SYSTEMS INNOVATION BOOK SERIES

CONSTRUCTION MANAGEMENT

Project Management Process Principles and Concepts

SECOND EDITION

Edited by

Abdul Razzak Rumane

CRC Press
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Construction Management

Management process groups along with the processes in the knowledge areas having to do with the principles and concepts used in the development of major construction activities are very important in the overall construction management process. This volume covers the application of these activities that manage the construction project from inception through to the completion of the construction project.

Construction Management: Project Management Process Principles and Concepts discusses the five elements of management functions which include planning, organizing, staffing, directing, and controlling, and explains how these activities/elements of management functions can be used in construction projects. Information about strategic planning, operational planning, intermediate planning, and contingency planning, and the steps involved with relevance to construction projections is offered in this volume. The different types of organizational structures, such as simple, functions, divisional, matrix, team-based, network, and modular, with an example organizational chart, are presented. Also covered are staffing processes such as acquisition, roles and responsibilities, assessment, team building, training, and development, along with directing and controlling elements of the management functions. This volume is rounded out with the inclusion of the five types of management processes, such as initiating, planning, executing, monitoring, controlling, and closing, along with applicable knowledge areas based on the PMBOK® methodology.

This volume provides significant information and guidelines to construction and project management professionals (owners, designers, consultants, construction managers, project managers, supervisors, contractors, builders, developers, and many others from the construction related industry) involved in construction projects (mainly civil construction projects, commercial A/E projects) and construction related industries.

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Construction Management

Project Management Process Principles and Concepts

Second Edition

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To
My Parents
For their prayers and love.
My prayers are always for my father and my mother who encouraged and inspired me all the time.
I wish they could have been here to see this book and give me blessings.

To
My Wife
I miss my wife, who stood with me all the time during the writing of my earlier books.

Contents

Preface

It's almost seven years since my book titled *Handbook of Construction Projects: Scope, Schedule, and Control* was published. The response was encouraging, and many people appreciated the book as it was totally devoted to providing significant information and guidelines to construction and project management professionals, (owners, designers, consultants, construction managers, project managers, supervisors, and many others from construction-related industry), involved in construction projects (mainly civil construction projects, commercial A/E projects), and construction related industries. It covers the importance of construction management principles, procedures, concepts, methods, and tools and their applications to various activities/components/subsystems of different phases of the life cycle of a construction project to improve the construction process in order to conveniently manage the project and make the project most qualitative, competitive and economical. I am happy and feel honored that I could share my knowledge that helped many of the readers in their day-to-day professional activities related to quality in construction projects.

Since then, ISO 31000 has been revised and ISO 45000 has already been published. There were certain quality management-related topics and some other construction management principles were missing in the first edition, which I feel are important to have comprehensive information about construction management. Furthermore, some of the figures and tables need to be updated to make a comprehensive understanding of the subject.

Due to the voluminous nature of the construction management process, and with the addition of certain missing topics, for proper understanding of the required information, the book is divided into two volumes mainly consisting of topics related to quality tools and techniques, and processes and systems for execution of construction projects.

Volume 1 is titled *Construction Management: Quality Tools and Techniques* and is divided into nine chapters and numbered sections.

Volume 2 is titled *Construction Management: Project Management Process Principles and Concepts* and is divided into five chapters and numbered sections.

Construction projects have the involvement of many participants comprising the owner, designer, contractor, and many other professionals from construction-related industries. These participants are both influenced by and depend on each other in addition to "other players" involved in the construction process. Therefore, construction projects have become more complex and technical, and extensive efforts are required to reduce rework and costs associated with time, materials, and engineering, etc.

There are mainly three key attributes in construction projects, which the construction/project manager has to manage effectively and efficiently to achieve a successful project. These are:

1. Scope
2. Time (Schedule)
3. Cost (Budget)

From the quality perspective, these three elements are known as the "Quality Trilogy" whereas when considered with a project/construction management perspective, these are known as "Triple Constraints."

In order for successful management of the project, the construction/project manager should have all the related information about construction management principles, tools, processes, techniques, and methods. The construction/project manager should also have professional knowledge about management functions, management processes, and project phases (technical processes), the skills and expertise to manage the project in a systematic manner at every stage of the project. Construction management is a framework for the construction/project manager to evaluate and balance these competing demands. To balance these attributes at each stage of project execution, the project phases and its subdivisions into various elements/activities/subsystems having functional relationships should be developed taking into consideration various management functions, management processes, and interaction and/or combination among some or all of their activities/elements.

The construction management process is a systematic approach to managing construction projects from project inception to the completion of construction and handover to the client/end user. Construction management is the application of professional processes, skills, and effective tools and techniques to manage project planning, design, and construction from project inception through to issuance of completion certificate. Some of these techniques are tailored to the specific requirements that are unique to the construction projects.

The main objective of construction management is to ensure that the client/end user is satisfied with the quality of project delivery. In order to achieve project performance goals and objectives, it is required to set performance measures that define what the contractor is to achieve under the contract. Therefore, to achieve the adequacy of a client brief, which addresses the numerous complex needs of the client/end user, it is necessary to evaluate the requirements in terms of activities and their functional relationships and establish construction management procedures and practices to be implemented and followed toward all the work areas of the project to make the project successful to the satisfaction of the owner/end user and to meet the owner's needs.

The book is developed to provide significant information and guidelines to construction and project management professionals, (owners, designers, consultants, construction managers, project managers, supervisors, and many others from construction related industry), involved in construction projects (mainly civil construction projects, commercial A/E projects) and construction related industries.

It covers the importance of construction management principles, procedures, concepts, methods, and their applications to various activities/components/subsystems of different phases of the life cycle of a construction project to improve the construction process and to conveniently manage the project to make the project most qualitative, competitive and economical. It also discusses the interaction and/or combination among some of the activities/elements of management functions, management processes, and their effective implementation and applications that are essential throughout the life cycle of a project to conveniently manage the project.

The construction project life cycle phases and its activities/elements/subsystems are comprehensively developed taking into consideration management functions and management process groups, and management processes knowledge areas described in PMBOK® published by Project Management Institute (PMI).

The book provides significant information about construction management practices and discusses in detail the management functions, management processes, and project life cycle phases (technical processes) pertinent to the construction industry. It covers all the topics/areas and activities related to construction management which can be used by construction professionals to implement the procedures and practices in their day-to-day work to evolve a comprehensive system to conveniently manage the construction.

For the sake of proper understanding, the book is divided into five chapters and each chapter is divided into a number of sections covering management process groups and processes in the knowledge areas and development of major construction activities that facilitate the application of these activities managing the construction project from inception through to the completion of construction project.

Chapter 1 is about project management processes. It details construction management practices and discusses in detail the management functions, management processes, and project life cycle phases (technical processes) pertinent to the construction industry. It covers all the topics/areas and activities related to construction management which can be used by construction professionals to implement the procedures and practices in their day-to-day work to evolve a comprehensive system to conveniently manage the construction. This chapter elaborates application of the principles/concepts and relevant construction-related activities of management functions, management processes, and interacting these activities to evolve comprehensive construction project life cycle phases and its activities/subsystems/elements to achieve a successful project. It also discusses the interaction and/or combination among some of the activities/elements of management functions, management processes, and their effective implementation and applications that are essential throughout the life cycle of a project to conveniently manage the project. The chapter discusses the five elements of management functions, which include planning, organizing, staffing, directing, and controlling, and explains how these activities/elements of management functions can be used in construction projects. Brief information about strategic planning, operational planning, intermediate planning, and contingency planning and steps in planning with relevance to construction projection is covered under this section. Different types of organizational structures such as simple, functions, divisional, matrix, team-based, network, and modular with example organization charts normally applicable in construction projects are also discussed. Staffing processes such as acquisition, roles and responsibilities, assessment, team building, training, and development are discussed. Brief information about directing and controlling elements of management functions is also discussed in this chapter. Five types of management processes such as initiating, planning, executing, monitoring and controlling, and closing along with applicable construction project-related knowledge areas based on PMBOK® methodology are discussed in this chapter. Different types of processes, tools, and techniques that are applied during the management of construction projects are discussed and related construction activities are evolved to understand the construction management process to enhance the success of the project. The management processes discussed in this chapter include

Integration Management, Stakeholder Management, Scope Management, Schedule Management, Cost Management, Quality Management, Resource Management, Communication Management, Risk Management, Contract Management, Health, Safety, and Environment Management (HSE), Financial Management, and Claim Management. These processes are further divided into construction-related activities that are essential to manage and control construction projects in an efficient and effective manner.

Chapter 2 is about construction management principles The chapter includes the development of lifecycle phases of construction projects developed on a systems engineering approach and how it is divided into manageable activities/elements/components segments to manage and control the construction project. It covers comprehensive information about seven phases of the construction project life cycle such as conceptual design, schematic design, detailed design, construction documents, bidding and tendering, construction, testing, commissioning, and handover and further dividing these phases into various elements/activities/subsystems having a functional relationship to conveniently manage major construction projects.

The development of scope, stakeholders' roles and responsibilities, project schedule, project cost, establishing project quality requirements, managing design quality, and monitoring design progress in each of the design phases are also discussed to ensure a "Zero Defect" policy during construction. The chapter also lists the risks which have to be considered and managed while developing the project design. Procedures to review and verify design to meet the owner's objectives are also discussed. The preparation of construction documents and the bidding and tendering process are discussed in this chapter. This chapter elaborates on various procedures and principles to be followed during the construction phase. These include mobilization, identification of project teams, identification of subcontractors, management of construction resources, communication, risks, contracts, management of execution of works, safety during construction, and inspection of executed works. It includes guidelines to the contractor about preparation and submission of transmittals, contractor's construction schedule, contractor's quality control plan, and safety plan. Change management, construction schedule monitoring, cost control, quality control, and risk control during construction are also discussed in this chapter. Processes to make progress payment and cash flow is also discussed in this chapter. Reasons for claims (variations) and how to avoid the claims and resolve conflicts are also discussed. Different activities to be performed during testing, commissioning, and handover are also included in this chapter.

Chapter 3 is about lean construction. This chapter covers an introduction to lean construction, a brief history of lean construction, and current challenges in the AEC Industry, lean construction response, lean goals and elimination of waste, Lean Project Delivery System, and lean tools and techniques.

Chapter 4 consists of brief information on post-handover activities such as operation and maintenance.

Chapter 5 is about facility management.

The book, I am certain, will meet the requirements of construction professionals, students, and academics and satisfy their needs.

Foreword

A lot has changed since Dr. Rumane's first edition of this book. This second edition has been both necessary after seven years of existence and required to update the essential parts of the process. The author has introduced additional concepts and tools not included in the first edition. This second edition is written by Dr. Abdul Razzak Rumane again as a compendium of tools and a detailed methodology for completing a construction project in an efficient and cost-effective manner. The logic and sequence of the chapters lend themselves to assist the modern construction manager, which includes students, professors, and practitioners to understand the requirements of today's complex and demanding construction environment.

This second edition of *Handbook of Construction Management: Scope, Schedule, and Cost Control*—now split into two volumes (*Quality Tools and Techniques* and *Construction Management: Project Management, Process Principles, and Concepts*)—is also an extension of Dr. Rumane's previous books. In this second edition, the construction community is provided with additional and updated management advice and concrete examples to establish and maintain quality during all aspects of the project life cycle.

All practitioners in the construction business can use this new edition to improve both their own internal as well as external construction management processes and practices. Included in this edition are numerous updated figures and tables that continue to support his understanding of construction management.

Dr. Rumane's own continued personal experiences and well-developed understanding allow him to improve the first edition into a much fuller and complete handbook for the construction manager and staff. He continues to explore the additional quality tools, management techniques, and practices used by leading construction companies in the industry of the construction business. The information presented in this second edition will give the reader a continued competitive edge when it comes to construction management processes, maintaining quality and effectively operating throughout the life cycle of a construction project.

It is always a pleasure to discuss these subjects and I value Dr. Rumane's professional and systemic approach to construction. As a retired quality engineer, I continue to stay involved in the quality business and hope this second edition will allow you to enjoy this next journey to learning and improving your own construction management knowledge. I know this book will provide you with additional tools to make your continuing journey a rewarding one.

Raymond R. Crawford,
Retired
Past Chair, Design and Construction Division, ASQ
Previous certificates included CMQ O/E, CQA, LEED AP
September 2024

About the Editor

Abdul Razzak Rumane, PhD, is a chartered quality professional fellow of The Chartered Quality Institute (UK) and KSE certified consultant engineer in the field of electrical engineering and project management. He obtained a bachelor of engineering (electrical) degree from Marathwada University (now Dr. Babasaheb Ambedkar Marathwada University) India in 1972 and received his Doctor of Philosophy (PhD) from Kennedy Western University, USA (now Warren National University) in 2005. His dissertation topic was "Quality Engineering Applications in Construction Projects."

Dr. Rumane has been honored by The International University of Ministry and Education, Missouri, USA awarded an honorary degree of doctor of philosophy (DPhil) for expertise in quality management in the year 2021 and The Yorker International University, USA, awarded an honorary doctorate of engineering in the year 2007. The Albert Schweitzer International Foundation honored him with gold medal for "Outstanding Contribution in the Field of Quality in Construction Projects" World Quality Congress awarded him "Global Award for Excellence in Quality Management and Leadership."

Dr. Rumane is an accomplished engineer. He is associated with a number of professional organizations. He is a fellow of The Institution of Engineers (India) and has an honorary fellowship of Chartered Management Association (HK), senior member of ASQ, member of PMI, member of KSE, among others.

Dr. Rumane has attended many international conferences and has made technical presentations at various conferences. Dr. Rumane is an author of nine useful books entitled *Quality Management in Construction Projects*, first edition (2010), *Quality Tools for Managing Construction Projects* (2013), *Quality Management in Construction Projects*, second edition (2017), *Quality Management in Oil and Gas Projects* (2021), *Risk Management Applications Used to Sustain Quality in Projects: A Practical Guide* (2022), *Quality Management: How to Achieve Sustainability in Projects* (2023), *Total Quality Management Applications and Concepts for Construction Projects* (2024), and the editor of a book titled *Handbook of Construction Management: Scope, Schedule, and Cost Control* (2016). All of these books are published by CRC Press (Taylor & Francis Group), USA. A book entitled *Quality Auditing in Construction Projects: A Handbook* (2019) is published by Routledge, UK (Taylor & Francis Group). His book *Quality Management in Construction Projects* is translated into the Korean language.

Presently he is International Liaison Committee Chair ASQ (Design and Construction Division). He also served this position in the year 2024. He earlier served as Treasurer of ASQ Kuwait Section for the year 2022. Secretary ASQ GC for the year 2019 and Secretary ASQ LMC, Kuwait for the year 2017 and 2018. He served as honorary chairman of The Institution of Engineers (India), Kuwait chapter for the years 2016–17, 2013–14 and 2005 to 2007.

Dr. Rumane is a trainer conducting training in the field of quality in construction projects, construction management, and project management.

Dr. Rumane's professional career exceeds 50 years including ten years in manufacturing industries and over 40 years in construction projects. Presently he is associated with SIJJEEL Co., Kuwait as Adviser and Director, Construction Management.

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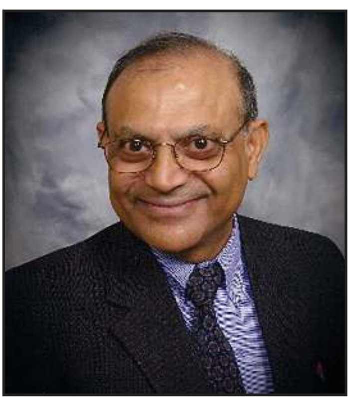
Lincoln H. Forbes, PhD, is a specialist in lean project delivery and lean management systems. He is a registered professional engineer and LEED® Accredited Professional, with over 35 years of experience in various aspects of facilities design, construction support, and quality/performance improvement. He is a member of the Lean Construction Institute (LCI), and the International Group for Lean Construction (IGLC). Dr. Forbes is a fellow of the Institute of Industrial and Systems Engineers, (IISE), and has served as founder and past president of their construction division. He holds the CM-Lean designation of the Associated General Contractors of America (AGC). His other professional memberships include the American Society for Quality (ASQ), His most recent book is titled *Lean Project Delivery and Integrated Practices in Modern Construction* (Forbes and Ahmed, 2020, CRC Press/Routledge). The 2010 edition titled *Modern Construction: Lean Project Delivery and Integrated Practices* was one of the first books on the subject of lean construction.

Lincoln has served in adjunct professor positions in the Department of Construction Management at East Carolina University (ECU) in Greenville, North Carolina as well as in the Construction Management Department of Florida International University (FIU). His courses have included Lean Construction, Construction Productivity Improvement, and Quality Control Systems. He earned a PhD at the University of Miami in Florida as well as an MS in industrial engineering and MBA degrees. He is the Principal Consultant for Harding Associates, Inc., a Miami firm that provides performance improvement solutions for organizations.



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Mr. Jitendra C. Patel, CPEA, FASSP, is an international HSE consultant who has a BS in chemistry and an MPhil in fuel science. For 21 years, Mr. Patel has provided health and safety professional services to Aramco, an oil and gas producing and processing corporation worth nearly $5 trillion. He also has provided technical training and conducted research for 15 years on fires, explosions, health, safety, and environmental issues at a heavy chemical manufacturing company in the UK. Mr. Patel has developed and conducted fire and safety seminars for safety and fire prevention engineers and line management of industry operations. He has presented many technical and safety presentations which are published in international publications. His work has taken him throughout the world serving on such boards and committees internationally in addition to US national and state level organizations. He is a membership chair of the ASSP International Professional Specialty Executive Board and a member of the BEAC Training and Education Board. He is a senior board adviser to the ASSP Arizona Chapter. He is a founder of many international ASSP chapters in the Middle East, SE Asia, and in India. He is a director of the Global Safety Institute, USA. He is the CEO of Global Safety Consultants, LLC, USA. He is the Chairman of the Global Society of HSE Professionals. He is a founder trustee and co-chair of J&A Bharat HSE Foundation, visit: https://jabharathsefoundation.org/ and J&A Global HSE Foundation, visit: https://jaglobalhsefoundation.org/.

- The ASSP AZ honored Mr. Patel with the Howard Hiedeman Award of Safety Professional of the Year 2006–2007.
- Mr. Patel is a member of the ASSP Technical Professional Recognition Committee.
- Mr. Patel was honored in 2011 in Chicago with the highest and most prestigious award of a "Fellow of the ASSP."
- Mr. Patel is also a recipient of the ASSP's Diversity Award of 2012.
- Mr. Patel is a BCSP Advocate.
- Mr. Patel is an executive adviser to the board of directors of many corporations.
- Mr. Patel was selected to be honored with a US Lifetime Achievement Safety Standout Award for recognizing workplaces exceptionally engaged in safety at BRL's Safety Summit in Orlando April 16–18, 2018.
- Mr. Patel is on the highest honor list of ASSP for promoting ASSP membership globally by engaging in developing the EHS profession and the professionals with up-to-date state-of-the-art available international information to help the industry achieve its safety goals.
- Mr. Patel is the author of an inspirational book, *What We Give: A Memoir.*

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Zofia K. Rybkowski, PhD, is an associate professor in the Department of Construction Science of the School of Architecture at Texas A&M University and an endowed Harold Adams Interdisciplinary Professor. Dr. Rybkowski holds degrees from Stanford, Brown, Harvard, the Hong Kong University of Science and Technology, and

UC Berkeley, where she earned a PhD. Her interdisciplinary background, which includes biology (MS, BS), architecture (MArch), and civil engineering (PhD, MS, MPhil) facilitates system-level research intersecting disciplinary boundaries. She specializes in implementing Target Value Design/Lean-Integrated Project Delivery simulation tools as a means to effectively address complex, multidisciplinary challenges, and has delivered a TEDx talk as a means to illuminate lean efficiency principles and align multidisciplinary teams toward common goals. For her research in interdisciplinary systems thinking, Dr. Rybkowski has been awarded the J. Thomas Regan Interdisciplinary Faculty Prize, the Harold L. Adams Interdisciplinary Professorship in Construction Science, and in 2019 was recognized by Texas A&M as recipient of the prestigious Presidential Impact Fellow. She has been invited to serve as a keynote speaker at conferences in Sweden, Korea, India, Hong Kong, and the US. Dr. Rybkowski has been the recipient of a Fulbright Fellowship and is a legacy LEED AP.

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Mr. Taylor was formerly the Director of the Construction Industry Research and Policy Center at the University of Tennessee, Knoxville. In that role, he led safety research under grants from agencies such as OSHA and the National Institute for Occupational Safety and Health (NIOSH). Previously, he spent two decades working as a structural engineer and later as a project manager in the highway industry. He is a retired professional engineer and holds advanced degrees in economics and business analytics.

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Share the knowledge with others is the motto of this book.

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- Edward Taylor

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Most of the data discussed in this book is from the author's practical and professional experience and is accurate to the best of the author's knowledge and ability. However, if any discrepancies are observed in the presentation, I would appreciate communicating them to me.

The contribution of my son Ataullah, my daughter Farzeen, and daughter-in-law Masum is worth mentioning here. They encouraged me and helped me in my preparatory work to achieve the final product. I thank my brothers, sisters, and all the family members for their support, encouragement, and good wishes all the time.

Abdul Razzak Rumane

Abbreviations

AAMA	American Architectural Manufacturers Association
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
AMCA	American Composite Manufacturers Association
ANSI	American National Standards Institute
API	American Petroleum Institute
ARI	American Refrigeration Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASTM	American Society of Testing Materials
ASQ	American Society for Quality
BMS	Building Management System
BREEAM	Building Research Establishment Environmental Assessment
BSI	British Standard Institute
CDM	Construction (Design and Management)
CEN	European Committee for Standardization
CIBSE	Chartered Institution of Building Services Engineers
CIE	International Commission on Illumination
CII	Construction Industry Institute
CMAA	Construction Management Association of America
CSC	Construction Specifications, Canada
CSI	Construction Specification Institute
CTI	Cooling Tower Industry
DIN	Deutsches Institute fur Normung
EIA	Electronic Industry Association
EN	European Norms
FIDIC	Federation International des Ingeneurs-Counceils
HQE	Higher Quality Environmental
ICE	Institute of Civil Engineers (UK)
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP	Ingress Protection
ISO	International Organization for Standardization
LEED	Leadership in Energy and Environmental Design
NEC	National Electric Code
NEC	New Engineering Contract
NEMA	National Electrical Manufacturers Association (USA)
NFPA	National Fire Protection Association
NWWDA	National Wood, Window and Door Association
PMI	Project Management Institute
PMBOK	Project Management Book of Knowledge

QS	Quantity Surveyor
RFID	Radio Frequency Identification
SDI	Steel Door Institue
TIA	Telecommunication Industry Association
UL	Underwriters Laboratories

Synonyms

Owner	client, employer
Consultant	architect/engineer (A/E), designer, design professional, consulting engineer, supervision professional
Engineer	resident project representative
Engineer's representative	resident engineer
Project manager	construction manager (Agency CN)
Contractor	Constructor builder
Quantity surveyor	cost estimator, contract attorney, cost engineer, cost and work superintendent
Main contractor	general contractor

Figures

Tables

1 Project Management Processes

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1.1 INTRODUCTION

The project management process is a systematic approach to managing construction projects from project inception to the completion of construction and handover to the client/end user. Project management/construction management is the application of professional services, skills, and effective tools and techniques to manage project planning, design, and construction from project inception through to issuance of the completion certificate. Some of these techniques are tailored to the specific requirements unique to construction projects.

The main objective of construction management is to ensure that the client/end user is satisfied with the quality of project delivery. In order to achieve project performance goals and objectives, it is required to set performance measures that define what the contractor is to achieve under the contract. Therefore, to achieve the adequacy of a client brief, which addresses the numerous complex needs of the client/end user, it is necessary to evaluate the requirements in terms of activities and their functional relationships and establish construction management procedures and practices to be implemented and following toward all the work areas of the project to make the project successful to the satisfaction of the owner/end user and to meet owner needs.

Construction management involves project execution related management work managed by a professional firm or a person called a construction manager. For successful management of the project, it is essential to have professional knowledge of management functions, management processes, and project phases (technical processes). The construction project quality is the fulfillment of owner's needs per defined scope of work within the specified schedule and budget to satisfy the owner's/user's requirements. There are mainly three key attributes in construction projects that the construction/project manager has to manage effectively and efficiently to achieve a successful project. These are:

1. Scope
2. Time (Schedule)
3. Cost (Budget)

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These are known as "Quality Trilogy" or "Triple Constraints."

From the project quality perspective, the phenomenon of these three components is called the "construction project quality trilogy" and is illustrated in Figure 1.1.

The construction project quality trilogy phenomenon when considered from the project management/construction management perspective is known as triple constraints. Scope (defined scope), time (schedule), and cost (budget) are three sides of a triangle. Figure 1.2 illustrates the principle of triple constraints.

Triple constraints are a framework for the construction manager or project manager to evaluate and balance these competing demands. It became a way to track and monitor projects. In pictorial form, triple constraints are a triangle in which one cannot adjust or alter one side of it without any effect, or alter the other side(s).

- If scope is increased, the cost will increase or the time must be extended, or both.
- If time is reduced, then cost must increase, or scope must decrease, or both.
- If cost is reduced, then the scope must be decreased, or the time must increase, or both.

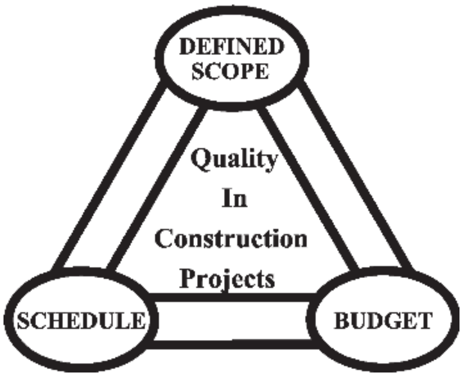


FIGURE 1.1 Construction quality trilogy.

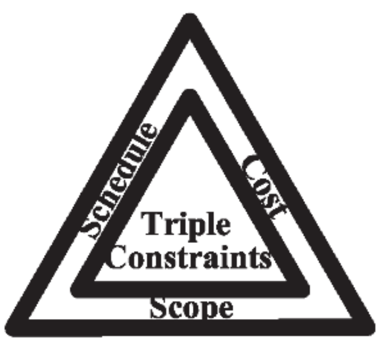


FIGURE 1.2 Triple constraints.

In order to achieve a successful project, the construction/project manager must handle these key attributes effectively and efficiently and track the progress of the work from the inception to completion of construction and handover of the project for successful completion. These three attributes have a functional relationship with many other processes, activities, elements/subsystems of the project. To achieve a successful project to the satisfaction of the owner/end user the construction/project manager has to manage the project in a systematic manner at every stage of the project and balance these attributes in conjunction with all the other activities that may affect the successful completion of the project. This can be done by implementing, amalgamating, and coordinating some or all the activities/elements of management functions, management processes, and project life cycle phases (technical processes). Thus, the construction management process can be described as the implementation and interaction of the following functions and processes:

- Management functions.
- Management processes.
- Project phases (technical processes).

Figure 1.3 illustrates construction management process elements.

In practice, it is difficult to separate one element from others while executing a project. Interaction and/or combination among some or all of the elements/activities of these processes and their effective implementation and applications are essential

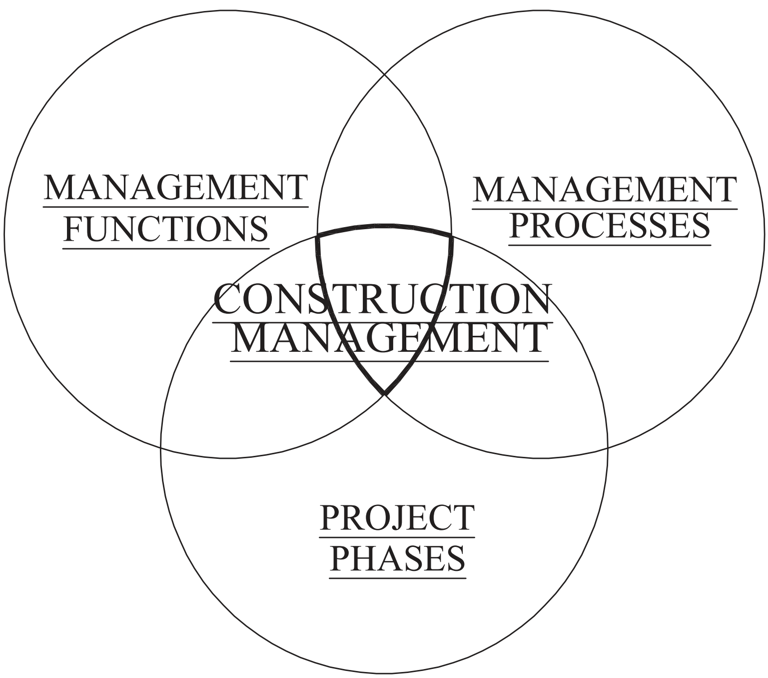


FIGURE 1.3 Construction management elements.

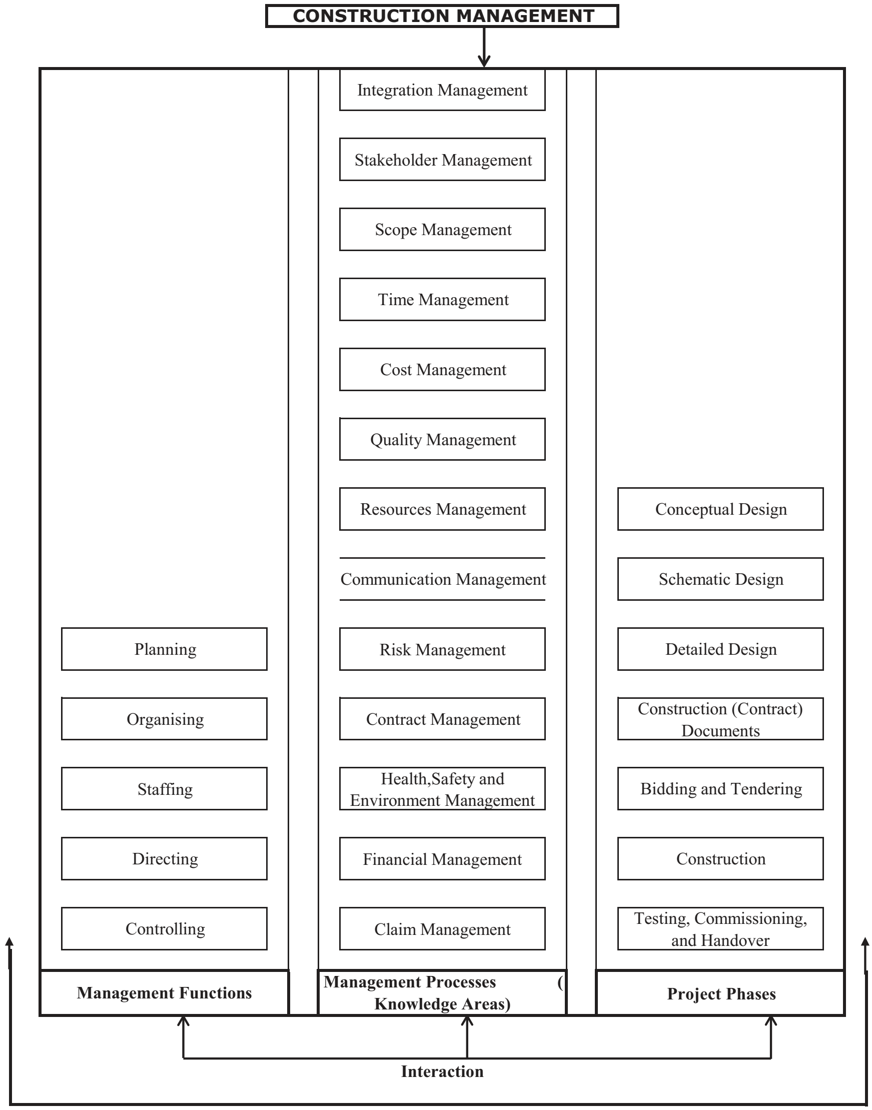


FIGURE 1.4 Construction management integration activities/components.

throughout the life cycle of the project to conveniently manage the project. Figure 1.4 illustrates an integration diagram of the components/activities of the three major elements of the construction management process.

1.2 MANAGEMENT FUNCTIONS

Management is a systematic way of managing processes in an efficient and effective manner toward the accomplishment of organizational goals. Management is a systematic application of knowledge derived from general principles, concepts, theories, and techniques and embodied in the management functions that are variables in terms of business practices as per organizational needs and requirements. Regardless of the type and scope of processes, there must be a plan that is organized, implemented, controlled, and maintained. Henri Fayol (1841–1925), a French engineer, was one of the most influential contributors to the modern concept of management. He was the first person to identify and describe the elements or functions of management. He outlined four managerial functions that are known as the foundation for all management concepts. These are:

1. Planning
2. Organizing
3. Leading
4. Controlling.

These functions are performed by managers at all levels (top management, middle management, and first-line managers) in an organization.

Fayol's original concept of four functions was subsequently modified as follows:

1. Planning
2. Organizing
3. Commanding
4. Coordinating
5. Controlling

Luther Gullick gave a new formula to suggest the elements of management processes. These are:

1. Planning
2. Organizing
3. Directing
4. Staffing
5. Coordinating
6. Reporting
7. Budgeting

These functions were modified according to the management perspective of the organizational business need. The five functions of management functions as explained by Koontz and O'Donnell are:

1. Planning
2. Organizing
3. Staffing
4. Directing
5. Controlling

These functions or elements are briefly discussed in the following section.

1.2.1 Planning

Planning is foreseeing future circumstances and requirements. It is deciding what is to be done in the future. Planning is establishing objectives (what to do) and making long and short-term plans (when to do). There are mainly four types of planning. These are:

1. Strategic Planning:
   Strategic planning is the process of defining and prioritizing long-term plans that include developing and analyzing an organization's mission, overall goals, general strategies, and allocating resources. SWOT (strength, weakness, opportunities, and threats) analysis is performed during strategic planning.
2. Operational Planning:
   It is short-term planning that deals with day-to-day operations.
3. Intermediate Planning:
   It is also known as midterm planning. It is prepared based on the existing performance and revised for the rest of the period of the plan.
4. Contingency Planning:
   It is developed to manage the problems that interfere with getting the work done.

1.2.1.1 Steps in Planning

The following are the steps to be considered during planning:

1. Defining the organization's mission and vision.
2. Performing SWOT analysis.
3. Setting goals and objectives.
4. Decide which task to be done to reach these goals.
5. Decide what course of action to adopt.
6. Define parameters to be measured.
7. Decide allocation of resources.
8. Define target values.
9. Update.

Table 1.1 illustrates an example SWOT analysis to establish a construction material testing laboratory.

1.2.1.2 Construction Project Planning

Project planning is a logical process to ensure that the work of the project is carried out:

- In an organized and structured manner.
- Reducing uncertainties to a minimum.
- Reducing risk to a minimum.
- Establishing quality standards.
- Achieving results within budget and scheduled time.

Project planning is the heart of good project management because it provides the central communication that coordinates the work of all parties. Planning also establishes the benchmark for the project control system to track the quantity, cost, and timing of work required to successfully complete the project.

TABLE 1.1
SWOT Analysis for Construction Material Testing Laboratory

Strength	Opportunities

• Advanced and modern test set up to carry out related tests and analysis.
• Temperature controlled test facility.
• Only laboratory in private sector offering testing and calibration facilities in:
  • Soil testing.
  • Aggregates.
  • Concrete materials.
  • Concrete blocks.
  • Reinforcement material.
  • Asphalt.
  • Hydrocarbon.
  • Calibration of instruments, meters, gauges.
  • Calibration of compression/testing machines.
  • Carbon emission tests.
  • Steel/Metal testing.
  • Weld test.
  • Fabrication.
  • Corrosion test.
	• There is no such laboratory in the local market.
	• Wide range of testing facility.
	• The is no local laboratory/facility to test and analyze material related to oil and gas industry products.
	• Private sector laboratories are not equipped to carry out all types of tests for the construction industry and oil and gas sector.
	• Many new construction projects in the offing.
	• Many new projects in the oil sector.
	• Government sector laboratories are fully loaded with testing of materials for government projects and there is delay getting test results.
	• Lack of sophisticated calibration facility in local market.
	• Internationally accredited and recognized.

Weakness	**Threat**
• Competition with government laboratories. • Government projects are less likely to be referred to private sector. • Products shipped to developed countries.	• Delay in getting approvals. • Delay in registering with local authorities. • Delay in obtaining accreditation and certification. • Similar laboratory set up by existing businesses.

Project planning determines how the project will be accomplished. It is the process of identifying all the activities needed to successfully complete the project. Project planning is the key to a successful project.

Table 1.2 lists the basic reasons for planning the project.

Project planning is a discipline for stating how to complete a project within a certain timeframe usually with defined stages and designated resources. Planning describes what needs to be done, when, by whom, and to what standards. The following are the steps to prepare a project plan:

1. The first step of project planning is to clearly define the problem to be solved by the project.
2. Once the problem is clearly defined, the next step is to define the project objectives or goals. Establishing properly defined objectives and goals is the most fundamental element of project planning. Therefore, the goals/objectives must be:
   Specific.
   Measurable.

TABLE 1.2
Reasons for Planning

1. To execute work in an organized and structured manner.
2. To eliminate or reduce uncertainty.
3. To reduce risk to the minimum.
4. To reduce rework.
5. To improve the efficiency of the process.
6. To establish quality standards.
7. To provide basis for monitoring and control of project work.
8. To know the duration of each activity.
9. To know cost associated with each activity.
10. To establish benchmark for tracking the quantity, cost and timing of work required to complete the project.
11. To know responsibility and authority of people involved in the project.
12. To establish timely reporting system.
13. Integration of project activities for smooth flow of project work.

Agreed upon/achievable.
Realistic.
Time (cost) limited.

