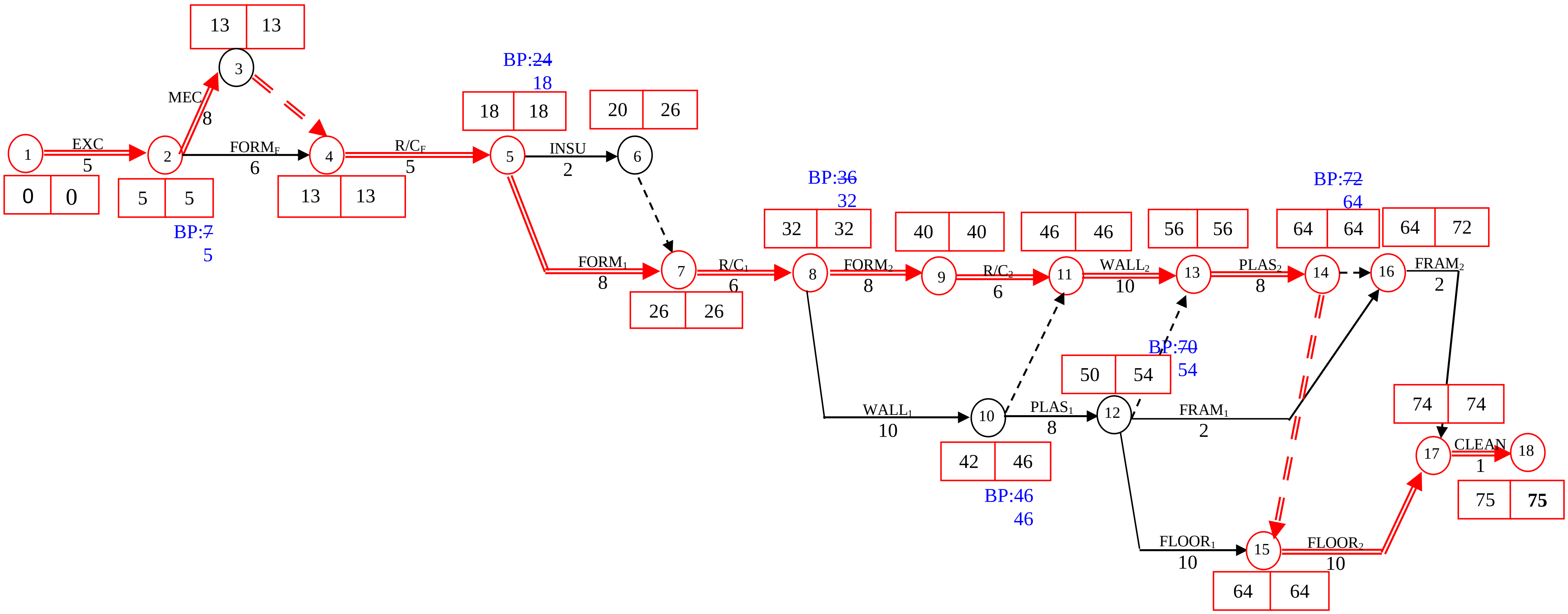
PART1: A-o-A diagram



CPM Calculations: Forward Pass



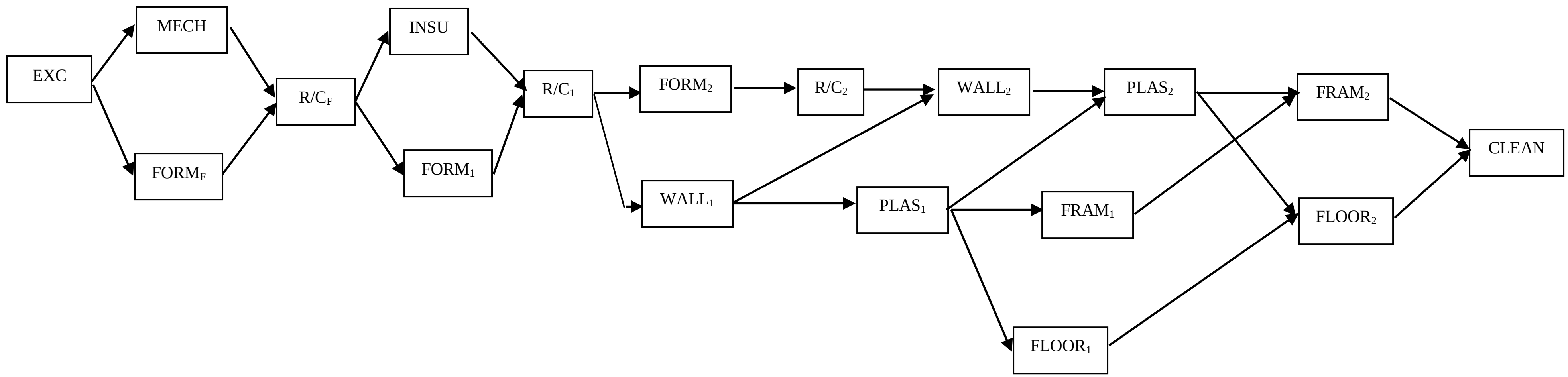
CPM Calculations: Backward Pass



PART 2: Following is the A-o-N diagram.

Activity	Duration (days)	EST	LST	EFT	LFT	TF	Critical
EXC	5	0	0	5	5	0*	Yes
$FORM_F$	6	5	7	11	13	2	No
MECH	8	5	5	13	13	0*	Yes
R/C_F	5	13	13	18	18	0*	Yes
INSU	2	18	24	20	26	6	No
$FORM_1$	8	18	18	26	26	0*	Yes
R/C_1	6	26	26	32	32	0*	Yes
$FORM_2$	8	32	32	40	40	0*	Yes
R/C_2	6	40	40	46	46	0*	Yes
$WALL_1$	10	32	36	42	46	4	No
$WALL_2$	10	46	46	56	56	0*	Yes
$PLAS_1$	8	42	46	50	54	4	No
$PLAS_2$	8	56	56	64	64	0*	Yes
$FRAM_1$	2	50	70	52	72	20	No
$FRAM_2$	2	64	72	66	74	8	No
$FLOOR_1$	10	50	54	60	64	4	No
$FLOOR_2$	10	64	64	74	74	0*	Yes
CLEAN	1	74	74	75	75	0*	Yes