3. The next step in project planning is to identify project deliverables.
4. After identifying project deliverables, these are subdivided into smaller activities to enable preparation time and cost estimates.
5. The next step is to estimate activity resources and activity duration and develop a schedule.
6. The next step is to estimate cost and develop a budget that is based on project deliverables and schedule.
7. Simultaneously supporting plans such as quality management, human resources, communication, risk management, and procurement/supply management are developed.
8. The next step is to compare the plan for compliance with the original project objectives.
9. The plan is updated, if required, to meet original objectives/goals keeping in mind three principal aspects of construction projects, that is, scope, time, and cost. To achieve a successful project, it is required to keep these three aspects in balance.
10. The project is launched based on this plan.

Figure 1.5 illustrates construction project planning steps.

A construction management plan is a process to define, establish, and document key management activities to manage project execution providing a baseline for scope, time, and cost to meet the project objectives. Figure 1.6 illustrates major elements in the construction project development process.

Effective project management requires planning, measuring, evaluating, forecasting and controlling all aspects of a project's quality and quality of work, cost, and schedules. The purpose of the project plan is to successfully control the project to ensure completion within the budget and schedule constraints.

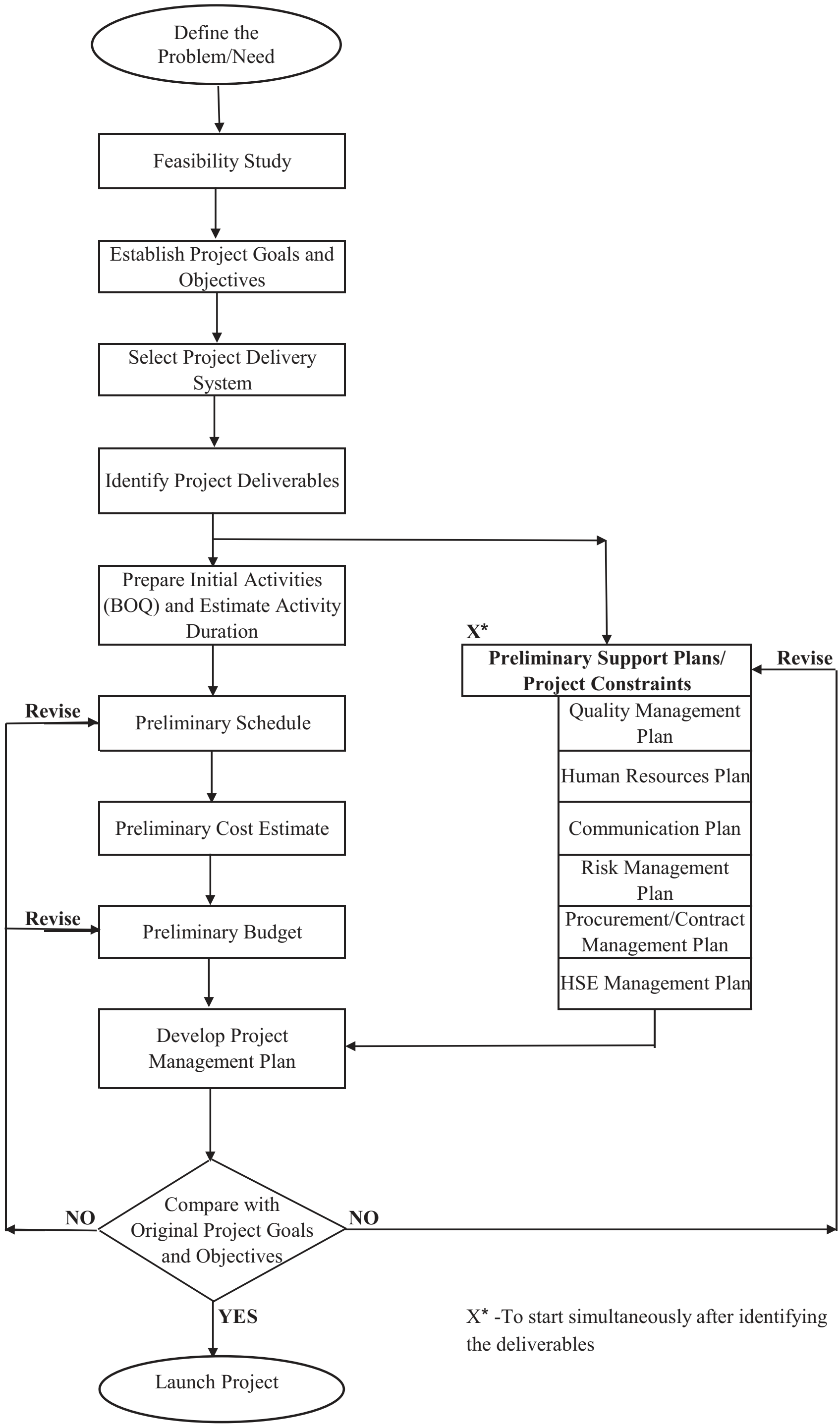


FIGURE 1.5 Construction project planning steps.

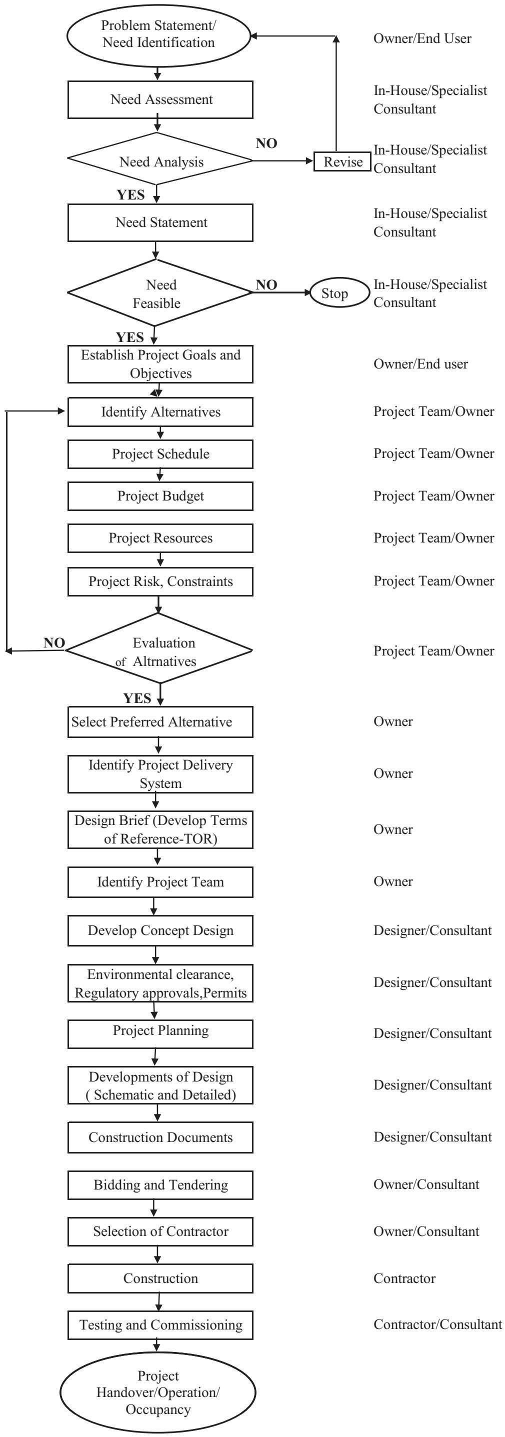


FIGURE 1.6 Major elements in construction project development process.

Planning is a mechanism that conveys or communicates to project participants what activity to be done, how, and in what order to meet the project objectives by scheduling the same. Project planning is required to bring the project to completion on schedule, within budget, and in accordance with the owner's needs as specified in the contract. The planning process considers all the individual tasks, activities, or jobs that make up the project and must be performed. It takes into account all the resources available, such as human resources, finances, materials, plants, equipment, etc. It also considers the work to be executed by the subcontractors.

1.2.2 Organizing

This function relates to the identification and classification of the required activities to be performed to achieve the objectives. The activities mainly include:

- Developing an organizational structure.
- Division of labor.
- Delegation of authority.
- Departmentalization.
- Span of control.
- Coordination.

These activities may be performed by two or more people who work together in a structured way to achieve a specific goal or a set of goals. Organizing means assigning the planned tasks to various individuals or groups within the organization and creating a mechanism to put plans into action. The design of the organizational structure is determined mainly by the following elements:

- Complexity
- Formalization
- Centralization

These three aspects can be combined to create many different organizational designs. An organization consists of a group of people working together in a structured way to reach goals that individuals acting alone could not achieve. One of the most important factors to design organizational structure is the span of control. Span of control refers to how many departments/managers/staff one can effectively supervise. The ideal number for a span of control depends on the nature of the job and the time required to supervise each of them and maintain close control.

1.2.2.1 Types of Organizational Structures

There are seven types of organizational structures. These are:

1. Simple
2. Functional
3. Divisional
4. Matrix
5. Team-Based

6. Network
7. Modular

A brief description of these types of structures is given below.

1. Simple

This is an organization with a simple structure, having centralized authority over a single person. This type of structure is common in small start-up businesses. When the business expands and more employees are added then the structure becomes complex and grows beyond the simple structure.

Figure 1.7 illustrates an example of a simple organization structure.

2. Functional:

In this type of organizational structure, people with similar occupational specialties are put together in a formal group. Figure 1.8 and Figure 1.9 are examples of different types of functional organization structures.

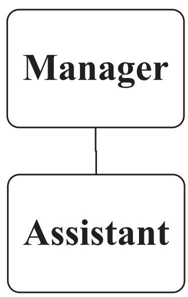


FIGURE 1.7 Simple organization structure.

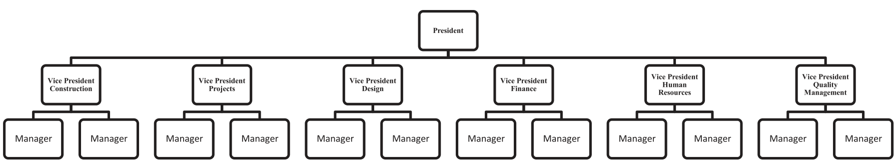


FIGURE 1.8 Functional organization structure (departmental).

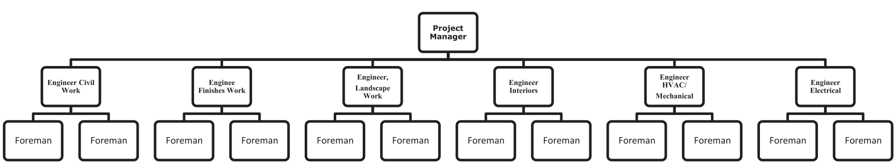


FIGURE 1.9 Functional organization structure (engineering discipline).

3. Divisional:

In this type of organizational structure, people with diverse specialties are put together in formal groups by similar products, services, customers, or geographical regions. Figure 1.10, Figure 1.11, Figure 1.12, and Figure 1.13 are examples of different types of divisional organization structures.

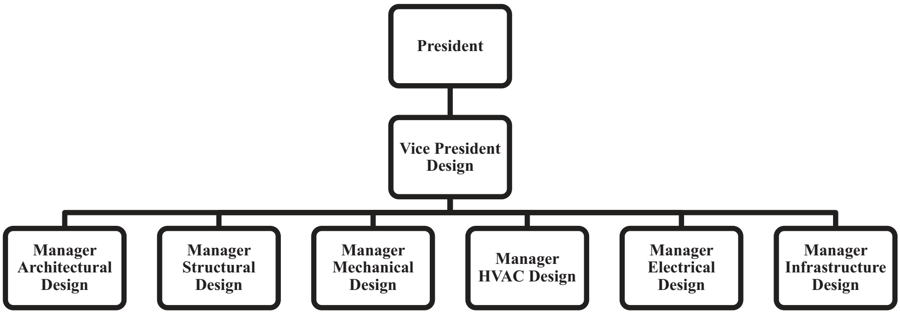


FIGURE 1.10 Divisional organization structure.

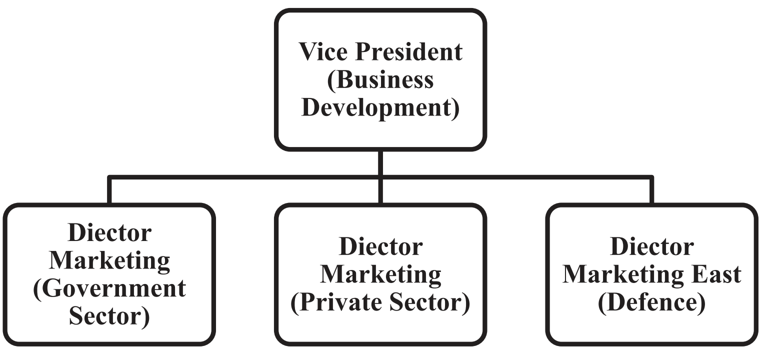


FIGURE 1.11 Divisional organization structure (customer).

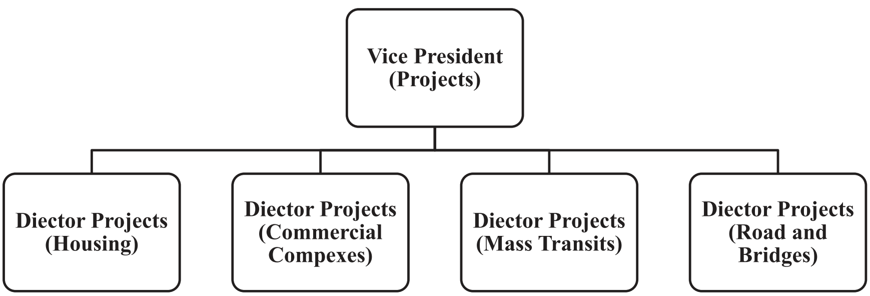


FIGURE 1.12 Divisional organization structure (construction categories).

4. Matrix:

A matrix organization is one in which specialists from functional departments are assigned to work on one or more projects led by a project manager.

It is a type of organizational structure in which there are multiple lines of authority and in certain cases, individuals report to at least two managers.

This type of organizational structure brings together managers and staff from different disciplines to work toward accomplishing a common goal for the organization. It is a combination of functional and divisional organizational structures. In this type of organizational structure, the assigned staff go back to their departments. Figure 1.14 illustrates an example matrix organization structure.

The following are the advantages of a matrix-type organization:

- It has professionals with specializations in the specific discipline.
- It has professionals with a broader range of responsibilities and experience.
- It has access to expert personnel.

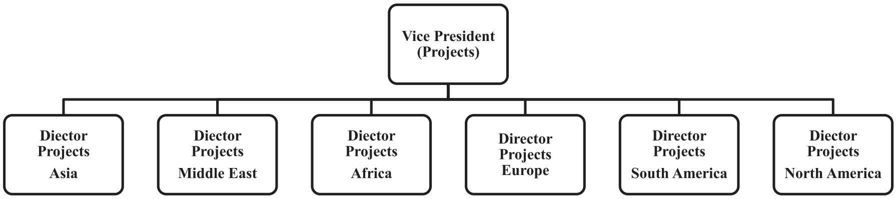


FIGURE 1.13 Divisional organization structure (geographical).

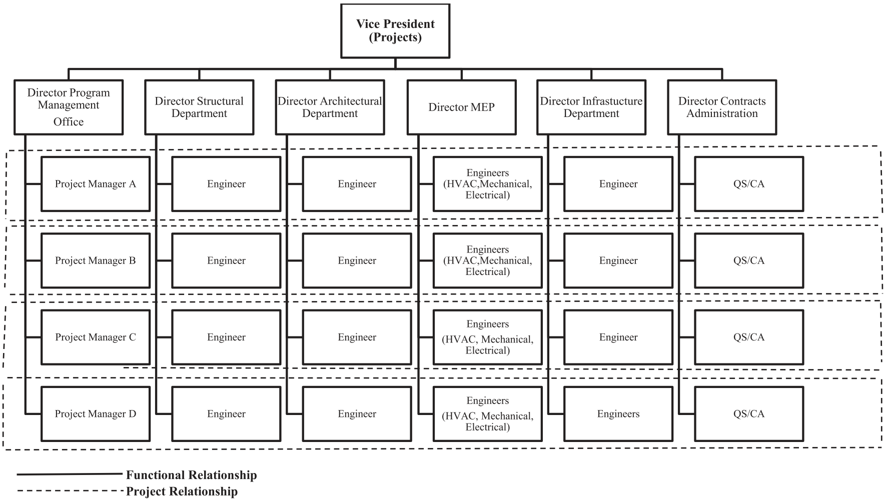


FIGURE 1.14 Matrix-type organization structure.

- It facilitates the use of specialized personnel and facilities, and having experience in the similar nature of projects.

The following are the disadvantages of a matrix-type organization:

- Since the organization has personnel attached to the functional head and project head, there is likely to be confusion in command, and working relationships become more complicated.
- It may cause uncertainty and lead to intense power struggles and conflicts.
- The decision process may take a long time as the personnel may have to refer to their functional head to make a decision.

4.1 Projectized Organization Structure:

It is similar to a matrix type of organization structure; however, when the project ends the staff doesn't go back to their departments and work continuously on projects. Figure 1.15 is an example projectized organization structure.

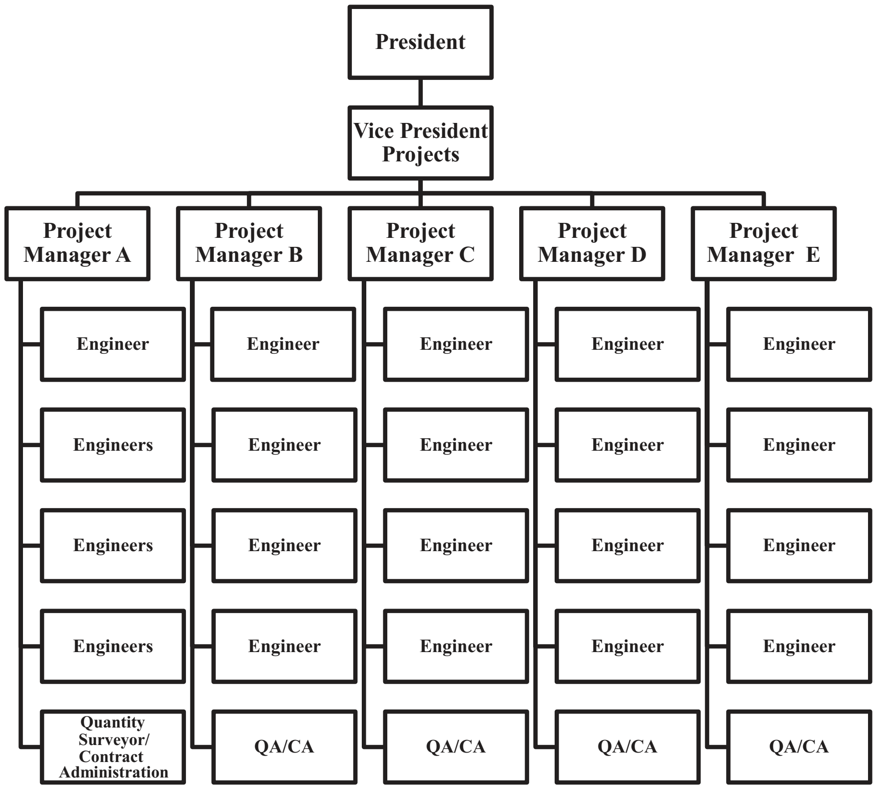


FIGURE 1.15 Functional organization structures (projectized).

5. Team-Based Organization Structure:

It is a type of organization that consists of the activity of teams or workgroups, either temporary or permanent and is used to improve horizontal relations and solve problems throughout the organization. Figure 1.16 is an example team-based organization structure.

6. Network/Boundaryless Organization Structure

It is a type of organization that is not defined or limited by boundaries or categories imposed by traditional organizational structures. Figure 1.17 is an example of a network-type organization structure.

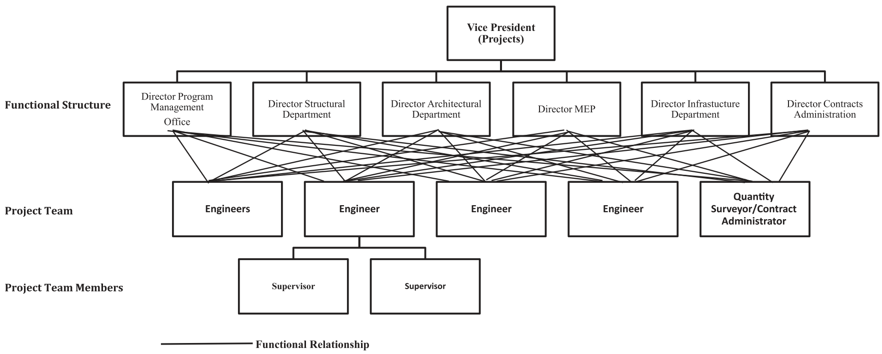


FIGURE 1.16 Team-based organization structure.

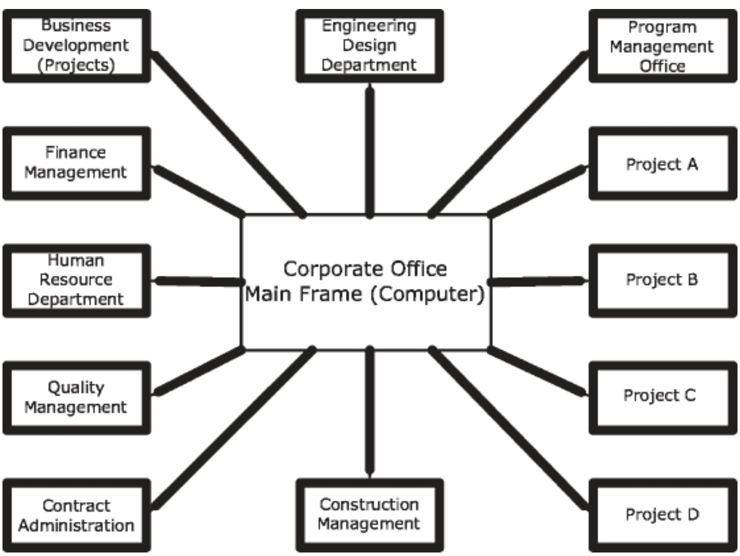


FIGURE 1.17 Network/boundaryless organization structure.

7. Modular Organization Structure

It is a type of organization consisting of separate modules assembled together to form a modular structure. In this type of organization, each module performs a specific function, and the module can be replaced by a similar module suitable to perform the same function. Each module has its own organizational structure.

1.2.3 Staffing

Staffing is managing the organizational structure through proper and effective human resources. Staffing involves the function related to the selection and development of people to fill the roles designed into the organization's structure.

Staffing process involves:

- Manning of organizational structure.
- Development of organizational structure.
- Assessment of human resources requirements.
- Establishing the roles, responsibilities, and competencies needed to complete the assigned tasks.
- Establishing the qualifications, knowledge, and skills required to suit the organizational requirements.
- Acquisition of human resources.
- Team building.
- Training and development.
- Optimum utilization of resources.

Figure 1.18 illustrates the procedure to select a candidate for employment with the organization.

In order to select a candidate to work for a particular position, it is required to develop a job analysis consisting of job definition (job requirements) and criteria for the selection of the candidate.

Figure 1.19 illustrates the project staffing process.

In the case of construction projects, an organizational framework is established and implemented by three major groups or parties. These are:

1. Owner
2. Designer/Consultant
3. Contractor

However, due to the complex nature of major projects, the owner engages the project manager or construction manager to assist/help the owner to perform project management or construction management services in an efficient manner from the beginning of the project to the completion of the project. The roles and responsibilities of PM or CM may vary depending on the owner's desire and requirements. Thus, the

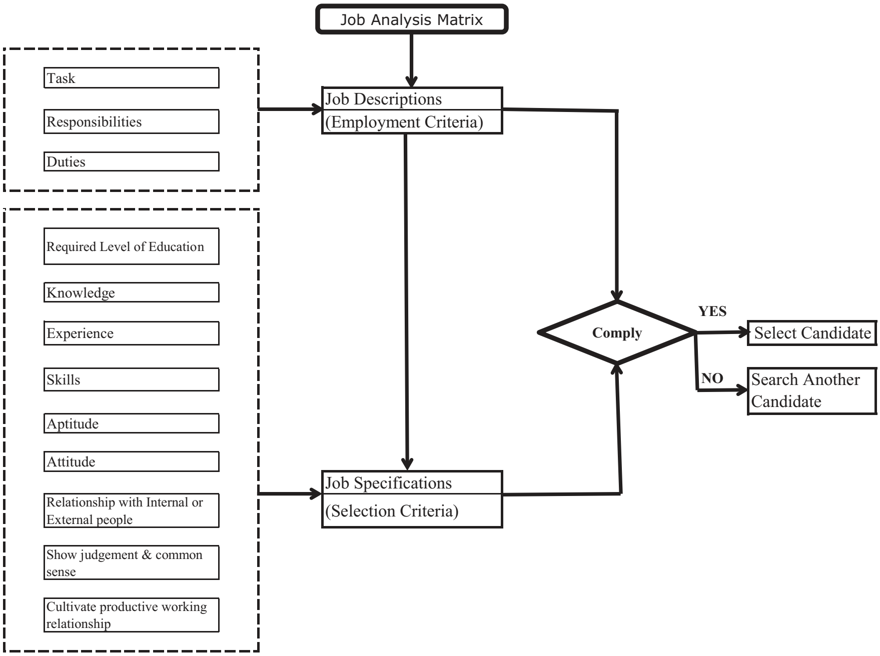


FIGURE 1.18 Candidate selection procedure.

project delivery system has the involvement of four major groups or parties. These are:

1. Owner
2. Project Manager or Construction Manager
3. Designer/Consultant
4. Contractor

The staffing requirements of these groups differ from each other. The roles and responsibilities of similar job titles differ for each of these project participants. For example, the role and responsibilities of the project manager employed by the owner/client differ from that of the project manager working with the designer (consultant), or contractor. Similarly, job requirements of engineering professionals of the same discipline (for example, structural engineering) vary with their affiliation to a particular project participant group.

The staffing (human resource) requirements of construction project-related organizations can be mainly divided into the following categories:

1. Corporate team members.
2. Project team members.

Each team member under these categories should possess job skills and competencies to perform assigned roles and responsibilities to complete the project efficiently.

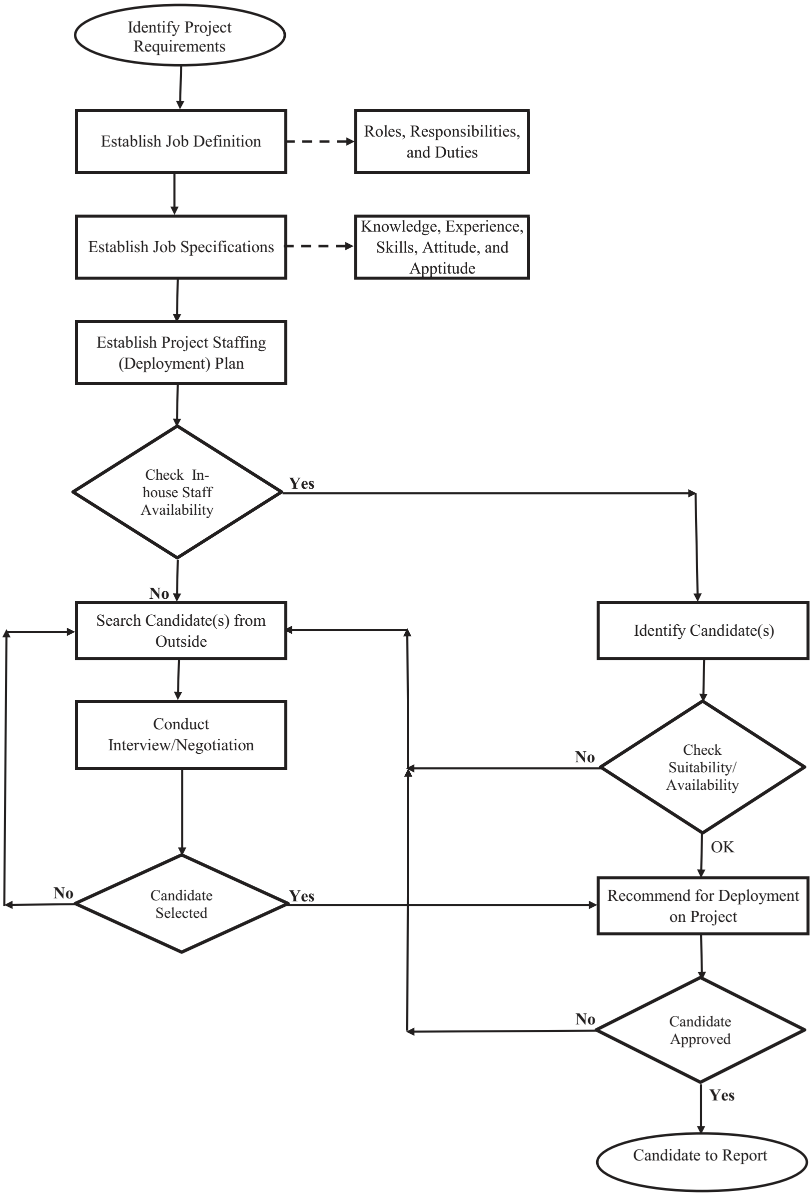


FIGURE 1.19 Staffing process.

Table 1.3 illustrates KESAA requirements for a project manager to be employed by the contractor.

1.2.3.1 Team Development Stages

In construction projects, team members are composed of individuals selected from different backgrounds and disciplines. When a group of people begin to work in

TABLE 1.3
KESAA Requirement for Contractor Project Manager

KESAA	Job Specifications	Description
K	Knowledge	• Thorough knowledge and understanding of construction process. • In-depth knowledge of construction activities. • Knowledge of construction codes and practices. • Knowledge and understanding of all disciplines of construction projects. • Knowledge of risk management. • Knowledge of HSE.
E	Experience	• Experience in execution of major projects. • Experience in execution of similar projects. • Experience in subcontractor management. • Experience in project management. • Experience in construction quality management. • Excellent technical background.
S	Skills	• Strong and responsive leadership skills. • Communication skills (oral and written). • Information technology. • Negotiation skills. • Interpersonal skills. • Conflict management.
A	Aptitude	• Collaborative thinking. • Teamwork. • Societal needs toward project.
A	Attitude	• Problem-Solving. • Able to motivate and encourage subordinates and other team members.

teams, they go through a fairly predictable series of stages in their growth and progress. As the team matures and member relationships grow, members gradually learn to cope with the emotional and group pressure they face, overcome differences, and build on each other's strengths. A team should have a clear understanding of what constitutes the team's work and what is important.

Bruce Tuckman (1965) summarized the results of over fifty studies into four-stage models for team development. These are:

- Forming
- Storming
- Norming
- Performing

Later, he added adjourning as the fifth stage.

These stages are considered an attempt to develop a collaborative team.

Table 1.4 illustrates different stages of team development.

TABLE 1.4
Team Development Stages

Serial Number	Stages	Description
1	Forming	• Team members are new and are learning to work together. • Members start feeling team experience. • Most team members are positive and polite. • This stage is the transition from individual to team member status. • This stage is also known as orientation. Members introduce themselves to each other. • During this stage the team members need to identify their purpose, develop group norms, identify group processes, define roles build relationship and trust. • The team leader plays a dominant role at this stage because the roles and responsibilities of team members are not clear.
2	Storming	• During this stage, individual expressions of ideas occur and there is open conflict between members. • Team members have individualist thinking. • Team members tend to exhibit increased conflict, confrontation, less conformity. • There is infighting, defensiveness, and competition. • Team members become hostile or overzealous as a way to express their individuality and group formation. • Team members resist the task. • Team members resist quality improvement approaches suggested by others. • Polarization of group members. • Disunity, increased tension and jealousy among members. • Establishment of unrealistic and unachievable goals. • Team members need to know how to resolve conflict, clarify their roles, power and structure, and build consensus through re-visiting purpose. • During this stage the team needs to select their desired leadership style and decision methodology. • Team needs leader who is willing to identify issues and resolve conflicts. • The team leader should guide the team processes toward clear goals, defined roles, acceptable team behavior, and a mutual feedback process for team communication.
3	Norming	• During this stage, the team members develop sense of cohesiveness with a common sprit and goals and work habits to work together avoiding any conflict. • The team members exhibit good behavior, more friendliness, cooperation, confidence, mutual trust, motivation, and positive team work. • The team demonstrates an improved ability to complete the task, solve problems, and resolve conflict.

(Continued)

TABLE 1.4 Continued
Team Development Stages

Serial Number	Stages	Description
		• Conflict among members reduces and focus is on team objective. • The team establishes and maintains the habits that support group rules, values, and boundaries. • The team leader continues to encourage participation and professionalism among the team members.
4	Performing	• At this stage the team becomes high performance team. • The team becomes efficient, energetic, mature, and knowledgeable about the processes and the work to be performed. • The team becomes a cohesive unit. • Members have insight into personal and group processes, and better understanding of each other's strengths and weaknesses. • The team becomes self-directing in development of plans and strategy to meet their goals and carryout the work. • The team is capable of accepting new projects and tasks and accomplishing them successfully. • The team is capable of diagnosing and solving problems and making decisions. • At this stage, the team is a completely self-directed team and requires little, if any, management direction. • During this stage every member shares the responsibility as a leader. • The leader becomes facilitator aiding the team in communication processes and helping if they revert to prior stage.
5	Adjourning	• At this stage the team has completed its mission or tasks. • The team wraps up its work and then team dissolves or disassembled. • This is a finalizing stage of team building.

1.2.3.2 Training and Development

Training and development are sets of systematic processes designed to meet learning objectives related to an organization's strategic plan. It is a subsystem of an organization. The main objective of training and development is to make sure the availability of required skilled professionals to an organization.

Training is a means of acquiring proficiency in skills or set of skills, new knowledge, and changing attitudes to perform desired objectives in an efficient and economical manner. It is the process of identifying performance requirements and the gap between what is required and what exists. It is a process that includes a variety of methods for helping the employee attain a specific level of knowledge, skills, and abilities (KSA) through professional development.

Development includes the acquisition of behavioral skills including communication, interpersonal relations, and conflict resolution. Development may also include processes aimed at the acquisition and development by employees of knowledge, understanding, behaviors, or attitudes those specifically required to perform the professional duties.

Training and development help in optimizing the utilization of human resources that further helps the employee to achieve the organizational goals as well as their individual goals. It also helps to provide opportunities and a broad structure for the development of human resources technical and behavioral skills in an organization. The training and development process cycle has mainly five steps or phases. These are:

1. Needs Assessment
2. Development
3. Training Implementation
4. Assessment (Evaluation)
5. Follow-Up

Figure 1.20 illustrates the training process cycle.

Construction projects are constantly increasing in technological complexity. Further, the competitive nature of business, comprehensive management system, accelerated changes in construction processes, and use of the latest equipment, machinery, products, and methods require more and more that the project team members and other stakeholders have technical training in addition to formal education in their respective field. Also, technological changes are occurring at an ever-increasing rate, and the need for continual individual development is crucial.

FIGURE 1.20 Training process cycle.

There is a need for improved quality-based performance of construction projects and, therefore, effective management services. Training in construction project management is considered an essential issue. Training can play an important role in improving the ability and efficiency of construction professionals, and construction workers, whether the training is a part of an ongoing process of professional skill development or simply about learning a specific skill. In both cases, it can improve people's skills and knowledge and help them to perform the task more effectively.

Construction projects are facing challenges of ever-changing construction technology, knowledge ideology, management techniques, project delivery systems, contracting practices, and the dynamic nature of site works. To meet these challenges, construction professionals require training on a regular basis to keep themselves abreast of these changes. Construction projects have the involvement of mainly three parties: Owner, designer (consultant), and contractor. There are many other participants such as subcontractors, suppliers, testing, and auditing agencies who are directly or indirectly involved in construction projects. Professionals working with each of these parties need to have skills and working knowledge to perform the organizational requirements for the competitive advantage of the organization as well as individual growth. The area of training can depend on the type of business and the field of expertise in a particular management field. In general, there is a need for training in the following management areas in the construction sector:

1. Project inception/development/feasibility.
2. Project cost estimation and cost management.
3. Project planning and scheduling.
4. Quality management.
5. Contract conditions.
6. Procurement and tendering procedures.
7. Risk management.
8. Health and safety management.
9. Environmental management.
10. Value management.

1.2.3.2.1 Needs Assessment

Training is directed toward agreed standards and objectives. The person being trained participates with the trainer or facilitator in the training activity. Training is a means of communicating new knowledge and skills to the trainee and changing his/her attitude toward work performance. It can raise awareness and provide the opportunity for people to explore their existing knowledge and skills. But to be effective, training should be based on the needs of the person(s) who is (are) being trained. Training need is the gap between what somebody already knows and what they need to know to do their job or fulfill their role effectively.

The first step in the training and development process is to conduct a needs assessment. The assessment begins with a need that can be identified in several ways but is generally described as a gap between what is currently in place and what is needed, now and in the future. In order to establish a need it is necessary to assess the current level of knowledge and skills, and what level of knowledge and skills are needed to do their job or task. In general, there are four objectives/levels of training and development. These are:

1. Organizational objectives (organization's goals).
2. Occupational objectives (jobs and related tasks that need to be learned).
3. Individual objectives (competencies and skills that are needed to perform the job).
4. Societal objectives.

However, the first three are more commonly used in construction projects to conduct needs assessment by organizations. Societal objectives are mainly taken care of by the governmental agencies.

In order to establish the needs, the following are to be considered:

1. Is the need mandated by a regulatory body (safety, fire, handling of hazardous material from an environmental perspective, health care, food quality)?
2. Is the need mandated by management's strategic requirements to achieve:
   a. Organizational objectives.
   b. Occupational objectives.
   c. Individual objectives.

Once the need is established, it is required to set objectives to:

1. Identify:
   Who needs training (individuals who are to be trained).
   What training is needed?
2. Establish how the data is to be collected.
3. Analysis of data.
4. Summarize the findings.