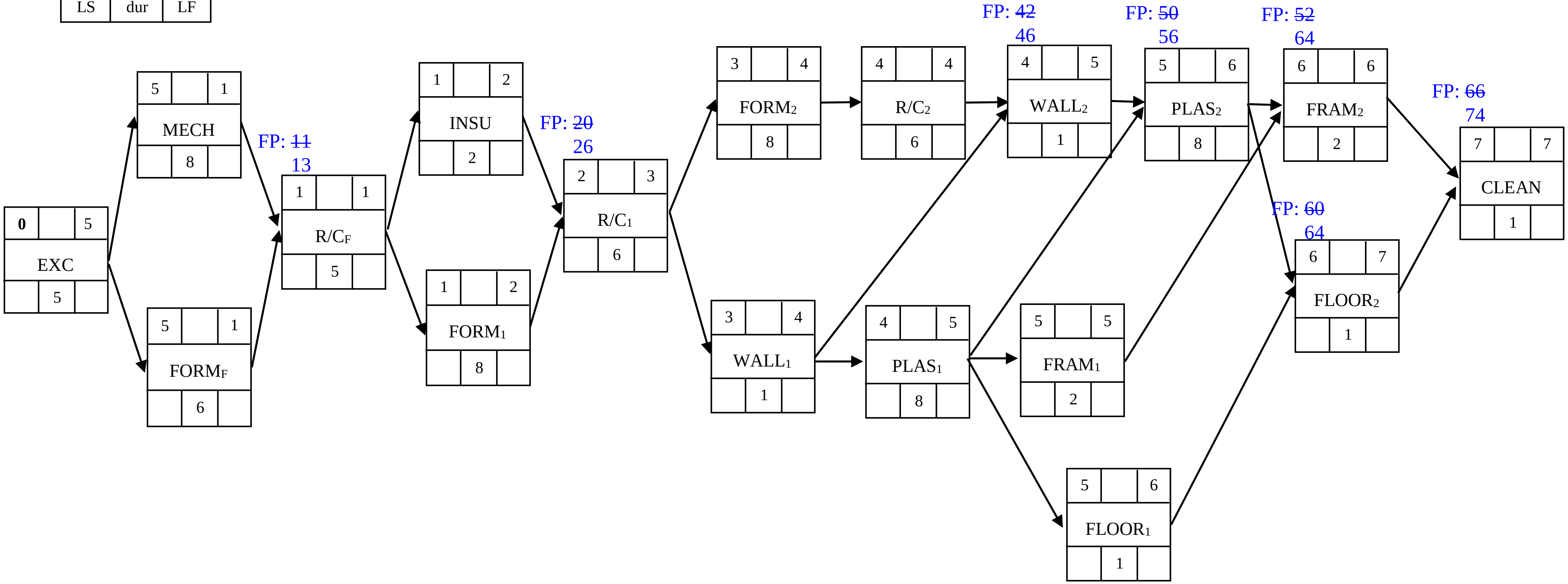
PART 2: A-o-N diagram



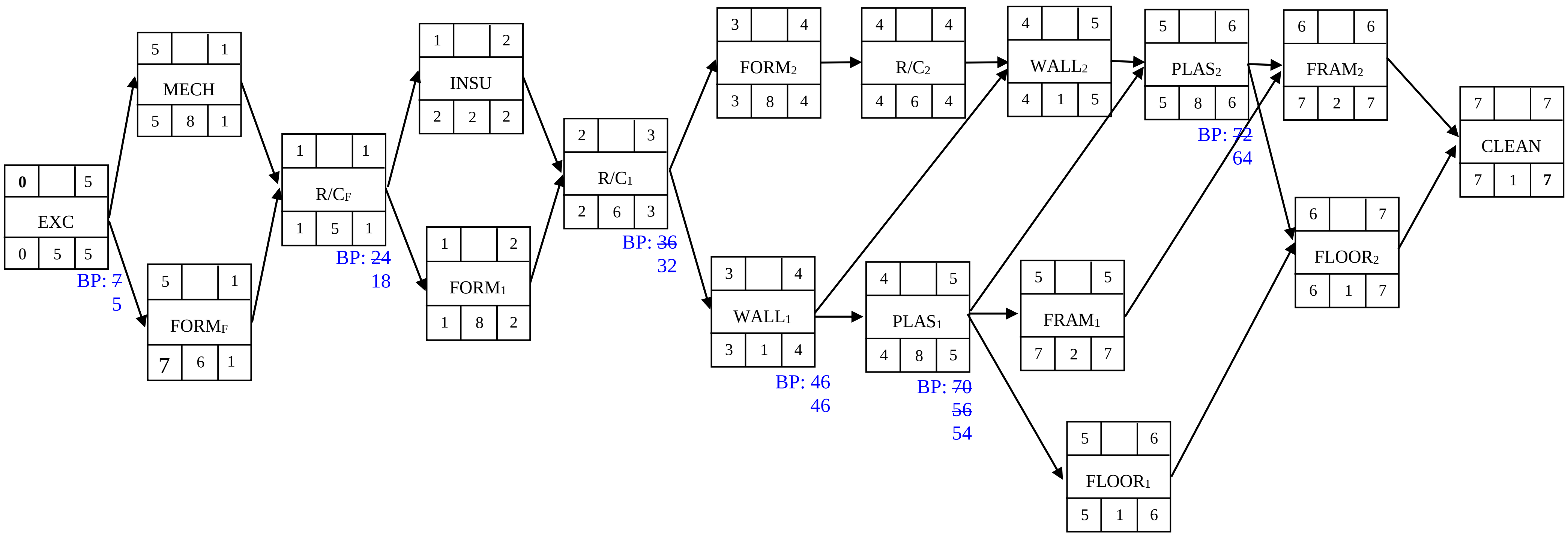
CPM Calculations: Forward Pass

Legend

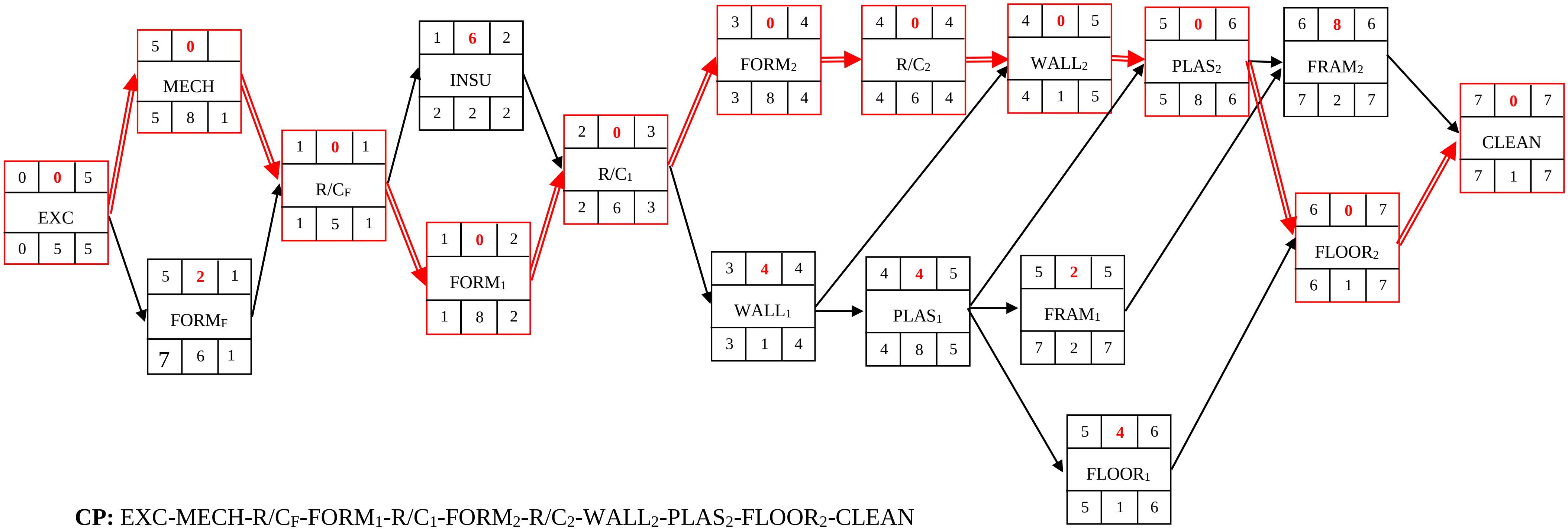
ES	TF	EF
	Act. name	
LS	dur	LF



CPM Calculations: Backward Pass



Calculation of total floats:



CP: EXC-MECH-R/C$_F$-FORM$_1$-R/C$_1$-FORM$_2$-R/C$_2$-WALL$_2$-PLAS$_2$-FLOOR$_2$-CLEAN

5.3 REFERENCES

1. Harris, F., and McCaffer, R. (2001). Modern Construction Management, 5th Edition, Blackwell Science, UK.
2. Fryer, B.G. (1997). The Practice of Construction Management, 2nd Edition, Blackwell Science, UK.
3. Oberlender, G.D. (1993). Project Management for Engineering and Construction, McGraw-Hill, USA.
4. Pilcher, R. (1992). Principles of Construction Management, 3rd Edition, Mc-Graw Hill International Series, UK.
5. Ackoff, R.L. (1970). A Concept to Corporate Planning, Wiley-Interscience, USA.

CHAPTER 6

MANAGING QUALITY

6.1 DEFINITION OF QUALITY

In everyday usage, the word "quality" is usually related with excellence or durability. In quality management however, quality means those features of a product, i.e. goods or services, which meet customer needs and thereby provide customer satisfaction. This definition implies freedom from deficiencies – i.e. from errors that require doing work over again (rework) or otherwise result in customer dissatisfaction. Quality implies "fitness for purpose" - that the product works for the purpose for which it was intended. A long-standing quality definition was "conformance to specification" however this definition can be in error, as customer needs may include many things not found in product specifications. On some occasions it may be extremely difficult for the customer to express his actual requirements.

Quality in the constructed project is achieved if the completed project conforms to the stated requirements of the principal participants (owner, design professional, constructor) while conforming to applicable codes, safety requirements and regulations (ASCE, 1990, quoted in Bennett 1996**).**

QUALITY OF PROCESSES

Quality management is now a major function within major construction companies. Unless a construction company can guarantee its clients a quality product, it can now no longer compete effectively in the modern construction market (Harris and McCaffer, 2001). Crucial to the delivery of such quality products is the quality of processes that produce the product. The reason is simple: technical specifications may not in themselves guarantee that a customer's requirements will be *consistently* met, if there are deficiencies in specifications or in the organizational system to design or produce the product or service. Quality of the product is the ultimate goal, but quality of the management processes is a significant contributor to the consistent quality of the company's products.

Quality assurance (QA) has the objective to provide the client with the quality of work required without the need for clients checking during the process. A customer for a car does not insist on checking the assembly of the car, for example. This objective is achieved by documenting what processes are performed and how they are accomplished, by self-checking that each process is completed correctly and finally by creating records of the processes. The policy of recording the processes undertaken, together with the checking and recording of procedures, provides the customer with the assurance that the company is aiming to achieve an acceptable standard of quality. Although 'satisfying the client' is the most important objective, the essence of QA is primarily to address 'getting it right first time' in order to avoid unnecessary costs to the contractor.

Management of quality normally involves three steps (Harris and McCaffer, 2001):

- Quality planning – determining the relevant quality standards
- Quality assurance – planning the quality activities
- Quality control – keeping errors out of the process

6.2 THE ISO 9000 SET OF STANDARDS

Every contractor may have his own quality system practiced at work but by the help of the standards, quality is understood easily and applied more efficiently by creating uniformity. Companies are being persuaded to adopt quality management systems in order to meet the demands of customers in a globalized market (Chini and Valdez, 2003). The most established and used international quality management standard is the ISO 9000 Standard, which is widely adopted by a large number of countries around the world.

The frame of reference for quality assurance is the ISO 9000 set of standards. The emergence of the ISO 9000 Quality Systems standard greatly increased the interest in formalized quality and certification. The role of ISO has also been important in coordinating the various national systems (Euronorm EN, TS, etc.) (Nee, 1996). ISO 9000 registration, or certification, is increasingly essential for anyone wishing to supply large corporations or to tender for public contracts. One idea about registration is that money can be saved on inspectors by simply demanding ISO 9000 from suppliers (Harris and McCaffer, 2001).

There are special features in the construction industry that limit the implementation of the ISO 9000 standard. The following are some of these features:

- A construction project is usually a unique collection of people, equipment, and materials brought together at a unique location under unique weather conditions, while most manufacturing is a system of mass production wherein all of these factors are consistent with producing typical products over and over again.
- Performance testing in construction is generally not feasible as a basis for acceptance.
- It is common to have separate contracts for design and construction.
- It is not feasible to reject the whole constructed project after completion while attached to the purchaser’s land.
- Decisions to reject a defective part of a constructed project need to be taken promptly before succeeding parts are constructed or installed.
- The number of parties involved in the constructed project’s procurement is more than those involved in manufacturing procurement. Achieving quality construction requires effort from all parties. This makes the interface and responsibilities of the various individuals and organizations more complicated than in manufacturing.

- The organizational structure of a construction company varies depending on the nature of the project, while the same structure in a manufacturing company is almost unchanging. This affects the smoothness of communication and interface between the responsible individuals.
- Turnover of manpower in construction is higher than in manufacturing, which affecting the precision of long-term plans.
- Construction projects are very complicated and their execution may take years. (Phenol, 1994)

There are also advantages of implementing the ISO 9000 to a construction company, which are:

1. Optimizes resources usage in the organization.
2. Improves awareness of company's objectives and policies.
3. Improves communication between various departments in the same organization.
4. Improves tractability of quality problems.
5. Cuts down material wastage.
6. Formalized systems ensure consistent quality services.
7. Provides useful documented reference.
8. Improves work quality with fewer rejects and less repeated work.
9. Rectifies errors at early stage.
10. Improves relationship with the owner, subcontractors, engineer – architect and material suppliers.
11. Improves corporate quality image.
12. Introduces continuous improvement through a review of the quality system.
13. Improves records and makes retrieval of information easy in case of litigation.
14. Helps project to be completed within the time frame stipulated in the contract.

(Chew and Chai, 1996)

A possible disadvantage of ISO 9000 is that registration may become the goal in itself. To be certified as operating to the ISO 9000 standard is now virtually seen as essential in today's construction industry, many companies has set up QA systems merely to register. Many clients will not do business with companies not certified to ISO 9000. ISO 9000 currently includes three main quality standards, as seen in Figure 6.1:

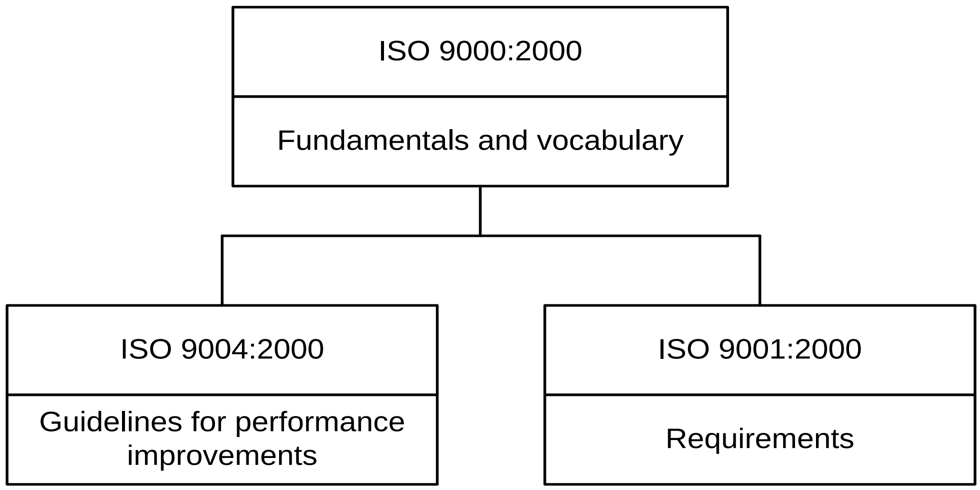


Figure 6.1: Structure of the ISO 9000 Standard (adapted from Nee, 1996)

ISO 9001 presents requirements, while ISO 9000 and ISO 9004 present guidelines. ISO 9004 is recommended as a guide for organizations whose top management wishes to move beyond the requirements of ISO 9001, in pursuit of continual improvement of performance. However, it is not intended for certification or for contractual purposes. All of these are process standards, not product standards.

6.3 QUALITY MANAGEMENT IN CONSTRUCTION

The quality actions required by a contractor vary according to type of contract. In a traditional contract where design is undertaken by an independent designer, the following list may apply (adapted from Harris and McCaffer, 2001).

Planning
▪ Receive tender documents; perform tender review; and prepare QA submission ▪ On award of contract undertake a contract review and set up site team ▪ Prepare project quality plan and submit for approval ▪ Conduct suppliers and sub-contractors assessment ▪ Place sub-contracts including QA conditions where appropriate to work package. Include requirement for documentation submissions, approvals and records ▪ Receive detailed quality plans from sub-contractors for approval prior to start of works
Site work

- Prepare detailed quality plans for own work
- Prepare inspection and test plans with 'hold points', etc. to monitor work packages and for approval prior to works
- Perform goods inwards inspection
- Undertake plant inspection
- Control work on site against quality plans, inspection checklist, etc.
- Audits on- and off-site according to audit schedule
- Ongoing supplier and sub-contractor evaluations
- Generate records as construction proceeds, e.g. filled-out inspection sheets
- Monitor off-site work (against detailed quality plans)

Hand-over / completion

- Mark up drawing to as-built state
- Prepare handover packages and submit

Figure 6.2: Contractors Quality Actions (adapted from Harris and McCaffer, 2001)

Some often used documents in construction site quality management are mentioned in the following text.

METHOD STATEMENTS

Method statements are frequently seen documents in construction QA. Method statements are the equivalent of a standard operating procedure (SOP), however SOP's are often used for works having a repetitive character. SOPs may apply to many functions in a construction firm, for example workflow in the site or head office. However, few site jobs in construction are completely identical and contractors are therefore required, as part of their QA submittals, to prepare site-specific method statement for major tasks, such as excavation, concreting, cladding, painting etc. The method statement serves to explain that proper procedures and best practice will be followed. In many cases a method statement is required for a very specific sub-task, such as concreting in extreme weather conditions, early striking of formwork or also where extraordinary construction methods are used.