1.2.3.2.1.1 Organizational Objectives The first level of training assessment is organizational objectives. The organizational analysis looks into the effectiveness of the organization's existing capabilities and determines where training is needed and under what conditions it will be conducted. The following are the major items to be identified and analyzed to establish organizational training objectives:

- Organizational goals.
- Strategic plans, objectives.
- Political impacts.
- Economic impacts.
- Environmental impacts.
- Global/world market.
- Future market trends.
- Technological changes.
- Competitor's approach to training and development.
- Organizational structure.

- Significance and importance of training in the organization.
- Codes, standards, and regulations.
- Willingness by the employees to participate in training.

A proper assessment of needs will help the organization to prioritize the availability of resources to address the current/future requirements.

1.2.3.2.1.2 Occupational Objectives The assessment for occupational training is to determine where a change or new way of working with a job or group of jobs is needed and to establish the knowledge, skills, attitude, and abilities needed to achieve optimum performance.

1.2.3.2.1.3 Individual Objectives The assessment for individual training analyzes how an individual employee is performing the job and determines which employees need training and what training. Individual training requirements are based on the annual performance (appraisal) report, with the employees and their line managers. Individual training helps in enhancing the skills of the employee to improve performance on the current job, and to deal with forthcoming changes, or developmental needs that will enable the individual to plan their career.

All the three levels of need analysis previously discussed are interrelated, therefore the need analysis at these three levels is to be considered in conjunction with one another. The data collected from each level is critical for a thorough and effective needs assessment.

1.2.3.2.1.4 Data Collection Data collection is an important instrumental and indispensable part of a complete needs assessment. The following types of data are normally collected for a needs assessment:

1. Business plans, objectives.
2. Interviews.
3. Observations.
4. Work sample.
5. Questionnaires.
6. Performance evaluation.
7. Performance problems.
8. Best practices followed by other companies/competitors.
9. Analysis of operating problems (work time).
10. Survey.

1.2.3.2.2 Development

Once the needs assessment is completed and training objectives are clearly identified, the development phase (design of training and development methods) is initiated. This phase/step consists of:

1. Selection of trainer/facilitator (internal or external).
2. Designing of course material.
3. Techniques or methods to be used to facilitate training.

4. Select the appropriate method (on-the-job or any other method).
5. Duration of training.

The type of training method depends on the training objectives or expected learning outcomes. It depends on how the professional needs to be trained and what are the needs of the participant (trainee). While planning for the type of training, the following points are to be considered:

- Needs and abilities of the participants.
- Communication method.
- Regulatory requirements, if any.

1.2.3.2.3 Training Implementation

The following are the most common training methods:

1. Seminars
2. Workshops
3. Lectures
4. Self-Study tutorials
5. Coaching
6. On-The-Job Training
7. Field Visits

The following are the most common materials used for training:

1. Projectors
2. Slides
3. Audiovisual Aids
4. Videos
5. Computer-Based Instruction Techniques
6. Flip Charts
7. Wall Charts
8. Flash Cards
9. Workbooks
10. Handouts
11. User Manuals
12. Case Study
13. Job Aids

1.2.3.2.4 Assessment

Evaluation of training is crucial for knowing the effectiveness of training programs and plans for future training. Evaluation is to be done for both the trainer as well as trainee. Normally, evaluation forms are distributed to all the participants at the end of the training session to get their opinion and to evaluate the understanding of the subject-training by the trainee, and also to know their views about the trainer.

1.2.3.2.5 Follow-Up

The training program is only a part of the knowledge and skills-acquiring process. Putting the acquired knowledge into practice is the most important step. The training will be considered successful only if the positive changes have taken place and improvement in the organizational and individual performance is recorded.

In order to know the effectiveness of training, a short session to discuss the training process and its on-the-job implementation is required.

Construction projects have the involvement of the owner, designer (consultant), and contractor. The roles and responsibilities of personnel vary according to their affiliation with a particular working group and also may vary from project to project. For example, an engineer working with a designer must have knowledge and skills related to design, whereas an engineer working with a contractor must know how to execute/implement the project. The knowledge and skills of the team members should be closely linked to the project requirements. Deployment of project staff is done in accordance with the specific qualifications listed under contract documents. Therefore, while establishing the needs assessment for project personnel, contract requirements should be taken into consideration.

Normally the construction professionals assigned to a particular project are, apart from client/owner representative(s), from the designer's (consultant), and contractor's regular staff, supplemented by additional hiring, if needed to fulfill contract requirements. It is assumed that these personnel are fully capable of taking up the responsibilities of performing the assigned project. Sometimes it is required to hire a local workforce to comply with regulatory requirements. In such cases, it is possible that these personnel may not possess the requisite knowledge and skills to perform the required tasks. Therefore, special training should be arranged for these personnel to maintain the organization's reputation.

Training needs of team members assigned or about to be assigned to a construction project are different than those of the normal employees working with the organization. The assigned team members should have knowledge about the site conditions, safety, environmental rules, quality and climatic conditions. Therefore, special training is required by establishing a special need assessment, taking into consideration project-specific roles and responsibilities. Project personnel hired for specific projects should be given induction training to become fully oriented in their respective job. Further, they should be made fully aware of the company's quality management system.

Table 1.5 lists training needs for the contractor's project manager to make him/her fully conversant with the project management.

1.2.4 Directing

Directing is putting a plan into action and using the resources to achieve the desired results. Directing involves the initiation of action and it entails three elements that are action-oriented in nature. These are:

- Motivation
- Communication
- Leadership

TABLE 1.5
Training Needs of Contractor's Project Manager

Serial Number	Areas of Training
1	Human relations.
2	Construction methods.
3	Project management.
4	Communication skills.
5	Resource management.
6	Quality analysis/quality control.
7	Cost management.
8	Project planning and scheduling.
9	Regulatory requirements about labors.
10	Safety, health, and environmental requirements.
11	Basic design principles (all trades).
12	Human resources management.
13	Management of subcontractors.
14	Valuation of work in progress.
15	Contract conditions.
16	Building contract laws.
17	Interpersonal skills.
18	Logistical/demographic conditions.
19	Organization planning.

Directing is also known as leading. Leading is the process of influencing people so that they will contribute to the organization's goals. The main objective of leading is to improve productivity.

1.2.5 Controlling

Controlling is a process to assess and regulate work in progress and take action to ensure that the desired results are attained. In controlling, it is required to:

- Establish objectives and standards and measure actual performance.
- Compare results with established objectives and standards.
- Take necessary action to improve performance and productivity.
- Reduce and prevent unacceptable performance.

In order to have effective controlling there must be real time feedback.

1.3 MANAGEMENT PROCESSES

Project Management Body of Knowledge (PMBOK® Guide) published by the Project Management Institute describes the application of project management processes during the life cycle of projects to enhance the chances of success over a wide range of projects. *PMBOK® Guide*, fifth edition, identifies and describes the five project management process groups required for the successful completion of any project. These are:

1. Initiating Process Group
2. Planning Process Group
3. Executing Process Group
4. Monitoring and Controlling Process Group
5. Closing Process Group

Figure 1.21 illustrates an overview of project management process groups.

These process groups are independent of application areas or industry focus. Project integration management is required from project initiation to the project closeout. The groups defined in *PMBOK® Guide*, fifth edition consist of 47 project management processes and are further grouped into ten separate knowledge areas. These are:

1. Project Integration Management
2. Project Scope Management
3. Project Time Management
4. Project Cost Management
5. Project Quality Management
6. Project Human Resource Management
7. Project Communication Management
8. Project Risk Management
9. Project Procurement Management
10. Project Stakeholder Management

Apart from these ten knowledge areas, an additional four knowledge areas comprising 13 project management processes have been added in *Construction Extension to the PMBOK® Guide*, third edition. These four knowledge areas are:

1. Project Safety Management
2. Project Environmental Management
3. Project Financial Management
4. Project Claim Management

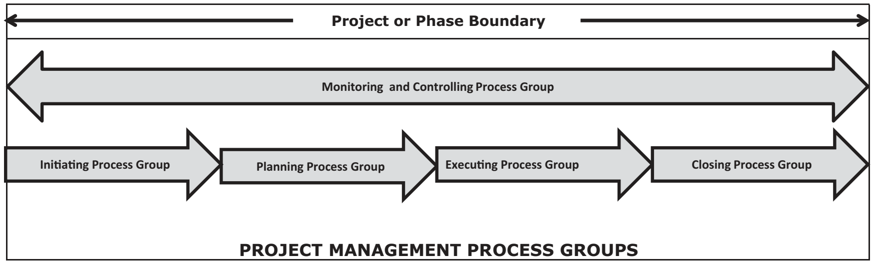


FIGURE 1.21 Overview of project management process groups.

Each of these management areas consists of processes, tools, and techniques that are applied during the management of a project to enhance the success of the project. The knowledge areas are not intended to represent phases in the project. The construction manager/project manager is required to have adequate knowledge of these processes.

Further, in the *Construction Extension to the PMBOK® Guide*, third edition, certain project management processes have been modified or added to address the specific attributes and requirements of the construction industry. For the construction industry, these four knowledge areas have been modified to three knowledge areas.

Thus, based on the principles of project management processes defined in *PMBOK® Guide* 5th edition and *Construction Extension to the PMBOK® Guide* 3rd edition, these knowledge areas are categorized into the following major management processes to manage and control various processes and activities to be performed in construction project management:

1. Project Integration Management
2. Project Stakeholder Management
3. Project Scope Management
4. Project Schedule Management
5. Project Cost Management
6. Project Quality Management
7. Project Resource Management
8. Project Communication Management
9. Project Risk Management
10. Project Contract Management
11. Project Health, Safety, and Environment Management (HSE)
12. Project Financial Management
13. Project Claim Management

The management processes previously mentioned have a variety of applications in construction projects. From the perspective of managing construction projects, it is difficult to generalize and evolve the exact equivalent processes of knowledge areas that are generally followed in the management of construction projects. However, each of the aforementioned management processes can be divided into construction-related technical activity(ies) that can further be subdivided into its element(s) to improve the efficiency and effectiveness of construction management. These management processes can be performed in any order as long as the required inputs are available. Each of the activities evolved will be single purpose and has to be managed, controlled, and completed within a specific duration of time. This will result in improving the practices followed in construction projects and help conveniently manage the construction projects.

Construction projects begin with the inception stage that results from a business case that suggests constructing a new project/facility. The owner of the facility could be an individual, a public/private company, or a government agency. Normally, the need for the project is created by the owner and is linked to the financial resources available to develop the facility. Construction projects are constantly increasing in technological complexity. In addition, the requirements of the construction project clients/users are on the increase and, as a result, construction projects must meet varied performance standards (climate, rate of deterioration, maintenance, and so on). Therefore, to ensure the adequacy of a client brief that addresses numerous complex client/user needs, it is now needed to evaluate the requirements in terms of activities and their interrelationship.

1.3.1 Project Management Process Groups

The major construction activities evolved based on the management processes and are described under five project management process groups.

1.3.1.1 Initiating Process Group

Table 1.6 illustrates the major construction activities relating to the initiating process group.

1.3.1.2 Planning Process Group

Table 1.7 illustrates major construction activities relating to the planning process group.

1.3.1.3 Executing Process Group

Table 1.8 illustrates major construction activities relating to executing process group.

1.3.1.4 Monitoring and Controlling Process Group

Table 1.9 illustrates major construction activities relating to monitoring and controlling process group.

1.3.1.5 Closing Process Group

Table 1.10 illustrates major construction activities relating to the closing process group.

1.3.2 Project Management Knowledge Areas

As previously discussed, there are 13 knowledge areas consisting of different processes that are useful in construction projects.

Each of these management areas consists of processes, tools and techniques that are applied during the management of a project to enhance the success of the project. The knowledge areas are not intended to represent phases in the project. The construction manager/project manager is required to have adequate knowledge of these processes.

These processes are discussed in detail referring to the construction industry.

1.3.2.1 Project Integration Management

Project integration management is the coordination and implementation of five project management process groups (initiating, planning, executing, monitoring,

TABLE 1.6
Major Construction Activities Relating to Initiating Process Group

Serial Number	Management Processes	Activities	Elements
1	Integration Management	1.1 Develop Project Charter	1.1.1 Project Inception
			1.1.2 Problem Statement/Need Identification
			1.1.3 Need Analysis
			1.1.4 Need Statement
			1.1.5 Need Feasibility
			1.1.6 Project Goals and Objectives
			1.1.7 Project Deliverables
			1.1.8 Design Deliverables
		1.2 Develop Preliminary Scope Statement	1.2.1 Project Terms of Reference (TOR)
			1.2.2 Contract Documents
2	Stakeholder Management	2.1 Identify Stakeholders	2.1 Project Delivery System
			2.2 Project Life Cycle
			2.3 Project Team Members
			2.4 Other Parties

Note: These activities may not be strictly sequential, however, the breakdown allows the implementation of project/construction management functions more effectively and manageable at different stages of the project life cycle phases.

TABLE 1.7
Major Construction Activities Relating to Planning Process Group

Serial Number	Management Processes	Activities	Elements
1	Integration Management	1.1 Project Baseline Plan	1.1.1 Preliminary Plans
2	Stakeholder Management	2.1 Responsibilities Matrix	2.1.1 Owner, Designer, Contractor, Other Stakeholders
		2.2 Stakeholders Requirement (Work Progress)	2.2.1 Design Progress
			2.2.2 Construction Progress
			2.2.3 Testing, Commissioning, and Handover
		2.3 Change Reporting	2.3.1 Updated Schedule
			2.3.2 Variation Report
			2.3.3 Cost Variation

(*Continued*)

TABLE 1.7 Continued
Major Construction Activities Relating to Planning Process Group

Serial Number	Management Processes	Activities	Elements
		2.4 Project Updates	
		2.5 Status Reports	2.5.1 Status Logs
			2.5.2 Performance Reports
			2.5.3 Issue Log
		2.6 Meetings	2.6.1 Kick off Meeting
			2.6.2 Progress Meetings
			2.6.3 Coordination Meetings
			2.6.4 Other Meetings
		2.7 Payments	2.7.1 Payment Status
3	Scope Management	3.1 Establish Scope Baseline Plan	
		3.2 Collect Requirements	3.2.1 Need Statement
			3.2.2 Project Goals and Objectives
			3.2.3 Project Terms of Reference (TOR)
			3.2.4 Owner's Preferred Requirements
		3.3 Project Scope Documents	3.3.1 Design Development • Concept Design • Schematic Design • Detailed Design
			3.3.2 Final Design
			3.3.3 Bill of Quantity
			3.3.4 Project Specifications
			3.3.5 Construction Documents
			3.3.6 Project Deliverables
		3.4 Organizational Breakdown Structure	3.4.1 Project Delivery System
			3.4.2 Organizing
			3.4.3 Staffing
			3.4.4 Concept Design
		3.5 Work Breakdown Structures	3.5.1 Project Life Cycle
			3.5.2 Work Packages
4	Schedule Management	4.1 Bill of Quantity	4.1.1 Quantities Take off
			4.1.2 Sequencing of Activities
			4.1.3 Estimate Activity Resources
			4.1.4 Estimate Duration of Activity
		4.2 Identify Project Assumption	4.2.1 Dependencies
			4.2.2 Risks and Constraints
			4.2.3 Milestones
		4.3 Develop Baseline Schedule	
		4.4 Develop Schedule	4.4.1 Predesign Stage

(*Continued*)

TABLE 1.7 Continued
Major Construction Activities Relating to Planning Process Group

Serial Number	Management Processes	Activities	Elements
			4.4.2 Design Development • Concept Design • Schematic Design • Detailed Design
			4.4.3 Contract Documents
			4.4.4 Bidding/Tendering and Contract Award
			4.4.5 Construction Phase
			4.4.6 Testing, Commissioning, and Handover
		4.5 Construction Schedule	4.5.1 Contractor's Construction Schedule
5	Cost Management	5.1 Estimate Cost	5.1.1 Conceptual Estimate
			5.1.2 Preliminary Estimate
			5.1.3 Detailed Estimate
			5.1.4 Definitive Estimate
		5.2 Estimate Budget	5.2.1 Prepare Budget
		5.3 Determine Project Cost Baseline	5.3.1 S-Curve
			5.3.2 Cost Loading
			5.3.3 Resource Loading
		5.4 Estimate Cost	5.4.1 Estimate Project Resources Cost
			5.4.2 Estimate Project Material Cost
			5.4.3 Estimate Project Equipment Cost
			5.4.4 Bill of Quantities
			5.4.5 BOQ Price Analysis
		5.5 Contracted Project Value	5.5.1 Progress Payments
		5.6 Change Order Procedure	5.6.1 Change Order
			5.6.2 Cost Variation
6	Quality Management	6.1 Project Quality Management Plan	6.1.1 Quality codes and standards to be compiled
			6.1.2 Design Criteria
			6.1.3 Design Procedure
			6.1.4 Quality Matrix (Design Stage)
			6.1.5 Well-Defined Specification
			6.1.6 Detailed Construction Drawings
			6.1.7 Quality Matrix (Construction Phase)
			6.1.8 Construction Process
			6.1.9 Detailed Work Procedures

(*Continued*)

TABLE 1.7 Continued
Major Construction Activities Relating to Planning Process Group

Serial Number	Management Processes	Activities	Elements
			6.1.10 Quality Matrix (Inspection, Testing during Execution)
			6.1.11 Defect Prevention/ Rework
			6.1.12 Quality Matrix (Testing and Handing Over Start-Up)
			6.1.13 Regulatory Requirements
			6.1.14 Quality Assurance/Quality Control Procedures
			6.1.15 Reporting Quality Assurance/ Quality Control Problems
			6.1.16 Stakeholders Quality Requirements
7	Resource Management	7.1 Project Human Resources	7.1.1 Construction/Project Manager
			7.1.2 Designer's Team
			7.1.3 Supervision Team
		7.2 Construction Resources	7.2.1 Contractor's Core Team
			7.2.2 Construction Material
			7.2.3 Construction Equipment
			7.2.4 Construction Labor
			7.2.5 Subcontractor (s)
8	Communication Management	8.1 Communication Plan	8.1.1 Communication Matrix
		8.2 Communication Methods	8.2.1 Design Progress
			8.2.2 Work Progress
			8.2.3 Project Issues
			8.2.4 Project Variations
			8.2.5 Authorities
		8.3 Submittal Procedures	8.3.1 Submittal Procedure
			8.3.2 Progress Payments
			8.3.3 Progress Reports
			8.3.4 Minutes of Meetings
			8.3.5 Other Meetings
		8.4 Documents	8.4.1 Design Documents
			8.4.2 Contract Documents
			8.4.3 Construction Documents
			8.4.4 As-Built Documents
			8.4.5 Authority Approved Documents/ Drawings
		8.5 Logs	8.5.1 Issue Log
			8.5.2 Correspondence with Stakeholders

(Continued)

TABLE 1.7 Continued
Major Construction Activities Relating to Planning Process Group

Serial Number	Management Processes	Activities	Elements
			8.5.3 Correspondence with Team Members
			8.5.4 Regulatory Authorities
9	Risk Management	9.1 Risk Identification	9.1.1 During Inception
			9.1.2 During Design
			9.1.3 During Bidding
			9.1.4 During Construction
			9.1.5 During Testing and Commissioning
			9.1.6 During Handing Over
		9.2 Managing Risk	9.2.1 Risk Register
			9.2.2 Risk Analysis
			9.2.3 Risk Response
10	Contract Management	10.1 Project Delivery System	10.1.1 Selection of CM
			10.1.2 Selection of Designer
		10.2 Bidding and Tendering	10.2.1 Prequalification of Contractors
			10.2.2 Issue Tender Documents
			10.2.3 Acceptance of Tender
11	Health, Safety, and Environment	11.1 Environmental Compatibility	
		11.2 Safety Management Plan	11.2.1 Safety Consideration in Design
			11.2.2 HSE Plan for construction site safety
			11.2.3 Emergency Evacuation Plan
		11.3 Waste Management Plan	
12	Financial Management	12.1 Financial Planning	12.1.1 Payments to Designer (Consultant), Construction/Project Manager, Contractor
			12.1.2 Material Procurement
			12.1.3 Equipment Procurement
			12.1.4 Project Staff Salaries
			12.1.5 Bonds, Insurance, Guarantees
			12.1.6 Cash Flow
13	Claim Management	13.1 Claim Identification	13.1.1 Design Errors
			13.1.2 Additional Works
			13.1.3 Delays in Payment
		13.2 Claim Quantification	13.2.1 Change order procedures • Time • Cost

Note: These activities may not be strictly sequential, however the breakdown allows implementation of project/construction management functions more effectively and manageable at different stages of project life cycle phases.

TABLE 1.8
Major Construction Activities Relating to Executing Process Group

Serial Number	Management Processes	Activities	Elements
1	Integration Management	1.1 Design Development	1.1.1 Concept Design
			1.1.2 Schematic Design
			1.1.3 Detailed Design
		1.2 Construction	1.2.1 Notice to Proceed
			1.2.2 Mobilization
			1.2.3 Submittals
			1.2.4 Execution
			1.2.5 Corrective Actions
			1.2.6 Project Deliverables
		1.3 Implement Changes	1.3.1 Approved Changes
			1.3.2 Preventive Actions
			1.3.3 Defect Repairs
			1.3.4 Rework
			1.3.5 Update Scope
			1.3.6 Update Plans
			1.3.7 Update Contract Documents
2	Stakeholder Management	2.1 Project Status/ Performance Report	2.1.1 Updated Plans
		2.2 Payments	2.2.1 Progress Payments
		2.3 Change Requests	2.3.1 Site Work Instruction
			2.3.2 Change Orders
			2.3.3 Schedule
			2.3.4 Materials
		2.4 Conflict Resolution	
		2.5 Issue Log	
3	Scope Management		
4	Schedule Management		
5	Cost Management		
6	Quality Management	6.1 Quality Assurance	6.1.1 Design Compliance to TOR
			6.1.2 Design Coordination with all Disciplines
			6.1.3 Material Approval
			6.1.4 Shop Drawing Approval
			6.1.5 Method Approval
			6.1.6 Method Statement
			6.1.7 Mock-Up
			6.1.8 Quality Audit
			6.1.9 Functional and Technical Compatibility
7	Resource Management	7.1 Project Staff	7.1.1 Project/Construction Manager Staff

(*Continued*)

TABLE 1.8 Continued
Major Construction Activities Relating to Executing Process Group

Serial Number	Management Processes	Activities	Elements
			7.1.2 Supervision Staff
		7.2 Project Manpower	7.2.1 Core Staff
			7.2.2 Site Staff
			7.2.3 Workforce
		7.3 Team Management	7.3.1 Team Behavior
			7.3.2 Conflict Resolution
			7.3.3 Demobilization Project Workforce
		7.4 Construction Resources	7.4.1 Material
			7.4.2 Equipment
			7.4.3 Subcontractor(s)
8	Communication Management	8.1 Submittals	8.1.1 Shop Drawings
			8.1.2 Material
			8.1.3 Change Orders
			8.1.4 Payments
		8.2 Documentation	8.2.1 Status Log
			8.2.2 Issue Log
			8.2.3 Minutes of Meetings
			8.2.4 Contract Documents
			8.2.5 Specifications
			8.2.6 Payments
		8.3 Correspondence	8.3.1 Stakeholders
			8.3.2 Regulatory Authorities
			8.3.3 Correspondence among Team Members
9	Risk Management	9.1 Manage Risk	9.1.1 Risk Register
			9.1.2 Risk Response
10	Contract Management	10.1 Contract Documents	10.1.1 Notice to Proceed
		10.2 Selection of Subcontractor(s)	
		10.3 Selection of Materials, Systems, and Equipment	
		10.4 Execution of Work	
11	Health, Safety, and Environment	11.1 HSE Management Plan	11.1.1 Site safety
			11.1.2 Preventive and Mitigation Measures
			11.1.3 Temporary Fire Fighting
			11.1.4 Environmental Protection
			11.1.5 Waste Management
			11.1.6 Safety Hazards

(*Continued*)

TABLE 1.8 Continued
Major Construction Activities Relating to Executing Process Group

Serial Number	Management Processes	Activities	Elements
12	Financial Management		
13	Claim Management		

Note: These activities may not be strictly sequential, however the breakdown allows implementation of project/construction management functions more effectively and manageable at different stages of project life cycle phases.

TABLE 1.9
Major Construction Activities Relating to Monitoring and Controlling Process Group

Serial Number	Management Processes	Activities	Elements
1	Integration Management	1.1 Project Performance	1.1.1 Design Performance
			1.1.2 Construction Performance
			1.1.3 Project Start-Up
			1.1.4 Forecasted Schedule
			1.1.5 Forecasted Cost
			1.1.6 Issues
		1.2 Change Management System	1.2.1 Design Changes
			1.2.2 Design Errors
			1.2.3 Change Requests
			1.2.4 Scope Change
			1.2.5 Variation Orders
			1.2.6 Site Work Instruction
			1.2.7 Alternate Material
			1.2.8 Specs/Methods
		1.3 Change Analysis	1.3.1 Review, Evaluate Changes
			1.3.2 Approve, Delay, Reject Changes
			1.3.3 Corrective Actions
			1.3.4 Preventive Actions
		1.4 Compliance to Contract Documents	
2	Stakeholder Management	2.1 Project Performance	2.1.1 Progress Reports
			2.1.2 Updates
			2.1.3 Safety Report
			2.1.4 Risk Report

(*Continued*)

TABLE 1.9 Continued
Major Construction Activities Relating to Monitoring and Controlling Process Group

Serial Number	Management Processes	Activities	Elements
		2.2 Project Updates	2.2.1 Contract Documents
		2.3 Payments	2.3.1 Payment Certificate
		2.4 Change Requests	2.4.1 Site Work Instruction
			2.4.2 Change Orders
		2.5 Issue Log	2.5.1 Anticipated Problems
		2.6 Minutes of Meetings	2.6.1 Progress Meetings
			2.6.2 Other Meetings
3	Scope Management (Contract Documents)	3.1 Validate Scope	3.1.1 Conformance to TOR
			3.1.2 Review of Design Documents
			3.1.3 Conformance to Contract Documents
			3.1.4 Approval of Changes
			3.1.5 Authorities Approval of Deliverables
			3.1.6 Stakeholders Approval of Deliverables
			3.1.7 Quality Audit
		3.2 Scope Change Control	3.2.1 Variation Orders
			3.2.2 Change Orders
		3.3 Performance Measures	
4	Schedule Management	4.1 Schedule Monitoring	4.1.1 Project Status
		4.2 Schedule Control	4.2.1 Progress Curve
		4.3 Schedule Changes	4.3.1 Approved Changes
		4.4 Progress Monitoring	4.4.1 Planned versus Actual
		4.5 Submittals Monitoring	4.5.1 Subcontractors
			4.5.2 Material
			4.5.3 Shop Drawings
5	Cost Management	5.1 Cost Control	5.1.1 Work Performance
			5.1.2 S-Curve
			5.1.3 Forecasted Cost
		5.2 Change Orders	
		5.3 Progress Payment	
		5.4 Variation Orders	
6	Quality Management	6.1 Control Quality	6.1.1 Quality Metrics
			6.1.2 Quality Checklist
			6.1.3 Material Inspection
			6.1.4 Work Inspection
			6.1.5 Rework
			6.1.6 Testing
			6.1.7 Regulatory Compliance
7	Resource Management	7.1 Conflict Resolution	
		7.2 Performance Analysis	
		7.3 Material Management	

(*Continued*)

TABLE 1.9 Continued

Major Construction Activities Relating to Monitoring and Controlling Process Group

Serial Number	Management Processes	Activities	Elements
8	Communication Management	8.1 Meetings	8.1.1 Progress Meetings
			8.1.2 Coordination Meetings
			8.1.3 Safety Meetings
			8.1.4 Quality Meetings
		8.2 Submittal Control	8.2.1 Drawings
			8.2.2 Material
		8.3 Documents Control	8.3.1 Correspondence
9	Risk Management	9.1 Monitor and Control Risk	9.1.1 Scope Change Risk
			9.1.2 Schedule Change Risk
			9.1.3 Cost Change Risk
			9.1.4 Mitigate Risk
			9.1.5 Risk Audit
10	Contract Management	10.1 Inspection	
		10.2 Checklists	
		10.3 Handling of Claims, Disputes	
11	Health, Safety, and Environment	11.1 Prevention Measures	11.1.1 Accidents Avoidance/Mitigation
			11.1.2 Fire Fighting System
			11.1.3 Loss Prevention Measures
		11.2 Application of Codes and Standards	
12	Financial Management	12.1 Financial Control	12.1.1 Payments to Project Team Members
			12.1.2 Payments to Contractor(s)/ Subcontractor(s)
			12.1.3 Material Purchases
			12.1.4 Variation Order Payment
			12.1.5 Insurance and Bonds
		12.2 Cash Flow	
13	Claim Management	13.1 Claim Prevention	13.1.1 Proper Design Review
			13.1.2 Unambiguous Contract Documents Language
			13.1.3 Practical Schedule
			13.1.4 Qualified Contractor(s)
			13.1.5 Competent Project Team Members
			13.1.6 RFI Review Procedure
			13.1.7 Negotiations
			13.1.8 Appropriate Project Delivery System

Note: These activities may not be strictly sequential, however, the breakdown allows the implementation of project/construction management functions more effectively and manageable at different stages of the project life cycle phases.

TABLE 1.10
Major Construction Activities Relating to Project Closing Process Group

Serial Number	Management Processes	Activities	Elements
1	Integration Management	1.1 Close Project or Phase	1.1.1 Testing and Commissioning
			1.1.2 Authorities' Approvals
			1.1.3 Punch List/Snag List
			1.1.4 Handover of Project/Facility
			1.1.5 As-Built Drawings
			1.1.6 Technical Manuals
			1.1.7 Spare Parts
			1.1.8 Lesson Learned
2	Resource Management	2.1 Close Project Team	2.1.1 Demobilization
			2.1.2 New Assignment
		2.2 Material and Equipment	2.2.1 Excess Material Removal/Disposal
			2.2.2 Equipment Removal
3	Contract Management	3.1 Close Contract	3.1.1 Project Acceptance/Takeover
			3.1.2 Issuance of Substantial Completion Certificate
			3.1.3 Occupancy
4	Financial Management	4.1 Financial Administration and Records	4.1.1 Payments to all Contractors, Subcontractors, and Other Team Members
			4.1.2 Bank Guarantees/Warranties
5	Claim Management	5.1 Claim Resolution	5.1.1 Settlement of Claims

Note: These activities may not be strictly sequential, however, the breakdown allows the implementation of project/construction management functions more effectively and manageable at different stages of the project life cycle phases.

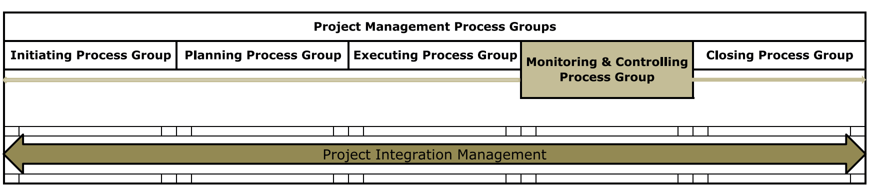


FIGURE 1.22 Integration management process cycle.

and controlling) from the time the project is conceived right to the closeout stage. Integration management involves putting all the process groups. Figure 1.22 illustrates the integration management process cycle.

Integration management of a construction project includes all the activities performed to effectively control the final output of project production (facility), and the input of the process is the owner's need for the construction project.

The management processes mentioned have a variety of applications in construction projects. From the perspective of managing construction projects, it is difficult to generalize and evolve the exact equivalent processes of knowledge areas that are generally followed in the management of construction projects. However, each of the previously mentioned management processes can be divided into construction-related technical activity(ies) that can further be subdivided into its element(s) to improve the efficiency and effectiveness of construction management. These management processes can be performed in any order as long as the required inputs are available. Each of the activities evolved will be single purpose and has to be managed, controlled, and completed within a specific duration of time. This will result in improving the practices followed in construction projects and help conveniently manage the construction projects.

Construction projects begin with the inception stage that results from a business case that suggests constructing a new project/facility. The owner of the facility could be an individual, a public/private company, or a government agency. Normally, the need for the project is created by the owner and is linked to the financial resources available to develop the facility. Construction projects are constantly increasing in technological complexity. In addition, the requirements of construction project clients are on the increase and, as a result, construction projects must meet varied performance standards (climate, rate of deterioration, maintenance, and so on). Therefore, to ensure the adequacy of a client brief that addresses numerous complex client/user needs, it is now needed to evaluate the requirements in terms of activities and their interrelationship.

Table 1.11 illustrates an overview of project integration management processes.

1.3.2.2 Project Stakeholder Management

A stakeholder is anyone who has involvement, interest or impact in the construction project processes in a positive or negative way. Stakeholders play a vital role in determining the formulation and successful implementation of the project processes. Stakeholders can mainly be classified as:

- Direct Stakeholders
- Indirect Stakeholders
- Positive Stakeholders
- Negative Stakeholders
- Legitimacy and Power

TABLE 1.11
Project Integration Management Processes

Serial Number	Project Management Process Group	Project Management Processes
1	Initiating Process Group	1.1 Develop Project Charter 1.2 Develop Preliminary Scope Statement
2	Planning Process Group	2.1 Develop Project Management Plan
3	Executing Process Group	3.1 Direct and Manage Project Works
4	Monitoring and Controlling Process Group	4.1 Monitor and Control Project Work 4.2 Perform Integrated Change Control
5	Closing Process Group	5.1 Close Project or Phases

Stakeholder management process consists of the following activities:

1. Identify Stakeholders
2. Plan Stakeholder Management
3. Manage Stakeholder Engagement
4. Control Stakeholder Engagement

1.3.2.2.1 Identify Stakeholder

Construction projects have direct involvement of the following three stakeholders:

1. Owner
2. Designer (Consultant)
3. Contractor

However, there are many other stakeholders who have a significant influence/impact on the outcome of the construction project. It is important to identify stakeholders who have an interest and significant influence in the project. The stakeholders include members from within the organization and people, agencies, and authorities outside the organization. A stakeholder register/log is developed using different types of classification models for stakeholders' analysis. The stakeholder register/log is maintained and updated throughout the life cycle of the project. Figure 1.23 illustrates stakeholders having involvement or interest in the construction project.

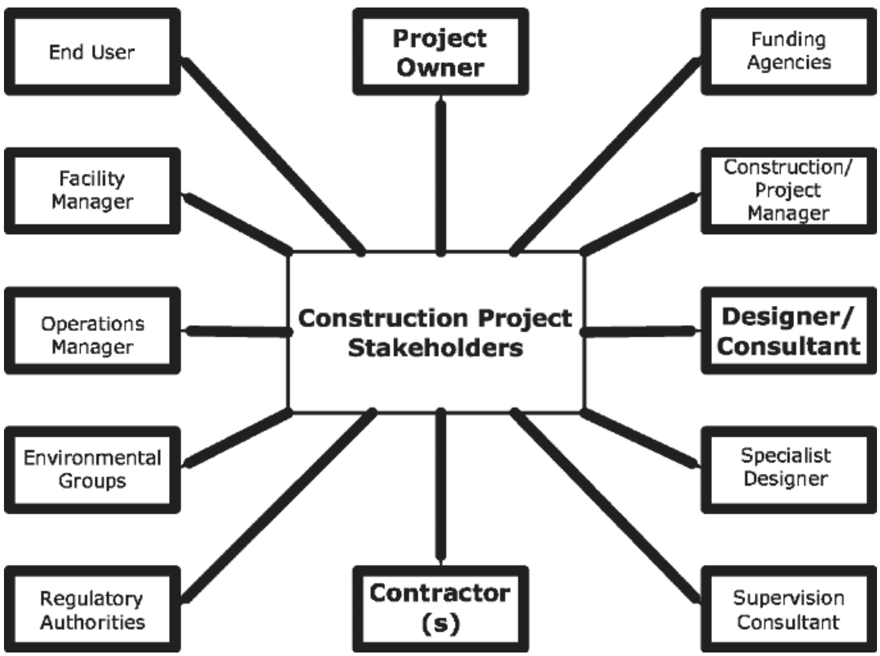


FIGURE 1.23 Stakeholders in construction projects.

1.3.2.2.2 Plan Stakeholder Management

In order to run a successful project, it is important to address the needs of project stakeholders effectively predicting how the project will be affected and how the stakeholders will be affected. Stakeholder management planning is a process to develop a stakeholder engagement plan depending on the roles and responsibilities of the stakeholders and their needs, expectations and influence on the project. While developing a stakeholder management plan, the following factors have to be considered:

- Who are the stakeholders of the project?
- What role each stakeholder will have in the project?
- What relationship project team members will have with the stakeholder?
- What opportunities do they present?
- What challenges or threats the stakeholder will have toward the project?
- What is the information or reports to be communicated to the stakeholder?
- Stakeholders' involvement in approvals and review of project activities?

In order to manage stakeholder's expectations in construction projects, the following construction-related activities have to be evolved:

1. Develop stakeholders responsibility matrix.
2. Develop stakeholders requirements.
3. Procedure to distribute performance report.
4. Procedure to distribute project update reports.
5. Stakeholders' involvement in approvals and reviews.
6. Progress payment.
7. Meetings.

Table 1.12 is an example stakeholders responsibility matrix for construction project.

1.3.2.2.3 Manage Stakeholder Engagement

Managing stakeholder engagement is a process of involving stakeholders through communicating and working together to address the needs/expectations, issues of the stakeholders. Successful completion of construction projects is dependent on meeting the expectations of stakeholders. Stakeholder engagement helps:

- Reduce risk in the project.
- Sharing experience and skills, thus resulting in mitigating the threats and uncertainties.
- Gain stakeholders' support.
- To respond efficiently and effectively to the difficulties that may arise or issues that need to be resolved.
- Reduce conflict.
- To deal with the changing needs of stakeholder.
- To ensure that the project deliverables meet stakeholder expectations.
- Successful completion of the project within schedule, budget, and as per the approved scope.

TABLE 1.12
Stakeholder Responsibility Matrix

LEGEND: P=Prepare/Initiate/Responsible, R=Review/Comment, B=Advise/Assist, A=Approve, E=Attend, C=Inform

Serial Number	Activity	Owner/ client	Construction Manager/ Project Manager	Designer/ Consultant	Contractor	Supervisor	Regulatory Authority	Funding Agency	End User/ Facility Manager	Notes/ Comments
1	Project Initiation	P	-	-	-	-	-	B	B	
2	Selection of Construction Manager	P	-	-	-	-	-	-	-	
3	Selection of Designer	P	B	-	-	-	-	-	-	
4	Preparation of Terms of Reference (TOR)	A	P	-	-	-	-	-	-	
5	Preparation of Design	A	B	P	-	-	R	-	-	
6	Value Engineering	A	R	P						
7	Preparation of Contract Documents	A	B	P	-	-	-	-	-	
8	Project Schedule	A	B	P	-	-	-	C	C	
9	Project Budget	A	B	P	-	-	-	B	-	
10	Preparation of Tendering Documents	A	P	B	-	-	-	-	-	
11	Submission of Bid	C	C	-	P	-	-	-	-	
12	Evaluation of Bid	C	C	P	-	-	-	-	-	
13	Selection of Contractor	A	P	B	-	-	-	C	C	
14	Approval of subcontractor	A	B	B	P	-	-	-	-	
15	Approval of Contractor's Staff	A	B	B	P	-	-	-	-	
16	Execution of Work	C	C	R	P	R	-	-	-	
17	Supervision of Work	C	C	R	P	P	-	-	-	
18	Approval of Material	C	A	R	P	B	-	-	-	
19	Approval of Shop Drawings	C	C	A	P	B	-	-	-	
20	Construction Schedule	C	A	R	P	B	-	-	-	

(*Continued*)

TABLE 1.12 Continued
Stakeholder Responsibility Matrix

LEGEND: P=Prepare/Initiate/Responsible, R=Review/Comment, B=Advise/Assist, A=Approve, E=Attend, C=Inform										
Serial Number	**Activity**	**Owner/ client**	**Construction Manager/ Project Manager**	**Designer/ Consultant**	**Contractor**	**Supervisor**	**Regulatory Authority**	**Funding Agency**	**End User/ Facility Manager**	**Notes/ Comments**
21	Monitoring Progress	C	P	P	P	B				
22	Monitoring Cost	C	P	P	B	B				
23	Payments	A	R	R	P	B	-	-	-	
24	Request for Information	C	C	R	P	B				
25	Approval of Change	A	B	R	P	B	-	-	-	
26	Quality Plan	C	B	R	P	B	-	-	-	
27	Project Quality	C	R	R	P	P				
28	Meetings	E	E	P	E	E	-	-	-	
29	Safety Plan	C	B	R	P	B	-	-	-	
30	Site Safety	C	C	B	P	P	-	-	-	
31	Testing and Commissioning	C	C	R	P	D	-	-	C	
32	Authorities Approval	C	C	B	P	B	A	-	-	
33	Snag list	C	C	R	P	P	-	-	C	
34	Substantial Completion Certificate	A	R	P	C	-	-	-	C	

In construction project, stakeholder engagement is required to address the following activities:

- Reporting project status/performance.
- Reporting changes in scope, schedule, budget.
- Project related issues.
- Project payments.
- Conflicts.
- Variation orders.
- Anticipated/forecasted problems.

1.3.2.2.4 Control Stakeholder Engagement

Control stakeholder engagement is a process to ensure that all the related information and reports are properly distributed to the concerned stakeholders.

In construction project, stakeholder engagement control is done by distributing the following information and reports:

- Project status/performance.
- Project status.
- Project updates.
- Project related issues.
- Project payments.
- Project conflicts.
- Change orders.
- Minutes of meetings.

1.3.2.3 Project Scope Management

As per the *PMBOK® Guide*, fifth edition, project scope management includes the processes required to ensure that the project includes all the work required, and only the work required, to complete the project successfully. Project scope management consists of six processes:

1. Plan Scope Management
2. Collect Requirements
3. Define Scope
4. Create Work Breakdown Structure (WBS)
5. Validate Scope
6. Control Scope

In construction projects, scope management is the process that includes the activities to formulate and define the client's need, by establishing project objectives and goals properly addressed in order for the project to have clear direction, and controlling what is or is not involved in the project. The project scope documents explain the boundaries of the project, establish project responsibilities for each team member, and set up procedures for how completed work will be verified and approved. The scope describes the features and functions of the end product or the services to be provided by the project.

During the project, the scope documentation helps the project team remain focused and on task. The scope statement also provides the project team with guidelines for making decisions about change requests during the project. It is essential that the scope statement should be unambiguous and clearly written to enable all the members of the project team to understand the project scope to achieve project objectives and goals.

Project development is a process spanning from the commencement of project initiation and ending with closeout and finalizing project records after project construction. The project development process is initiated in response to an identified need by the owner/end user. It covers a range of time-framed activities extending from the identification of a project need, the development of contract documents, and the construction of the project.

By applying the concept of scope management process methodology in the development of a construction project, the following construction-related activities can be evolved:

1. Develop Scope Management Plan
   a. Project assumptions.
   b. Constraints.
   c. Key deliverables.
   d. Project organization.
   e. Roles and responsibilities.
   f. Dependencies.
   g. Milestones.
   h. Project cost.
   i. Quality.
   j. Risks.
   k. Safety regulations.
   l. Environmental considerations.
   m. Change control.
2. Collect Requirements
   a. Need statement.
   b. Project goals and objectives.
   c. Terms of reference (TOR).
3. Develop Project Scope Documents
   a. Collect owner's preferred requirements.
   b. Develop design:
      i. Concept Design
      ii. Schematic Design
      iii. Detail Design
   c. Project specifications:
      i. General Specifications
      ii. Particular Specifications
   d. Contract documents:
      i. General Conditions
      ii. Particular Conditions
      iii. Tender/Bidding Documents

4. Work Breakdown Structure
    a. Project breakdown structure:
        i. Project Life Cycle Phases
        ii. Project Scope
        iii. Bill of Quantities
        iv. Schedule Milestones
        v. Cost Estimates
        vi. Quality Management
        vii. Resource Management
        viii. Risk Management
        ix. Documents
    b. Organizational breakdown structure.
    c. WBS dictionary.
    d. Responsibility assignment matrix.
    e. Scope baseline.
5. Validate Scope
    a. Review of design documents.
    b. Approval of design documents.
    c. Review of contract documents.
    d. Approval of contract documents.
    e. Regulatory approvals.
    f. Acceptance of project.
6. Control Scope
    a. Scope change control.
    b. Variation orders.
    c. Change orders.
    d. Performance measures.

1.3.2.3.1 Develop Scope Management Plan

The project scope management plan is a part of the overall project management plan that describes how the scope will be defined, developed, validated, and controlled. It explains how the project will be managed and how scope changes will be incorporated into the project management plan. The scope management plan establishes a structured process to ensure that the work performed by the project team is clearly within the established parameters and ensures that all project objectives are achieved.

The key benefit of this process is that it provides guidelines and direction on how the scope will be managed throughout the project. Scope management plan documents:

- Scope definition.
- The scope management approach.
- Roles and responsibilities of stakeholders pertaining to the project scope.
- Work breakdown structure (activity list).
- Organization breakdown structure.
- Procedures to verify and approve the completed works.
- Managing any changes in the project scope baseline.
- Guidelines for making decision about change requests during execution of project and controlling project scope.

1.3.2.3.2 Collect Requirements

Construction project development is initiated with the identification of the need to develop a new facility or renovation/refurbishment of the existing facility. It is essential to get a clear definition of the identified need or the problem to be solved by the new project. The owner's needs must be well-defined, indicating the minimum requirements of quality and performance, an approved budget, and the required completion date. The need should be based on real (perceived) requirements. The identified need is then assessed and analyzed to develop a need statement. Need assessment is conducted to determine the need. Need assessment is a systematic process for determining and addressing needs or "gaps" between current conditions and desired conditions "want." Need analysis is the process of identifying and evaluating needs. The need statement is written based on the need analysis and is used to perform a feasibility study to develop project goals and objectives and subsequently to prepare project scope documents.

The feasibility study takes its starting point from the output of project identification needs. The need statement is the input to perform a feasibility study. The main purpose of the feasibility study is to evaluate the project's needs and decide whether to proceed with the project or stop. Depending on the circumstances, the feasibility study may be short or lengthy, simple or complex. In any case, it is the principal requirement in project development as it gives the owner/client an early assessment of the viability of the project and the degree of risk involved.

Feasibility study can be categorized into the following functions:

- Legal
- Marketing
- Technical and Engineering
- Financial and Economical
- Social
- Environmental
- Risk
- Scheduling of Project

The project feasibility study is usually performed by the owner through their own team or by engaging a specialist agency or individual.

After completion and approval of the feasibility study, it is possible to establish project goals and objectives. The goals and objectives must be:

1. Specific
2. Measurable
3. Attainable/Achievable
4. Realist
5. Time (Cost) Limited

Once project goals and objectives are established, a comprehensive scope statement (terms of reference) is prepared by the owner/client or by the project manager on behalf of the owner describing in detail the project objectives and requirements to develop the project. The terms of reference are a document that describes the intention of a project, the approach in which it will be constructed, and how it will be implemented. It can also be described as a specification of a team member's responsibilities and influence within a project. A TOR is an outline of a project, including its mission statement, procedures and rules, and the different administrative aspects of the entire project.

1.3.2.3.3 Develop Project Scope Documents

Construction project scope documents are developed based on the requirements described in the TOR prepared by the owner/client or construction manager/project manager on behalf of the owner/client. The TOR gives the designer (consultant) a clear understanding of the development of the project. The designer (consultant) utilizes TOR to develop contract documents to suit the project delivery system. The contract documents for the design-bid-build type of project delivery system mainly consist of:

1. Scope of Work
2. Design Drawings
3. Bill of Quantities
4. Technical Specifications
5. Conditions of Contract
6. Project Schedule
7. Tender/Bidding Documents

In the case of the design-build type of project delivery system, tendering/bidding documents are prepared taking into consideration performance specifications for the project.

Figure 1.24 is an illustrative flowchart for the development of terms of reference (construction project documents) and Figure 1.25 illustrates the construction project development process.

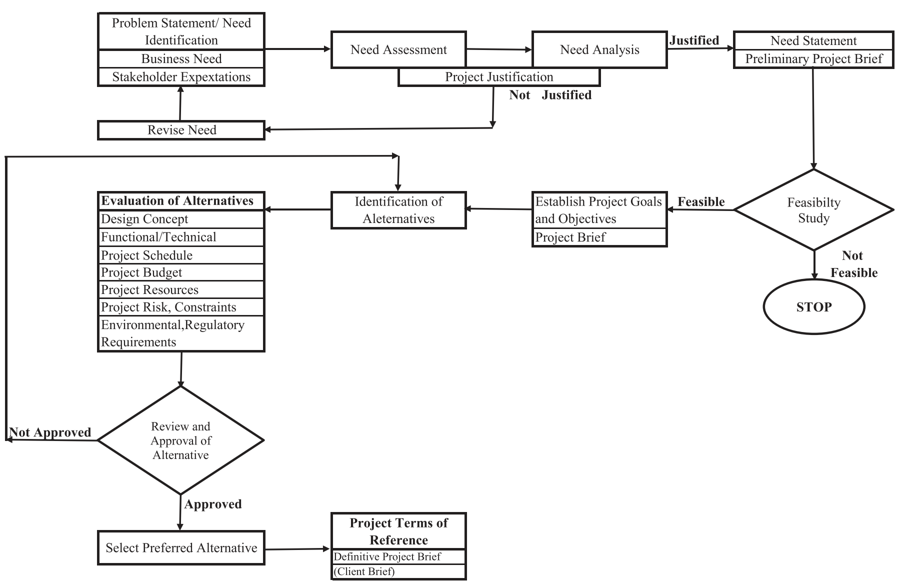


FIGURE 1.24 Flowchart for development of terms of reference (TOR).

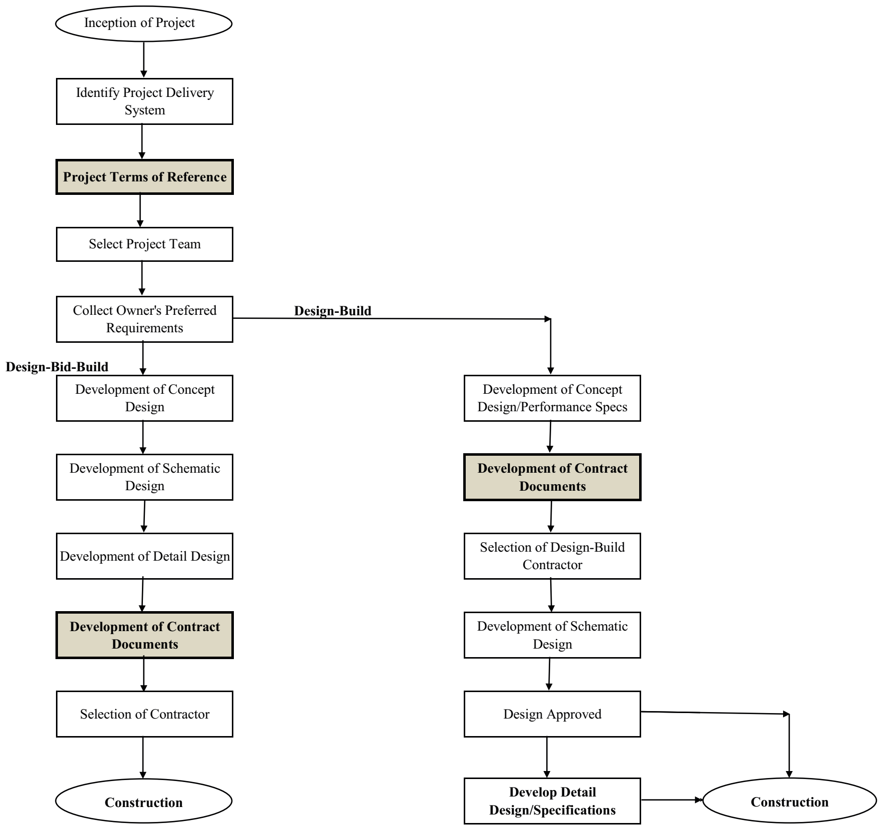


FIGURE 1.25 Development of construction project scope documents.

1.3.2.3.4 Work Breakdown Structures

The Work Breakdown Structure (WBS) is a hierarchical representation of system levels. WBS is a family tree, consisting of a number of levels, starting with the complete scope of work at level 1 at the top and progressing downward through as many levels as necessary, to obtain work elements (activities) that can be conveniently managed. WBS involves envisioning the project as a hierarchy of goals, objectives, activities, sub-activities, and work packages. WBS is constructed by dividing the project into major elements with each of these being divided into subelements. This is done till a breakdown is done in terms of manageable units of work for which responsibility can be defined. The hierarchical decomposition of activities continues until the entire project is displayed as a network of separately identified and non-overlapping activities. Each activity will be of a single purpose, of specific time duration, and manageable, with time and cost estimates easily derived, deliverables clearly understood, and responsibility for completion clearly assigned.

In order to manage and control the project at different levels in the most effective manner, the project is broken down into a group of smaller sub-projects/subsystems and then into small well-defined activities. Each element (activity) should be:

- Definable
- Manageable
- Measurable
- Estimable
- Independent
- Integratable
- Adaptable

Figure 1.26 illustrates an approach to the development of a work breakdown structure.

1.3.2.3.4.1 Project Breakdown Structures Construction projects are constantly increasing in technical complexity, and the relationships and contractual groupings of those who are involved are also more complex and contractually varied. The WBS approach to construction projects helps understand the entire process of project management, and to manage and control its activities at different levels of various phases to ensure timely completion of the project with economical use of resources to make the construction project most qualitative, competitive, and economical. WBS is a deliverable-oriented grouping of project work elements shown in a graphical display and organized and subdivided the total scope of work into small and manageable components (activities).

WBS development involves the following major steps:

1. Identify final product(s) necessary to achieve total project scope.
2. Identify major deliverables.
3. Divide these major deliverables to a level of detail appropriate to meet the managing and controlling requirements of the project.
4. Divide each of these deliverables into its components.

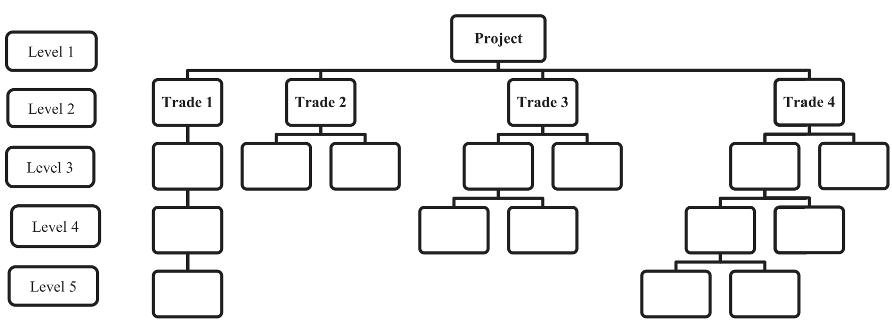


FIGURE 1.26 Work breakdown structure (WBS).

While preparing WBS, the following points need to be considered:

- Complexity of the project.
- Size of the project.
- Reporting requirements.
- Resource allocation.
- Work included in the scope of work is only included in the WBS.
- Duration of tasks or activities should be as per industry common practice which is the "8–80 rule." This rule recommends that the lowest level of work should be no less than 8 hours and no more than 80 hours.
- Each level is assigned a unique identification number.

The lowest level of work breakdown structure is known as the "Work Package." A work package can be divided into specific activities to be performed.

Figure 1.27 illustrates the typical levels of the WBS process in construction projects.

Traditional construction projects have involvement of three main parties. These are:

1. Owner/Client
2. Designer/Consultant
3. Contractor

The involvement and interaction between the owner/client, designer/consultant, and contractor(s) depends on the construction project procurement strategy followed by the owner. Based on the strategy, the WBS for construction projects can be developed to suit the requirements of the project development at different stages (study, design, and construction) of the project.

There are typically two types of work breakdown structures. These are:

1. Project WBS
   It is prepared by the contractor taking into consideration the requirements listed in contract documents. It is also known as the contractor's construction schedule.
2. Project Summary WBS
   It is prepared by the designer (consultant) summarizing the entire project requirements. It is part of the contract documents signed between the owner/client and contractor.

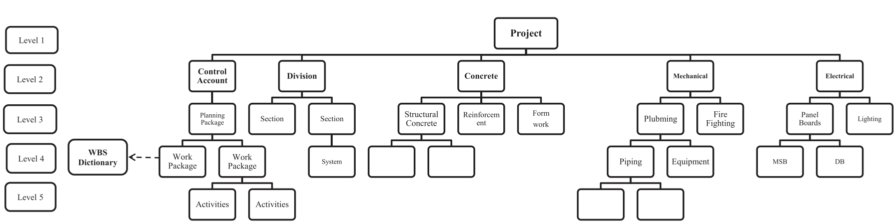


FIGURE 1.27 Typical level of WBS.

There are different approaches followed for the development of WBS. These are:

- Physical location, which is further divided into floor levels, zones.
- Project development stages such as study, design, construction.

Figure 1.28 illustrates WBS for project design.

In most construction projects, the CSI MasterFormat® coding system is followed to develop WBS. The following figures are guidelines to develop WBS taking into consideration divisions, sections, and titles for MasterFormat®. More detailed levels can be developed according to the project requirements.

Figure 1.29 illustrates WBS for concrete work in construction projects.

Figure 1.30 illustrates WBS for fire suppression work in construction projects.

Figure 1.31 illustrates WBS for plumbing work in construction projects.

Figure 1.32 illustrates WBS for HVAC work in construction projects.

Figure 1.33 illustrates WBS for electrical work in construction projects.

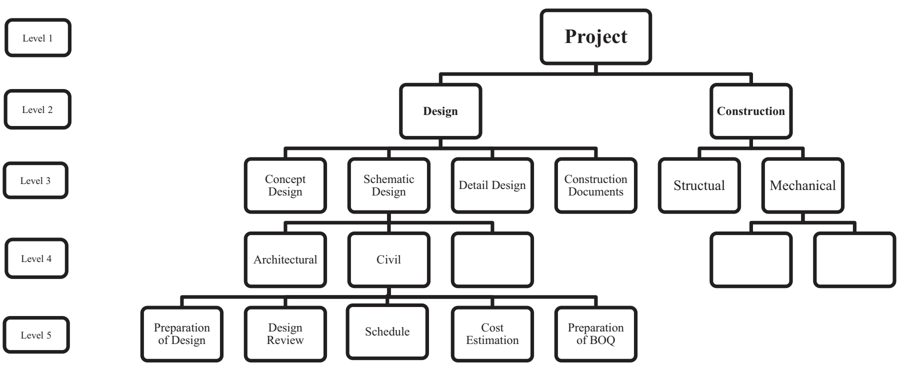


FIGURE 1.28 WBS for project design.

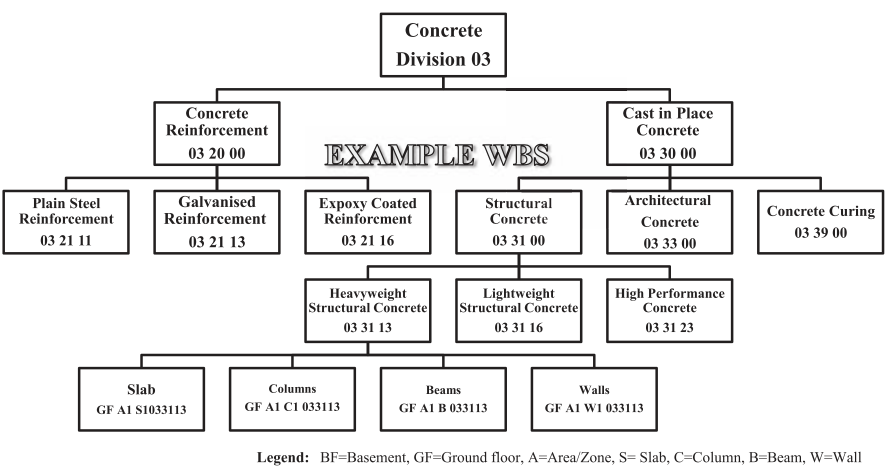


FIGURE 1.29 WBS for concrete work in construction projects.

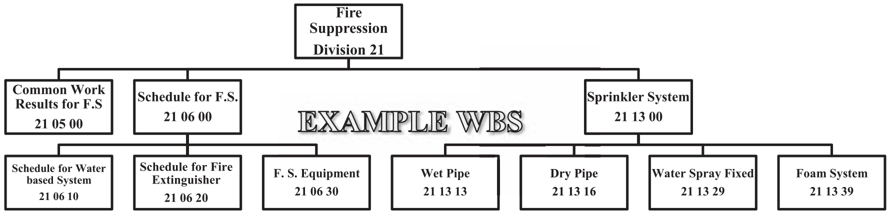


FIGURE 1.30 WBS for fire suppression work.

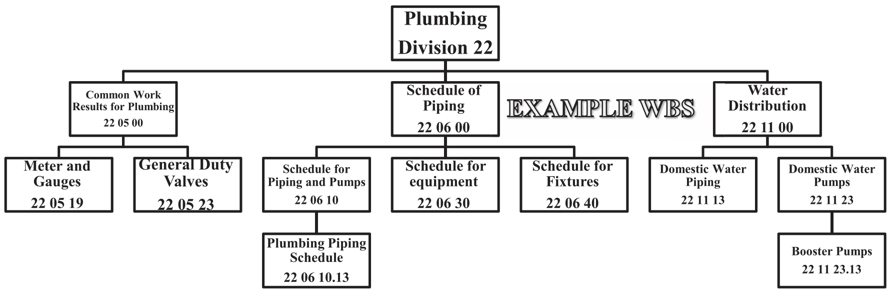


FIGURE 1.31 WBS for plumbing work.

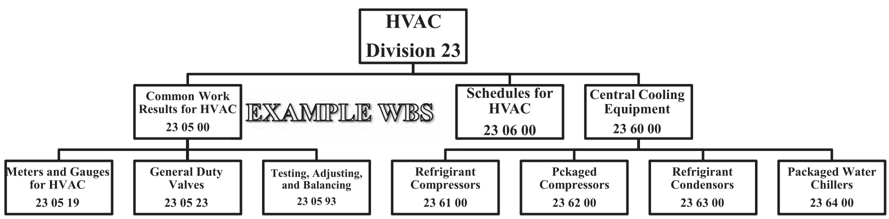


FIGURE 1.32 WBS for HVAC work.

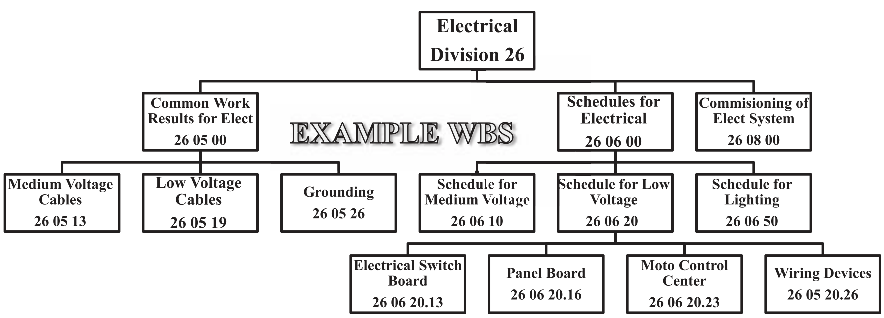


FIGURE 1.33 WBS for electrical work.

1.3.2.3.4.2 Organizational Breakdown Structure (OBS) Organizational Breakdown Structure (OBS) is a hierarchical organizational relationship of the project teams, including subcontractors, responsible for managing the designated scope of work described within the WBS. It is used as a framework for assigning work relationships. The WBS identifies what work needs to be done, whereas OBS identifies the individual who will do the work. An organizational breakdown structure for the project can be simple or complex depending on the size and complexity of the project. WBS with the appropriate type of organization (projectized, functional, matrix) assures that all the scope of work is accounted for, and each element of work is assigned to the level of responsibility for planning, tracking progress, costing, and reporting. The organizational and personal relationship can be established at any of several levels within the project and functional organization.

Figure 1.34 illustrates the construction supervisor's site organization for the construction project.

Figure 1.35 illustrates the contractor's site organization for construction projects.

1.3.2.3.4.3 WBS Dictionary WBS dictionary is a set of companion documents to WBS, that describes WBS elements in the work breakdown structure and includes:

1. Code of account identifier for each WBS element.
2. Scope description (statement of work).

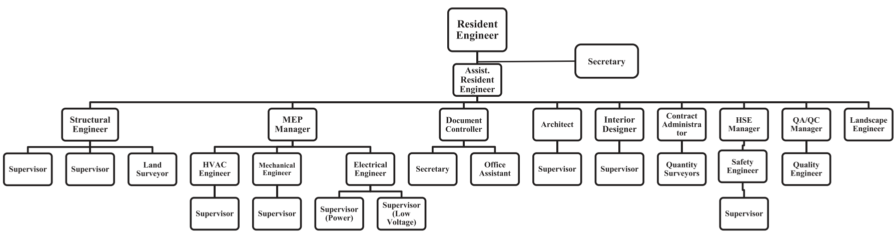


FIGURE 1.34 Construction supervisor's site organization chart.

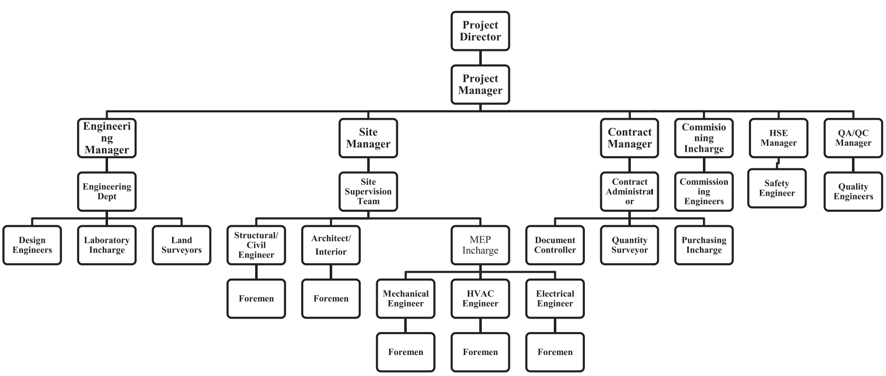


FIGURE 1.35 Contractor's site organization chart.

3. Bill of quantities.
4. Activities.
5. Schedule milestone.
6. Cost estimates.
7. Resources requirements.
8. Quality requirements.
9. Technical and other references.
10. Responsible organization/person.
11. Deliverables.
12. Contract information.

Table 1.13 illustrates an example WBS dictionary for construction project.

1.3.2.3.4.4 Responsibility Assignment Matrix (RAM) Responsibility Assignment Matrix (RAM) depicts the intersection of WBS and OBS. It identifies the specific responsibility for specific project tasks, provides a realistic picture of the resources needed, and can identify if the project has enough resources for successful completion of the project. RAM uses the WBS and OBS to link deliverables and/or activities to resources and relates the WBS element/task to the organization and the named individual responsible for the assigned scope of a control account. The following is the procedure to prepare RAM:

TABLE 1.13
WBS Dictionary

Serial Number	WBS Element	WBS Code	WBS Element Description
1	Demolition/ Site Preparation	024113	Clear and remove surface matters, windblown sand, heaps of soil or debris of any kind on the proposed roads, shoulders, side slopes and existing road and shoulder, if any, all as per specifications and drawings.
2	Cast-In-Place Concrete	033000	Plain concrete using sulfate-resistant cement including formwork and additives.
3	Concrete Unit Masonry Assembly	042200	Block work non-load bearing including control joints, filler and sealant at wall heads, mortar, anchors, reinforcement.
4	Bituminous Damp Proofing	071113	2 nos. layers of torch applied 4 mm thick waterproofing membrane, including laps and bituminous primer.
5	Plumbing System	221400	Supply, install, commission and handover water drainage system.
6	HVAC System	230593	Testing, adjusting, and balancing of HVAC.
7	Switchboards and Panelboards	262413	Supply, install, and test the following main low-tension board complete with all accessories as per the requirements of the drawings and specifications.

- Develop WBS and prepare a complete list of project deliverables.
- Identify team members who will be assigned to the project.
- Allocate responsibility to team members according to their field of competency, expertise, and required experience that will support the work to produce different project deliverables.
- Prepare the RAM.

Figure 1.36 illustrates the relation between WBS and OBS for construction projects.

The responsibility assignment matrix can be a simple tick box (check mark) or RACI type. Table 1.14 illustrates an example responsibility assignment matrix for a construction project and Table 1.15 illustrates an example RACI matrix for a construction project.

Work breakdown structure is a critical tool for organizing the work, and preparing realistic schedules and cost estimates. It helps with reporting, monitoring, and controlling the project. WBS supports integrating responsibilities for performing various work with various organizations and individuals by having a direct relationship between the WBS elements related to the identified individual through RAM.

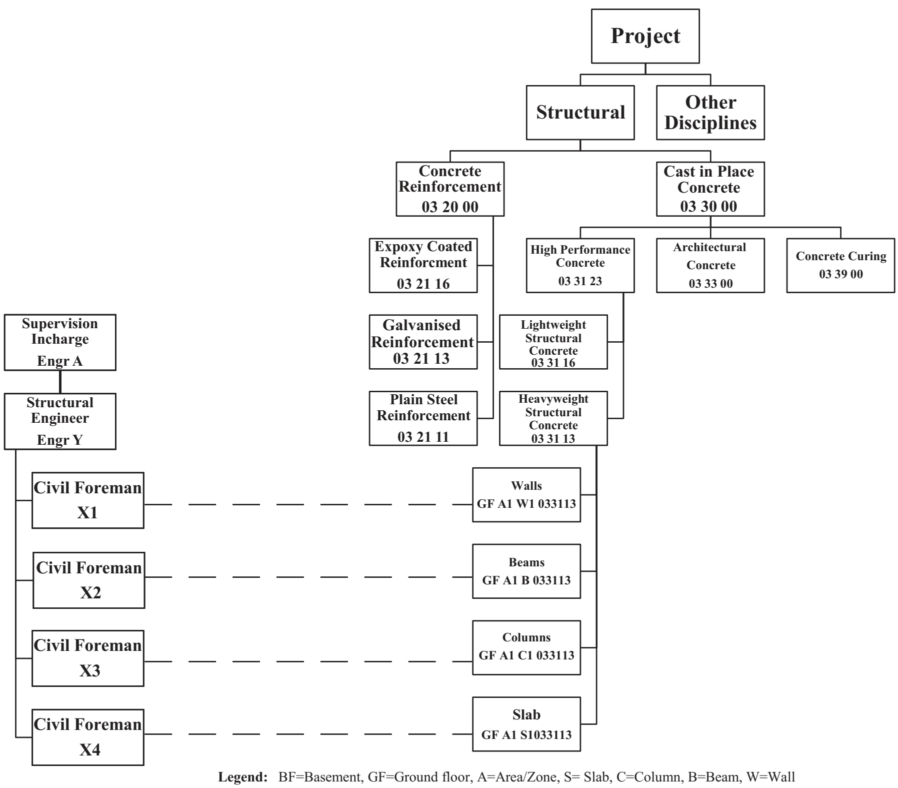


FIGURE 1.36 Relationship between WBS and OBS.

TABLE 1.14
Responsibilities Assignment Matrix

WBS Element	Office, Role, or Person				
	Owner	Resident Engineer	Planning and Control	Quality Manager	Quantity Surveyor
Notice to Proceed	X				
Approval, Permits	X				
Conduct Meetings		X			
Action on Request for Information (RFI)		X			
Project Monitoring			X		
Construction Quality				X	
Review of Progress (Interim) Payment					X

TABLE 1.15
RACI Matrix

WBS Element	Person			
	Owner	Project Manager	Consultant	Contractor
Bonds and Guarantees	I	I	A	R
Subcontractor Approval	A	C	C	R
Construction Schedule	I	C	A	R
Meetings	C	C	R	I
Submittal Logs	I	C	A	R
As-Built Drawings	I	I	A	R
Substantial completion certificate	A	C	R	I

R: Responsible, A: Accountable, C: Consulted, I: Informed

RACI:

R: Responsible: The person(s) responsible for performance of the concerned activity.

A: Accountable: The person(s) accountable for ensuring the activity is completed.

C: Consulted: The person(s) who must be consulted prior to or during the execution of the activity.

I: Informed: The person(s) who must be informed about the progress and outcome of the activity.

1.3.2.3.4.5 Scope Baseline As per PMI PMBOK, "The Scope Baseline is the approved version of a scope statement, work breakdown structure (WBS), and its associated WBS Dictionary, that can be changed only through formal change control procedures and is used as a basis for comparison."

For construction projects, the scope baseline is the technical scope baseline that describes the performance capabilities that the project must provide at the end of the construction phase to meet the owner's needs. The scope baseline is the contract documents developed by the designer based on the requirements described in the TOR. The scope baseline (contract documents) is developed based on the following construction documents that are handed over to the successful bidder:

- Working Drawings
- Technical Specifications (Particular specifications)
- Bill of Quantities (BOQ)
- General Specifications
- General Conditions
- Particular Condition

The contractor has to follow these documents for the implementation/execution of project work.

1.3.2.3.5 Validate Scope

Validate scope is the process of formalizing acceptance of completed project deliverables. It is a method to ensure that:

- Project design conforms to current applicable codes and standards.
- Project design takes care of all the requirements listed under the terms of reference.
- Assess whether value engineering analysis has been performed and the recommendations are incorporated in the project baseline.
- All the materials and equipment installed comply with specification requirements.
- All the work at the site is performed per approved shop drawings with approved material.
- Regulatory approval is obtained.
- Installed/executed work is checked and inspected at every stage to confirm that they have been installed/executed as specified, using specified and approved materials, the installation method recommended by the manufacturer, to meet the intended use of the project.
- Corrective actions or defect repairs completed.
- Inspection and tests are carried out to ascertain operational requirements.
- The work is documented, changes are recorded.
- Records of inspection and tests are maintained to verify approved construction methods and materials were used.
- Outstanding defects, work (punch list) are listed and documented.
- As-Built drawings, documents, manuals are ready for handover.
- Start-Up test plans are established to demonstrate that all the systems installed in the project meet required operations and safety requirements.
- Handover/takeover program is established.
- All the requirements for facility management are documented with all the information and knowledge that is required to strategically and physically manage the new facility.

In a construction project, the project elements (intermediate deliverables) need to be verified, reviewed, approved, and accepted at different stages of the project life cycle to ensure that completed project deliverables meet owner's needs and expectations (goals and objectives). It is the assessment of readiness of construction or execution, and to confirm the completeness and accuracy of the project as per agreed-upon scope baseline.

It is performed mainly during the following phases of a construction project:

1. Design phase.
2. Construction phase.
3. Testing, commissioning, and handover phase.

The following are the four main steps needed to establish an assessment, review, approve, and accept the project:

1. Identify the elements, items, materials, systems, and products to be reviewed and checked in each of the trades (architectural, structural, fire suppression, plumbing, HVAC, electrical, low voltage systems, landscape, external, etc.).
2. Identify the frequency of checking, inspection.
3. Identify the agency/persons authorized to check and approve.
4. Identify the indications/criteria for performance monitoring and control.

Figure 1.37 illustrates the scope validation process for construction projects.