A method statement can include:

- Scope/location of work task
- References to shop drawings
- Responsibilities
- Method (execution steps)
- Correlation to an inspection plan
- Health, safety and environmental (HSE) issues
- Special requirements and areas of risk
- Records (e.g. an inspection and test plan)

The execution steps are normally explained in plain language. As an example for an excavation job:

- *Excavation will be commenced with stripping of topsoil. It will be stockpiled on site for reuse.*
- *Excavated area will be surrounded by safety band.*
- *Slope of excavation will be XX/YY as per excavation drawing EXC.123*
- *In case of ground water a pit pump will be placed in the excavation.*
- *The excavation bottom will be levelled and compacted with cylinder.*
- *Levelled and compacted soil surface will be covered with lean concrete.*
- *Etc….*

The method statement must emphasize those details that are critical for quality. For example, a method statement for concreting works must stress the issues of joints - e.g. exposure of aggregate in joint prior to adjacent casting - temperature control, curing conditions, formwork level and plane, and so on.

INSPECTION AND TEST PLANS

Inspection and test plans (ITPs) are lists with check-points of a specific work tasks. It may or may not also function as record of work performed, in some cases the ITP will just refer to the relevant quality document or record. In-process activities that cannot be verified after the fact by inspection must have stringent in-process controls by qualified personnel to assure conformance to specifications. Construction has numerous such examples and many features of a construction project are hidden by subsequent construction, and these are often the most vital. Examples are the concrete reinforcement or sealing of concrete walls prior to backfill. In such cases check items may be *hold points*; i.e. points where production cannot continue before the item is checked off on the inspection sheet, a typical example is reinforcement before concrete is poured. A variety of the hold point is the *witness point*, meaning that the work item cannot continue unless the controlling engineer is witnessing the work.

Table 6.1: Example Excerpt of Inspection and Test Plan for a Deep Excavation

Item	Inspection	Inspection methods and reference papers	When	Who	Criteria of acceptance	Documentation (QD)
Excavation plan	Earthwork supervisor, Site personal	Construction sequence drawings	All excavations	Site engineers	In accordance to drawing	RIW
Plant requirements	Earthwork supervisor	Plant dept.	All excavations	Site engineers		Site diary
Dewatering	Site engineer	FOR/MS/1303	All excavations	Site engineers	60 m^3/h	Site diary

NON-CONFORMANCE REPORTS

A non-conformance report (NCR) is an important instrument to register works that have been performed not in accordance with specifications. The finding of improperly done site work causes a NCR to be 'raised' and signed by both contractor and Engineer. The procedure for an NCR can be simplified as follows:

1. A non-conformance is observed on site → NCR is raised and registered
2. NCR is reviewed, typically by Engineer in collaboration with designer and contractor, etc.
3. Engineer decides the *disposition* (action to be taken), these are typically one of the following: *Demolish/Rework, Repair or Accept-as-is*.
4. Contractor carry out the disposition
5. Works are checked to be in conformance with Engineers disposition
6. Contractor takes appropriate steps to avoid recurrence

ISO 9000 requires documented procedures for handling of non-conforming product, and the NCR is the typical instrument in construction. The objectives for such control are to prevent the customer receiving nonconforming product and to optimize costs of further processing. NCR forms often require several signatures, and the NCR work flow can be very bureaucratic, having a negative bearing on progress. It is therefore important to have a simple NCR system. The accept-as-is solution to an NCR can be chosen when the non-conformance is a deviance from the specification, but extremely costly to rectify and not a major breach of design intent. The disposition must therefore be made by someone with authority, and the owner's representative must have the final signature.

IMPLEMENTATION PROBLEMS IN CONSTRUCTION

Quality assurance was not adapted as easily in construction as in manufacturing and other sectors. Within traditionally procured construction problems experienced in implementing quality assurance often occur at interface points in the building process, notably at the interface between the client and designer and the interface between the designer and the contractor. Some reasons for the project failing to meet with the client's needs may include the following (Nee, 1996; Griffith, 1990):

- Client and designer may misunderstand the details of the brief with regard to the building's purpose, performance or appearance.
- The designer may perceive quality in a different way to the client. The designer may, through misunderstanding or ignorance, misinterpret the objectives regarding quality specified by the client.
- The construction may be insufficiently financed to build to the quality levels desired by the client. Failure to balance cost with quality at the brief and design

stages can lead to a reduction in the level of quality achieved during construction through re-specification of some items to an inferior standard.

- The time schedule may be strained, putting at risk the desired quality level through hasty work.
- The designer may design the building that cannot be built to the required levels of quality due to buildability issues not being addressed.
- The contractor may fail to understand what the desired standards of quality are. If the design stage is completed before appointing the contractor, as in the case of 'traditional' procurement, there is no opportunity for the designer to effectively communicate desired quality levels to the contractor first hand. The designer has to rely on the clarity of drawings and specifications and upon the contractor's correct interpretation of these when construction proceeds. The builder does not always know the 'real' standards before commencing work on site.
- The contractor may not be able to build to the desired quality standards due to a mismatch between the design and construction systems. The contractor may not be sufficiently competent to undertake the task or may misunderstand the requirements through inadequate communication of the design concept.
- Construction quality assurance has in certain instances been confined to ‘permanent works’, i.e. excluding the contractor’s temporary works. In many types of construction, this is a very are artificial division. QA must include all aspects vital to the permanent works, and temporary works must not escape QA.
- Design requirements may not be communicated simply and effectively to the operative at the workplace.
- Life cycle, operation and maintenance cost of the project are not properly addressed. This can result from an inadequate brief making the building too expensive to operate and maintain.

6.4 QUALITY-RELATED COSTS

In Quality Management, the most often used definition of Quality Costs are the costs associated with preventing, finding, and correcting defective work. It is the cost of “not getting it right the first time” (Juran, 1999).

There are two aspects of the cost of quality:

1. Cost of conformance – cost of the company’s quality efforts
2. Cost of non-conformance

This cost of attaining quality is very difficult to quantify. It would be an oversimplification to equate the cost of attaining quality to, for example, the cost of running the Quality Department. It has been proposed that quality costs be assigned to one of three categories: Prevention costs, appraisal costs and failure costs. Feigenbaum (1991) (as quoted in Bennett, 1996) suggested the following breakdown of various elements of quality cost:

Cost of conformance:

(a) Prevention

- Quality planning
- Process control
- Design and development of quality information equipment
- Quality training and work force development
- Product design verification
- Systems development
- Other prevention costs

(b) Appraisal

- Test and inspection of purchased materials
- Laboratory acceptance testing
- Laboratory and other measurement services
- Inspection, testing, checking labor, setup for test and inspection
- Test and inspection and material and minor quality equipment
- Quality audits
- Outside endorsements
- Maintenance and calibration of quality information test and inspection equipment
- Product engineering review and shipping release
- Field testing

Cost of Non-conformance

(a) Internal failures

- Scrap
- Rework
- Material procurement costs
- Factory contact engineering

(b) External failures

- Complaints in warranty
- Complaints out of warranty
- Product service
- Product liability
- Product recall

These are not the only ways of organizing costs. In construction some of these do not apply, and certain costs are often seen in construction or project work in general:

- Inspection of subcontractor work and QA documentation
- Removal of punch-list items
- Cost of handling claims and litigation

It should be kept in mind that the more effort spent on prevention means that the less failure costs will arise. In quality environment this principle is summarized by the general rule of thumb: “Ounce of prevention is worth a pound of cure” On the other hand spending too much money on the prevention and appraisal costs decreases the failure but increases the total cost of quality. Figure 6.3 indicates conceptually the trade-off between failure cost and prevention/appraisal costs. The figure indicates the optimal level of quality efforts, at which the total quality costs are minimized.

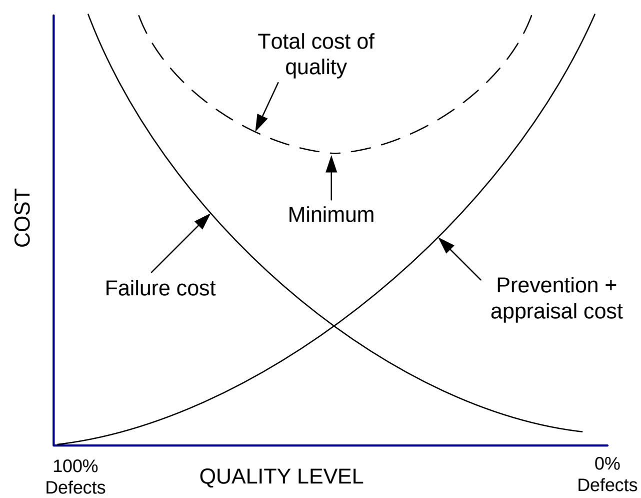


Figure 6.3: Cost versus Quality Level – classic view adapted from Brown and Kane, 1984

An important non-conformance cost is revenue loss (lost sales) due to poor quality – this is a ‘hidden’ cost because it is not easily measured. Costs associated with poor quality are identified and measured for three reasons:

- To quantify the size of the quality problem to help justify an improvement effort
- To guide the development of that effort
- To track progress of improvements

Quality cost data should not be used for ‘reporting’ purposes; publication of costs alone has shown to solve no problems. Quality-related costs should be used to support a quality improvement program and to ‘sell’ the quality efforts to higher management by using the language of money.

6.5 THE QUALITY MANAGER

Quality is a commitment from top management. To this effect executive management must appoint it own representative who, irrespective of other responsibilities, shall have authority to ensure that the quality system is established, implemented, maintained and improved. The management representative shall oversee the quality system and report on its performance to management for review and improvement. There must not be any conflict of interest if the representative has other duties than quality, and typically the Quality Manager will report directly to the General Manager.

This management representative can be entitled the Quality Manager, Quality Assurance Manager, QA/QC Manager or similar. In a construction firm, however, there is usually a project official with quality-related duties assigned to the quality of each project. This official will usually be entitled QA Manager or similar.

A quality manager may have the following duties:

- Setting up the quality system
- Writing procedures
- Staff training
- Monitoring performance of QA system
- Coordinate sampling of construction materials
- Ensure compliance with ISO9001 through internal quality audits
- Ensure that subcontractors QA system conforms with contract requirements
- Working with external assessors
- Revising and continuously improving the system

Subordinates of a project quality manager in construction are typically quality engineers, site inspectors, site engineers and material engineers.

6.6 REFERENCES

1. Harris, F., and McCaffer, R. (2001). Modern Construction Management, 5th Edition, Blackwell Science, UK.

2. EN ISO 9001:2000, Quality management systems–Requirements, International Standards Organization.

3. Nee, P. (1996). ISO 9000 in Construction, John Wiley & Sons, Inc.

4. Griffith, A. (1990). Quality Assurance in Building, Macmillan.

5. Bennett, F.L. (1996). The Management of Engineering, Wiley & Sons, Inc.

6. Juran, J.M. (1999). Juran's Quality Handbook Fifth Edition, McGraw-Hill.

7. Brown, F.B., and Kane, R.W. (1984). Quality cost and profit performance, in: Campanella, J. Editor, Quality costs: Ideas and application, Milwaukee, WI: ASQC Press.

8. Bubshait, A.A. and Al-Atiq T.H. (1999). "ISO 9000 Quality Standards in Construction", Journal of Management in Engineering, Vol. 15, No. 6, November/December 1999, pp. 41-46.

9. Chini, A.R. and Valdez, H.E. (2003). "ISO 9000 Implementation in Turkish Industry", Journal of Management in Engineering, Vol. 19, No. 2, April 2003, pp. 69-77.

10. Phenol, L.U. (1994). "ISO 9000: Implementation Problems in the Construction Industry", Quality World, American Society of Quality Control, May, pp. 2-4.

11. Chew, Y.S., and Chai, L.N. (1996). ISO 9002 in Malaysian Construction Industry. McGraw Hill Book Co.
12. http://www.iso.org/iso/en/ISO 9000-14000/ISO 9000/ISO 9000index.html
13. http://www.baldrige.nist.gov/
14. http://www.efqm.org/model_awards/eqa/intro.htm
15. http://www.juse.or.jp/e/deming/index.html
16. http://www.kalder.org.tr
17. http://www.bath.ac.uk/management/agile/summary/summary.html

CHAPTER 7

MANAGING HEALTH and SAFETY

7.1 THE FACTS ABOUT JOB SAFETY

Safety is engineer's liability. It is a liability that can be shared but never completely delegated, a responsibility for the lives and well-being of the workers themselves.