1.3.2.3.6 Control Scope

Control scope is the process of monitoring the project scope and managing any changes to the scope baseline. It is common that despite all the efforts devoted to

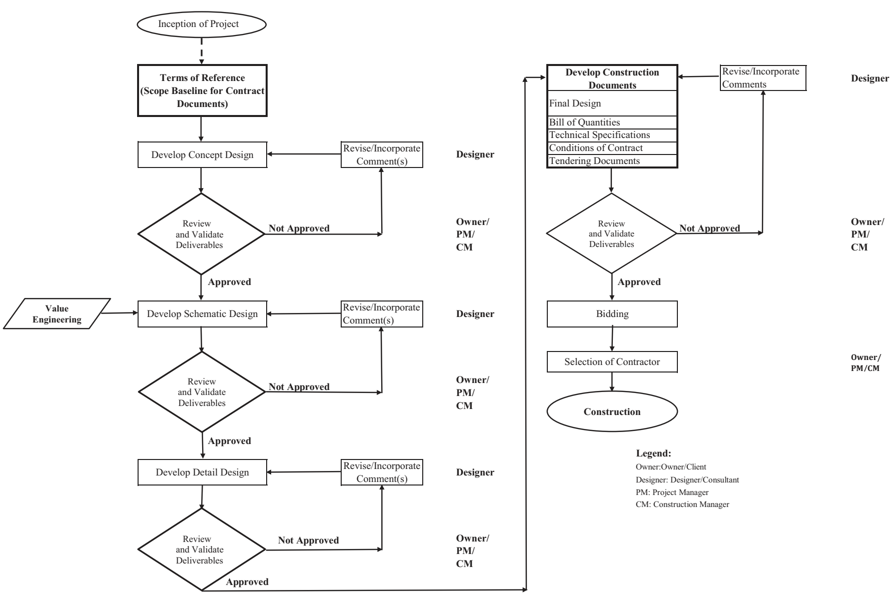


FIGURE 1.37 Scope validation process for construction projects.

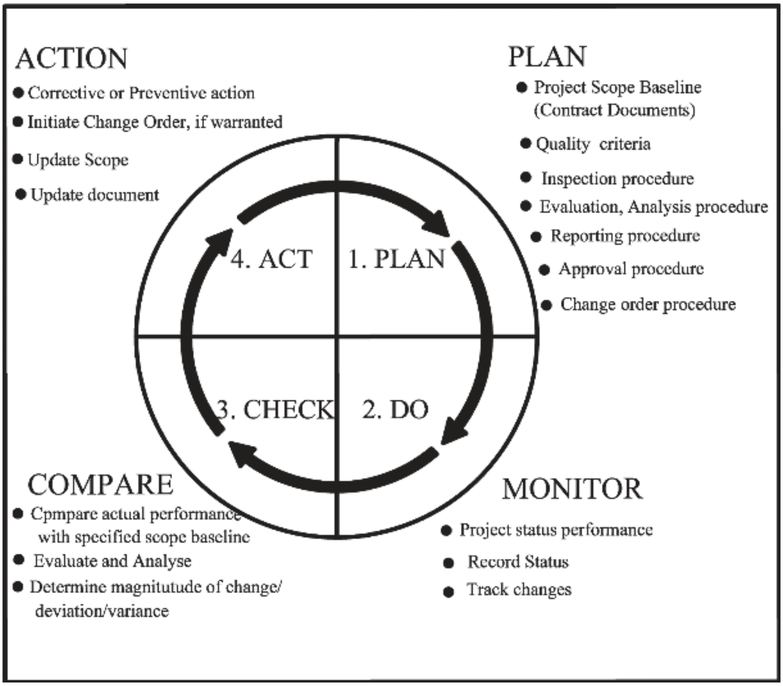


FIGURE 1.38 Scope control process.

developing the contract documents (scope baseline), the contract documents cannot provide complete information about every possible condition or circumstance that the construction team may encounter. Figure 1.38 illustrates the scope control process in construction projects.

During the construction process, circumstances may come to light that necessitate minor or major changes to the original contract. These changes may occur due to the following causes:

1. Differences/errors in contract documents.
2. Construction methodology.
3. Non-Availability of specified material.
4. Regulatory changes to use certain types of material.
5. Technological changes/introduction of new technology.
6. Value engineering process.
7. Additional work instructed.
8. Omission of some work.

Table 1.16 lists the causes of changes in construction projects.

These changes are identified as the construction proceeds. These changes or adjustments are beneficial and help build the facility to achieve project objectives. Prompt identification of such requirements helps both the owner and contractor to

TABLE 1.16
Causes of Changes in Construction Projects

Serial Number	Causes	
I	**Owner**	
	I.1	Delay in making the site available on time.
	I.2	Change of plans.
	I.3	Financial problems/payment delays.
	I.4	Change of schedule.
	I.5	Addition of work.
	I.6	Omission of work.
	I.7	Project objectives are not well-defined.
	I.8	Different site conditions.
	I.9	Value engineering.
II	**Designer (Consultant)**	
	II.1	Inadequate specifications: a. Design Errors b. Omissions
	II.2	Scope of work not well-defined.
	II.3	Conflict between contract documents.
	II.4	Coordination among different trades and services.
	II.5	Design changes/modifications.
	II.6	Introduction of latest technology.
III	**Contractor**	
	III.1	Process/methodology.
	III.2	Substitution of material.
	III.3	Non-Availability of specified material.
	III.4	Charges payable to outside party due to cancelation of certain items/products.
	III.5	Delay in approval.
	III.6	Contractor’s financial difficulties.
	III.7	Unavailability of manpower.
	III.8	Unavailability of equipment.
	III.9	Material not meeting the specifications.
	III.10	Workmanship not to the mark.
IV	**Miscellaneous**	
	IV.1	New Regulations
	IV.2	Safety Considerations
	IV.3	Weather Conditions
	IV.4	Unforeseen Circumstances
	IV.5	Inflation
	IV.6	Fluctuation in Exchange Rate
	IV.7	Government Policies

Source: Abdul Razzak Rumane. (2013). *Quality Tools for Managing Construction Projects*. Reprinted with permission from Taylor & Francis Group.

avoid unnecessary disruption of work and its impact on cost and time. The impacts and consequences of changes in the construction project vary according to:

- Type and nature of changes.
- Time of occurrence or observance of error or omission.
- Change needed for the benefit of the project.

A critical change may have a negative impact on the project baseline(s). It is important to establish a reliable change control system to manage changes to the project scope. The changes should be managed to maximize the benefits to the project and minimize the negative impacts and effects on the project. The change control system should include:

- Submission procedure.
- Evaluation and review procedure.
- Impact on project.
- Approval.
- Reporting.
- Baseline(s) updates.
- Document update.

The changes that arise during construction can be initiated by the owner, the contractor, or even by any of the stakeholders in the construction project.

Identification of discrepancies/errors and changes in the specified scope is common in construction projects. Prompt identification of such requirements helps both the owner and contractor to avoid unnecessary disruption of work and its impact on cost and time. The contractor uses the RFI form to request technical information from the supervision team. These queries are normally resolved by the concerned supervising engineer. However, it is likely that the matter has to be referred to the designer as the RFI has many other considerations to be taken care which may be beyond the capacity of a supervision team member to resolve. Normally there is a defined period to respond to the RFI. Such queries may result in variations to the contract documents. It is in the interest of both the owner and the contractor to resolve RFI expeditiously to avoid their effect on the construction schedule.

Figure 1.39 illustrates the RFI form that the contractor submits to the consultant to clarify differences/errors observed in the contract documents, changes in construction methodology, changes in the specified material, etc.

Figure 1.40 illustrates the process to resolve scope change (contractor initiated).

Figure 1.41 illustrates a variation order request form the contractor submits to the owner/consultant for approval of change(s) in the contract.

Figure 1.42 illustrates the process to resolve a request for variation (contractor initiated).

Figure 1.43 illustrates a SWI form. It gives instructions to the contractor to proceed with the change(s). All the necessary documents are sent along with the SWI to the contractor. SWI is also used to instruct contractors for owner-initiated changes.

Project Name

Consultant Name

REQUEST FOR INFORMATION (TECHNICAL)

CONTRACT NO. : ______________________ R.F.I. NO. ________

CONTRACTOR. : ______________________ DATE : ________

To: Resident Engineer ______________________

REF:

SUBJECT:

REQUEST FOR INFORMATION (Technical)

This form is used by the contractor to request information and is normally sent to the A/E who responds on the same form.

SAMPLE FORM

CONTRACTOR: ______________________

DISTRIBUTION: Employer ☐ Engineer ☐ R.E. ☐

RESPONSE BY R.E.:

Signature of R. E. ______________________ Date ________

RESPONSE RECEIVED:
FOR CONTRACTOR: ______________________ DATE: ________

DISTRIBUTION: Employer ☐ Engineer ☐ R.E. ☐

FIGURE 1.39 Request for information (RFI) form.

Similarly, if the contractor requires any modification to the specified method, then the contractor submits a request for modification to the owner/consultant. Figure 1.44 illustrates the request for modification. Usually, these modifications are carried out by the contractor, without any extra cost and time obligation toward the contract.

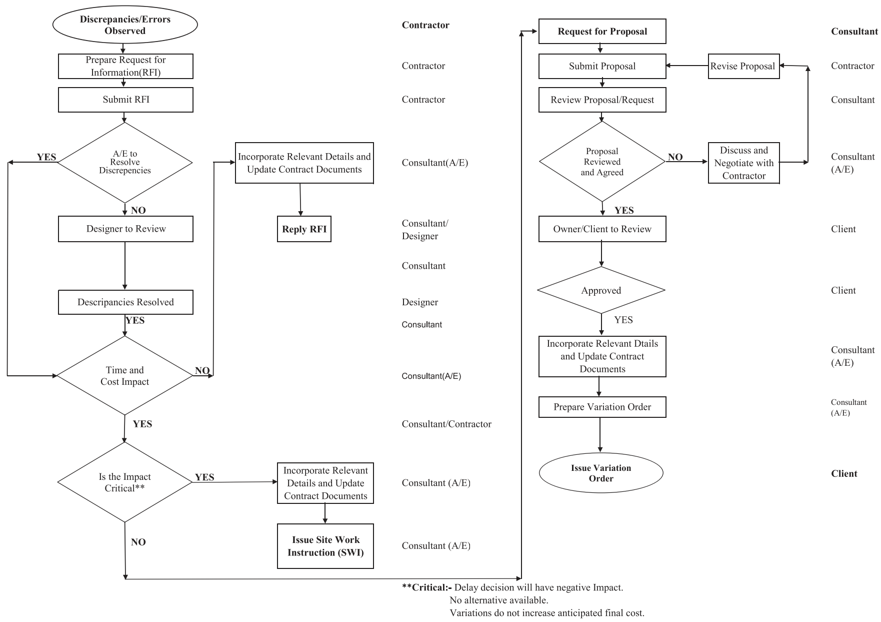


FIGURE 1.40 Process to resolve scope change (contractor initiated).

Figure 1.45 illustrates the process to resolve scope of change (owner initiated).

It is the normal practice that, for the benefit of the project, the engineer's representative assesses the cost and time related to SWI or request for changeover and obtains preliminary approval from the owner and the contractor is asked to proceed with such changes. The cost and time implementation are negotiated and formalized simultaneously/later to issue the formal variation order. In all the circumstances where a change in contract is necessary the owner's approval has to be obtained. Figure 1.46 illustrates the form used by the engineer's representative to obtain change order approval from the owner.

Once cost and time implications are negotiated and finalized and both the owner and contractor approve the same, a variation order is issued to the contractor and changes are adjusted with the contract sum and schedule. Figure 1.47a illustrates the variation order form issued to formalize the change order and Figure 1.47b illustrates the attachment to the variation order.

1.3.2.4 Project Schedule Management

Planning and scheduling are often used synonymously for preparing construction programs because both are performed interactively. Planning is the process of identifying the activities necessary to complete the project while scheduling is the process of determining the sequential order of the planned activities and the time required to complete the activity. Scheduling is the mechanical process of formalizing the planned functions, assigning the starting and completion dates to each part

Project Name
Consultant Name

REQUEST FOR VARIATION

CONTRACT NO. : ____________________ NO. : __________
CONTRACTOR: ____________________ DATE : __________

TO :

SAMPLE FORM

PROPOSED VARIATION:

☐ PRODUCT ☐ METHOD OF FABRICATION ☐ METHOD OF INSTALLATION

SPECIFIED PRODUCT ____________________
PROPOSED PRODUCT ____________________
SPEC. SECTION # __________ PAGE # __________ ARTICLE # __________
DRG REF __________ DRG # __________ REV# __________
SPECIFIED MANUFACTURER ____________________
PROPOSED MANUFACTURER ____________________
BRIEF PRODUCT DESCRIPTION ____________________
REASON FOR PROPOSED VARIATION

CHANGE IN DESIGN | REQUIRED BY AUTHORITIES | SITE CONDITIONS | SWI

COST AND TIME EFFECT

COST	NO	☐	YES	☐	AMOUNT ---------(ADDITION)
TIME	NO	☐	YES	☐	DAYS ----------

ATTACHMENTS:
1 Schedule of additions/ommissions
2 Bill Summary
3 Rate Analysis
4 Measurements

Technical and cost comparison sheets must be attached with this request, otherwise it will not be reviewed. Contractor shall fill and submit two fonnato the OWNER.
Front sheet only shall be returned to Contractor with OWNER action.

WE (THE MAIN CONTRACTOR) CERTIFIES AND UNDERTAKES THAT:

CONTRACTOR'S REP ____________________ DATE/TIME __________
RECEIVED BY A/E ____________________ DATE/TIME __________

REVIEW AND ACTION BY OWNER

☐ Approved ☐ Not Approved ☐ Approved as Noted ☐ Incomplete Data Resubmit

COMMENTS

APPROVED SUBJECT TO COMPLIANCE WITH CONTRACT DOCUMENTS

Authorised Signature __________ __________ DATE/TIME: __________

THE APPROVAL OF ANY VARIATION REQUEST SHALL BE SOLELY AT THE DIRECTION OF THE OWNER AND
SUCH APPROVAL SHALL IN NO WAY RELIEVE THE CONTRACTOR OF ANY OF HIS LIABILITIES AND OBLIGATIONS UNDER THE CONTRACT.

RECEIVED BY CONTRACTOR: ____________________ DATE/TIME: __________

cc: OWNER ☐ EMPLOYER ☐ R.E. ☐ ☐

FIGURE 1.41 Variation order request form.

or activity of the work that will be carried out in such a manner that the whole work proceeds in a logical sequence and in an orderly and systematic manner. Scheduling is a time-based graphical presentation of project activities/tasks utilizing information on available resources and time constraints. Table 1.17 illustrates the advantages of project planning and scheduling.

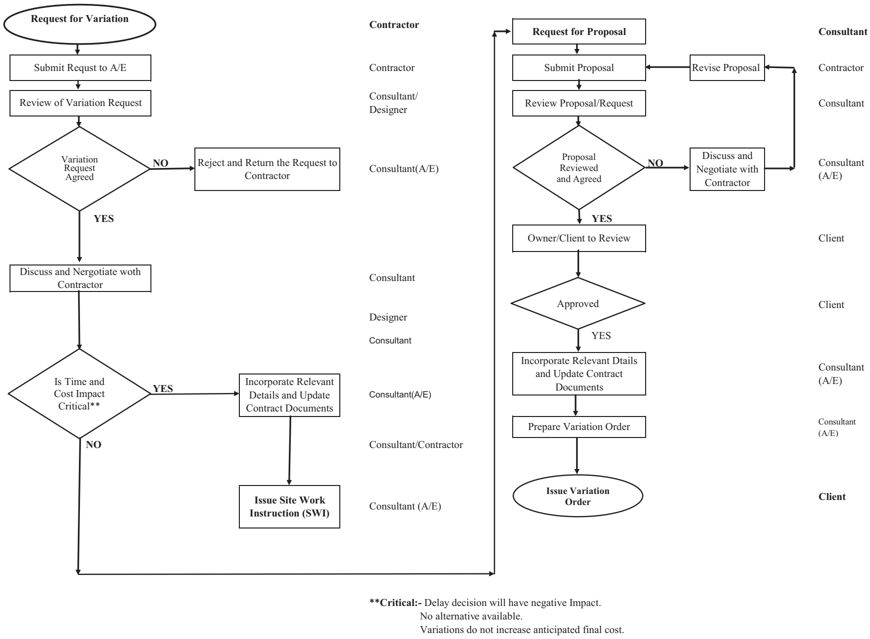


FIGURE 1.42 Process to resolve request for variation (contractor initiated).

As per the *PMBOK® Guide*, fifth edition, project time management includes the processes required to manage the timely completion of the project. Project time management consists of seven processes:

1. Plan Schedule Management
2. Define Activities
3. Sequence Activities
4. Estimate Activity Resources
5. Estimate Activity Duration
6. Develop Schedule

As per the *Construction Extension to the PMBOK® Guide*, third edition, there are three additional processes applicable for construction projects. These are:

1. Activity Weights Definitions
2. Progress Curves Development
3. Progress Monitoring

In construction project, project time management methodology can be termed schedule management having the following construction-related activities:

1. Identify Project Activities/Tasks
   1.1 Study Stage
   1.2 Design Stage

Project Name
Consultant Name

SITE WORK INSTRUCTION

CONTRACT NO. :	______	NO. :	______
CONTRACTOR :	______	DATE :	______

SUBJECT:

SITE WORK INSTRUCTION (SWI)

SAMPLE FORM

S.W.I. involves an anticipated change in the work. All S.W.I. must be authorize and signed by the Owner Representative OR Authorised Signatory.

A S.W.I. is an instruction to the contractor to proceed prior to the issuing of a Variation Order (V.O.). Whenever time allows, a V.O. will be issued instead of S.

Owner Rep. Signature **Date**

THIS SITE WORKS INSTRUCTION (S.W.I.) IS A NOTICE TO PROCEED AND MAY INVOLVE CHANGE IN COST AND OR TIME. YOU ARE REQUIRED TO ADVISE THE ENGINEER WITHIN 14 DAYS OF ANY ADDITIONAL COST AND OR TIME REQUIRED TO COMPLY WITH THIS INSTRUCTION.

RECEIVED FOR CONTRACTOR: ______ **DATE:** ______

DISTRIBUTION: Owner ☐ Engineer ☐ R.E. ☐

FIGURE 1.43 Site work instruction (SWI) form.

  1.3 Bidding and Tendering
  1.4 Construction Stage
2. Sequence Project Activities
  2.1 Study Stage
  2.2 Design Stage

Project Name
Consultant Name

REQUEST FOR MODIFICATION
(AT NO EXTRA COST & OR TIME TO THE EMPLOYER)

CONTRACTOR : ____________ DATE : ________
CONTRACT NO : ____________ NO : ________

TO : Owner Name **CC:** **A/E** ☐

PROPOSED MODIFICATION TO:
☐ DESIGN DRAWING ☐ METHOD OF FABRICATION ☐ METHOD OF INSTALLATION
DESIGN DRAWING NO ____________
SECTION # ____________
CONTRACTOR'S PROPOSED DRAWING NO. ____________
REASON FOR MODIFICATION ____________

COST AND TIME SAVINGS *At no extra cost and or time to the Employer*
COST NO ☐ YES ☐ AMOUNT ------- (DEDUCTION) ________
TIME NO ☐ YES ☐ DAYS

ATTACHMENTS:
Supplier confirmation letter

SAMPLE FORM

CONTRACTOR'S REP ____________ DATE/TIME ________
RECEIVED BY A/E ____________ DATE/TIME ________

REVIEW AND ACTION BY OWNER
☐ Approved ☐ Not Approved ☐ Approved as Noted ☐ Incomplete Data Resubmit
COMMENTS

Authorised Signatories ____________ DATE/TIME: ________

RECEIVED BY CONTRACTOR: ____________ DATE/TIME: ________
cc: Owner ☐ Engineer ☐ R.E. ☐ ☐

FIGURE 1.44 Request for modification form.

2.3 Bidding and Tendering
2.4 Construction Stage
3. Develop Project Network Diagram
3.1 Study Stage
3.2 Design Stage

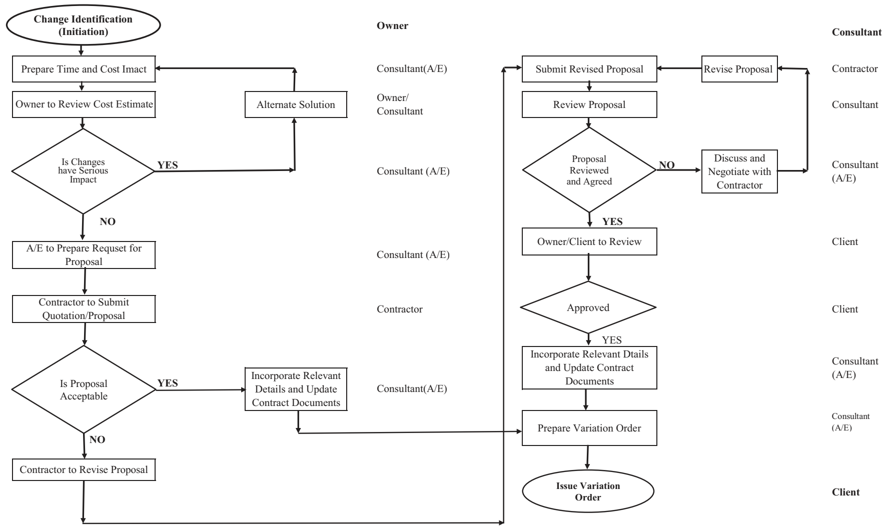


FIGURE 1.45 Process to resolve scope of change (owner initiated).

3.3 Bidding and Tendering
3.4 Construction Stage
4. Estimate Activity Resources
4.1 Study Stage
4.2 Design Stage
4.3 Construction Stage
5. Estimate Activity Duration
5.1 Study Stage
5.2 Design Stage
5.3 Bidding and Tendering
5.4 Construction Stage
6. Develop Schedule
6.1 Project Master Schedule (Project Life Cycle)
6.2 Design Development Schedule
6.3 Construction (Project) Schedule (Tendering Documents)
6.4 Contractor's Construction Schedule
6.4.1 Detailed Schedule
6.4.2 Monthly Schedule
6.4.3 Weekly/Biweekly Schedule
6.4.4 Look Ahead (15 Days)
7. Analyze Schedule
8. Project Schedule (Schedule Baseline)
9. Monitor and Control Schedule
9.1 Schedule Monitoring
9.2 Progress Status
9.3 Progress Reporting

Project Name
Consultant Name

VARIATION ORDER PROPOSAL (VOP)

CONTRACT NO: ______________________ VOP No. ____________

CONTRACTOR: ____________ Date: ______________

The "Employer" decision is requested for approval / rejection of this Variation Order Proposal as described below. Should the VOP be approved by the "Employer" an order to proceed shall be issued to the Contractor for his further action.

INITIATED / PROPOSED BY:

☐ ENGINEER ☐ ENGINEER'S REP. ☐ CONTRACTOR ☐ OTHERS

REASONS:

☐ CHANGE IN DESIGN ☐ SWI ....

☐ REQUIRED BY AUTHORITIES ....

☐ REQUIRED BY SITE CONDITIONS

BRIEF DESCRIPTION & LOCATION:

SAMPLE FORM

BASIS OF V.O. EVALUATION:
PRORATA BOQ PRICES: ☐

PROPOSAL from CONTRACTOR: ☐

APPROXIMATE COST IMPACT __________________ APPROXIMATE % _________

APPROXIMATE TIME IMPACT __________________ ANY DELAY _________

RELATED REFERENCES:

ENGINEER'S RECOMMENDATION:

RESIDENT ENGINEER'S SIGNATURE ____________ DATE: ____________

Distribution: ☐ Employer ☐ Engineer ☐ Resident Engineer ☐

FIGURE 1.46 Change order approval form.

9.4 Forecasting
9.5 Schedule Update
9.6 Schedule Control
9.7 Performance Reporting

Figure 1.48 illustrates the schedule development process.

Project Name
Consultant Name

VARIATION ORDER (VO)

CONTRACT NO. :________________ V.O. NO. :________

CONTRACTOR ________________ DATE :________

In accordance with clause ----- of Document ---- Conditions of Contract, you hereby ordered to undertake work and/or amend the Contract as detailed below:

DESCRIPTION OF WORK

SAMPLE FORM

According to Clause ---------, Extension of Time for Completion and Valuation of V.O. are as follows:

Original Contract Price: ________	Contract Completion Date: ________
Previous Vos: ________	Previous Extension(s): ________
Value This VO: ________	Extension This VO: ________
Revised Contract Price: ________	Revised Completion Date: ________

We the undersigned Contractor hereby agree to carry out the works as ordered by this Variation Order and accept in full and final settlement of all related consequential costs and time

Recommended by Resident Engineer	Agreed by Contractor
Recommended by Engineer	Agreed by Employer

Distribution ☐ Employer ☐ Engineer ☐ Resident Engineer ☐ Contractor

FIGURE 1.47A Variation order form.

1.3.2.4.1 Identify Project Activities

Project activities are the lowest level of the work breakdown structure evolved from the decomposition of the work package. Each project activity has a specific duration in which the activity is performed (started and completed). The project activity consumes time (duration), consumes resources, has a definable start and finish, is

Project Name
Consultant Name

ATTACHMENT TO VARIATION ORDER

CONTRACTOR: ______________________________CONNTRACT No.: _________________

V. O. No. ______________ Date: _______________

1. Site Works instructions incorporated into this Variation Order:

2. Previous correspondence references (attached):

SAMPLE FORM

3. Revised Drawings and Specifications (attached):

4. Schedule of Omissions/Additions:

5. Rate Analysis for New Items:

FIGURE 1.47B Attachment to variation order.

associated with cost, and is easy to monitor and manage. It is assignable, measurable, and quantifiable. In construction projects, the terms "project activities" and "project tasks" are used interchangeably. The definition of project activity is an important factor for identification and documentation. Many of the activities are repeated in construction projects but their use and performance requirements are different. For example, pipes can be water system pipes, firefighting system pipes, or pipes for

TABLE 1.17
Advantage of Project Planning and Scheduling

Serial Number	Advantages
1	It facilitates management by objectives.
2	It facilitates execute the work in an organized and structured manner.
3	It eliminates or minimizes uncertainties.
4	It reduces risk to the minimum.
5	It helps proper coordination.
6	It helps integration of project activities for smooth flow of project work.
7	It helps reduce rework.
8	It improves the efficiency of the process and increase productivity.
9	It improves communication.
10	It establishes timely reporting system.
11	It establishes the duration of each activity.
12	It provides basis for monitoring and controlling of project work.
13	It helps to establish benchmark for tracking the quantity, cost, and timing of work required to complete the project.
14	It helps foresee problems at early stage.
15	It helps to know the responsibility and authority of people involved in the project.

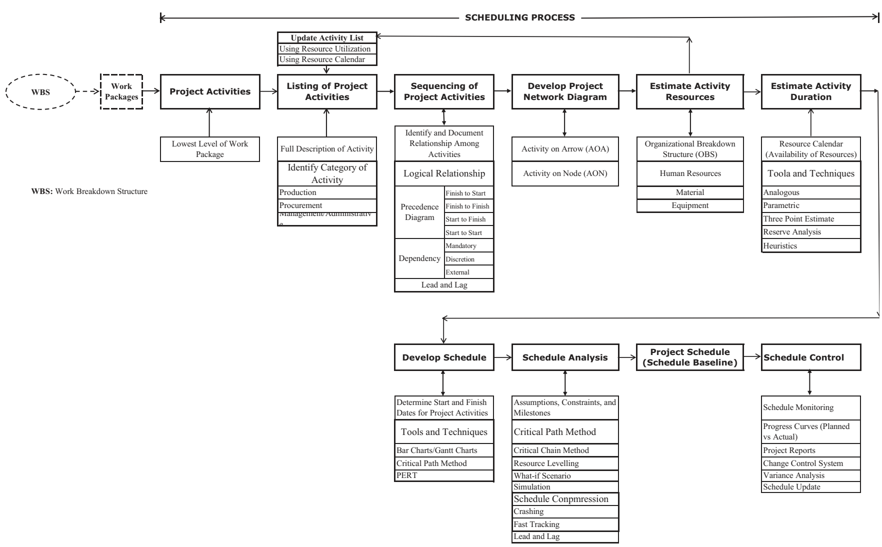


FIGURE 1.48 Schedule development process.

chilled water in the HVAC system, therefore proper identification and documentation of specific activity is important. Activities are normally categorized into three types. These are:

1. Management/Administrative
2. Procurement
3. Production

Figure 1.49 illustrates example project activities and codes of a construction project. The activity categories are as follows:

- Administration/Management
- Submittal
- Approval
- Procurement
  Procurement
- Production
- Install
- Testing

The activity code ID is developed taking into consideration the following:

- L: General
- A: Submittal
- W: Women
- CSI Division and Subdivisions

1.3.2.4.2 List Project Activities (Bill of Quantities)

An activity list is a tabulation of activities to be performed in the project and is to be included in the project schedule. An activity list should contain the following information related to an activity:

- Activity name.
- Activity identification number.
- Brief description of the activity.

The list of activities is known as the Bill of Quantities (BOQ). BOQ is an itemized listing of project-specific activities identified by the drawings and specifications prepared by the designer/quantity surveyor (consultant) to meet the project objectives. The quantities may be measured in number, length, area, volume, weight, and time depending upon the scale of unit required to define the activity. BOQ is basically listed under different trades the activity/task belongs. BOQ is frequently used to:

- Develop total estimate of the project.
- Develop bidding documents.

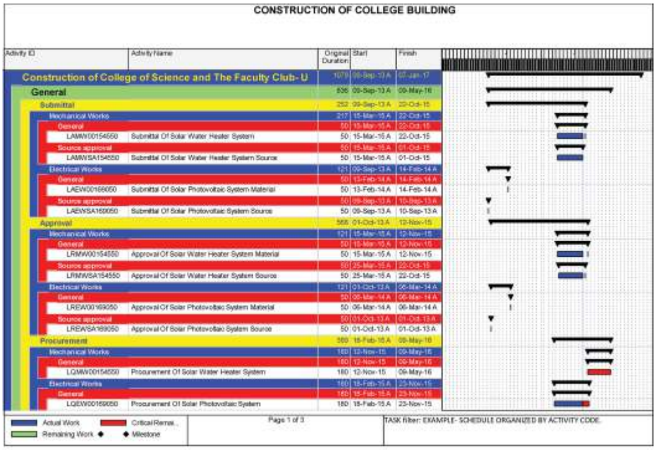
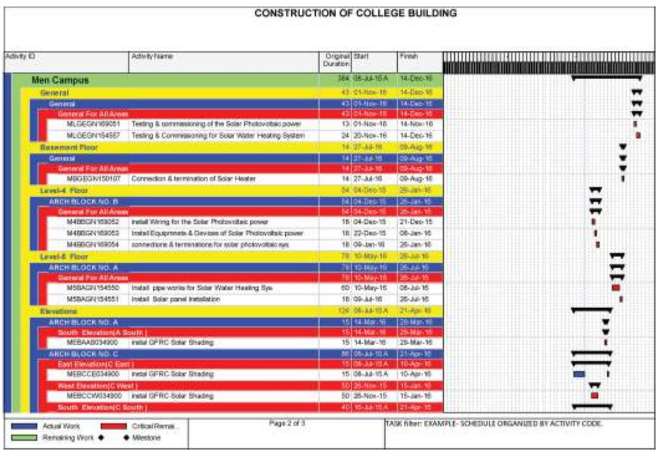


Figure 1.49
Project Activities and Codes



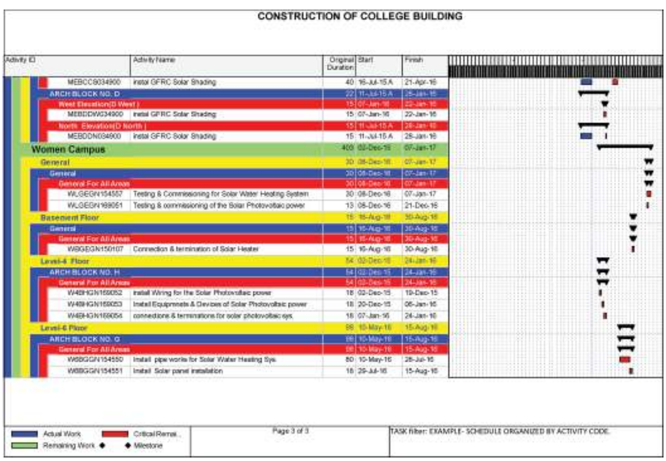


FIGURE 1.49 Project activities and codes.

- Monitoring the progress of the project.
- Making progress payments.

Table 1.18 is an example BOQ for concrete in a construction project.

1.3.2.4.3 Sequence Project Activities

Once project activities/tasks have been defined and listed, it is required to identify the relationship and dependency among the project activities. The activities may have a direct relationship or may be further constrained by an indirect relationship. The following are direct logical relationships or dependencies among project-related activities:

- **Precedence**
  - Finish-To-Start: Activity A must finish before activity B can begin.
  - Start-To-Start: Activity A must start before activity B can start.
  - Finish-To-Finish: Activity A must finish before activity B can finish.
  - Start-To-Finish: Activity A must start before activity B can finish.
- **Dependency**
  - **a. Mandatory**
    - Inherent in the nature of work being performed. It is also called hard logic. In building construction, the superstructure can't begin unless the foundation work is complete.
  - **b. Discretionary**
    - These are preferred or preferential logic. These are used at the discretion of the project team. It is also called soft logic.
  - **c. External**
    - These dependencies are outside of the project's control. For example, approval from a regulatory authority/agency.
- **Lead and Lag**

Lead may be added to start an activity before the predecessor activity is completed (a jump of the successor activity), while lag is the inserted waiting time (time delay) between activities. Lead allows the acceleration of successor activity, and lag delays in the start of successor activity. For example, concrete curing time is added before the start of tiling work.

- **Relationship**
  - **a. Predecessor**
    - The relationship as to which activity must occur "before" the other.
  - **b. Successor**
    - The relationship as to which activity must occur "after" the other.
  - **c. Concurrent**
    - When one activity can occur "at the same time" as the other.

Figure 1.50 a) illustrates activity relationship diagrams and b) illustrates dependency relationship diagrams.

TABLE 1.18
BOQ Form

Owner Name

Project Name

Project Number:

ITEM	DESCRIPTION	QTY.	UNIT	RATE	AMOUNT
	DIVISION 3—CONCRETE				
	The contractor is referred to the specifications and drawings for all details related to this section of the work and he/she is to include for complying with all the requirements contained therein, whether or not they are specifically mentioned within the item descriptions.	SAMPLE BOQ			
	03300: CAST-IN-PLACE CONCRETE				
	SUBSTRUCTURE				
	Plain concrete 17.5MPa using sulfate-resisting cement (Type V), including formwork and additives.				
A	100mm Blinding	411	m3		
	Plain concrete 17.5MPa using ordinary Portland cement (Type I), including formwork and additives.				
B	Concrete Filling	55	m3		
C	To kerb Foundation	19	m3		
	Reinforced concrete 28MPa using sulfate-resisting cement (Type V), including formwork, reinforcement, water stops, expansion and construction joints, joint filler, and additives.				
D	Raft Foundation	5,006	m3		
E	300mm Walls	51	m3		
F	400mm Ditto	66	m3		
	CARRIED TO COLLECTION				

ITEM	DESCRIPTION	QTY.	UNIT	RATE	AMOUNT
	DIVISION 3—CONCRETE				
	03480: PRECAST CONCRETE SPECIALTIES				
	Depressed curbs including reinforcement, finish, anchors, fixings, grouting, fair face finish, and painting.	SAMPLE BOQ			
A	250 x 180mm Barrier Curb	200	m		
B	Ditto, Curve on Plan	52	m		
C	350 x 150mm Flush Curb	21	m		
	Wheel stoppers, fair face finish, and painting.				
D	2000 x 140 x 100mm Overall Size, Parking Area	548	no		

(*Continued*)

TABLE 1.18 Continued

BOQ Form

Owner Name

Project Name

Project Number:

	03520: LIGHTWEIGHT CONCRETE				
	Lightweight concrete laid in bays of 25m2 minimum, maximum length of bay 7m, and expansion joints filled with impregnated compressible foam and resilient packing.				
E	50mm Thick, Laid to Falls, to Roof	282	m2		
F	170mm Thick, Laid to Falls, to Pathways	6,189	m2		
	CARRIED TO COLLECTION				

ITEM	DESCRIPTION	QTY.	UNIT	RATE	AMOUNT
	DIVISION 3—CONCRETE				
	03530: CONCRETE TOPPING/SCREED				
	Plain concrete grade 30MPa using ordinary Portland cement (Type I), including expansion joints, formwork, construction joints, additives, and joint filler.				
A	50–100mm average thickness, including welded wire fabric, to driveways, to receive polyurethane coating.	20,017	m2		
B	Ditto, Ramps	1,323	m2		
C	80mm Thick, to Pathway, to Receive Polyurethane Coating	5,748	m2		
D	Ditto, Ramps	441	m2		
E	100mm Thick, to Receive Ceramic Floor Tiles	329	m2		
F	180mm Thick, to Receive Stone Flooring	550	m2		
G	50mm Thick, to Receive Terrazzo Floor Tiles	172	m2		
	03535: SAND CEMENT SCREED				
H	20mm Thick, to Roof	282	m2		
J	25mm Thick, to Receive Terrazzo Floor Tiles, to Pump Station	48	m2		
K	50mm Screed, to Protect Horizontal Waterproofing	3,973	m2		
	CARRIED TO COLLECTION				

SAMPLE BOQ

ITEM	DESCRIPTION	AMOUNT
	DIVISION 3—CONCRETE	
	COLLECTION	
	Total of page No. 3/1	
	Total of page No. 3/2	
	Total of page No. 3/3	
	CARRIED TO SUMMARY	

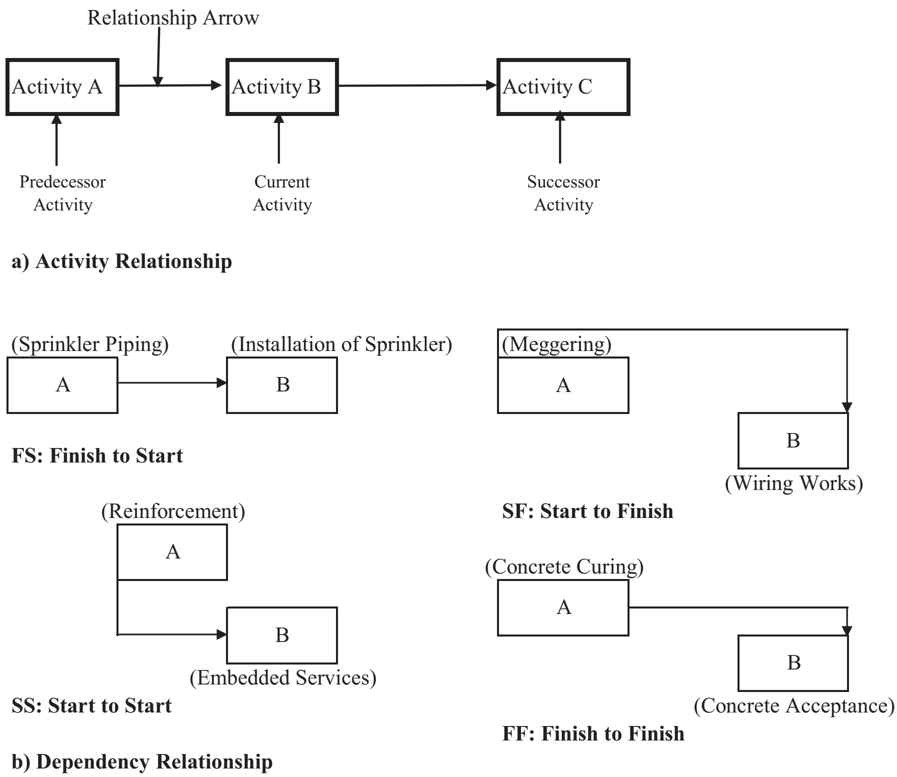


FIGURE 1.50 a) Activity relationship and b) dependency relationship.