Safety affects the bottom line (AGC, 1989). Accidents are expensive. They incapacitate skilled workers, disrupt construction activities, raise the company's insurance and workman's compensation rates, and can place the company in legal threat. On the other hand, a good safety record and safe working conditions boost employee morale and therefore contribute to increased productivity. Safety is also the law (MCAA, 1984).

7.2 SAFETY PROGRAMS

All construction firms need a carefully planned and directed safety program to minimize accidents and ensure compliance with the safety regulations. However, no safety program will be successful without the active support of top management. Job-site supervisors have traditionally neglected safety in their haste to get the job done on time and within budget. Only when supervisors are convinced by higher management that safety is equally as important as production, will the benefits of an effective safety program be achieved. An effective safety program must inspire a sense of safety consciousness in every employee (Nunnally, 1993).

Although there are many ingredients in a comprehensive safety program, some of the major elements are listed below.

1. A formal safety training program for all new employees.
2. Periodic refresher training for each worker.
3. A formal supervisory safety training program for all supervisors.
4. A program of regular site visits by safety personnel to review and control job hazards.
5. Provision of adequate personal protective equipment, first-aid equipment and trained emergency personnel.
6. An established procedure for the emergency evacuation of injured workers/
7. Provisions for maintaining safety records and reporting accidents in compliance with the safety regulations.

7.3 COMPANY POLICIES

MCAA (1984) states that an effective project safety program begins with a written company safety program that provides:

- Safety measures for all projects
- Safety measures pertinent to each individual project
- Compliance with all pertinent sections of the safety regulations

A company should base its safety program not on one source of safety information but on a variety of sources, such as:

- Current laws
- Company records and experience
- Industry safety materials such as Jobsite Safety Manuals.

Where possible, one individual in the company should be appointed Safety Engineer and charged with responsibility for staying informed on new safety developments and laws, reviewing company policies and recommending changes, and enforcing company safety policies on the jobsite.

7.4 PROJECT REQUIREMENTS

Each project should have a written safety policy that addresses the job's particular safety situations. The policy should be prepared by the project team based on the company's normal safety program. It should also include pertinent parts of the safety program established by the project owner and/or the general contractor.
To develop an inclusive safety policy, the project team must obtain copies of the owner's and/or general contractor's safety policies and review it carefully to identify:

- Points to be included in the contractor's policies, and
- Areas where safety policies are unclear or lacking.

This review should be followed by a meeting with the owner's and/or general contractor's safety representative to discuss (MCAA, 1984):

- Introduction of the project authority's safety representative to the member of the project team who is responsible for the company's safety policies
- Overall safety strategies

- Specific safety requirements and procedures related to the job
- Necessary safety procedures that are lacking or unclear in the existing policies
- Specific safety responsibilities of both parties
- Scheduling of regular safety inspections and regular meetings to discuss safety topics
- Procedures for identifying, reporting and correcting hazardous job situations in a timely fashion

7.5 SAFETY ENGINEER

Some companies have a designated Safety Engineer. Others rely on their project managers to assign responsibilities for safety on each individual project. Regardless of which situation holds true in your company, the duties of the responsible person are essentially the same, namely to (MCAA, 1984):

- Provide and maintain safety-related equipment such as: first aid kits, hard hats, gloves, goggles, helmets, respirators, and other personal protection equipment
- Regularly inspect tools and construction equipment, including extension cords, and tag worn or damaged items for return to the company shop for repair or replacement
- Regularly inspect personnel and material handling equipment and facilities, particularly hoists and rigging, scaffolding and man lifts, storage areas and traffic paths
- Enforce and verify lock-out/tag-out procedures
- Regularly check the condition of special items such as fire extinguishers and acetylene and oxygen cylinders, valves, hoses and other accessories
- Ensure that mechanics know how to use the tools needed for the job, instructing new mechanics in the proper use of bask tools and all mechanics in the proper use of specialized tools
- Monitor the use of all tools, construction equipment, and jobsite facilities
- Enforce safety procedures for special conditions such as working inside tanks, enclosures and other confined spaces
- Monitor compliance of company personnel and subcontractors with all company and project-specific safety policies
- Correct or have corrected all safety violations and hazardous conditions that are the responsibility of the contractor
- Report to the project manager or other project authority all unsafe practices by other trades and hazardous conditions that are the responsibility of the general contractor or the owner to correct
- Educate field personnel in safety matters, making sure that every employee receives a copy of and clearly understands all company, owner/general contractor, and the safety regulations

- Post safety information, as required, including the safety regulations, emergency telephone numbers, hand signals for directing cranes, special project safety notices, and the address and telephone number of the company office where the government-required illness and accident reports are stored, and
- Conduct weekly safety meetings to cite safety procedures not being followed in the field, introduce new safety policies, and review procedures for handling emergency situations.

7.6 SAFETY PROCEDURES (Nunnally, 1993)

It has been found that most serious construction accidents involve construction equipment operations, trench and embankment failure, fall from elevated positions, collapse of temporary structures and formwork, or the failure of structures under construction. The safety regulations are quite specific in many of these areas, and special management attention should be devoted to the safety of these activities.

Lumber, used formwork and other material lying around a work area increase the likelihood of falls and puncture wounds. Different types of safety procedures to be directed by the safety engineer and/or project manager are discussed below:

7.6.1 Equipment Operations

- Utilize guides or signalmen when the operator's visibility is limited or when there is danger to nearby workers. Backup alarms or guides must be used when equipment operates in reverse.
- Exercise extreme caution and comply with safety regulations when operating near high-voltage lines. In case of contact with a high-voltage line, the operator should attempt to move the equipment enough to break contact.
- Use care when operating equipment on side slopes to prevent overturning.
- When operating cranes, be extremely careful not to exceed safe load limits for the operating radius and boom position. Electronic load indicators are available.
- Do not allow workers to ride on equipment unless proper seating is provided.
- Park equipment with the brake set, blade or bowl grounded, and ignition key removed at the end of work.
- When hauling heavy or oversized loads on highways, make sure that loads are properly secured and covered if necessary. Slow-moving and over-sized vehicles must use required markings and signals to warn other traffic.
- Take positive action to ensure that equipment under repair cannot be accidentally operated.
- Utilize blocking or other positive support when employees must work under heavy loads supported by cables, jacks, or hydraulic systems.

- Ensure that any guards or safety devices removed during equipment repair are promptly replaced.
- Shut down engines and do not allow smoking during refueling.

7.6.2 Construction Plant

- Set equipment containing hot or flammable fluids on firm foundations to prevent overturning. Clearly mark high-temperature lines and containers to prevent burns. Be especially careful of live steam. Provide fire extinguishers and other required safety equipment.
- Aggregate bins and batching plants should be emptied before performing major repairs.
- When electrical equipment is being repaired, shut off and tag electrical circuits.
- Ensure that wire rope and cable is of the proper size and strength, well maintained, and inspected at least weekly.

7.6.3 Excavations

- The sides of excavations must be properly shored or sloped to the angle of repose to prevent cave-ins in accordance with safety regulations.
- Avoid the operation of equipment near the top edge of an excavation because this increases the chance of slope failure. The storage of materials near the top edge of an excavation, vibration, and the presence of water also increase the chance of slope failure. When these conditions cannot be avoided, additional measures must be taken to increase slope stability. If workers are required to enter the excavation, no spoil or other material may be stored within the close edge of the excavation.
- Ensure that workers are not allowed under loads being handled by excavators or cranes.
- Watch out for buried lines and containers when excavating. Possible hazards include toxic and flammable gases, electricity, and collapse of side slopes due to sudden release of liquids. If a gas line is ruptured and catches fire, get personnel and flammable material away from the fire and have the gas turned off as quickly as possible. Do not attempt to extinguish the fire because an accumulation of unburned gas poses a great threat for environment.

7.6.4 Construction of Structures

- Properly guard all openings above ground level.
- Provide guard rails, safety lines, safety belts, and/or safety nets for workers on scaffoldings or steelwork.
- Ensure that temporary structures are properly designed, constructed, and braced.

- Special caution should be exercised in high-rise concrete construction. Forms must be of adequate strength and properly braced. The rate of pour must be maintained at or below design limits. Shoring and re-shoring must be adequately braced and not removed until the concrete has developed the required strength.

7.6.5 Marine or Over-Water Construction

Marine or over-water construction operations present all of the usual construction hazards plus additional hazards posed by the marine environment. These additional hazards include drowning, slippery surfaces, height hazards, as well as weather and wave action. Some of the major safety precautions that should be taken are listed below.

- Unless workers can safely step onto vessels, a ramp or safe walkway must be provided. Access ways must be adequately illuminated, free of obstructions, and located clear of suspended loads.
- Working areas should have nonslip surfaces, be maintained clear of obstructions, and be equipped with adequate handrails.
- Workers on unguarded decks or surfaces over water must wear approved lifejackets or buoyant vests. Life rings and a rescue boat must also be available. Workers high above a water surface must be protected by safety belts, safety nets, or similar protective equipment.

7.7 REFERENCES

1. AGC Guidelines for a Basic Safety Program (1989). The Associated General Contractors of America, Inc., Washington, D.C.
2. Akçalı, Ünal (1998). Yapı Yasaları ve Şartnameleri Dökümü. Yapı İşlerinde İşçi Sağlığı ve İş Güvenliği Tüzüğü. 6. Baskı, Ankara.
3. Feld, J. (1968). Construction Failure. New York: Wiley.
4. Manual of Accident Prevention in Construction (1992). The Associated General Contractors of America, Inc., Washington, D.C.
5. MCAA Project Managers Manual (1984). Mechanical Contractors Association of America, Inc. Bethesda, MD.
6. Nunnally, S.W. (1993). Construction Methods and Management. Third Edition. Regents /Prentice Hall, Englewood Cliffs, NJ 07632.

CHAPTER 8

CONSTRUCTION MACHINERY AND EQUIPMENT

8.1 INTRODUCTION

Construction can also be defined as making a facility, on land, for the use of people using the materials of nature, raw or processed, by the help of manpower and equipment. In the definition, the word equipment has been used in general to mean also machines and plants. A few examples of construction machines, equipment and plants are given below.

Machines	Equipment	Plants
Excavators	Formwork	Concrete Plant
Loaders	Scaffolding	Crushing Plant
Dozers	Surveying Instruments	Asphalt Plant

It should be noted that plant is also meant to be the collection of several machines, equipment and plants. In this chapter, the words machines, equipment and plants will be used to mean the same thing.

Why should machines be used? What are the points to consider to be economical when machines are used in construction?

Should standard or special machines be used? What about maintenance of machines?

<u>Reasons to use construction machines</u>

1. Increased production (trench excavation),
2. Reduction in overall construction costs (foundation excavation),
3. Carrying out activities which cannot be carried out by the traditional manual methods (pile driving),
4. Eliminating heavy manual works thus reducing fatigue and as a consequence increase the productivity (rock crushing, moving materials with forklift),
5. Replacing labor where there is a shortage of personnel with the necessary skills (concrete pouring, alignment by laser instruments for suspended ceilings),

6. Maintaining the high standards required particularly in the context of structural engineering works (concrete plant).

Economical considerations

To be economical, machines and equipment must be fully utilized and not left standing idle since they will have to be paid for if hired or they will cost if owned even if when they are non-productive. Full utilization of plant is usually considered to be in the region of 85% of on-site time, thus making an allowance for routine, daily and planned maintenance. Maintenance of machines needs to be carried out to avoid, as far as practicable, machine breakdowns which could disrupt the construction program. Many pieces of plant work in conjunction with other items of plant such as excavators and haulage trucks, therefore a correct balance of such plant items must be obtained to achieve an economical result. In Table 8.1, purchase costs (initial brand new purchase price) of some of construction equipment are given.

Table 8.1: Initial (Brand new) Purchase Prices of Some Construction Machines

LOADERS			
Type	**HP**	**Bucket (m^3)**	**A ($)**
WA320-1	150	2.5	140,000
WA420-1	204	3.7	165,000
WA500-1	291	4.0	210,000
WA600-1	415	5.4	258,000
EXCAVATORS			
Type	**HP**	**Bucket (m^3)**	**A ($)**
PC200-5	123	0.80	152,000
PC300-5	207	1.32	187,000
PC400-5	276	1.3-2.2	360,000
PC650-3	404	3.8-4.5	800,000
MOTOR GRADERS			
Type	**HP**	**Blade Size**	**A ($)**
GD611A-1	155	3710x645x19mm	259,000
GD621A-1	155	3710x645x19mm	283,000
GD661A-1	180	3710x645x19mm	307,000

Maintenance considerations

On large contracts where quite a number of plant items are to be used, it may be advantageous to employ a skilled mechanic to be on site to carry out all the necessary daily, preventive and planned maintenance tasks together with any running repairs which could be carried out on site. If there are many different types of machines and equipment, it might be necessary to set up a workshop.

Standard equipment versus special equipment

There is no clear-cut definition, but a standard equipment can be considered as the one which is commonly manufactured and easily available for the use of any prospective user.

e.g. 1 m^3 capacity power shovel = standard

50 m^3 capacity power shovel = special

If possible, contractor should prefer the purchase of standard equipment because:

- their delivery is generally much quicker,
- they may be used on more than one job,
- spare parts can be obtained more easily and quickly,
- they can be disposed of more easily and at a more favorable price.

It is also important to consider whether to purchase or hire an equipment since it may be more advantageous to hire for short time usage and for special equipment.

8.2 ESTIMATING HOURLY COST OF EQUIPMENT

Whether the equipment is owned or hired, the hourly cost of the equipment should be known for the purpose of:

- pricing,
- consciousness (it means that unnecessary idleness of the equipment is not allowed), and
- cost control.

In general, the hourly cost of a machine is broken into two main components as fixed cost and operating costs. Fixed cost consists of those costs that occur whether the machine is used or not, on the other hand operating costs occur when the machine is used. Breakdown of the main components may change from company to company or from country to country. In this Chapter, the practice of Turkish Ministry of Environment and Urban Planning will be explained. In Table 8.2, the cost components given by Peurifoy and Schexnayder (2002) are also indicated to compare with the Ministry's cost breakdown.

Table 8.2: Hourly Cost Components by Turkish Ministry of Environment and Urban Planning and by Peurifoy

Hourly Cost Components	
Turkish Ministry of Environment and Urban Planning	**Peurifoy**
A. Fixed Costs	***A. Ownership Costs***
1. Depreciation	1. Purchase expense without tires cost (but including shipping)
2. Spare parts	2. Salvage value
3. Maintenance and repair	3. Tax saving from depreciation
4. Investment cost, insurance, storing, legal dues	4. Major repairs and overhauls
5. Freight, unloading, assembling	5. Property taxes
	6. Insurance
	7. Storage and miscellaneous
B. Operating Costs	***B. Operating Costs***
- Fuel	- Fuel
- Motor oil, lube oils, grease, etc.	- Motor oil, lube oils, grease
- Manpower	- Repairs
	- Tires
	- Replacement of high-wear items
	C. Manpower Costs

PROCEDURE PRACTICED BY TURKISH MINISTRY OF ENVIRONMENT AND URBAN PLANNING

A) <u>Fixed Cost Components</u>

Depreciation, spare parts, maintenance and repair, investment and freight costs are fixed cost components and are explained below.

1) <u>Depreciation Cost:</u>

This is the cost contribution of initial price (cost) of machine due to the loss in value of the machine due to time.

Turkish practice is to use Straight Line Depreciation with no salvage value, therefore:

Hourly Depreciation Cost = A/(Nn)

where,

A = Initial purchase price of the equipment,

N = Depreciation life of the equipment

n = Working hours per year

For some equipment, <u>N and n values used by the Ministry</u> → **given in Table 8.3.**

2) <u>Spare Parts</u>

Spare parts cost is assumed to be 53% of depreciation cost:

Hourly Spare Parts Cost = 0.53 A/(Nn)

3) <u>Maintenance and Repair</u>

Maintenance and repair cost is assumed to be 13% of depreciation cost.

Hourly Maintenance and Repair Cost = 0.13 A/(Nn)

4) <u>Investment Cost</u>

Investment cost is considered because money spent to purchase the equipment could be made use of in other ways to earn money, for example could be deposited in a bank.

Either capital recovery or average value per year consideration can be employed. Ministry's practice is to use average value of equipment for interest amount calculations. Average value per year can be calculated directly from the following expression:

Average Value per year= A (N+1) / (2N)

or can be numerically evaluated as shown in Table 8.4 for an equipment purchased for 75,000 TL with a depreciation life of 5 years and no salvage value, (Depreciation per year =75,000/5 = 15,000 TL)

Table 8.4: Illustration of Average Value Calculation

Year	Depreciation Amount (TL)	Book Value (TL)
0	-	75.000
1	15.000	60.000
2	15.000	45.000
3	15.000	30.000
4	15.000	15.000
5	15.000	-
	Total Value in 5 years	225.000
	Average Value per year	45.000

Using average value per year expression,

Average Value/year=75000*(5+1)/(2*5) =45000 TL is obtained.

If interest rate per year is i, then investment cost per year = i x 45000

Hence,

Hourly Investment Cost = i A (N+1) / (2 N n)

Turkish Ministry takes 8% for i.

Hourly Investment Cost = 0.08 A (N+1) / (2 N n)

5) <u>Freight, Unloading and Assemble</u>

It is assumed that the equipment is moved once a year from one place to another and this cost is assumed to be 2% of the initial cost "A". Annual cost of freight etc. = 0.02 A

Hourly Cost of Freight etc. = (0.02 A) / n

Hourly Fixed Cost

Hourly fixed cost is given by the summation of the expressions expressed above for fixed cost components.

Hourly Fixed Cost= A/(Nn) + 0.13A/(Nn) + 0.53A/(Nn) + 0.08 A(N+1)/(2Nn) + 0.02A/n

$$\text{Hourly Fixed Cost} = [A/(Nn)]\,[1 + 0.13 + 0.53 + 0.04\,(N+1) + 0.02\,N]$$

$$\textbf{Hourly Fixed Cost} = \mathbf{(1.7 + 0.06N)\,[A/(Nn)]}$$

Caution: Use this expression when all data is same as Ministry's data, for example if i=12% expression will not hold.

B) Operating Cost Components

1) Fuel Cost

Fuel consumption is directly related to engine power of the machine.

- for a diesel engine = (0.0855 kg/HP) per hour
- for a gasoline engine = (0.114 kg/HP) per hour

where HP is engine power in Horse Power.

2) Lubricating Oil Cost

Even though the oil consumption will depend on factors as:

- the capacity of the crankcase;
- the conditions of piston rings;
- the number of hours between oil changes,

The average value for cost purpose is estimated to be: 0.0171 kg/HP per hour.

3) Workmanship Cost

i) Hourly paid labor is paid for the hours they actually worked

Cost = Number of Hours Actually Worked x Hourly Rate

ii) Monthly paid personnel (operators, foremen, etc.) are paid for 240 hours but actual hours worked in a month is usually 167 hours (2000 hours per year/12 months), the remaining hours are weekends, holidays and paid vacations.

Hourly rate calculation of monthly paid personnel is:

Hourly rate = Total Cost of Salary / 240 hours

This rate is valid if the person works actually 240 hours per month. Therefore, actual hours worked must be adjusted to the 240 hours by which the hourly rate is established.

Actual hours worked in a year = n → **given in Table 8.3**

Hours in a year paid by monthly salary = **240 hours * 12**

Therefore, Adjustment factor for actual hours worked = **240 * 12 / n**

or directly obtain hourly rate of operator as = **(12 x salary) / n**

Example 8.1

In this example, rate calculation of a 1 cu.yd. excavator is given according to the procedure of the Ministry Environment And Urban Planning. Calculations are shown in Table 8.5 in the same way as it is shown in the Price Analysis Book of the Ministry (Bayındırlık ve İskan Bakanlığı, 2006). Prices are for the year 2006. For comparison, cost rates are also given in US dollars.

Table 8.5: Hourly Rate Calculation of The Excavator: Pos. No. 05.501

EXAMPLE 8.1							
Pos.no.03.501/1 EXCAVATOR (3/4-1&5/8) cu.yd. diesel engine 125HP							
year =	2006						
A =	169,713.00						
i =	0.08						
N =	8.00	(Table 8.3)					
n =	2,000.00	(Table 8.3)					
HP =	125.00						
1$ =	2.20						
		Annual	**Annual**			**Hourly**	
	Depreciation	A/N	21,214.125			10.607	
	Spare Parts	0.53 * A/N	11,243.486			5.622	
	Maintenance	0.13 * A/N	2,757.836			1.380	
	Investment Cost	i*(N+1)*A/2N	7,637.085			3.819	
	Freight, Unloading	0.02 * A	3,394.26			1.697	
	∑ Fixed Cost		46,246.792			23.125	
	by fixed cost factor	(1.7+0.06N)/(Nn)	*A	$1.3625*10^{-4}$	*A	**23.123**	
			Unit	**Amt.**	**Unit Price**	**Total**	
04 – 109	**Motorin**	0.0855 kg / HP hrly	Kg	10.6875	2.02	21.589	
04 – 109	**Engine Oil, Grease, Lub. Oil**	0.0171 kg / HP hrly	Kg	2.1375	2.02	4.318	
01 – 404	**Operator**		Hour	1.4400*	4.08 hrly	5.875	
01 – 408	**Helper**		Hour	0.3333**	2.64 hrly	0.880	
	∑ Operating Cost					32.662	
03 - 005/1	**∑ Fixed Cost**	$1.3625*10^{-4}$ * A				23.123	
				Total Cost		**55.785**	TL/hr
				Profit (25% of cost)		13.946	
				∑ Hourly Rate		**69.731**	TL/hr
				Hourly Rate in $'s		31.696	$/hr
Note							
Daily Cost = Hourly Rate* 8 hrs/day					Daily Cost	557.85	TL/day
Monthly Cost = Daily Cost * 25 days/month					Monthly Cost	13,946.25	TL/month
*Operator works "n" hours as Machine → Adjustment factor for operator = (240x12)/2,000=1.44							
**Helper works independently however serves for three Machines → Adjustment factor for helper = 1/3 = 0.3333							

Example 8.2

In this example, hourly rate calculation of a wheel loader is shown for year 2002 in Table 8.6 where the tires cost is included in the initial purchase price A.

Table 8.6: Hourly Rate Calculation of The Wheel Loader: Pos. No. 03.521

EXAMPLE 8.2							
Pos.no.03.521 LOADER WITH TIRES 1.5 cu.yd. diesel engine 80HP							
yr=	2002						
A =	26,190.00						
i =	0.08						
N =	5.00	(Table 8.3)					
n =	2,000.00	(Table 8.3)					
HP =	80.00						
1$ =	2.20						
		Annual	**Annual**			**Hourly**	
	Depreciation	A/N	5,238.00			2.619	
	Spare Parts	0.53 * A/N	2,776.14			1.388	
	Maintenance	0.13 * A/N	680.94			0.341	
	Investment Cost	i*(N+1)*A/2N	1,257.12			0.629	
	Freight, Unloading	0.02 * A	523.80			0.262	
	∑ Fixed Cost		10,476.00			5.238	
	by fixed cost factor	(1.7+0.06N)/(Nn)	*A	0.0002	*A	**5.238**	
				Amt.	**Unit Price**	**Total**	
04 – 109	**Motorin**	0.0855 kg / HP hrly	Kg	6.8400	0.92	6.293	
04 – 109	**Engine Oil, Grease, Lub. Oil**	0.0171 kg / HP hrly	Kg	1.3680	0.92	1.259	
01 – 404	**Operator**		Hour	1.4400*	1.89 hrly	2.722	
01 - 408	**Helper**		Hour	0.3333**	1.23 hrly	0.410	
	∑ Operating Cost					10.684	
03 - 005/1	**∑ Fixed Cost**	0.0002 * A				5.238	
				Total Cost		**15.922**	TL/hr
				Profit (25% of cost)		3.981	
				∑ Hourly Rate		**19.903**	TL/hr
				Hourly Rate in $'s		9.047	$/hr
Note							
Daily Cost = Hourly Rate* 8 hrs/day					Daily Cost	159.224	TL/day
Monthly Cost = Daily Cost * 25 days/month					Monthly Cost	3,980.60	TL/month
*Operator works "n" hours as Machine → Adjustment factor for operator = (240x12)/2,000=1.44							
**Helper works independently however serves for three Machines → Adjustment factor for helper = 1/3 = 0.3333							

Example 8.3

Tires are considered separately

Same loader as in **example 8.2**, but tires are taken separately to see how much it effects the hourly cost.