1.3.2.4.4 Develop Project Network Diagram

A network diagram is a schematic display of project activities indicating logical relationships among the activities. It shows how the work progresses from the start till the completion of the project. There are two methods typically used to prepare the network diagram. These are:

1. Activity-On-Arrow (AOA)
2. Activity-On-Node (AON)

Activity-On-Arrow: Arrow diagrams or AOA is a diagramming method to represent the activities on arrows and connect them at nodes (circles) to show the dependencies. With the AOA method, the detailed information about each activity is placed on an arrow or as footnotes at the bottom.

Figure 1.51 illustrates the activity-on-arrow diagramming method for concrete foundation work.

Activity-On-Node: "Activity-On-Node" network diagram has the activity information written in a small box that is the nodes of the diagram.

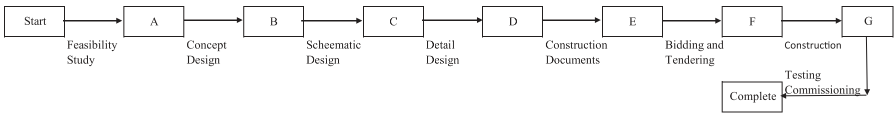


FIGURE 1.51 Activity-On-Arrow relationship.

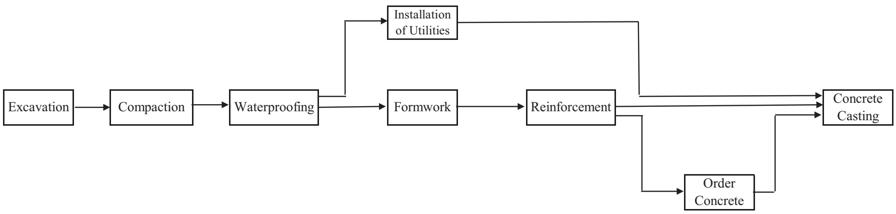


FIGURE 1.52 Activity-On-Node relationship.

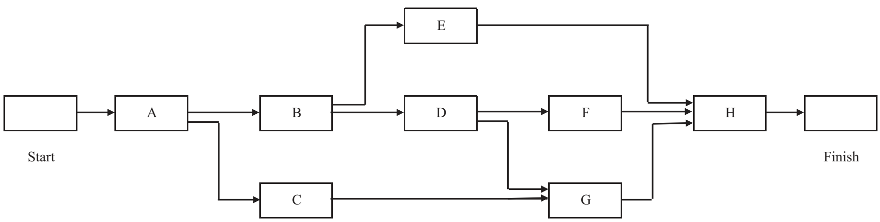


FIGURE 1.53 Precedence diagramming method.

> Arrows connect the boxes to show the logical relationships between pairs of activities.

Figure 1.52 illustrates the activity-on-node diagramming method for concrete foundation work.

"Activity-On-Node" (AON) is also referred to as the PDM (precedence diagramming method) technique because it shows the activities in a node (box) with arrows showing dependencies. Figure 1.53 illustrates the precedence diagramming method (PDM). PDM is used to establish precedence relationships or dependencies (sequencing of activities) and also in the Critical Path Methodology (CPM) for constructing the project schedule network diagram.

1.3.2.4.5 Estimate Activity Resources

It is the identification and description of types and quantities of resources required to perform the activity/task. Resource estimates are made by the project team based on the resource productivity, related experience, and availability of resources to carry out a particular activity/task. Efficient utilization of resources is critical to a successful project. The organizational breakdown structure is used to determine the related resources for a particular activity. There are different types of resources required in a certain quantity to perform and complete the activity. These are:

- Human Resources (Manpower)
- Equipment
- Material

In construction projects, the availability of subcontractors (sub-consultants, subcontractors for designated works) is also to be considered while estimating the resources to perform the work.

While estimating the resources, the following points should be considered:

- Availability of particular resource (resource histogram).
- Availability of the exact number of resources.
- Identification of the required skill (manpower) to perform the assigned activity/task.
- Availability of specific types of equipment and the installation/operating crew.
- Availability of space to perform certain types of activity simultaneously with other activities.
- Availability of specified material.
- Availability of funds to perform the activity.

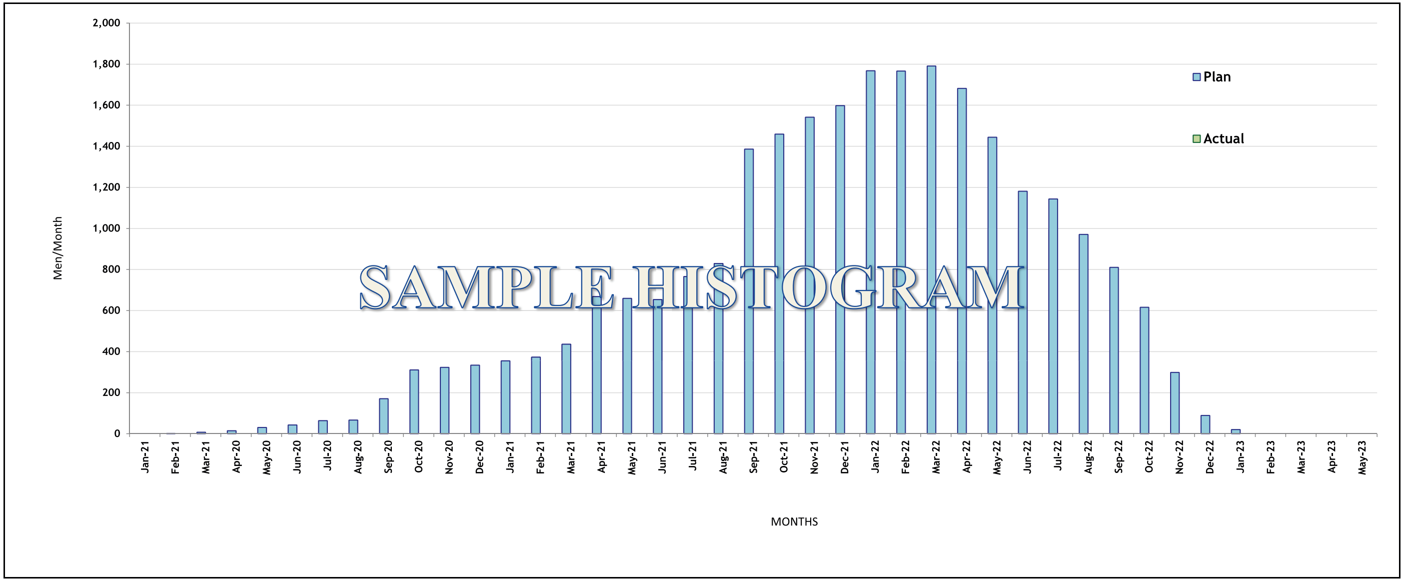
Figure 1.54 illustrates resource estimation (manpower histogram) for a construction project.

1.3.2.4.6 Estimate Activity Duration

Once the activities/tasks are sequenced, the types and quantities of resources are identified and determined as it is required to estimate the amount of time required to complete each activity, in order to enable the preparation of the schedule.

Activity duration is the time between the start and finish of an activity/task. Estimation of activity duration is important to approximate the amount of time or period required to complete all project activities with the available resources. The following points are to be considered while estimating the activity duration:

- Work methodology.
- Nature of work.
- Resource (labor, equipment) type and availability.
- Resource (labor, equipment) productivity.
- Resource calendar.
- Time contingency.
- Quantum of work.
- Quality of work.
- Environmental factors.
- Weather conditions.
- Organizational factors.
- Work restriction.



	0	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20
	Jan-21	Feb-21	Mar-21	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21
Plan		2	8	14	30	43	64	67	171	311	324	334	355	373	436	668	659	653	766	829	1,386
Actual																					

	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36	#REF!	#REF!	#REF!	#REF!
	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23
Plan	1,459	1,541	1,598	1,768	1,767	1,791	1,682	1,444	1,181	1,144	971	810	616	299	89	20				
Actual																				

FIGURE 1.54 Resource estimation.

There are several tools and techniques that are used to estimate activity duration. The following are the basic techniques most widely used by project professionals to estimate activities to prepare the schedule:

1. Expert Judgment
   - Expert judgment is normally from the project members having expertise in the subject matter. It is a mix of historical information from previous projects. It also uses a published database about duration estimation.
2. Analogous Estimating
   - This technique uses information from previous projects of similar nature and size. It is also known as top-down estimation.
3. Parametric Estimating
   - This technique uses mathematical, statistical, or quantitative relationships to estimate activity duration. This method has better accuracy than that of expert judgment and analogous estimation techniques.
4. Three-Point Estimating
   - This technique is used to estimate the duration for an activity having a higher risk and not known very well. The following formula is used to calculate activity duration:
     Activity Duration = (P+4M+O)/6
     Where P is Pessimistic (worst-case scenario),
     M is Most Likely (realistic), and
     O is Optimistic (best-case scenario).
     To calculate the installation of block masonry work per square meter by a crew of one mason and two laborers, the following assumptions can be made:
     Pessimistic—35 square meters per crew per day.
     Most likely—20 square meters per crew per day.
     Optimistic—15 square meters per crew per day.
     Therefore, the estimated duration per crew per day is:
     Te = (35 + 4 * 20 + 15)/6 = 21.67, say 22 square meters.

If the activity is well-known with little risk, then it is possible to estimate the duration of an activity by using the available information from the organization's database. This technique is known as a "one-time estimate."

1.3.2.3.7 Develop Schedule

Once activity resources and activity duration are estimated, it is possible to determine the start and finish dates for each activity. Thus, by sequencing all the activities, the overall project schedule can be developed showing the start and finish of the project. Project schedule is a calendar-based graphical representation of all the activities that need to be performed in order to achieve project scope objectives. A schedule is one of the critical elements for successful management of a project. In order to develop a schedule, the following information is required:

1. Project scope statement (assumptions, milestones, constraints).
2. Activities list.

3. Network diagram.
4. Resources needed.
5. Duration for each activity.
6. Resource calendar (availability of resources).
7. Working calendar.

There are various methods used to develop project schedules. The following methods/tools are used to develop the project schedule:

- Gantt or Bar Charts
- Bar charts area graphical presentation of project schedule information by listing the project activities on the vertical axis and showing the corresponding start and finish date on the horizontal axis as well as expected duration in a calendar format. Bar chart method was developed by Henry Gantt in 1917 by listing the activities on a time scale by drawing in the bar chart format.
- Critical Path Method (CPM)
- The critical path is the longest path through a network, hence it is the shortest project time. The critical path method was developed by DuPont and Remington Rand in 1958. It was developed for industrial projects (maintenance programs for chemical plants), where activity durations are generally known. CPM is a network diagramming technique use to predict total project time. CPM identifies the activities in the critical path that are likely to affect the completion of project duration as required. There could be more than one critical path if the lengths of two or more paths are the same. The critical path can change as the project progresses. CPM is represented by the following types of network diagrams:
  1. Activity-On-Arrow
  2. Activity-On-Node
- Project (Program) Evaluation and Review Technique (PERT)
- PERT is a project management tool used to schedule, organize, and coordinate activities/tasks within the project. PERT was developed by the US Navy for the Polaris missile project (program). It was developed for R&D projects where activity times are generally uncertain. PERT is a flow chart diagram that depicts the sequence of activities needed to complete the project and the time or cost associated with each activity. It uses a three-point estimation formula {Estimated time Te = (To + 4Tm + Tp)/6} to calculate the expected activity duration. Where **To** is an optimistic estimate, **Tm** is the most likely estimate, and **Tp** is a pessimistic estimate.

CPM and PERT tools are also known as mathematical techniques.

Bar chart or Gantt chart and critical path method (network diagramming or precedence diagramming network) scheduling techniques are the most commonly used techniques to develop project schedules.

The following are the terminologies used to prepare network diagramming:

- **Activity Block:**

The activity block is a graphic display of activity information.

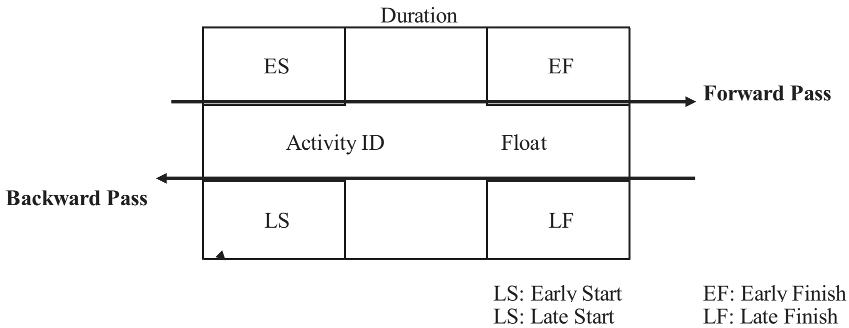


FIGURE 1.55 Activity block.

Figure 1.55 is an illustrative block showing the related information about an activity.

- **Early Start (ES):** The earliest date an activity can start.
- **Early Finish (EF):** The earliest date an activity can finish.
- **Late Start (LS):** The latest date an activity can start.
- **Late Finish (LF):** The latest date an activity can finish.
- **Duration:** Number of working days or hours needed to perform the specific activity.
- **Milestone:** It is a specific point (s) having significant importance shown in the project schedule having no duration.
- **Forward Pass:** Forward pass is used for calculating early start and early finish of each activity.
- **Backward Pass:** Backward pass is used for calculation late start and late finish of each activity.
- **Float:** Float (Slack) is the measure of time the work can be delayed without delaying (affecting) the project completion date.

Table 1.19 is an illustrative example of activities for the construction of a substation building. Figure 1.56 illustrates the schedule for the construction of a guardhouse building using Gantt chart/bar chart format whereas Figure 1.57 shows the CPM diagram for construction of the guardhouse building.

Advantages of CPM:

1. It shows a logical relationship between activities and their interdependence.
2. It is easy to understand the activity's relationship.
3. It identifies the activities that are critical to the timely completion of the project.
4. It shows the minimum completion time for completion of the project.
5. It clearly demonstrates how a change in one activity impacts other activities in the schedule.
6. It enables easy calculation of the shortest time to complete the project.

TABLE 1.19
Activities for Construction of Guardhouse Building

Activity Number	Description of Activity	Duration in Days	Preceding Activity
1	Start	0	
2	Mobilization	21	1
3	Preparation of Site	15	2
4	Staff Approval	15	2
5	Material Approval	15	2,4
6	Shop Drawing Approval	15	2,5
7	Procurement (Structural work)	15	5
8	Procurement (Pipes, Ducts, Sleeves)	7	5
9	Procurement (Security System Equipment)	60	5
10	Procurement (Civil, MEP, Furnishing)	30	5
11	Excavation	4	3,6
12	Blinding Concrete	4	5,7,11
13	Raft Foundation	7	5,6,7,12
14	Utility Services (Embedded)	4	8,12
15	Raised Flooring	3	13,14
16	Concrete (Floor)	1	6,13,14,15
17	Embedded Services	2	8,13
18	Walls and Columns	7	16
19	Form Work for Slab	3	6,7,18
20	Reinforcement	2	7,19
21	Embedded Services for Security System	1	8,19
22	Concrete (Roof Slab)	1	20,21
23	Masonry Work	14	6,10,22
24	Cabling for Security System	3	15,17,21
25	Installation of CCTV, Access Control System	7	9,21,24
26	Installation of Electromechanical Items	14	6,10,22,23
27	Installation of Ventilation System	4	10,22,23
28	Finishes	7	10,23
29	Installation of Final Fixes	3	10,28
30	Furnishing	2	10,28
31	Testing of Security System	3	25
32	Testing of HVAC, Firefighting, Electrical System	4	25,26,27
33	Handing Over	1	29,30,31,32
34	End	0	

Note: The duration is indicative only to understand sequencing and the relationship of activities.

7. It provides accurate and detailed pictures of forecasted project completion dates.
8. It is easy to apply resources and determine resources or time trade-offs.
9. It shows how much float other activities have.
10. It is easy to assign lead and lag between two activities to solve a dead time problem.

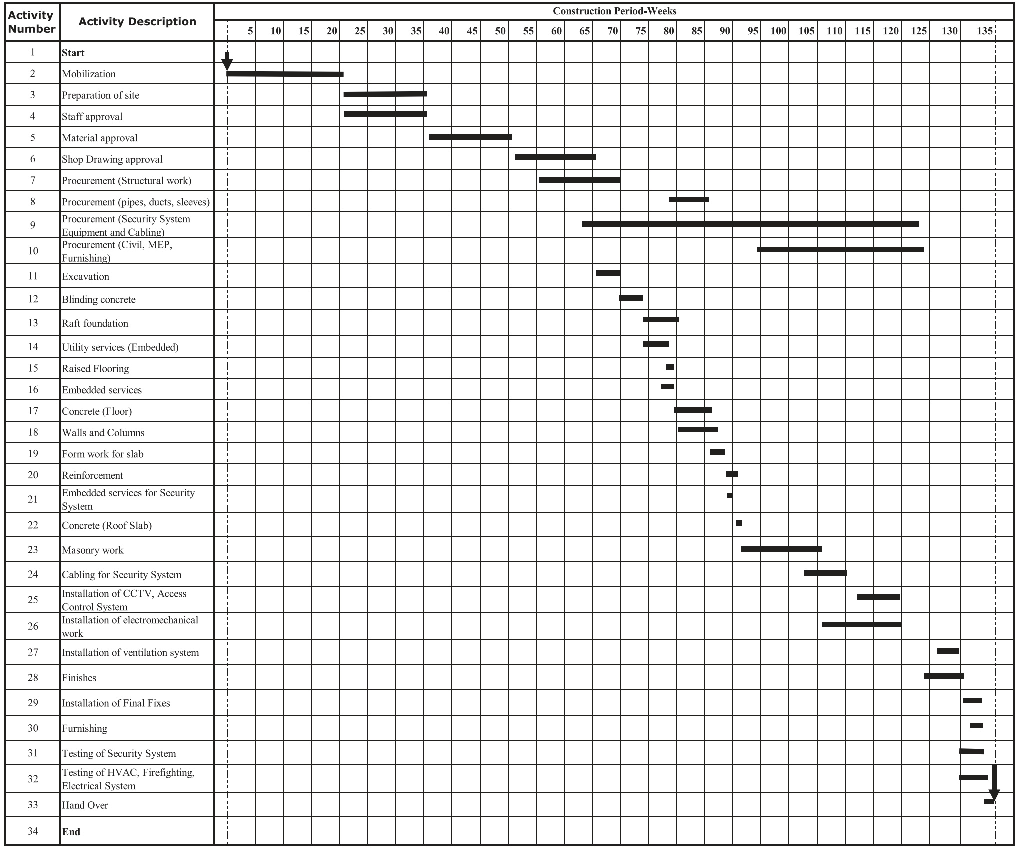


FIGURE 1.56 Bar chart schedule for guardhouse building.

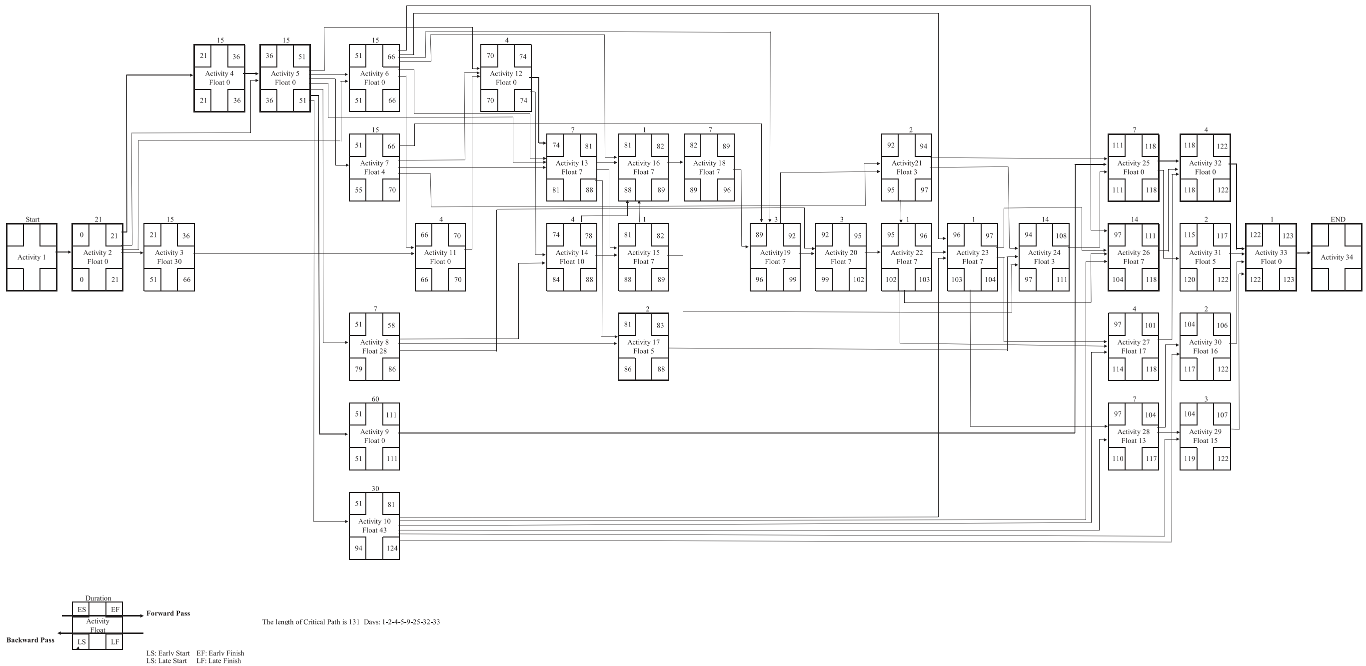


FIGURE 1.57 CPM diagram for guardhouse building.

1.3.2.4.8 Analyze Schedule

Once the basic schedule is developed, it needs to be reviewed and analyzed to make sure the timing of each activity is aligned with resources and to ensure schedule accuracy with the relevant assumptions, constraints, and milestones. Scheduling is an iterative process. If the results obtained with the creation of the schedule match with project requirements, the iteration must stop. Otherwise, the schedule has to be reviewed and analyzed by adjusting the dependencies and resources. Schedule analysis is important to determine schedule accuracy and create a project schedule (schedule baseline). The following points should be considered to develop an accurate and realistic baseline schedule:

1. All the activities are properly identified and listed to meet the scope of work.
2. Project logic dependencies and relationships are properly considered while sequencing the activities to be performed.
3. All the resources and durations are correctly estimated.
4. Sufficient resources have been identified and allocated.
5. Assumptions and constraints are sound and true.
6. Schedule reserves/contingencies have been identified.
7. Realistic and feasible project duration is considered.
8. Regulatory requirements.
9. Contractual requirements.

The following tools and techniques are used to improve the project schedule:

- **Schedule Compression**

In order to shorten the project schedule to meet the imposed dates, schedule constraints, or other objectives without changing the scope of work. This is achieved by the following methods:

- Crashing
- To decrease total project duration by analyzing how to get maximum compression with the least cost effect.
- Fast Tracking
- Compression of project duration by changing the sequences of activities to do in parallel or allowing some activities to overlap.
- Critical Chain Method

It is the technique that modifies the project schedule to account for limited resources.

- Resource Leveling

This technique is used when shared or critical required resources are only available at certain times, are only available in limited quantities, or to keep resource usage at a constant level.

- Simulation

It involves calculating project durations with different sets of activity assumptions to assess the feasibility of the project schedule under adverse conditions. The following are techniques used for simulation:

- Monte Carlo Analysis
- What-If Analysis

There are many computer-based programs available for preparing the network and critical path of activities for construction projects. These programs can be used to analyze the use of resources, review of project progress, and forecast the effects of changes in the schedule of work or other resources. Most computer programs automate the preparation and presentation of various planning tools such as bar charts, PERT, and CPM analysis. The programs are capable of storing huge data and help process and update the program quickly. It manipulates data for multiple usages from the planning and scheduling perspectives. It is useful for updating and tracking, sorting, filtering, and resource leveling.

1.3.2.4.9 Project Schedule (Baseline Schedule)

A baseline schedule is the project plan developed to meet the project objectives and the scope of work and accepted by the stakeholders as a benchmark for tracking and measuring the project performance and progress. An accurate baseline schedule is necessary to assess the actual performance (status) of the project, determine the significance of variance, and forecast to complete the project. The baseline schedule is saved (freeze) once the schedule is approved and accepted by all the stakeholders (project team members) at the start of the project. Any change to the baseline schedule must be approved by the change control board (authorized project team members).

The baseline schedule is:

- Commitment by all stakeholders (project team members) to accomplish project objectives within the agreed time.
- Representation of project assumptions, constraints, and milestones.
- A benchmark to perform the activities.
- A datum for measuring project performance and progress and to forecast project completion date.
- Used as a framework for identification of impacts on the project.
- Saved (frozen) as the original plan upon acceptance by all the stakeholders (authorized project team members).
- Updated with formal approval by the change control board (authorized project team members).

Construction project development has four stages. These are:

1. Study
2. Design
3. Bidding and Tendering
4. Construction

There are many activities/tasks that need to be performed during each of these stages. In order for smooth flow and performance of activities during these stages, it is necessary to prepare a schedule at every stage of the construction project life cycle to perform the work in an organized and structured manner. The following are the stages/phases at which schedules are developed by various project participants:

- Predesign Phase (Feasibility Stage)—by Owner
- Design Phases—by Designer (Consultant)
- Concept Design
- Preliminary Design
- Detailed Design
- Construction Documents Preparation
- Bidding and Tendering and Contract Award—by Owner, Designer
- Construction Phase—by Contractor
  - Construction
  - Testing, Commissioning, and Handover

The schedule developed at these stages (phases) serves as a baseline schedule for the specific stage and helps to accomplish all the key activities/tasks and to achieve overall project objectives.

1.3.2.4.9.1 Schedule Levels

There are different levels at which the project schedule is presented. There are five levels of schedules typically developed in construction projects. The objective is to establish appropriate levels of schedule detail for planning, scheduling, monitoring, controlling, and reporting on the overall project.

Level 1: Project Master Schedule (Executive Summary)
Level 2: Summary Master Schedule (Management Summary)
Level 3: Project Coordination Schedule (Publication Schedule)
Level 4: Project Working Level Schedule (Execution Schedule)
Level 5: Detailed Schedule

The amount of information desired at each level depends on the requirements of stakeholders and the project stage (phase). Table 1.20 illustrates schedule-level deliverables.

In order to improve the understanding and communication among stakeholders involved with preparing, evaluating, and using project schedules, AACE International has published the guideline to classify schedules into five levels. Figure 1.58 illustrates classification versus levels that a schedule can be developed and/or presented.

TABLE 1.20
Schedule Levels

	Schedule Level 1
Schedule Title	Project Master Schedule (Executive Summary)
Description	Level 1 schedule is a high-level schedule that reflects key milestones and high-level project activities by major phase, stage or project being executed. This schedule level may represent summary activities of an execution stage, specifically engineering, procurement, construction and start-up activities. Level 1 schedules provide high-level information that assist in the decision-making process (go/no go prioritization and criticality of projects). Level 1 schedule can be used to integrate multiple contractors/multiple schedules into an overall program management process. Level 1 audience includes, but is not limited to client, senior executives, and general managers. Level 1 schedule may be used in the proposal stage of a potential project/contract.
Scheduling Method	Graphical representation in the bar chart format.
Usage in Construction Projects	Study stage, predesign phase, feasibility study.
Schedule Level 2	
Schedule Title	Summary Master Schedule (Management Summary)
Description	Level 2 schedules are generally prepared to communicate the integration of work throughout the life cycle of a project. Level 2 schedules may reflect, at a high-level, interfaces between key deliverables and project participants (contractors) required to complete the identified deliverables. Level 2 schedules provide high-level information that assist in the project decision-making process (re-prioritization and criticality of project deliverables). Level 2 schedules assist in identifying project areas and deliverables that require actions and/or course correction. Audiences for this type of schedule include, but are not limited to general managers, sponsors, and program or project managers.
Scheduling Method	Typically presented in the Gantt (bar chart) format.
Usage in Construction Projects	Overall design schedule, overall construction schedule.
Schedule Level 3	
Schedule Title	Project Coordination Schedule (Publication Schedule)
Description	Level 3 schedules are generally prepared to communicate the execution of the deliverables for each of the contracting parties. Level 3 reflects the interfaces between key workgroups, disciplines, or crafts involved in the execution of the stage.

(*Continued*)

TABLE 1.20 Continued
Schedule Levels

	Schedule Level 1
	Level 3 schedule includes all major milestones, major elements of design, engineering, procurement, construction, testing, commissioning, and handover. Level 3 schedules provide enough detail to identify critical activities. Level 3 schedules assist the team in identifying activities that could potentially affect the outcome of a stage or phase of work, allowing for mitigation and course correction in short course. Level 3 audiences include, but are not limited to program or project managers, CMs or owner's representatives, superintendents, and general foremen.
Scheduling Method	Typically presented in Gantt or CPM network format, and is generally the output of CPM scheduling software.
Usage in Construction Projects	Detail design, detail construction.
Schedule Level 4	
Schedule Title	Project Working Level Schedule (Execution Schedule)
Description	Level 4 schedules are prepared to communicate the production/execution of work packages at the deliverable level. Level 4 schedule reflects interfaces between key elements that drive completion of activities. Level 4 schedules usually provide enough detail to plan and coordinate contractor or multidiscipline/craft activities. Level 4 schedule displays the activities to be accomplished by identifying all the required resources. Level 4 audiences include but are not limited to project managers, superintendents, and general foremen.
Scheduling Method	Typically presented in Gantt or CPM network format.
Usage in Construction Projects	Monthly schedule, lookahead schedules.
Schedule Level 5	
Schedule Title	Detail Schedule
Description	Level 5 schedules are prepared to communicate task requirements for completing activities identified in a detailed schedule. Level 5 schedules are usually considered work schedules that reflect hourly, daily, or weekly work requirements. Level 5 schedules are used to plan and schedule utilization of resources (labor, equipment, and materials) in hourly, daily, or weekly units for each task. Level 5 audiences include but are not limited to superintendents, general foremen and foremen.
Scheduling Method	Typically presented in an activity listing format without time-scaled graphical representation of work to accomplish.
Usage in Construction Projects	Daily work schedule, daily progress report.

Source: AACE International Recommended Practice No. 37R-06. Reprinted with permission of AACE International.

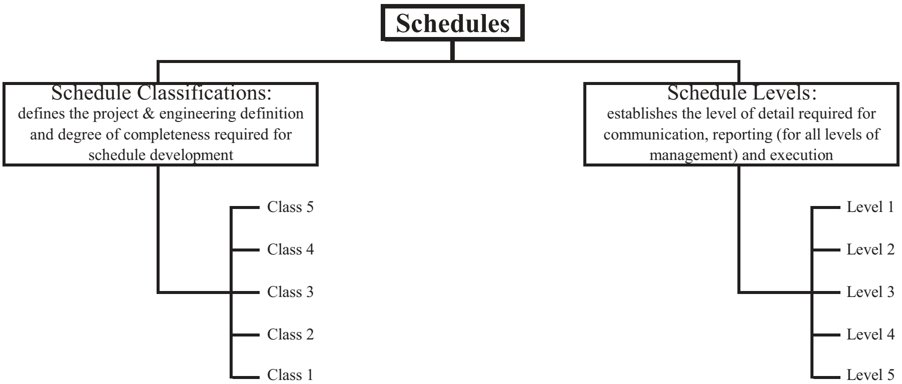


FIGURE 1.58 Schedule: Classification versus levels.

Table 1.21 illustrates a generic schedule classification matrix and Table 1.22 illustrates characteristics of schedule classifications.

1.3.2.4.10 Monitor and Control Schedule

Monitor and control of the schedule is the process of determining the current status of the schedule, identifying the influencing factors that cause the schedule changes, determining that the schedule has changed, and managing the changes in the approved project schedule baseline by updating and taking appropriate actions, if necessary, to minimize deviation from the approved schedule.

Monitoring is collecting, recording, and reporting information concerning project performance. Monitoring involves the measurement of the current status of the project accomplishment and performance.

The current schedule (as-built schedule) is a reflection of the current situation of all activities/tasks, milestones, sequencing, resources, duration, constraints, and project updates.

A control process is established for managing the current schedule. Controlling is using the actual data collected through monitoring and comparing the same to the planned performance to bring actual performance to planned performance by correcting the variances or implementing approved changes. Analysis of variance between the baseline and current schedule dates and duration provides necessary information for management and stakeholders' decisions.

Monitoring construction projects is normally done by compiling the status of various activities in the form of progress reports. These are prepared by the contractor, supervision team (consultant), and construction/project management team. The objectives of project monitoring and control are:

1. To report the necessary information in detail and in an appropriate form that can be interpreted by management and other concerned personnel to provide them with the information about how the resources are being used to achieve project objectives.

TABLE 1.21
Generic Schedule Classification Matrix

	Primary Characteristic	Secondary Characteristic	
SCHEDULE CLASS	**DEGREE OF PROJECT DEFINITION (Expressed as % of Complete definition)**	**END USAGE**	**SHEDULING METHODS USED**
Class 5	0% to 2%	Concept Screening	Top-Down planning using high-level milestones and key project events.
Class 4	1% to 15%	Feasibility Study	Top-Down planning using high-level milestones and key project events. Semi-Detailed.
Class 3	10% to 40%	Budget, Authorization, or Control	"Package" top-down planning using key events. Semi-Detailed.
Class 2	30% to 75%	Control or Bid/Tender	Bottom-Up planning. Detailed.
Class 1	65% to 100%	Bid/Tender	Bottom-Up planning. Detailed.

Source: AACE International Recommended Practice No. 27R-03. Reprinted with permission of AACE International.

2. Provide an organized and efficient means of measuring, collecting, verifying, and quantifying data reflecting the progress and status of execution of project activities, with respect to schedule, cost, resources, procurement, and quality.
3. Provide an organized, efficient, and accurate means of converting the data from the execution process into information.
4. To identify and isolate the most important and critical information about the project activities to enable decision-making personnel to take corrective action for the benefit of the project.
5. Forecast and predict the future progress of activities to be performed.

The following information is required to prepare a current (as-built) schedule and compare it with the baseline schedule:

- Percentage of completion of each activity based on approved checklist.
- Actual start/finish dates for the completed activities.
- Activities scheduled to start but not yet started.
- Activities scheduled to be completed but under progress.

TABLE 1.22
Characteristics of Schedule Classifications

Class 5 Schedule Characteristics	
Description	Class 5 schedules are generally prepared based on very limited information, and subsequently have a very wide accuracy range. The Class 5 schedule is considered a preliminary document, usually presented in either Gantt (bar chart) or table form. The Class 5 schedule should have, as a minimum, a single summary per stage with major project milestones identified.
Degree of Project Definition Required	0% to 2%.
End Usage	Class 5 schedules are prepared for any number of strategic business planning purposes, such as but not limited to: Market studies, assessment of initial viability, evaluation of alternative schemes, project screening, project location studies, evaluation of resource need and budgeting, long-range capital planning, etc.
Scheduling Methods Used	Gantt, bar chart, milestone/activity table. Top-Down planning using high-level milestones and key project events.
Class 4 Schedule Characteristics	
Description	Class 4 schedules are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of "do-ability," concept evaluation, and to support preliminary budget approval. The Class 4 schedule is usually presented in either Gantt (bar chart) or table form. The Class 4 schedule should define the high-level deliverables for each specific stage going forward (since the previous stage has passed). This document should also provide an understanding regarding the timing of key events, such as independent project reviews, committee approvals, as well as determining the timing of funding approvals. A high-level WBS may be established at this time.
Degree of Project Definition Required	1% to 15%.
End Usage	Class 4 schedules are prepared for a number of purposes, such as but not limited to: detailed strategic planning, business development, project screening at more developed stages, alternate scheme analysis, confirmation of "do-ability," economic and/or technical feasibility, and to support preliminary budget approval or approval to proceed to next stage. It is recommended that the Class 4 schedule be reconciled to the Class 5 schedule to reflect the changes or variations identified as a result of more project definition and design. This will provide an understanding of the changes from one schedule to the next.
Scheduling Methods Used	Gantt, bar chart, milestone/activity table top-down planning using high-level milestones and key project events. Semi-Detailed.