A = 26,190 TL

A_t= cost of tires = ~2,600 TL

N_t = life of tires = 2 years

n_t = 2,000 hours per year

Maintenance and repair of tires = 0.15 (A_t / N_t),

where (A_t / N_t) is depreciation of tires

Transportation of tires = 0.05 (A_t / N_t)

A_l = initial cost of loader without tires

A_l =26,190 – 2,600 = 23,590 TL

Hourly Fixed Cost without Tires

(1.7 + 0.06N) A_l / nN = 0.0002 A_l = 4.72 TL

Hourly Cost of Tires

Investment cost = [0.08 (N_t + 1) A_t] / (2 n_t N_t) =

[0.08 (2+1) 2,600]/ [(2) x (2,000) x (2)] = 0.08 TL/hr;

Depreciation cost = A_t / $n_t N_t$ = 2,600 / (2,000 x 2) = 0.65 TL/hr

Maintenance and repair =0.15(A_t/N_t)= 0.15 x 0.65= 0.10 TL/hr

Transportation of tires = 0.05(A_t/N_t)= 0.05 x 0.65= 0.03 TL/hr

Total cost of tires = 0.86 TL/hr

Total hourly fixed cost = 4.72 + 0.86 = 5.58 TL/hr

Compare 5.58 TL/hr with 5.238 TL/hr when tires are included in the machine cost.

When tires are considered separately, the fixed cost is 6.5 % more than the fixed cost when tires are included in the initial purchase price.

For realistic value of hourly fixed cost, tires should be considered separately and then added to the fixed cost of the machine. If not, the hourly rate of the machine can be over or underestimated. In this example, it is underestimated.

8.3 EXCAVATING EQUIPMENT

8.3.1 INTRODUCTION

Excavation is an important work item in construction works. For example, there is excavation in road, airport, dam, building constructions, etc. Some of the excavated material is sometimes left near-by the excavation area for back-fill such as in foundation or trench excavation. But most of the time, all of the excavated material is to be transported (hauled) to another place such as fill area or dump area.

Excavating, Loading and Hauling Machines

- Power shovels also called Front shovels
- Backhoes also called Excavators
- Draglines
- Clamshells
- Loaders – tractor shovels
- Scrapers (are used for large area excavations such as highways and airports)
- Dozers
- Graders
- Hauling equipment
    - wheel borrows and hoist drawn carriages
    - trucks and other heavy hauling equipment
    - scrapers
    - conveyer belts
    - cabled transport
    - rail wagons
    - compressed air

Depending upon the type of excavation and other factors, one of the above machines or combination of them can be used for excavation and hauling.

In general, following factors affect the excavation and hauling:

1. Types of machines used,
2. Skill of the operators of the machines,

3. Method of excavating,
4. Job conditions,
   - Excavating and loading conditions
     - Large, open quarry situation, well-drained floor, trucks can be spotted on either side of the machine,
     - Muddy floor will delay the movement of trucks
   - The terrain of the natural ground, uniformly leveled; the height of cut always close to optimum,
     - The cut is narrow; no room for truck to come on the side of the machine, the angle of swing is too large
   - Haul road conditions, not affected by climatic conditions
5. Management conditions
   - Maintenance of equipment
   - Availability of spare parts
   - Haul-road condition
   - Loading area layout
   - Haul-unit sizing and number
   - Competency of field management
   - Project housekeeping (keeping good records of equipment operations)

8.3.2 HYDRAULIC EXCAVATORS: Front Shovels and Backhoes

Hydraulic excavators make use of the hydraulic pressure to develop bucket penetration into the material for digging. The bucket, which is hydraulically controlled, is attached to a two-piece (boom and stick) attachment that may be mounted on a

- Crawler tractor base or
- Wheel tractor base

Hydraulic excavators are classified by the digging motion of the hydraulically controlled boom and stick to which the bucket is attached (see Figure 8.1). A downward arc unit is classified as a “hoe”. It develops excavation breakout force by pulling the bucket toward the machine and curling the bucket inward. An upward motion unit is known as a “front shovel”. A shovel develops breakout force by crowding material away from the machine.

The downward swing of a hoe dictates usage for excavating below the running gear. The boom of a shovel swings upward to load; therefore, the machine requires a material face above the running gear to work against.

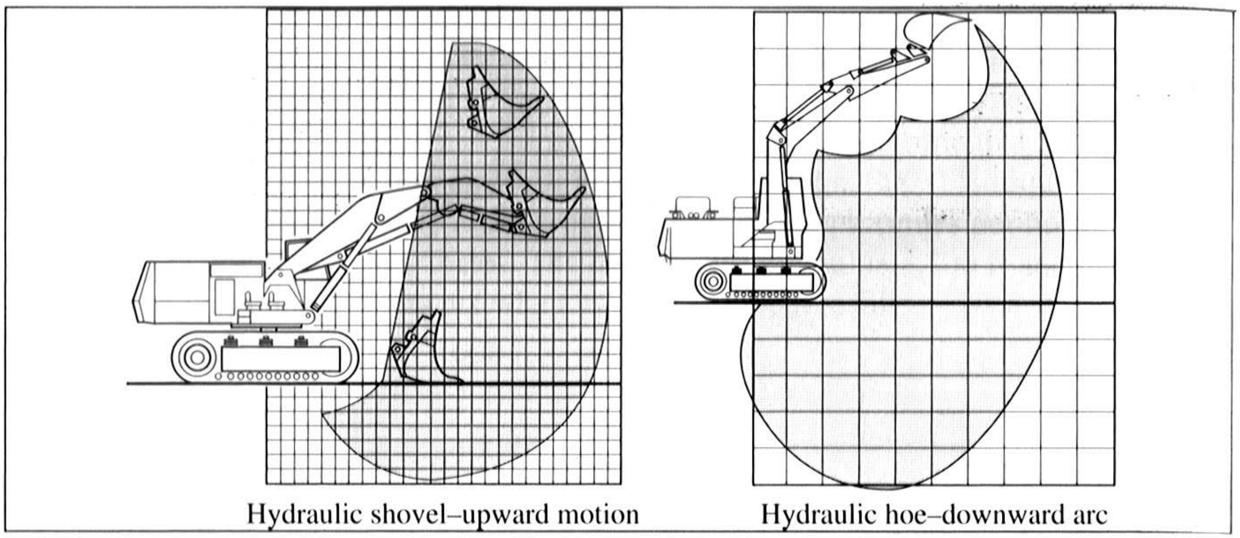


Figure 8.1: Digging Motion of Hydraulic Excavators

If an excavator is considered as an independent unit (a one-link system) its production rate can be estimated using the following steps:

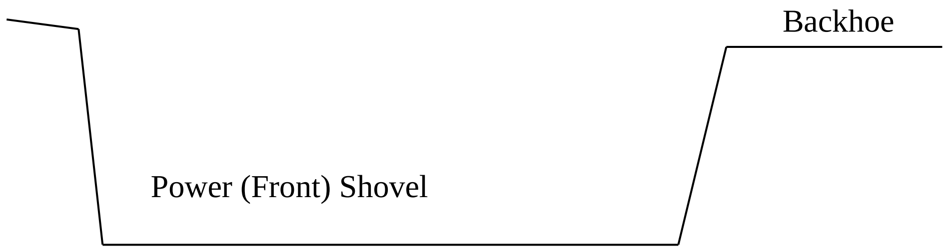
Step 1. Obtain the heaped bucket load volume from the manufacturers' data sheet. This would be a loose volume value.

Step 2. Apply a bucket fill factor based on the type of machine and the class of material being excavated.

Step 3. Estimate a cycle time. This is a function of machine type and job conditions to include angle of swing and depth or height of cut.

Step 4. Apply an efficiency factor.

- Bulk pit excavation: large area, large volume, excavating equipment stands inside the area, excavates the faces (e.g. foundation excavation of a large building) – front shovel, loaders and hauling equipment
- Limited area, vertical excavation (e.g. trench excavation, small channel) – excavators or backhoes



Backhoes – equipment stands on top, not inside of the excavated area.

Selecting an Excavator

Two main factors, which should be taken into account when selecting an excavator, are the cost per cubic meter of excavated material and the job conditions under which the excavator will operate. The main factor, of course, is the cost but sometimes a more powerful excavator is needed for the hard job conditions even if it becomes costly.

The following factors should be considered for cost:

1. The size of the job, a larger job may justify the cost of a large excavator.
2. The cost of transporting the machine.
3. The combined cost of drilling, blasting and excavating. A large excavator will handle larger pieces of rock justifying the higher cost by savings in drilling and blasting (less drills and less explosives).
4. The direct unit cost of excavation.

The following factors should be considered for job conditions:

1. Large excavator if the material to be excavated is hard and tough because the bucket, which exerts higher digging pressures, will handle the material more easily,
2. Large excavator if blasted rock is to be handled because the large size bucket will handle bigger individual pieces better,
3. The size of hauling units should be considered in selecting the excavator. For large hauling units large shovel should be used to save for the spotting time.

Power shovels are more specialized compared to backhoes. Shovels are mostly utilized in large excavation.

In this lecture notes, the output of backhoes will be discussed since these equipment are more known in Turkey.

BACKHOE PRODUCTION

The components of a hydraulic excavator are illustrated in Figure 8.2. In this machine, the boom and dipper arms are raised and lowered by hydraulic cylinders. In addition, the dipper is pivoted at the end of the dipper arm so that a wrist-like action is provided.

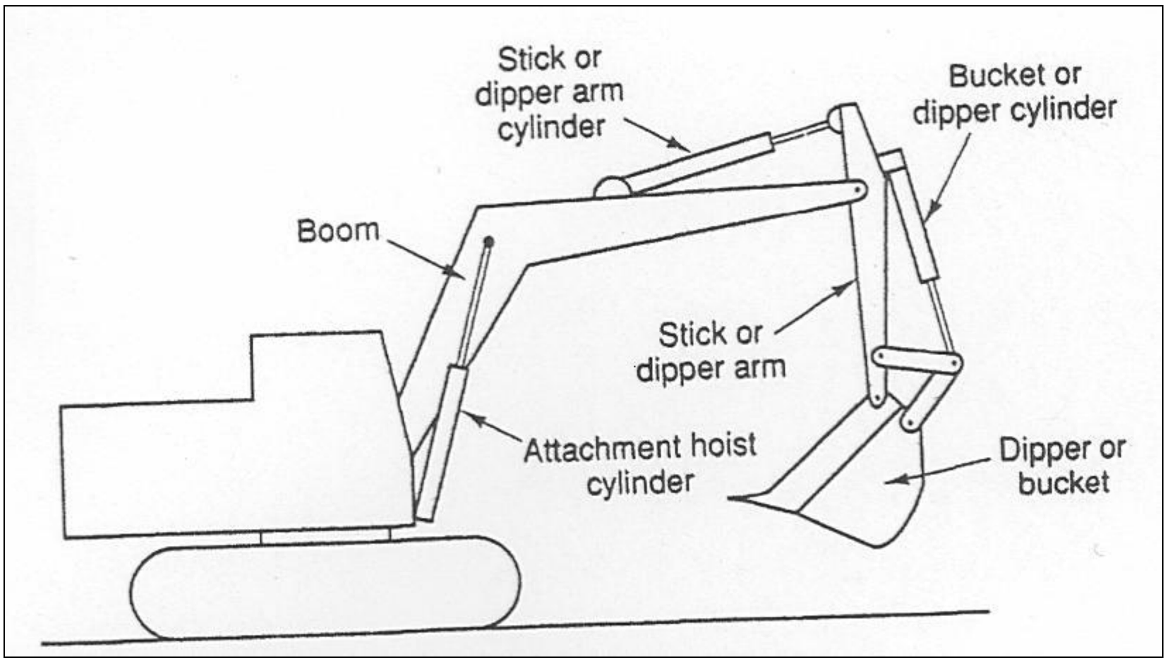


Figure 8.2: Components of a Hydraulic Excavator (Backhoe)

When dipper is filled, the dipper is curled up to reduce spillage, and the bottom is raised and swung to the unloading position. The load is then dumped by swinging the dipper up and away from the machine.

The backhoe is widely utilized for trenching work. In addition to excavating the trench, it can perform many other trenching functions, such as laying pipe bedding, placing pipe, pulling trench shields, and backfilling the trench. In trench excavation the best measure of production is the length of trench excavated per unit of time. Therefore, a dipper width should be chosen which matches the required trench width as closely as possible. For this reason, dippers are available in a wide range sizes and widths. Side cutters are also available to increase the cutting width of dippers. Other suitable backhoe applications include excavating basements, cleaning roadside ditches, and grading embankments.

The size of an excavator is indicated by the size of the bucket, expressed either in cu.yd or in m^3. Depending on the manufacturer, the bucket size is either given for struck capacity or heaped capacity or both, though usually it is the heaped capacity used in output estimation calculations.