(*Continued*)

TABLE 1.22 Continued
Characteristics of Schedule Classifications

Class 3 Schedule Characteristics	
Description	Class 3 schedules are generally prepared to form the basis of execution for budget authorization, appropriation, and/or funding. As such, they typically form the initial control schedule against which all actual dates and resources will be monitored. The Class 3 schedule should be a resource loaded, logic-driven schedule developed using the precedence diagramming method (PDM). The schedule should be developed using relationships that support the overall true representation of the execution of the project (with respect to start-to-start and finish-to-finish relationships with lags). The amount of detail should define, as a minimum, the work package (WP) level (or similar deliverable) per process type/unit and any intermediate key steps necessary to determine the execution path. (The WP rolls up into the predefined WBS.) In some circumstances, where there is a high degree of parallel activities, the critical nature of the project, or the extreme complexity and/or size of the project, it may be warranted to provide further detail of the schedule to assist in the control of the project.
Degree of Project Definition Required	10% to 40%.
End Usage	Class 3 schedules are typically prepared to support full project funding requests, and become the first of the project phase "control schedules" against which all start and completion dates and resources will be monitored for variations to the schedule. They are used as the project schedule until replaced by more detailed schedules. It is recommended that the Class 3 schedule be reconciled to the Class 4 schedule to reflect the changes or variations identified as a result of more project definition and design.
Scheduling Methods Used	PDM, PERT, Gantt/bar charts, "package" top-down planning using key events. Semi-Detailed.
Class 2 Schedule Characteristics	
Description	Class 2 schedules are generally prepared to form a detailed control baseline against which all project work is monitored in terms of task starts and completions and progress control. The Class 2 schedule is a detailed, resource-loaded, logic-driven schedule that should be developed using the critical path method (CPM) process. The amount of detail should define as a minimum, the required deliverables per contract per work package (WP). The schedule should further define any additional steps necessary to determine the critical path of the project necessary for the appropriate degree of control.
Degree of Project Definition Required	30% to 70%.

(*Continued*)

TABLE 1.22 Continued
Characteristics of Schedule Classifications

End Usage	Class 2 schedules are typically prepared as the detailed control baseline against which all actual start and completion dates and resources will now be monitored for variations to the schedule and form a part of the change/variation control program. It is recommended that the Class 2 schedule be reconciled to the Class 3 schedule to reflect the changes or variations identified as a result of more project definition and design.
Scheduling Methods Used	Gantt/bar charts, PDM, PERT, bottom-up planning. Detailed.
Class 1 Schedule Characteristics	
Description	Class 1 schedules are generally prepared for discrete parts or sections of the total project rather than generating this amount of detail for the entire project. The updated schedule is often referred to as the current control schedule and becomes the new baseline for the cost/schedule control of the project. The Class 1 schedule may be a detailed, resource loaded, logic-driven schedule and is considered a "production schedule" used for establishing daily or weekly work requirements
Degree of Project Definition Required	70 % to 100 %.
End Usage	Class 1 schedules are typically prepared to form the current control schedule to be used as the final control baseline against which all actual start and completion dates and resources will now be monitored for variations to the schedule and form a part of the change/variation control program. They may be used to evaluate bid-schedule checking, to support vendor/contractor negotiations, or claim evaluations and dispute resolution. It is recommended that the Class 1 schedule be reconciled to the Class 2 schedule to reflect the changes or variations identified as a result of more project definition and design.
Scheduling Methods Used	Gantt/bar charts, PDM, PERT, bottom-up planning. Detailed.

Source: AACE International Recommended Practice No. 27R-03. Reprinted with permission of AACE International.

- Remaining duration to complete each activity.
- Percentage of completed activities.
- Percentage of partially completed activities.
- Percentage not yet started.
- Material, equipment yet to be received.
- Available resources.
- Regulatory approvals.
- Milestones not yet reached.
- Logic and duration revision to keep the schedule unchanged.
- Problems and issues.

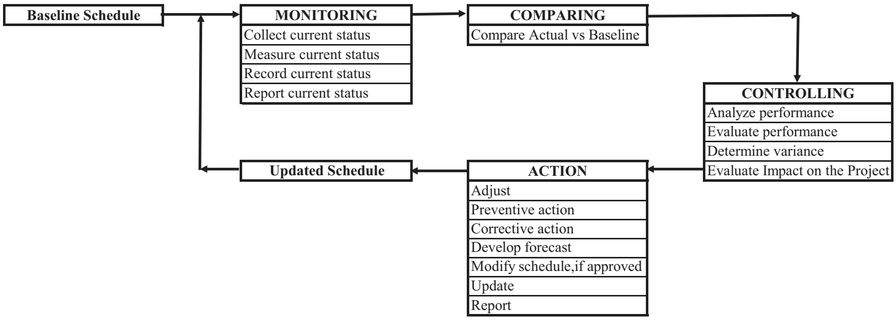


FIGURE 1.59 Schedule monitoring and controlling process.

- Risks.
- Change orders.

After analyzing the current status with the actual, the schedule performance report is prepared consisting of the following information:

- Project status: Where the schedule stands at the current situation.
- Project progress: Plan versus actual.
- Forecasting: Prediction of future status and progress trends.

Figure 1.59 illustrates the schedule monitoring and controlling process.

1.3.2.5 Project Cost Management

Cost management is the process involving planning, cost estimating, budgeting, and cost control to ensure that the project is successfully completed within an approved budget.

Construction projects are mainly capital investment projects. They are customized and non-repetitive in nature.

Cost management in a construction project is planning and managing the cost of a facility throughout the project life cycle. The capital cost for a construction project includes the following expenses:

1. Land Acquisition
   This cost depends on the location and market price of the land. The owner may purchase the land on ownership or may lease the land to construct the facility.
2. Project Construction
   Cost expended by the owner for:
   Project study stage.
   Project design development (concept, schematic, detail, construction documents, bidding and tendering).
   Construction supervision (construction management, project management).
   Site preparation.
   Construction of project (material, equipment, systems, furnishing, and human resources).
   Inspection and testing (may be included as part of costs for different stages/phases).

Apart from the aforementioned expenses, such as license fees, permits, regulatory taxes, insurance, and project-related owner's overhead, costs are incurred by the owner.

In addition to the aforementioned costs, operation and maintenance costs also required till the functional life of the facility.

Total cost related to construction is also known as hard costs. Hard costs are those mainly by the decisions of the designer (consultant) engaged in the preparation of design for the construction project.

The construction project initiation starts with the identification of need and a business case. The owner is interested in having the best facility, meeting the owner's schedule, and within the budget to have the best facility to meet the investment plan and objectives.

Cost management in construction projects includes the following processes:

1. Estimate cost.
2. Prepare project budget.
3. Control cost.

1.3.2.5.1 Estimate Cost

It is important to estimate the total cost involved in the construction of the project in order to evolve the project budget and manage cost variance on the project. Cost estimation is a prediction of the most likely total cost of the identified need and business case. Construction project estimates are based on identifying, quantifying, and estimating the cost of all the resources (material, equipment, systems, furnishing, and people) required to complete all the activities within the required schedule and specifications. Cost estimates in construction projects vary as they progress through feasibility to the bidding/tendering stages. Construction project costs are generally estimated at the following stages:

- Project feasibility study stage.
- Client brief or terms of reference.
- Concept design.
- Schematic design.
- Detail design.
- Contract document.
- The contract sum agreed during the bidding and tendering stage is considered as cost baseline (contract cost) and is used to manage cost variance in the project.

1.3.2.5.1.1 Cost Estimation Tools Following are the basic tools and techniques generally used for cost estimation in construction projects:

- Analogous or Top-Down Estimates
- Analogous estimating method relates to using the actual cost of a previous, similar nature of the project as the basis for estimating the cost of the current project. Analogous estimation is used when there is a limited amount of detailed information about the project is available.

- Top-Down estimating approach recognizes all the activities, systems, and equipment required to complete the project are included in the total cost of the project.
- Bottom-Up Estimates
- Bottom-Up estimates involve the estimating cost of all the individual activities, materials, equipment, and resources, and aggregating all the costs to get the total project cost.
- Bottom-Up estimates ensure that all known activities, components, and systems are accounted for to get the total cost.
- Parametric Estimate
- It uses a statistical relationship between the historical data and other variables to estimate the total cost of the project.

For example, in the construction of buildings, the following factors are used:

- Buildings (offices, factories, mixed-use)—Square meters of floor area.
- Schools—Number of students.
- Hospitals—Number of patents.
- Hotels—Number of beds/rooms.
- Theater/cinema—Number of seats.
- Parking facility—Per parking bay.

In construction projects, the cost estimates vary as the project design progresses. At the inception of the project, the cost estimate is based on the rough order of magnitude. When a detailed design is available, the cost estimates become definitive.

The cost estimated by the designer (consultant) is based on assumptions and historical data available from experience on similar projects.

The contractor's estimation is more realistic and is based on the actual costs the contractor will incur to execute the project.

Table 1.23 illustrates cost estimation levels for construction projects.

Contract awarded (negotiated) total project cost is considered as most accurate cost as it is derived from the detailed information provided in the bidding/tendering documents. In the case of the design-bid-build type of project delivery system, a detailed BOQ is worked out by the designer (consultant) and included in the bidding/tendering documents. The BOQ is used to prepare estimates.

In order to estimate the accurate cost of the project, the contractor has to consider the following points:

- Location of the project.
- Site conditions.
- Project specifications.
- Codes and standard to be followed.
- Project schedule.
- Risks and constraints in the project.
- Inflation.
- Project delivery system.

TABLE 1.23
Cost Estimation Levels for Construction Projects

Project Stage/Phase	Tools/Methodology	Accuracy	Purpose
Inception	Analogous	−50% to +100%	Project Initiation (Rough Order of Magnitude)
Feasibility	Analogous	−25% to +75%	Justification to Proceed (Screening Estimate)
Concept Design	Parametric	−10% to +25%	Budgetary (Conceptual Estimate)
Preliminary Design	Elemental Parametric	−10% to +25%	Budgetary (Preliminary Estimate)
Detail Design	Elemental Parametric/ Detailed Costing	−5% to +10%	Detailed Estimate
Bidding and Tendering	Detailed Costing	−5% to +5%	Bid Estimate/Definitive Estimate
Construction	Detailed Costing	Project Cost Baseline (Contracted Value)	Contract Cost (Control Estimate)

- Taxes.
- Currency exchange rate, if applicable.
- Contingency.
- Cost toward subcontracted items.

In the case of the design-build type of project delivery system, the project cost is developed based on the performance specifications and conceptual BOQ.

Figure 1.60 is an example of an analysis of the estimation of prices form used to work out activity unit price and total project cost estimate.

1.3.2.5.2 Establish Budget

Establishing a budget is the process of aggregating in a time-phased manner the estimated costs to perform all the known activities to establish an authorized baseline.

In construction projects, the budget is established at various stages as the project life cycle progresses. It helps the project owner control and adjust the project cost and achieve the intended project objectives within the investment limit. The degree of accuracy of establishing a project budget varies at different stages of the project.

At the early stage of the project, that is, the feasibility stage, the budget is developed on specific project information using an order of magnitude estimation tool. The budget is further refined in the succeeding phases as more information and details are available. The budget prepared by the designer (consultant) at the bidding/tendering stage is of a definitive nature as at this stage the project details are clearly defined and detailed drawings, BOQ, technical specifications, and project schedule are available for cost estimation. The project budget is the approved funding amount required to complete the project within the approved schedule. The project budget is based on the total anticipated cost to complete the project and also includes

Project Name

Analysis of Estimation of Prices

Serial Number	BOQ Reference	Brief Description	Unit	Material Cost	Labor Cost	Equipment Cost	Sub Total -1 Activity Cost Estimate	Overhead & Profit (% of e)	Sub Total-2 (e+f)	Main Contractor's Overhead {% of (g)}	Sub Total-3 (g+h)	Main Contractor's Profit (Mark up) { % of (j)}	Total (j+k) Unit Price
			(a)	(b)	(c)	(d)	(e)=(b+c+d)	(f)	(g)	(h)	(j)	(k)	(l)

FIGURE 1.60 Analysis of estimation of prices form.

contingency and management reserves. Figure 1.61 illustrates the process of establishing a construction budget (hard cost).

1.3.2.5.2.1 Cost Baseline The construction project's cost baseline is developed based on the construction budget. The cost baseline is a time-phased budget that is used as a basis against which to measure, monitor, and control the overall cost performance of the project. The cost baseline is usually shown in an S-Curve graph. The S-Curve predicts how much amount will be spent over the established project schedule (time). The S-Curve is used to measure project performance and predict the expenses over project duration. The cost baseline helps the owner/client to know the project funding requirements. Funding requirements, total and periodic, are derived from the cost baseline. Figure 1.62 illustrates an example S-Curve (budgeted).

Any changes to the baseline need the approval of the change control board. Figure 1.63 illustrates the baseline change request form.

1.3.2.5.3 Control Cost

Cost control is the process of monitoring the status of the project to update the project cost and manage changes to the baseline. This process provides the means to recognize variance from the approved plan, evaluate possible alternatives, and take corrective action to minimize the risk. In order to have successful cost control, it is essential to have the necessary information and data to take appropriate action. If

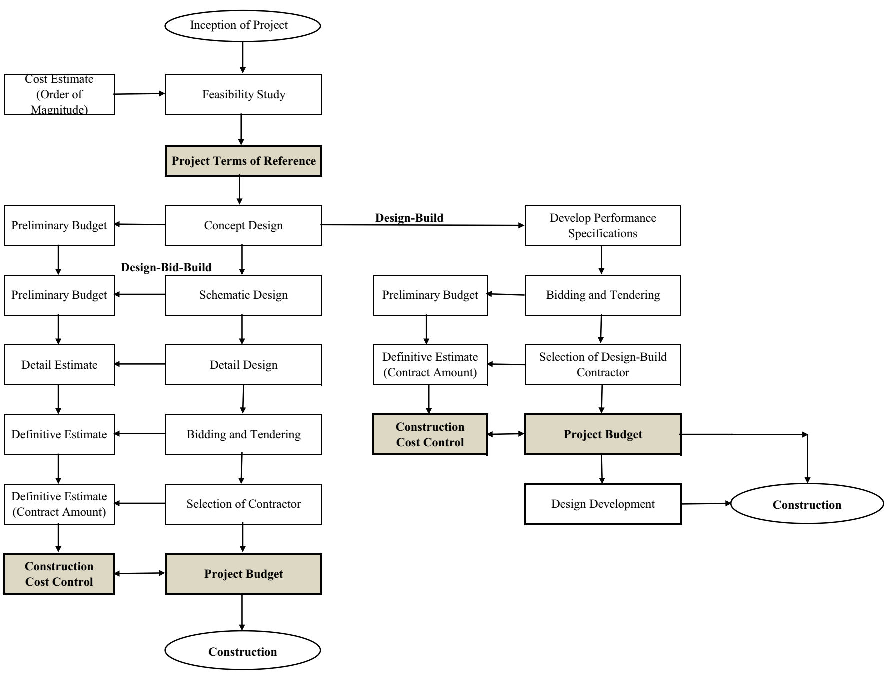


FIGURE 1.61 Process of establishing construction budget.

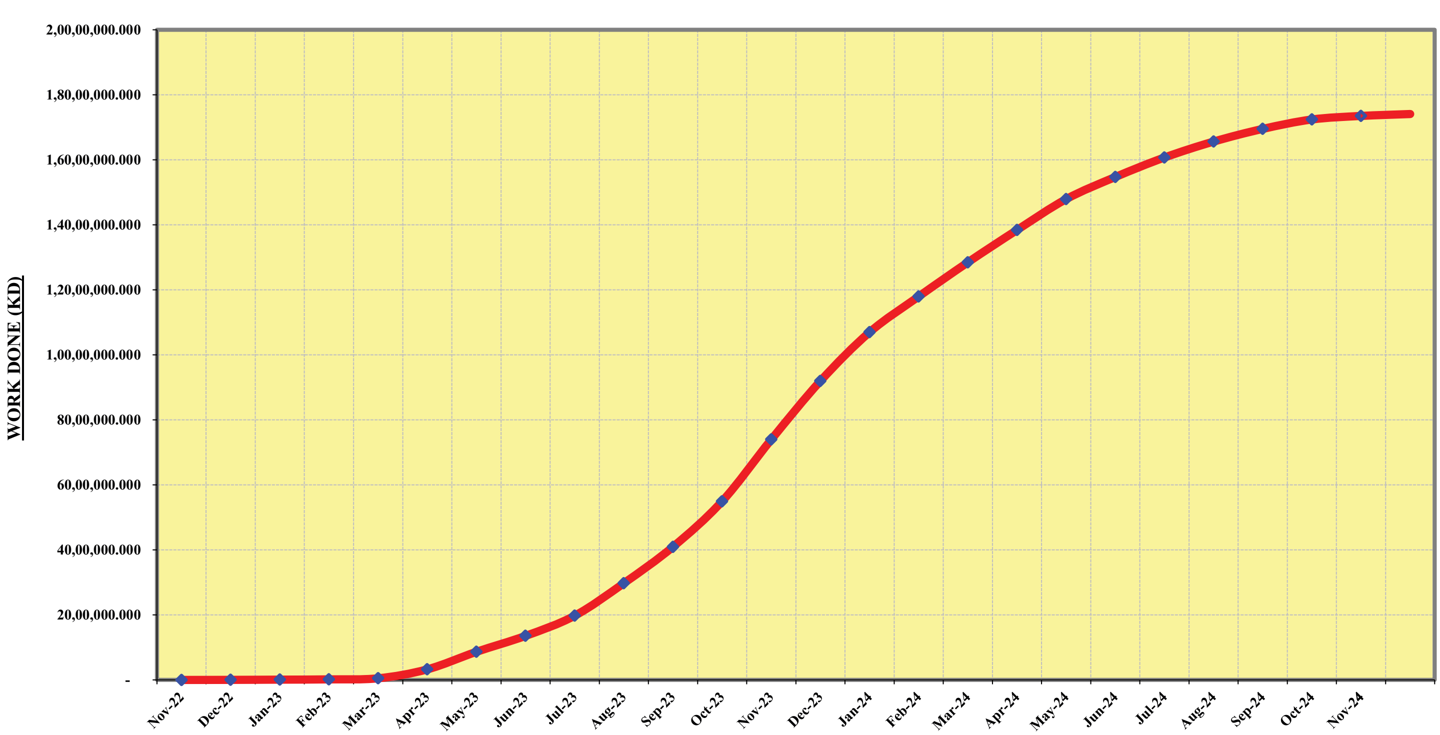


FIGURE 1.62 Project S-Curve (budgeted).

Project Name

Consultant Name

BASELINE CHANGE REQUEST

CONTRACT NO. :________________________________ BCR. NO. :______________

CONTRACTOR ________________________________ DATE :______________

BCR ORIGINATOR ________________________________

In accordance with clause ----- of Document ---- Conditions of Contract, We hereby request for Baseline Change as follows;

SCOPE ☐ SCHEDULE ☐ COST ☐

Reason for Change:

Change Impact:

Following Supporting Documents Attached:

1) Cost Estimate

2) Schedule

3) Other

APPRIVALS: **YES** _______ **NO** _______

Signature:

Resident Engineer	**PM/CM**	**Employer**

Date:

Distributi ☐ Employer ☐ Engineer ☐ Resident Engineer ☐ Contractor

FIGURE 1.63 Baseline change request form.

the necessary information and regular updates are not available or if the action is inefficiently executed, then the risk to cost control on a project is raised considerably.

The purpose of cost control is to manage the project delivery within the approved budget. Regular cost reporting will facilitate:

- Establish project cost to date.
- Anticipate final budget of the project.
- Cash flow requirements.
- Understanding potential risk to the project.

Cost control process focused on:

- Identifying the factors that influence the changes to the cost baseline.
- Determining the cost baseline has changed.
- Ensuring that the changes are beneficial for the project.
- Establishing the cost control structure and policy.
- Managing the actual changes when and as they occur.
- Monitoring cost performance to detect cost variance from the actual budget.
- Recording all appropriate changes.
- Informing/reporting concerned stakeholders about the approved changes.
- Preventing unauthorized changes to the cost baseline.
- Working to bring cost overruns within acceptable limits.

Construction project development has mainly four stages. These are:

1. Study
2. Design
3. Bidding and Tendering
4. Construction

It is essential to perform cost-controlling processes at these stages in order to ensure that total project cost does not increase the investment plan set by the owner and to achieve the project value proposition.

In construction projects, the designer plays an important role in influencing the final cost of the project to ensure the owner that there will not be a budget overrun. The designer has to not only control the project cost but also ensure that the design:

- Has minimum errors.
- Minimum omissions.
- Properly written specifications.
- Realistic construction schedule.
- Includes all the requirements to achieve owner's need and objectives.

In the case of the design-bid-build type of project delivery system, cost control during the study stage, design stage, and bidding/tendering stage are carried out by the owner/designer. The contractor is responsible for controlling the cost during the construction phase.

In the case of the design-build type of project delivery system, the contractor carries out most of the cost control. During the design phase, if the designer (consultant) finds that the approved budget is inadequate, then they should seek revision/adjustment to the budget from any contingency amount that the owner might have.

During the construction phase, it is the contractor who is interested in completing the construction within the contracted amount and the construction manager/project manager controls the cost to ensure that there is no overrun and changes to the cost baseline.

The contractor has to mainly control the following costs:

- Material
- Labor
- Resource (Labor) Productivity
- Equipment/Plant Productivity
- Rework
- Delays
- Subcontractor's Work
- Currency Exchange

The construction manager/project manager, on behalf of the owner should:

- Compare and monitor project progress.
- Identify and control approved variations.
- Identify cash flow forecasts.
- Compare current budget forecast for remaining work.

1.3.2.5.3.1 Earned Value Management Earned value management is a methodology used to measure and evaluate project performance against cost, schedule, and scope baseline. It compares the amount of planned work with what is actually accomplished to determine whether the project is progressing as planned. Earned value analysis is used to:

- Measure the progress of the project budget, schedule, and scope to know how much percentage of:
- Budget spent.
- Time elapsed.
- Work done.
- Forecast its completion date and cost.
- Provide budget and schedule variances.

The following are the basic terminologies used in earned value management.

1. BCWS → Budgeted Cost of Work Scheduled or Planned Value (PV)
   It is the planned cost of the total amount of work scheduled to be performed by the milestone date.
2. BCWP → Budgeted Cost of Work Performed or Earned Value (EV)
   It is the actual cost incurred to accomplish the work that has been done to date.
3. ACWP → Actual Cost of Work Performed or Actual Cost (AC)

It is the planned cost to complete the work that has been done.

These three key values are used in various combinations to determine cost and schedule performance and provide an estimated cost of the project at its completion.

Table 1.24 illustrates the terms used in Earned Value Management (EVM) and their interpretation whereas Table 1.25 illustrates the formulas used in EVM and their interpretations.

Figure 1.64 illustrates a diagram for earned value method.

TABLE 1.24
Terms Used in EVM

Serial Number	Term	Description	Interpretation
1	PV (BCWS)	Planned Value (Budgeted Cost of Work Scheduled)	Planned cost of total amount of work scheduled to be performed by the milestone date.
2	EV (BCWP)	Earned Value (Budgeted Cost of Work Performed)	Planned/budgeted cost to complete the work that has been done.
3	AC (ACWP)	Actual Cost (Actual Cost of Work Performed)	Actual cost incurred to accomplish the work that has been done to date.
4	BAC	Budget at Completion	Estimated total cost of project when completed.
5	EAC	Estimate at Completion	Expected total cost of project when completed.
6	ETC	Estimate to Completion	Expected additional cost needed to complete the project.
7	VAC	Variance at Completion	Amount over budget OR under budget we expect at the end of the project.

1.3.2.6 Quality Management

Quality management is an organization-wide approach to understanding customer needs and delivering solutions to fulfill and satisfy the customer. Quality management is managing and implementation of quality system to achieve customer satisfaction at the lowest overall cost to the organization while continuing to improve the process. The quality system is a framework for quality management. It embraces the organization structure, policies, procedures, and processes needed to implement a quality management system.

Quality management in construction projects is different from that of manufacturing.

Quality in construction projects is not only the quality of products and equipment used in the construction, it is the total management approach to complete the facility as per the scope of work to the customer/owner satisfaction within the budget and to be completed within specified schedule to meet the owner’s defined purpose. Quality management in construction addresses both the management of the project and the product of the project and all the components of the product. It also involves the incorporation of changes or improvements, if needed. Construction project quality is the fulfillment of the owner’s needs as per the defined scope of work within a budget and specified schedule to satisfy the owner’s/user’s requirements.

Quality management system in construction projects mainly consists of:

- Quality management planning.
- Quality assurance.
- Quality control.

TABLE 1.25
Formulas Used in EVM

Serial Number	Name	Formula	Interpretation
1	Cost Variance (CV)	BCWP-ACWP (EV-AC)	A comparison of the budgeted cost of work performed with actual cost. POSITIVE result means under budget. NEGATIVE result means over budget.
2	Schedule Variance	BCWP-BCWS (EV-PV)	A comparison of the amount of work performed during a given period of time to what was scheduled to be performed. POSITIVE result means ahead of schedule. NEGATIVE result means behind schedule.
3	Cost Performance Index (CPI)	EV/AC BCWP/ACWP	Greater than one means work is being produced for less than planned. Less than one means the work is costing more than planned.
4	Schedule Performance Index (SPI)	EV/PV BCWP/BCWS	Greater than one means project is ahead of schedule. Less than one means project has accomplished less than planned and behind schedule.
5	Estimate at Completion (EAC)	AC+ETC	Expected total cost of project when completed.
6	Estimate to Complete (ETC)	EAC-AC	Expected additional cost needed to complete the project.
7	Variance at Completion (VAC)	BAC-EAC	How much over budget OR under budget we expect at the end of the project?

Each of these processes and activities is to be performed during the following main stages of the construction project:

1. Study
2. Design
3. Bidding and Tendering
4. Construction

1.3.2.6.1 Develop Quality Management Plan

The quality management plan for construction projects is part of the overall project documentation addressing and describing the procedures to manage construction quality and project deliverables. The quality management plan identifies the following key components:

- Details of the quality standards and codes to be complied.
- Project objectives, project scope of work.
- Stakeholders' quality requirements.
- Regulatory requirements.

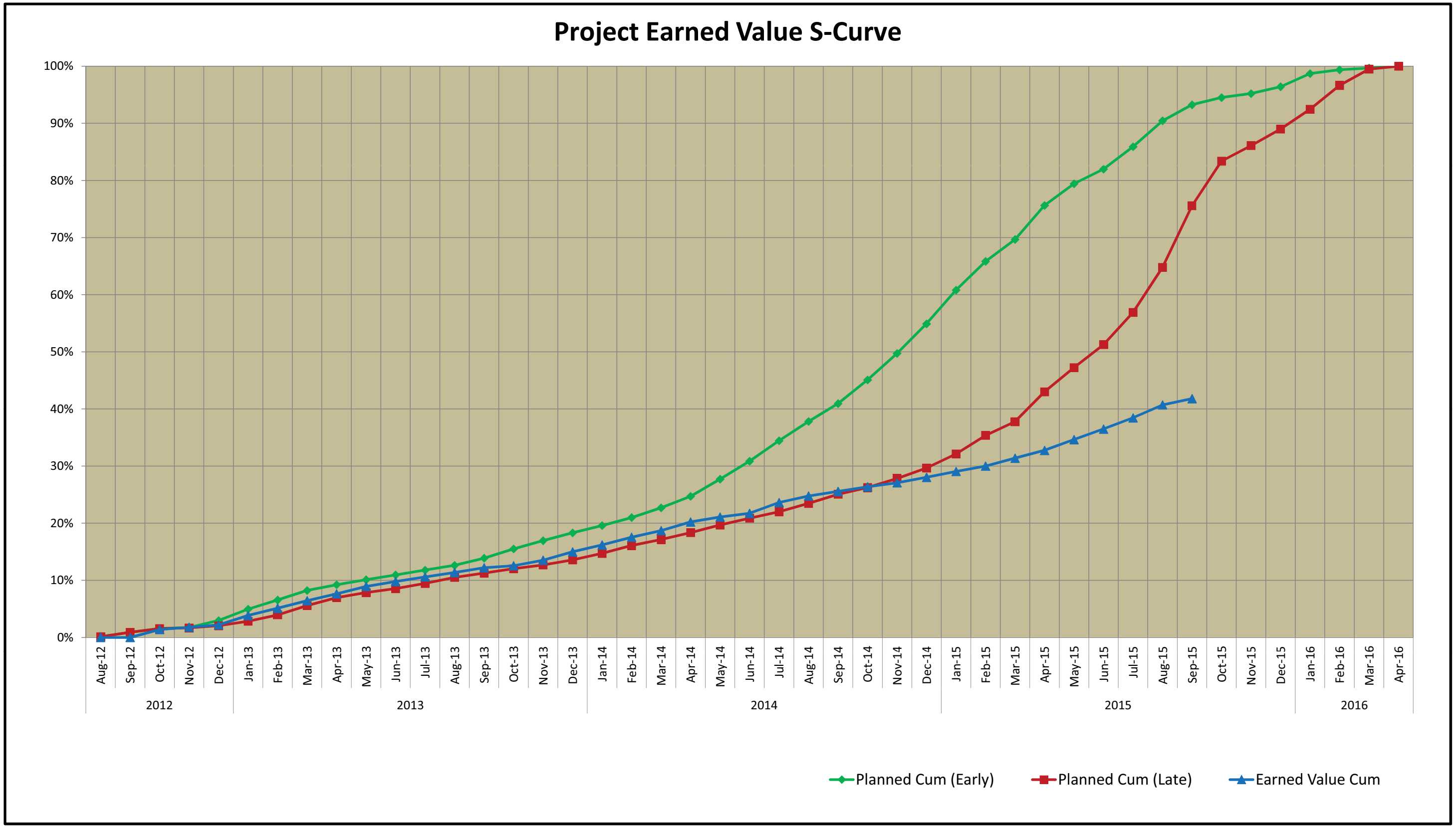


FIGURE 1.64 Earned value method diagram.

- Quality matrix for different stages.
- Design criteria.
- Design procedures.
- Detailed construction drawings.
- Detailed work procedure.
- Well-Defined specification for all the materials, products, components and equipment to be used to construct the facility.
- Manpower and other resources to be used for the project.
- Inspection and testing procedures.
- Quality assurance activities.
- Quality control activities.
- Defect prevention, corrective action, and rework procedure.
- Project completion schedule.
- Cost of the project.
- Documentation and reporting procedure.

1.3.2.6.1.1 Designer's Quality Management Plan Construction projects have the involvement of the owner, designer (consultant), and contractor. In order to achieve project objectives both the designer as well as the contractor have to develop a project quality management plan. The designer's quality management plan shall be based on the owner's project objectives whereas the contractor's plan shall take into consideration the requirements of contract documents.

Figure 1.65 illustrates a project quality management plan for the design stage.

1.3.2.6.1.2 Contractor's Quality Control Plan During the construction stage, the contractor prepares the Contractor's Quality Control Plan (CQCP) based on project-specific requirements. The CQCP is the contractor's everyday tool to ensure meeting the performance standards specified in the contract documents. Its contents are drawn from the company's quality system, the contract, and related documents. It is a framework for the contractor's process for achieving quality construction. It is a document setting out the specific quality activities and resources pertaining to a particular contract or project. It is the documentation of the contractor's process for delivering the level of construction quality required by the contract. A quality plan is virtually a quality manual tailor-made for the project and is based on contract requirements. Figure 1.66 illustrates the process for the development of the CQCP and Table 1.26 illustrates a table of contents of the contractor's quality control plan.

1.3.2.6.1.3 Quality Matrix In the case of construction projects, an organizational framework is established and implemented mainly by three parties: Owner, designer/consultant, and contractor.

Table 1.27 illustrates the responsibilities matrix for quality control-related personnel.

1.3.2.6.2 Perform Quality Assurance

Quality assurance in construction projects covers all activities performed by the design team, contractor, and quality controller/auditor (supervision staff) to meet the

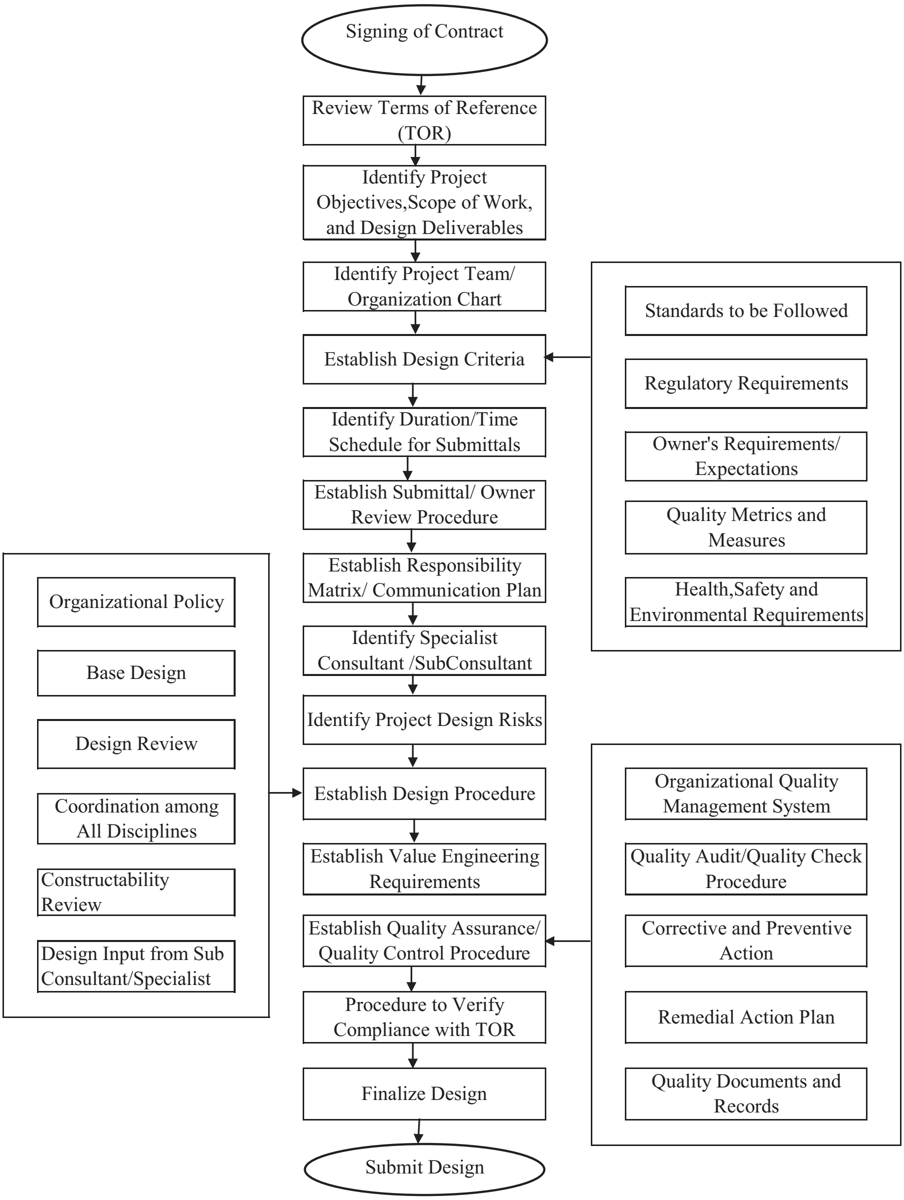


FIGURE 1.65 Project quality management plan for design stage.

owner's objectives as specified and to ensure and guarantee that the project/facility is fully functional to the satisfaction of the owner/end user. Auditing is part of the quality assurance function.

Quality assurance is the activity of providing evidence to establish confidence among all concerned that quality-related activities are being performed effectively.