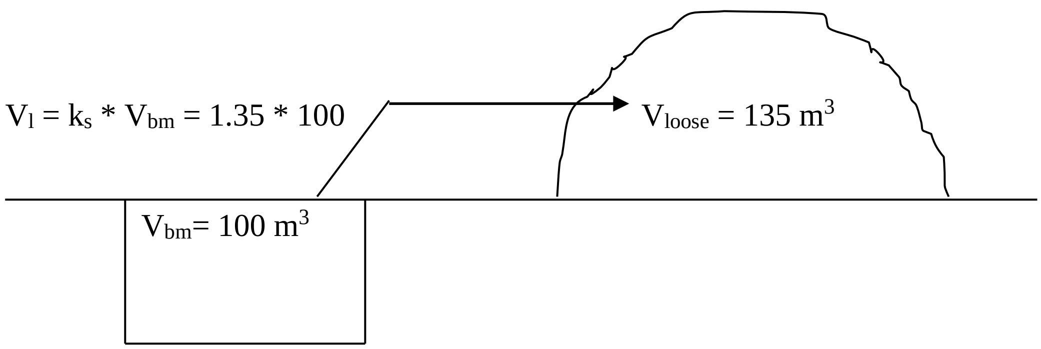
Standard Bucket Size: range from $3/8$ cu.yd (0.285 m^3) to 2 $\frac{1}{2}$ cu.yd (1.9 m^3) but may be as large as up to 5 to 6 m^3.

Struck Capacity: The volume actually enclosed by the bucket with no allowance for the bucket teeth is the struck capacity.

Heaped Capacity (q_h): The maximum volume of the material which can be held in the bucket without spillage (allowance for the bucket teeth is also considered). Depending upon rating standard, the heaped volume is given either for a repose angle of 1:1 or 2:1.

Fill Factors (k_d): Rated heaped capacities represent a net section bucket volume; therefore they must be corrected to an average value by the characteristics of the material being handled. These corrections suggested by the manufacturers are known as "fill factors" or "dipper factors" which will be designated by k_d as the dipper factor of the shovel (See Table 8.7).

It should be mentioned that the material in the bucket after being excavated is in loose form. That is to say the volume of the material before excavation is not same as the volume after it is excavated due to swelling of the material. One must be careful in excavation calculations with the form of the material. The volume of material before excavation is referred as in-place or bank-measure (bm), on the other hand the volume after excavation is referred as loose. For example, a typical clay of 100 m^3 (bm) in-place volume will measure 135 m^3 loose volume after excavation due to swelling (See Table 8.8).



Factors Effecting Output (Production) of a Backhoe

One must be able to calculate (estimate) how much a specific backhoe will excavate in an hour so that right sizes and numbers of backhoes and of trucks can be selected for a certain excavation job.

For example, one must be able to answer the following questions:

- How many and what type of backhoes are needed?
- How many and what capacity trucks are needed to haul the excavated material to dump to a distance of 7 km?

For an excavation job of 8000 m^3 is to be finished in 10 work-days.

In general, followings effect the output of a backhoe:

1. Type of soil
2. The bucket size
3. Angle of swing
4. Depth of cut
5. Job conditions
6. Management conditions
    - Operator skill
    - Physical condition of the shovel
    - Size of hauling units, etc.

It should be restated that job conditions such as conditions of haul roads and loading area, variability in depth of cut, possibility for the trucks to spot on both sides, etc. and management conditions such as good maintenance of equipment, providing sufficient number of trucks, a good supervisor, bonuses or incentives for personnel do considerably affect the production and, forms the basis to apply an efficiency factor.

A) <u>Calculation of Output of a Backhoe/Shovel</u>

OUTPUT = Volume per cycle * Cycles per hour * Efficiency

OUTPUT = Q_l = (q_h k_d)* (n_c) * (k_e) m^3 or cu.yd. / hour

Q_l = production of backhoe/shovel in one hour in loose volume,

q_h = bucket (dipper) size = heaped capacity of bucket (loose),

k_d = dipper/fill factor for backhoe/shovel depending on the material handled,

n_c = number of cycles in one hour,

If c_t is the cycle time of backhoe/shovel in seconds then,

$$n_c = \frac{3600}{c_t} = \frac{3600}{c_s}(k_{\alpha d})$$

c_t is obtained by correcting c_S, standard cycle time, for angle of swing and maximum depth of cut where c_S is picked up from manufacturers' tables or from past data where cycle time of backhoe/shovel is observed for an optimum angle of swing and depth of cut.

The output is corrected by a, so called, swing-depth factor which is given in Table 8.10 for depth of cut % of maximum and angle of swing.

Type of Material & Machine Size → Cs & Maximum Digging Depth **(Table 8.9)**

Calculate → Depth Ratio (%) = Actual Average Depth of Cut / Maximum Depth of Cut * 100

Depth Ratio (%) & Angle of Swing → Swing-Depth Factor ($k_{\alpha d}$) **(Table 8.10)**

Hence, knowing angle of swing and depth ratio, from Table 8.10 correction factor $k_{\alpha d}$ can be picked up.

k_e = correction due to job and management conditions efficiency; it will be found from estimated working time in an hour for the specific job and management conditions.

$$Q_l = q_h \times k_d \times \frac{3600}{c_s} \times k_{\alpha d} \times k_e = q_h \times k_d \times \frac{3600}{c_t} \times k_e \quad \text{where } c_t = \frac{c_s}{k_{\alpha d}}$$

The **volume of an excavation** job is usually calculated by bank-volume.

V_b = volume of material in bank-form

k_s = swelling factor of the material (conversion from loose to bm)

Loose Volume (V_l) = Bank Volume * Swelling Factor

$V_l = V_b * k_s$ volume after swelling and $k_s \geq 1$

If the hourly output of equipment is required to be calculated in bank-form, either the bucket capacity of the shovel or output in loose measure should be converted into bank-measure using swelling factor. For example for the bucket,

q_b = capacity of bucket in bank-measure

$q_h = q_b\ k_s$ and

$q_b = (1 / k_s)\ q_h$

Example 8.4

A ¾ cu. yd backhoe will be used to excavate 3,980 m^3 of earth (average) in bm. Average depth of cut is about 3.5 meter and angle of swing is about 120°. For job and management conditions, 45 minutes working time is estimated per hour. Determine how many hours it will take to finish this job if backhoe works 8 hours per day.

Solution:

Bucket capacity: q_h = ¾ * 0.76 = 0.57 m^3

Dipper factor: k_d = (0.85+1.10)/2 = 0.975 from Table 8.7

Standard cycle time: c_S = 18 seconds from Table 8.9 for earth and ¾ cu. yd.

Maximum depth of cut: d_{max} = (4+6)/2 = 5 m average from Table 8.9 for earth and ¾ cu. yd

Depth ratio: $d_r = (d/d_{max}) * 100 = (3.5/5) * 100 = 70\%$

Swing-depth correction $k_{\alpha d}$ = 0.94 from Table 8.10 for d_r=70% and 120°

Job and management efficiency correction k_e = 45/60 = 0.75

Finally substituting the values in output expression:

$$Q_l = q_h \times k_d \times \frac{3600}{c_s} \times k_{\alpha d} \times k_e$$

$$Q_l = 0.57 * 0.975 \frac{3600}{18} * 0.94 * 0.75 = 78.4\, m^3/hr(loose)$$

Q_b = 78.4 / 1.25 where 1.25 is the swelling factor, k_s, for earth (Table 8.8)

Q_b = 62.72 m^3/hr (bm)

Daily output = 62.72 * 8 = 501.76 m^3 (bm)

Hence,

No of work-days needed to finish the job= 3,980/501.76= 7.93 work-days → 8 work days

B) <u>Calculation of Number of Trucks Needed</u>

V_t = Volume of truck (heaped, loose),

k_t = Truck capacity correction for heaped volume,

$t_{ct} = t_l + t_h + t_d + t_r + t_s$ = Truck Cycle Time (usually expressed in minutes)

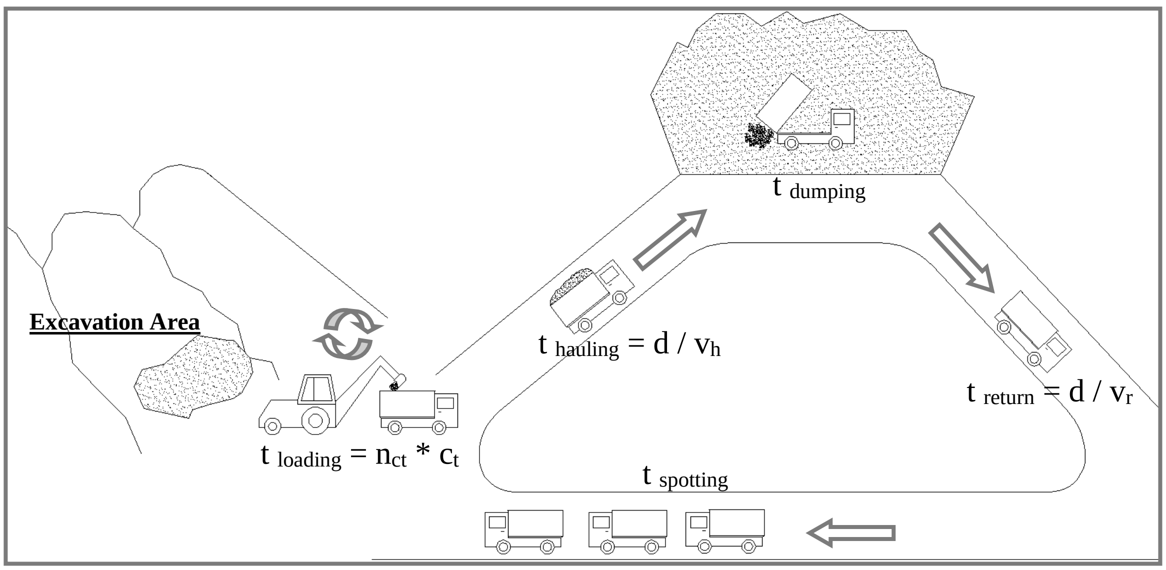


Figure 8.3: Truck Cycle Time (t_{ct})

t_l = truck loading time, t_d = truck dumping time

t_h = truck hauling time = $\frac{d}{v_h}$, t_r= truck return time = $\frac{d}{v_r}$

t_s = truck spotting time (waiting in line to be loaded)

where d=hauling distance, and vh and vr are hauling and return speeds respectively

k_{et} = truck job and management efficiency, Then, **output of a truck** in one hour is:

Output of Truck (Q_t) = Capacity of truck * No of cycles/hour * Efficiency

$$Q_t = V_t \times k_t \times \frac{60}{t_{ct}} \times k_{et} \text{ (loose)}$$

On the other hand, the **output of a backhoe** is:

$$Q_l = q_h \times k_d \times \frac{3600}{c_t} \times k_e \text{ (loose)}$$

Number of Trucks (N_{tr}) = Output of Backhoe / Output of Truck

If same size of trucks are used, then **number of trucks** needed (N_{tr}) is:

$$N_{tr} = \frac{Q_l}{Q_t} = \frac{q_h \times k_d}{V_t \times k_t} \times \frac{3600}{c_t} \times \frac{t_{ct}}{60} \times \frac{k_e}{k_{et}}$$

The **number of cycles needed to load the truck** (nct) is:

Number of Cycles Needed to Load Truck (n_{ct}) = Corrected Capacity of Truck / Corrected Capacity of Bucket

$$n_{ct} = \frac{V_t \times k_t}{q_h \times k_d}$$

hence, N_{tr} equation simplifies to $N_{tr} = \frac{1}{n_{ct}} \times \frac{3600}{c_t} \times \frac{t_{ct}}{60} \times \frac{k_e}{k_{et}}$

Truck Loading Time (t_l) = Number of cycles needed to load the Truck * Cycle Time of Backhoe

$$t_l = n_{ct} \times c_t \text{ (in seconds) or } t_l = \frac{n_{ct} \times c_t}{60} \text{ (in minutes)}$$

In estimating the truck loading time, it is reasonably assumed that while the shovel is loading the truck, which is about 3 to 6 minutes, the shovel works with 100% efficiency. In other words, it is not expected that for example, the operator will stop for a break to have a cup of coffee or the rain will start all of a sudden in the middle of loading or the machine will break suddenly. Therefore, only angle of swing and depth of cut are to be considered in estimating the cycle time.

Then, $n_{ct} = \frac{t_l \times 60}{c_t}$ and $\frac{1}{n_{ct}} = \frac{c_t}{t_l \times 60}$ then Ntr is:

$$N_{tr} = \frac{c_t}{t_l \times 60} \times \frac{3600}{c_t} \times \frac{t_{ct}}{60} \times \frac{k_e}{k_{et}}$$

$$N_{tr} = \frac{t_{ct}}{t_l} \times \frac{k_e}{k_{et}}$$, if truck cycle time is expressed in components then,

$$N_{tr} = \frac{t_l + t_h + t_d + t_r + t_s}{t_l} \times \frac{k_e}{k_{et}}$$

The number of trucks expression simplifies to

$$N_{tr} = 1 + \frac{t_h + t_d + t_r + t_s}{t_l} \quad \text{if } k_e = k_{et}$$

That is to say, if job and management efficiency of the backhoe is same as those of the trucks which usually is.

Example 8.5

An excavation of 16,500 m^3 (bm) is to be made for the foundation excavation of a building in 3 weeks assuming 6 workdays per week and 10 hours working time per day. It is expected that during excavation 1.5 workdays will be lost due to bad weather conditions.

The excavation will be done in dry clay (hard) with an average depth of cut of 3 meter. Angle of swing is about 75°. Estimated working time in an hour is about 51 minutes.

a) Determine the size of the backhoe if only one backhoe will be used?

b) If distance to dump area is 7.5 km, determine the number of trucks for: Truck capacity=12 m^3 (loose), v_h=30 km/hr, v_r=60 km/hr, t_s=2 min., t_d=3.5 min. Truck efficiency and dipper factor are same as those of the shovels.

c) Calculate the equipment cost and unit cost of excavation if hourly costs are 40 TL for the selected shovel and 15 TL for the trucks.

Solution:

a) Determine the size of the excavator:

Required Hourly Output (bm) $= \dfrac{16{,}500}{(3 \times 6 - 1.5) \times 10} = 100\, m^3/hr\ (bm)$

k_s = 1.35 (Table 8.8)

Required Hourly Output (loose) = 1.35*100 = 135 m^3/hr (loose)

<u>i) Try 1 cu. yd. backhoe</u>

q_h = 1*0.76 = 0.76 m^3

$$k_d = \frac{0.75+0.95}{2} = 0.85$$ (Table 8.7)

c_s = 23 seconds (Table 8.9)

d_{max} = (4+6)/2 = 5 m (Table 8.9)

Ratio of depth, dr = 3/5 * 100 ≅ 60%

$k_{\alpha d}$ = (1.16+1.05) / 2= 1.105 for depth ratio=60% and α=75° (Table 8.10, by linear interpolation)

k_e = 51/60 = 0.85 (job and management conditions are expressed with working time in an hour)

then,

$$Q_l = (0.76\times 0.85)\times\frac{3600}{23}\times 1.105\times 0.85 = 95\, m^3/hr\ (loose)$$

Q_1< Required output=135 m^3/hr

ii)Try $1\frac{3}{4}$ cu. yd. shovel

q_h = 1.75*0.76 = 1.33 m^3

$$k_d = \frac{0.75+0.95}{2} = 0.85$$ (Table 8.7)

c_s = 28 seconds (Table 8.9)

d_{max}= (5.5+7.5)/2 = 6.5 m (Table 8.9)

ratio of depth, d_r = 3/6.5 * 100 = 46%

$k_{\alpha d}$ = 1.21 – [(1.21-1.16)/20*(46-30)] = 1.17 for depth ratio=46 and α=75° (Table 8.10, linear interpolation)

k_e = 51/60 = 0.85

then,

$$Q_l = (1.33\times 0.85)\times\frac{3600}{28}\times 1.17\times 0.85 = 145\, m^3/hr\ (loose)$$

Q_l > Required output=135 m^3/hr

Select $1\frac{3}{4}$ cu. yd. shovel

Days needed to finish the job:

Q_b = 145/1.35 = 107.407 m^3/hr (bm)

Daily output = 107.407 * 10 = 1074. 07 m^3

No. of workdays needed = 16500/1074.07 =15.36 → take 16 work-days

b) No of trucks needed for $1\frac{3}{4}$ cu. yd. shovel:

$N_{tr} = 1 + \frac{t_h + t_d + t_r + t_s}{t_l}$ can be used in this case since k_e=k_{et}.

t_h = 7.5 / 30 * 60 = 15 minutes

t_d = 3.5 minutes (given)

t_r = 7.5 / 60 *60 = 7.5 minutes

t_s = 2 minutes (given)

t_l = n_{ct} * ct (truck loading time=no. of cycles needed to load * cycle time of shovel)

$$n_{ct} = \frac{V_t \times k_t}{q_h \times k_d} = \frac{12 \times 0.85}{1.33 \times 0.85} = 9.023\, cycles\ are\ needed$$

and

c_t = c_s / $k_{\alpha d}$ = 28 / 1.17 = 23.93 seconds

t_l = (9.023 * 23.93)/60 = 3.60 minutes

$N_{tr} = 1 + \frac{15 + 3.5 + 7.5 + 2}{3.60} = 8.78$ → Take 9 trucks

Alternative solution for number of trucks:

Q_l = $q_h \times k_d \times \frac{3600}{c_t} \times k_e$ (loose)

$$Q_l = (1.33 \times 0.85) \times \frac{3600}{28} \times 1.17 \times 0.85 = 145\, m^3/hr\ (loose)$$

Q_t = $V_t \times k_t \times \frac{60}{t_{ct}} \times k_{et}$ (loose)

t_{ct} = t_l + t_h + t_d + t_r + t_s = 3.60 + 15 + 3.5 + 7.5 + 2 = 31.6 min

$Q_t = 12 \times 0.85 \times \frac{60}{31.6} \times 0.85 = 16.46$ m^3/hr (loose)

$N_{tr} = Q_l / Q_t$ = 145 / 16.46 = 8.81 → Take 9 trucks

c) Cost calculations:

The equipment must work 16 work-days and must stay idle 1.5 work-days. Therefore, the idle staying cost of equipment is needed. Since manpower is paid during this idle time, fuel and oil costs should not be considered. For this kind of equipment, it can be seen from the equipment data that fuel and oil cost is about 35% to 45% of the total cost. So the cost of equipment when idle can be taken as about 60% of the total cost.

Hence, total cost of equipment:

When worked for 16 work-days = 16*10 (1*40 + 9*15) = 28,000 TL

When idle for 1.5 work-days = 1.5*10*0.60 (1*40 + 9*15) = 1,575 TL

Total cost of equipment = 29,575 TL

Unit cost of excavation is usually calculated for (bm) measure. Then,

Since 16,500 m^3 (bm) of excavation work is done,

Unit cost of excavation = (29,575/16,500) = 1.79 TL/m^3 (bm).

8.4 REFERENCES

1. Bayındırlık ve İskan Bakanlığı (2006). İnşaat Birim Fiyat Analizleri.
2. Nunnally, S.W. (2003). Construction Methods and Management, 6th edition, Pearson Prentice Hall, USA.
3. Peurifoy, R.L., and Schexnayder, C.J. (2002). Construction Planning, Equipment and Method, 6th edition, McGraw-Hill, USA.

Table 8.3: Hourly and Yearly Depreciation Periods of Various Construction Machines

Name of Equipment	Working Hours per Year (n)	Years (N)	Hours (N_1)
Excavator or Power Shovel (Ekskavatör)	2,000	8	16,000
Excavator or Back-hoe	2,000	8	16,000
Forklift (Kaldırıcı güç sistemi) (2.0,3.5 ton)	2,000	8	16,000
5 Ton Crane	2,000	6	12,000
Tractor Scraper (Traktör + Skreyper)	2,000	6	12,000
Tractor Bulldozer (Traktör + Buldozer)	2,000	6	12,000
Tractor Ripper (Traktör + Ripper)	2,000	6	12,000
Motor Grader (Motor Greyder)	2,000	6	12,000
Wheel Tractor Scraper (Lastik tekerlekli traktör + Skreyper)	2,000	6	12,000
Vibrating Roller (Titreşimli Silindir)	2,000	6	12,000
Smooth Wheel Roller and Pneumatic-tired Roller (Demir ve lastik tekerlekli silindir)	2,000	6	12,000
Sheep's-foot Roller (Keçi ayağı)	2,000	6	12,000
Wheel or Crawler Loader or Tractor-shovel (Lastik tekerlekli ve paletli yükleyici)	2,000	5	10,000
Pump, Concrete Mixer, Motor Compactor (Motopomp, betonyer, motorlu kompaktör)	1,000	6	6,000
Compressor, Vibrator (Kompresör, Vibratör)	1,250	6	7,500
Water Sprinkling Truck (Kamyon Arazöz)	250	6	1,500
Truck with water tank (Su tanklı kamyon)	2,000	6	12,000
Pneumatic Hammer (Kompresörlü şahmerdan)	2,000	6	12,000
Steam Hammer (Buharlı şahmerdan)	2,000	9	18,000
Crusher (konkasör)	2,000	6	12,000
Sieving Machines (Eleme makinaları)	2,000	6	12,000
Drilling Equipment for Bored Piles (Fore kazık için delgi makinası)	2,000	9	18,000
Generator (Jeneratör)	2,000	8	16,000
Barger (Duba)	2,000	9	18,000
Tug-boat (Römorkör)	2,000	9	18,000
Dockyard Crane (Maçula)	2,000	9	18,000
Darbeli tip su sondaj makinesi	4,000	6	24,000
Rotari tip su sondaj makinesi	5,000	6	30,000
Agricultural Tractor (Ziraat Traktörü) – Lawnmover (Çim biçme makinesi)	1,000	5	4,500
Briquette Production Machine (biriket imal makinası)	1,000	6	6,000
Aluminum Production Plant (alüminyum imalat atölyesi)	1,000	6	7,500
PVC door and window systems Production Plant (Plastik doğrama imalat atölyesi)	1,000	6	7,500
Mechanical Concrete Plant (otomatik beton santrali)	2,000	6	12,000

Table 8.7: Bucket (Dipper) Fill Factors for Backhoes

Material	***Bucket Fill Factor (k_d)***
Common Earth, Loam, Soft Clay	0.85 – 1.10
Sand and Gravel	0.90 –1.05
Hard Clay (dry)	0.75 – 0.95
Wet Clay	0.65 – 0.90
Rock, well blasted	0.65 –0.85
Rock , poorly blasted	0.40 – 0.65

Table 8.8: Properties of Earth and Rock

Material	***Bank weight*** kg/m^3	***Loose weight*** kg/m^3	***Swelling factor*** (k_s)
Clay, dry	1,600	1,185	1.35
Clay, wet	1,780	1,305	1.35
Earth, dry	1,660	1,325	1.25
Earth, wet	1,895	1,528	1.25
Earth and gravel	1,895	1,575	1.20
Gravel, dry	1,660	1,475	1.12
Gravel, wet	2,020	1,765	1.14
Limestone	2,610	1,630	1.60
Rock, well blasted	2,490	1,565	1.60
Sand, dry	1,542	1,340	1.15
Sand, wet	1,600	1,400	1.15
Shale	2,075	1,470	1.40

Table 8.9: Standard Cycle Time (C_S) of Backhoes (In Seconds)

Type of Material	Machine Size in cu. yd. Small Excavator: 1 yd (0.76 m^3) or less	 Medium Excavator: 1 ¼ - 2 ¼ yd (0.95-1.72 m^3)	 Large Excavator: Over 2 ½ yd (1.72 m^3)
Soft	15	18	24
Average	18	23	30
Hard	23	28	36
Maximum Digging Depth **(In Meter)**	4-6	5.5-7.5	7.5-9

Soft : Sand, gravel, loam
Average: Common earth, soft clay
Hard : Tough clay, rock

Note: Cycle time picked up from Table 8.9 is modified by dividing it with the swing-depth factor obtained in Table 8.10

Table 8.10: Swing-Depth Factor for Backhoes

Depth of Cut (% of Maximum)	**Angle of Swing (degree)** **45°**	 **60°**	 **75°**	 **90°**	 **120°**	 **180°**
30	1.33	1.26	1.21	1.15	1.08	0.95
50	1.28	1.21	1.16	1.10	1.03	0.91
70	1.16	1.10	1.05	1.00	0.94	0.83
90	1.04	1.00	0.95	0.90	0.85	0.75