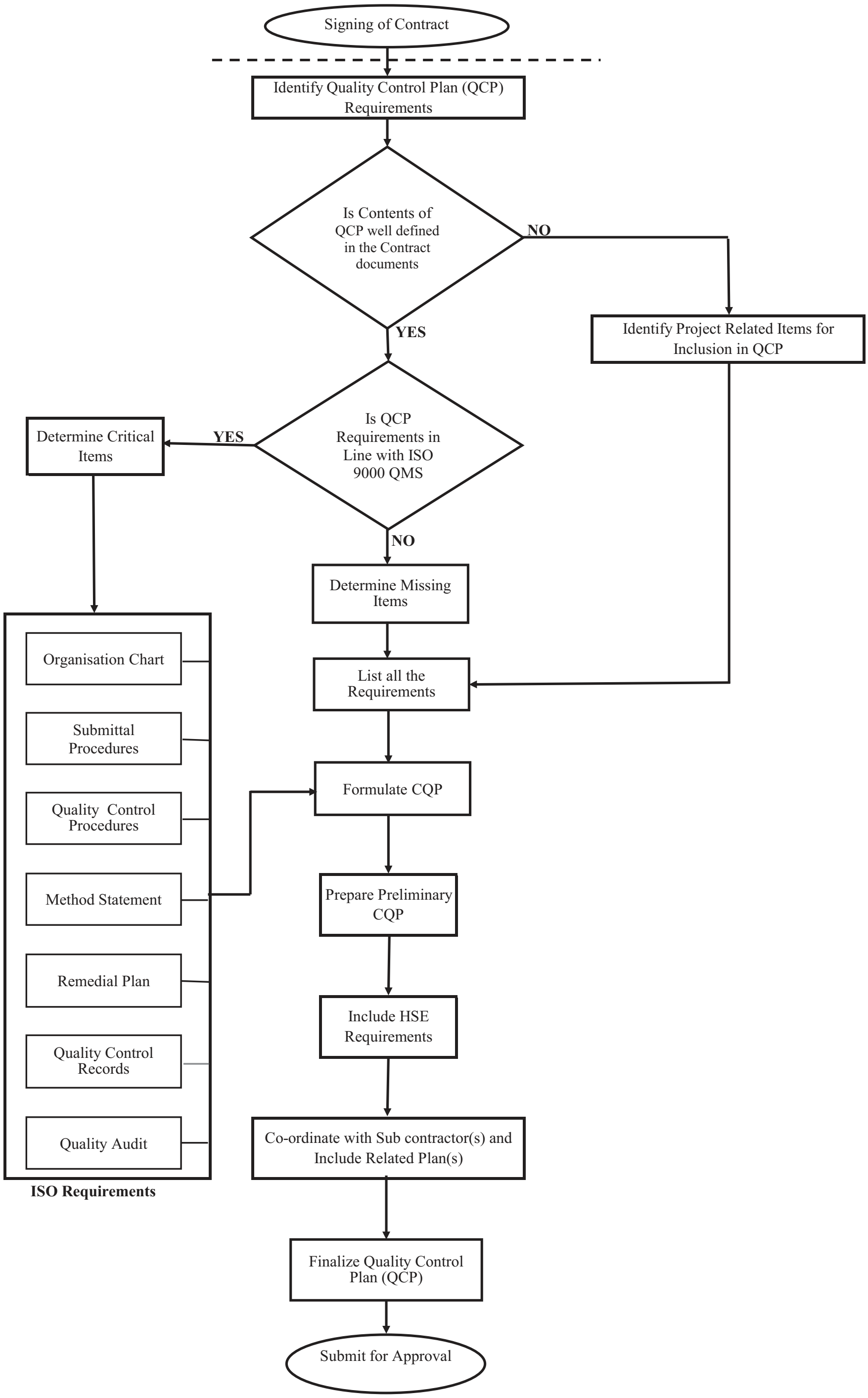


FIGURE 1.66 Logic flow diagram for contractor's quality control plan.

TABLE 1.26
Contents of Contractor's Quality Control Plan

Section			Topic
1			Introduction
2			Description of Project
3			Quality Control Organization
4			Qualification of QC Staff
5			Responsibilities of QC Personnel
6			Procedure for Submittals
	6.1		Submittals for Subcontractor(s)
	6.2		Submittals for Shop Drawings
	6.3		Submittals for Materials
	6.4		Modification Request
	6.5		Construction Program
7			Quality Control Procedure
	7.1		Procurement
	7.2		Inspection of Site Activities (Checklist)
		7.2.1	Definable Feature of Work
		7.2.2	Earthwork and Site Work
		7.2.3	Concrete
		7.2.4	Masonry
		7.2.5	Metal Work
		7.2.6	Wood, Plastics, and Composite
		7.2.7	Doors and Windows
		7.2.8	Finishes
		7.2.9	Furnishing
		7.2.10	Equipment
		7.2.11	Conveying System
		7.2.12	Mechanical Work
		7.2.13	Automation System
		7.2.14	Electrical Work
		7.2.15	Landscape
	7.3		Inspection and Testing Procedure for Systems
	7.4		Off-Site Manufacturing, Inspection, and Testing
	7.5		Procedure for Laboratory Testing of Material
	7.6		Inspection of Material Received at Site
	7.7		Protection of Work
	7.8		Material Storage and Handling
8			Method Statement for Various Installation Activities
9			Project Specific Quality Procedures
10			Risk Management
11			Quality Control Records
12			Company's Quality Manual and Procedures
13			Periodical Testing of Construction Equipment
14			Quality Updating Program
15			Quality Auditing Program
16			Testing, Commissioning, and Handover
17			Health, Safety, and Environment

All these planned or systematic actions are necessary to provide adequate confidence that a product or service will satisfy given requirements for quality.

Quality assurance covers all activities from design, development, production/construction, installation, and servicing to documentation and also includes regulations of the quality of raw materials; assemblies, products and components, services related to production; and management, production, and inspection processes. The following are major activities to be performed for quality assurance of the construction project:

- Confirm that the owner's needs and requirements are included in the scope of work (TOR).
- Review and confirm design compliance with the terms of reference (TOR).
- Executed work to comply with the specified standards and codes.
- Conformance to regulatory requirements.
- Work executed as per approved shop drawings.
- Installation of approved material, equipment on the project.
- Method of installation as per approved method statement or manufacturer's recommendation.
- Coordination among all the trades.
- Continuous inspection during the construction/installation process.
- Identify and correct the deficiencies.
- Timely submission and review of transmittals.

1.3.2.6.3 Control Quality

Quality control in construction projects is performed at every stage through use of various control charts, diagrams, checklists, etc., and can be defined as:

- Checking and review of project design.
- Checking and review of bidding/tendering documents.
- Analysis of contractor's bids.
- Checking of executed/installed work to confirm that work has been performed/executed as specified, using specified/approved materials, installation methods, and specified references, codes, and standards to meet the intended use.
- Controlling budget.
- Planning, monitoring, and controlling the project schedule.

The construction project quality control process is a part of contract documents that provide details about specific quality practices, resources, and activities relevant to the project. The purpose of quality control during construction is to ensure that the work is accomplished in accordance with the requirements specified in the contract. Inspection of construction work is carried out throughout the construction period either by the construction supervision team (consultant) or an appointed inspector agency. Quality is an important aspect of construction projects. The quality of the construction project must meet the requirements specified in the contract documents. Normally, the contractor provides on-site inspection and testing facilities at the construction site. On a construction site, inspection and testing are carried out at three stages during the construction period to ensure quality compliance.

TABLE 1.27
Responsibilities for Site Quality Control

Sr. No.	DESCRIPTION	LINEAR RESPONSIBILITY CHART							
		OWNER	CONSULTANT	CONTRACTOR					
		OWNER/PROJECT MANAGER CONSTRUCTION MANAGER	CONSULTANT/ DESIGNER	CONTRACTOR MANAGER	QUALITY INCHARGE	QUALITY ENGINEERS	SITE ENGINEERS	SAFETY OFFICER	HEAD OFFICE
1	Specify Quality Standards	□	■						
2	Prepare Quality Control Plan			□	■	□			□
3	Control Distribution of Plans and Specifications			□	■	□			□
4	Submittals			■	□		■		
5	Prepare Procurement Documents			□			■		■
6	Prepare Construction Method Procedures			□	□	□	■		
7	Inspect Work in Progress		■	■		□	■		
8	Accept Work in Progress		■						
9	Stop Work in Progress	■	□						
10	Inspect Materials Upon Receipt		■	□	■		■		
11	Monitor and Evaluate Quality of Work		■	□	■	■	■		
12	Maintain Quality Records			□	■				
13	Determine Disposition of Nonconforming Items	□	□	■					
14	Investigate Failures	□	□	■	■	□	■		
15	Site Safety			□				■	
16	Testing and Commissioning	□	■	□			■		
17	Acceptance of Completed Work	■	□	□					

Legend: ■ Primary Responsibility □ Advise/Assist

1. During the construction process. This is carried with the checklist request submitted by the contractor for testing of ongoing work before proceeding to the next step.
2. Receipt of subcontractor or purchased material or services. This is performed by a material inspection request submitted by the contractor to the consultant upon receipt of the material.
3. Before final delivery or commissioning and handover.

1.3.2.7 Resource Management

Resource management in construction is mainly related to the management of the following processes:

1. Human Resources (Project Teams)
   Project Owner Team (Project Manager, Construction Manager)
   Designer (Consultant)
2. Construction Resources (Contractor)
   Manpower
   Equipment
   Material

Construction projects are of non-repetitive in nature and have a definite beginning and a definite end. The important factor in a construction project is to complete the facility as per the defined scope within a specified schedule and budget. In order to meet the project quality, the construction manager firm, designer firm, and contractor have to ensure that the right human resources and the right type of materials and equipment are available at the right time. Since construction projects are of a temporary nature, every time a new project starts, the human resource configuration changes, depending on the company's policies and practices to engage human resources for a particular project.

Similarly, it has to be ensured that specified materials and equipment are available to meet the installation/execution schedule.

1.3.2.7.1 Manage Human Resource

Construction project human resource management process includes the following:

1. Plan human resources (project teams).
2. Acquire project team.
3. Develop project team.
4. Manage project team.
5. Release/demobilize project team.

1.3.2.7.1.1 Plan Human Resources (Project Teams) Every project needs people to complete the project. Traditional construction projects involve three main groups. These are:

- Owner
- Designer (Consultant)
- Contractor(s)

Depending on the type of project delivery system, each of these groups needs human resources to manage the project. Human resource planning is executed in the initial stage for the overall requirement of the project and is performed iteratively and interactively during each of the project stages with other aspects of the project, such as scope, schedule, and cost of the project and adjusted as per project requirements.

For example, the construction/project management firm plans its human resources as per the scope of work and project schedule. The designer (consultant) plans their resources depending on the size of the project and design deliverables. The contractor is responsible for all types of human resources to complete the project.

The human resource planning process includes organizational planning taking into consideration the requirements of the project and the stakeholders involved, detailing the project roles, responsibilities, and required skills, and reporting relationships to the appropriate people or group of people. Human resource planning includes:

- Documenting staffing requirements (roles, responsibilities, skills).
- Project organization chart.
- Staff deployment charts.
- Team acquiring process.
- Team development, training needs.
- Release/demobilization plan.

1.3.2.7.1.2 Acquire Project Team Acquiring a project team is the process of obtaining project team members for completing the project. There are mainly three project teams associated with three groups involved in a construction project. These are:

1. Construction Management or Project Management Firm (depending on the type of project delivery system selected by the owner)
2. Designer (Consultant)
3. Contractor's Core Staff

Acquiring a project team is a process of getting the right people having the right knowledge, skills, and experience that is required to work on the project and to perform the assignment within a given time frame. A project team is a group of professionals committed to achieving a common goal to complete the project successfully. Acquiring a project team is a continuous process that is performed throughout the project when a particular category of team member is required as per the project deployment chart. For example, a resident engineer for a project is acquired at the beginning of the project and is released after completion of the project. Other team members are acquired as per the agreed-upon deployment chart depending on the project needs and project organizational structure. Acquiring a project team includes:

- Negotiation.
- Internal or externally hired member.
- Deployment chart.

While engaging a team member it is necessary to consider the following criteria:

- Require a level of experience.
- Organizational breakdown structure.
- Project specifics requirements/needs.
- Professional qualification.
- Member's experience in a similar type of project.
- Project knowledge.
- Technical skills and capabilities in relevant areas.
- Management skills.
- Collaborative skills.
- Communication capabilities.
- Availability of the candidate to meet work schedule.
- Professional membership and training certification.
- Cost.
- Staff approval requirements by the project owner/client.
- Regulatory constraints.

Figure 1.67 illustrates the project team acquiring process.

1.3.2.7.1.3 Develop Project Team A project team is a combination of professionals acquired to do project-specific activities to complete the project successfully. Each of the project team members is committed to achieving a common goal to complete the project as per the defined scope within a specified time and budget. Most construction projects have a projectized, or matrix type of organizational structure. (Types of organizational structures have already been discussed under Section 1.2.2.1.) In either case, the team members are composed of different backgrounds and disciplines.

There are five stages of team development. These are:

1. Forming
2. Storming
3. Norming
4. Performing
5. Adjourning

(These stages have already been discussed under Section 1.2.3.1.)

In construction projects, there are mainly three project teams. Once the team members are assigned and a team is formed, a meeting to be arranged where every member is introduced and given a clear understanding about:

- Project goals.
- Project overall mission.
- Roles and responsibilities of each team member.
- Coordination process.
- Working in collaborative climate.
- Communication method.

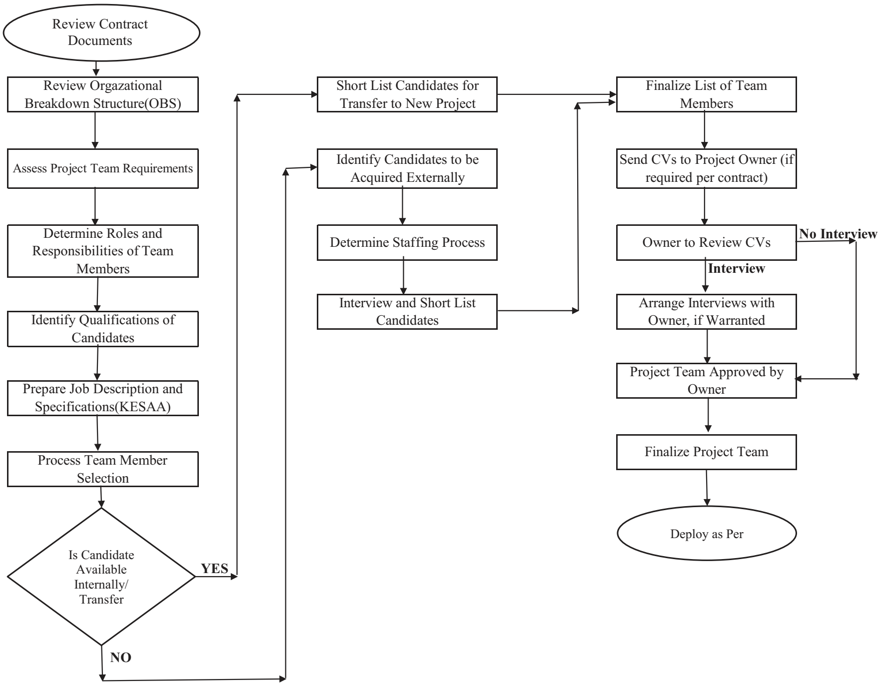


FIGURE 1.67 Project team acquisition process.

- Member's relationship with each other.
- Commitment of each member toward the project.

Normally, project team members are selected as having the required competency in the specific field for which they are assigned and responsible to perform efficiently. However, it is necessary to improve the knowledge and skills of team members in order to increase their ability and competency to complete project work to meet or exceed the specified quality of the project. In order to enhance the competency and ability of the project member, appropriate training can be arranged by ascertaining the gap for which training is to be arranged for the team member. (Training and development have already been discussed under Section 1.2.3.2.) The performance evaluation process helps determine the training requirements for the project team members and provides training identified by gap analysis to improve the technical competencies of project team members.

1.3.2.7.1.4 Manage Project Team It is a process to keep track of team member performance, provide feedback, resolve issues, and manage changes to ensure project performance optimization.

Construction projects are of a temporary nature, and project team members are collected from different backgrounds and disciplines, therefore, it is inevitable that issues/conflicts may arise among the members. There are mainly three project teams in construction. Each project manager has to resolve the issues as they arise and manage the team effectively by maintaining cohesion among all the team members. This can be achieved by:

- Establishing ground rules.
- Coordinating with all team members to understand their issues.
- Creating shared vision among team members.
- Tracking team performance.
- Training, recognition, and rewards.
- Conducting meetings, exchanging relevant information, and resolving issues.
- Problem identification and providing a quick solution.
- Conflict management.

Manage Conflict

There exist several types of conflict. Each conflict can assume a different intensity at different stages of the project. The causes of disagreement vary in different phases of the project as different members are involved at different phases of the project. The following are typical sources of conflict that may arise during the project:

- Priorities
- Project Schedule
- Resources
- Cost
- Scope Change
- Technical Opinions
- Personality Conflict
- Communication Problem
- Lack of Coordination by Team Members
- Administrative Procedures

The project manager has to resolve the conflict by searching an alternate solution. The following methods are normally used to resolve conflicts:

1. Withdrawing/Avoiding
   It means both parties retreat from the conflict issue.
2. Smoothing/Accommodating
   It is emphasizing friendly relationships and agreement rather than differences of opinion.
3. Collaborating
   In this method, parties try to incorporate multiple viewpoints in order to lead to consensus.
4. Confronting/Problem-Solving
   It is a fact-based approach where both parties solve their problems by focusing on the issues, looking at alternatives, and selecting the best alternative.

5. Compromising
   Compromising is finding a solution that brings some degree of satisfaction to both parties.
6. Forcing
   Forcing is the use of authority and power in resolving a conflict by exerting one's viewpoint over another at the expense of another party.

Figure 1.68 illustrates the conflict management flowchart.

Dealing with Conflicts in Project Teams (This section is an article that is reproduced with permission of Michael Stanleigh)

Team conflict is challenging for project leaders but it is not necessarily bad. Conflict can lead to new ideas and approaches and facilitate the surfacing of important issues between teams if it is managed well.

According to various research studies on team conflict, the major sources of conflict among project teams are project **goals not agreed upon, disagreement of the project priorities, and conflicting work schedules.** This is no surprise since most organizations today run multiple projects and employees often find themselves serving on a variety of project teams. To add fuel to the fire, employees may report to a variety of project managers while reporting directly to functional managers. This sets the stage for further conflict opportunities due to communication and information flow. After all, when reporting relationships are complex it becomes more difficult to share information.

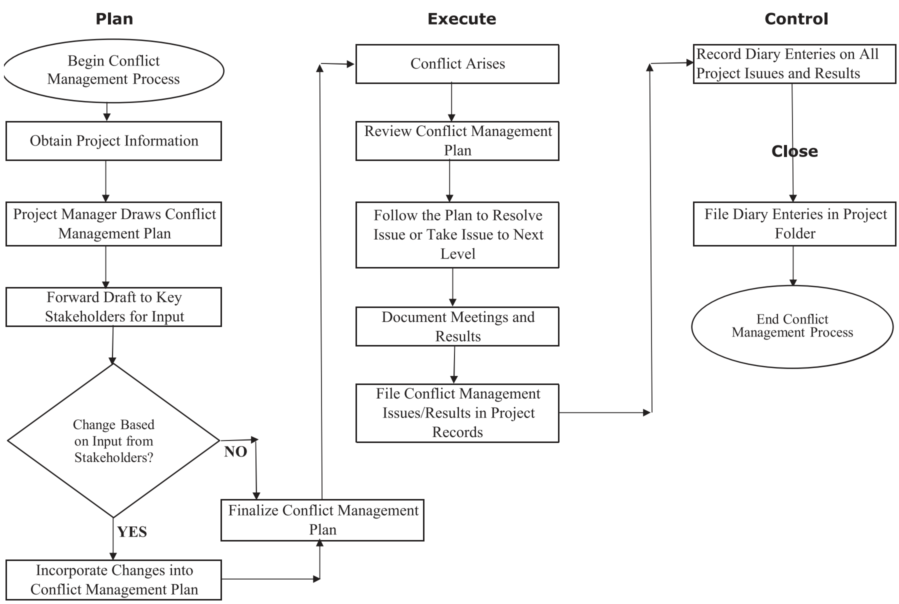


FIGURE 1.68 Conflict management flowchart.

Source: Project Management Handbook, Second Edition, September 2007. Reprinted with permission of California Department of Transportation Office of Project Management Process Improvement.

Personality and interpersonal issues may also draw conflict, particularly in high-technology environments, where cross-functional, self-directed teams with technical backgrounds must rely on the work of others to get their own work done.

So, what is the learning from these research studies? The lesson here is clear. It's very important for cross-functional team members to receive training in communication and interpersonal skills.

Here are some recommendations for project leaders and project team members:

1. Hold more frequent meetings and status review sessions to increase **communication** between functions and reduce misinterpretations of project goals and priorities.
2. Give team members soft skill training in human relations and facilitate more active team-building efforts.
3. Foster an environment of mutual respect. No method of managing conflict will work without mutual respect and a willingness to disagree and resolve disagreements.

If conflict erupts in your team, try taking the following four steps to calm things down: Listen, acknowledge, respond, and resolve remaining differences.

Listen: Clear your mind from distractions and really try to concentrate on what the person is trying to communicate. Listen to both the words and non-verbal cues from gestures and body language. Gestures are often more important than words. After all, when resolving disagreements, you often have to deal with feelings first.

Acknowledge: Acknowledgment does not mean agreement. You can acknowledge what someone is saying without necessarily agreeing with them. Everyone's opinion and feelings are valid, even if different from yours. For example, statements like "I understand you're angry," "Let's explore your suggestion further," or "If I understand you, you're saying that you disagree." These are all ways of acknowledging their communication and their point of view. While you may not agree with what you are saying, it shows that they are being heard.

Respond: Now you have acknowledged to them that you have heard what they have to say, it's your turn to respond. If you don't agree with what the person is saying, be sure that your feedback is constructive and offers alternative suggestions. A good way to pose your response is to speak from personal experience. For example, "In my experience, I have found that approach is ineffective because," (be prepared to explain your position and remain open to being challenged or questioned about it).

Resolve Remaining Differences: If you have listened carefully to people around you, you have probably figured out what's causing the disagreement. Once you have defined the real problem, you should be able to break it down into manageable parts. This will help you to generate alternative solutions and then select the alternative to which everyone can agree.

Remember, for individuals to work effectively in a team there has to be a certain level of trust among the group. Each team member needs to feel "safe" about sharing their ideas. While others may not be in full agreement with another person's ideas, it's important for the team leader to foster an appreciation for the different views presented and explore the best alternative in a respectful manner with honest intent.

Most importantly, when conflict does occur in a team, leaders can gain ground by not avoiding it. By managing it well, acknowledging it, and tolerating it, a team leader can actually use conflict as a tool to generate revitalized team engagement and innovation.

If the conflict is too great and the project leader is unable to get the team past it, then hiring a **team coach** is a good idea.

1.3.2.7.1.5 Release/Demobilize Project Team Construction projects are a temporary endeavor. Every time a project is initiated, project team members are acquired to complete the project. The organization's structure depends on the strategic policy of the organization. Once the project is completed, the project team members are released and sent back to their original functional department, engaged in other projects, or terminated from the work.

1.3.2.7.2 Construction Resources Management

In most construction projects, the contractor is responsible for managing their resources. It includes:

1. Manpower
2. Material
3. Equipment
4. Subcontractor(s)

1.3.2.7.2.1 Manage Manpower It is the contractor's responsibility to arrange the necessary manpower to execute the project. This includes:

- Contractor's site staff to supervise the construction (core staff).
- Field workers to execute the work.

The contract documents normally specify a list of a minimum number of core staff to be available at the site during the construction period. The absence of any of these staff may result in a penalty to be imposed on the contractor by the owner.

The contractor has to consider the qualifications and related experience mentioned in the contract documents while acquiring the team members to work on the project.

1.3.2.7.2.2 Manage Equipment The contractor has to provide the required equipment to execute the construction work. Normally, contract documents specify a minimum number of equipment to be available at the site during the construction process to ensure the smooth operation of all the construction activities. The typical equipment list is as follows:

- Tower Crane
- Mobile Crane

- Normal Mixture
- Concrete Mixing Plant
- Dump Trucks
- Compressor
- Vibrators
- Water Pumps
- Compactors
- Concrete Pumps
- Trucks
- Concrete Trucks
- Diesel Generator Set(s)

Figure 1.69 illustrates an example equipment status listing quantities of different types of equipment that are available at the site during the construction period for a major building construction project.

The contractor has to maintain the equipment in good condition to ensure efficient utilization of the equipment.

1.3.2.7.2.3 Manage Material In most construction projects, the contractor is responsible for the procurement of materials, equipment, and systems to be installed on the project. The contractors have their own procurement strategies. While submitting the bid, the contractor obtains quotes from various suppliers/subcontractors. The contractor has to consider the following as a minimum while finalizing the material procurement:

- Contractual Commitment.
- Specification Compliance
- Statutory Obligations
- Time
- Cost
- Performance

Figure 1.70 illustrates the material management process for construction projects and Figure 1.71 illustrates the contractor's procurement log (Report E-2) normally called Log E-1.

1.3.2.7.2.4 Manage Subcontractor In construction projects, the main contractor (general contractor) is responsible for managing subcontractors' work. Much of the work required to be carried out on major projects is performed by subcontractors and specialist contractors. The main contractor has to manage their work by carefully planning, scheduling, and coordinating to complete the project successfully. Areas of subcontracting are generally listed in the particular conditions of the contract document. The main contractor is responsible to manage the subcontractors' work.

Serial Number	Description	Months																												
		Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23
1	Tower Crane						1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2								
2	Mobile Crane								1	1	2	2	2	2	2	2	2	2	2	2	2	2								
3	Tractor (Loader)				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					
4	Trailer							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
5	Excavator				1	1	1	1	1	1	1	1	1																	
6	Truck				2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1					
7	Tipper Truck				2	2	2	2	2	2	2	2	2																	
8	Generator					1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
9	Half Lorry							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
10	Pickup							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
11	Air Compressor							2	2	2	2	2	2	2	2	2	2	2	2	2	2	2								
12	Welding Machine							2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2					
13	Bar Bending Machine							2	2	2	2	2	2	2	2	2	2	2	2	2	2	2								
14	Bar Cutting Machine							2	2	2	2	2	2	2	2	2	2	2	2	2	2	2								
15	Vibrator							2	2	2	2	2	2	2	2	2	2	2	2	2	2	2								
16	Compactor						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
17	Wood, Marble, Brick Cutter									2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			
18	Total Station				1	1	1	1	1	1	1	2	1	1	1	1	1	2	1	1	1	1	1	2	1	1	1			
19	Dumpy Level				2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			
20	Bobcat										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			
21	Water tanker						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
22	Boom Truck										1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					
23	Forklift										1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
24	Bus Coaster							2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			
25	Mini Bus							2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			
	Total Equipment				**9**	**10**	**13**	**31**	**33**	**35**	**40**	**41**	**40**	**36**	**36**	**36**	**36**	**37**	**36**	**36**	**36**	**36**	**23**	**24**	**22**	**16**	**16**	**3**	**1**	**1**

EXAMPLE STATUS

FIGURE 1.69 Equipment status.

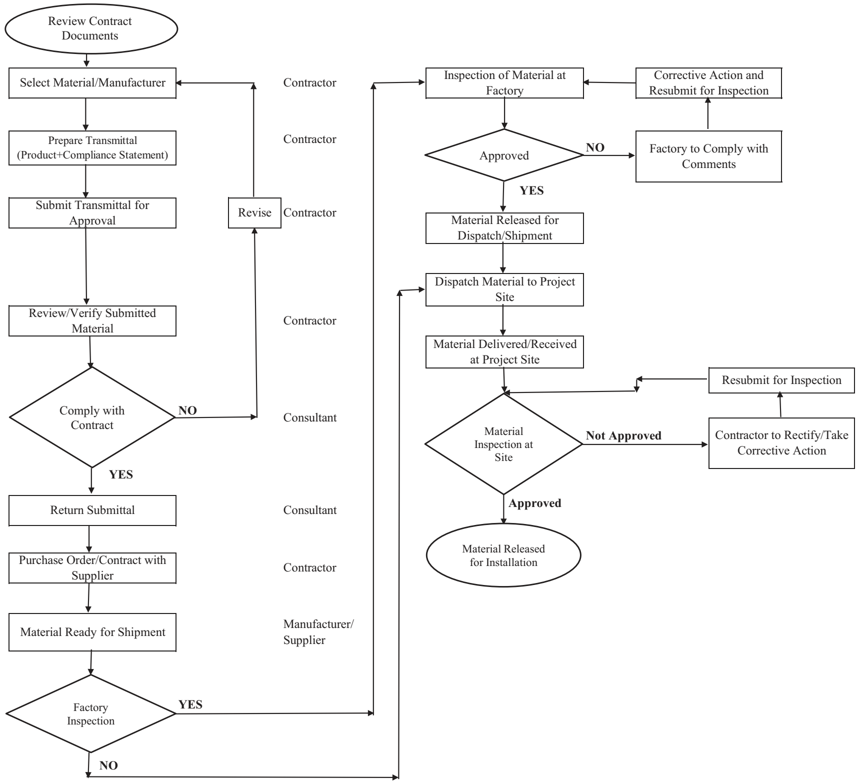


FIGURE 1.70 Material management process for a construction project.

1.3.2.8 Project Communication Management

Communication is the process by which information is transmitted by a sender to a receiver via a channel/medium. The receiver encodes the message and gives feedback to the sender. Figure 1.72 illustrates the communication model.

The standard methods of communication methods widely used are either written or oral. Written means letters, notices, emails, or messaging (electronic media). Oral means meeting, telephonic conversation. Apart from these two mechanisms, nonverbal communication is another method used to assess communication within the organization. Communication is either formal or informal.

Formal communication is planned and delivered as part of the standard operating policies and procedures of the organization.

Informal communication is not mandated or otherwise required but occurs as part of people functioning collectively.

Communication can be internal and external.

Direction of communication can be top to bottom vertical communication (downward) or bottom-to-top (upward) or horizontal.

Project Name
Consultant Name

CONTRACTOR'S PROCUREMENT LOG (REPORT E-2)

CONTRACT NO. : ______ NO. : ______
CONTRACTOR : ______ DATE : ______

Activity No.	Description	B.O.Q./ Specification. No.	Estimated Quantity	Ordered Quantity	Reqd. Order Date	Date Pur. Ord. Issued	Purchase Order No.	Supplier	Method Of Shipping	Shipping Date to Kuwait	Required On Job Date	E.D.A. To Site	A.D.A. To Site	Lead Time	Remarks

SAMPLE FORM

FIGURE 1.71 Contractor's procurement log E-2.

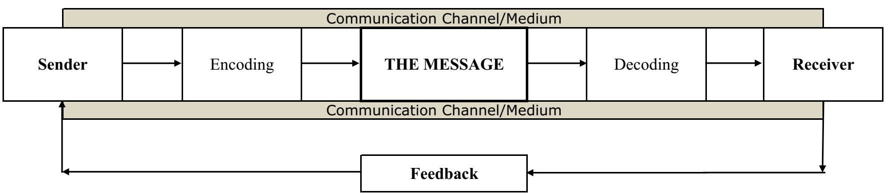


FIGURE 1.72 Communication model.

As per *PMBOK® Guide*, fifth edition, project communication management includes the processes that are required to ensure timely and appropriate planning, collection, creation, storage, retrieval, management, control, monitoring, and ultimate disposition of project information. Project communication management includes the following processes:

1. Plan communication.
2. Manage communication.
3. Control communication.

The construction project has the involvement of many stakeholders. The project team must provide timely and accurate information to identified stakeholders who will receive communications. Effective communication is one of the most important factors contributing to the success of a project. Project communication is the responsibility of everyone on the project team. Communication management process in construction project consists of the following activities:

1. Develop Communication Plan
2. Manage Communication
3. Control Documents

1.3.2.8.1 Develop Communication Plan

The communication plan helps project team members to identify internal and external stakeholders involved in the project. Figure 1.73 illustrates the communication plan development process.

A comprehensive communication plan for the construction project can be developed by analyzing the questions listed in Table 1.28.

1.3.2.8.1.1 Establish Communication Matrix For a smooth flow of communication in a construction project, a proper communication matrix among all the stakeholders needs to be established at the start of each stage of the project. A communication matrix is used as a guideline for what information to communicate, who is the team member to initiate, who will receive and take appropriate action when to communicate, and what method of communication. Table 1.29 illustrates an example guideline to prepare a communication matrix for site administration during the construction phase.

1.3.2.8.1.2 Determine Communication Methods The method of communication in construction projects depends on the project stage and needs of the stakeholders. There are number of methods for determining requirements of stakeholders, however, it is imperative that they are completely understood in order to effectively manage their interest, expectations, and influence and ensure a successful project. The following are common methods used in construction projects:

- Letters and other hard copy.
- Specific type of transmittal forms.
- Meeting.
- E-mails.
- Telephone calls.
- Conferencing (voicemail).
- Web-Based.

1.3.2.8.1.3 Establish Submittal Procedure

In construction projects, there are various types of documents that are to be sent to different stakeholders. Proper correspondence and reporting methods are important to distribute this information.

Construction projects involve many stakeholders. Large numbers of documents move forward and backward between these stakeholders for information or action. During the design stage, the communication is mainly between the owner (project/

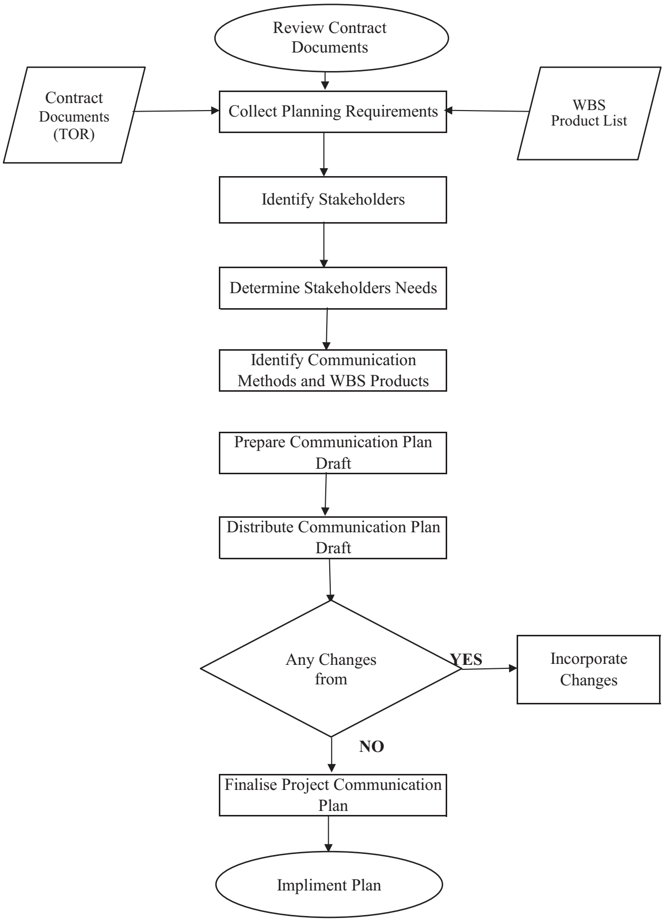


FIGURE 1.73 Communication plan development process.

TABLE 1.28
Analysis for Communication Matrix

Serial Number	W+H	Related Analyzing Question
1	What	What is the purpose of communication?
2	What	What type of information needs to be communicated?
3	Who	Who will initiate (send) the communication?
4	Who	Who are the stakeholders to receive the information?
5	When	When the information to be sent (frequency)?
6	What	What method of communication to be used?
7	How many	How many copies to be distributed?
8	How much	How much time to wait to receive the feedback?
9	How	How to archive the documents?

TABLE 1.29
Communication Matrix

Project Name

Name of Construction/Project Manager:						Name of Consultant:		
Contractor Name:						Project Number:		
Serial Number	**Type of Document**	**Originator**	**Receiver(s)**	**Purpose**	**Frequency**	**Method**	**Responsible Person for Action**	**Comments**

construction manager) and the designer (consultant). However, once the contractor is selected depending on the type of project delivery system (design-build contractor or construction contractor or CM at risk), then the contractor is actively involved in the project communication system. Apart from form these three parties, some other stakeholders, who have interest, expectations, and influence in the project, are also sent a copy of information/documents for their information or action.

During the design stage, the following are the major documents the designer sends to the owner:

- Design Drawings
- Reports
- Minutes of Meetings
- Review Comments
- Contract Specifications
- Bidding/Tendering Documents

These documents are normally transmitted by the designer using the transmittal form. Figure 1.74 illustrates a sample transmittal form.

During the construction phase, there are many documents sent forth and back between the owner, construction supervisor (A/E, consultant), and contractor. The originator of these documents is mentioned in the communication matrix. The following are the types of documents exchanged among the owner, supervisor, and contractor:

- Administrative
- Contract Related
- Engineering Submittals
- Project Monitoring and Control
- Quality

Table 1.30 illustrates a list of forms normally used during the construction phase to communicate different types of documents.

The detailed procedure for submitting materials/products/systems, samples, and shop drawings is specified under the section "SUBMITTAL" of contract specifications. The contractor has to submit the same to the owner/consultant for their review and approval. The contract documents under Section 013300 Submittal Procedures (CSI Format General Requirements) specify administrative and procedural requirements for submission of submittals and other documents. The contractor has to comply with the contractual requirements for submittal requirements.

The submittal process, in construction projects, is essential to ensure that the contractor's understanding of product specifications, contract drawings, and installation method matches with the designer's intent of product usage and installation method. The submittal process provides the owner with the assurance that the contractor is complying with the design concept and the installed material will function as required by the contract documents. Submittals are documents that are presented by the contractor for approval, review, decision, or consideration.

PROJECT NAME

PROJECT/CONSTRUCTION MANAGER

DESIGNER (CONSULTANT NAME)

TRANSMITTAL FORM

To: ______________________ Date: __________

Attn: ______________________ Ref. No.: __________

Phase No.: ______________________ Copies to : __________

Drawings ☐ **Specifications** ☐ **Report** ☐ **Minutes** ☐

No.	Copies	Name of Document	Description

SAMPLE FORM

Purpose of issuing:

Sent by : ______________ Signed: ______________ Date : __________

Rec'd by: ______________ Signed: ______________ Date : __________

FIGURE 1.74 Transmittal form.

Generally, these submittals fall into three categories. These are:

1. Approval Submittals
2. Review Submittals
3. Information Submittals

TABLE 1.30
List of Project Control Documents

Serial Number	Document Name	
I	**Administrative**	
	I.1	Material Entry Permit
	I.2	Material Removal Permit
	I.3	Vehicular Entry Permit
	I.4	Site Entry Permit
	I.5	Visitor Entry Permit
	I.6	Municipality Permit
	I.7	Request for Overtime
	I.8	Theft and Damage Report
	I.9	Performance Bonds
	I.10	Advance Payment Guarantee
	I.11	Insurance
	I.12	Accident Report
	I.13	Sample Tag
II	**Contracts Related**	
	II.1	Notice to Proceed
	II.2	Job Site Instruction
	II.3	Site Work Instructions
	II.4	Attachment to Site Work
	II.5	Request for Staff Approval
	II.6	Request for Subcontractor Approval
	II.7	Variation Order
	II.8	Attachment to Variation Order
	II.9	Material Delivered at Site
	II.10	Baseline Change Request Form
	II.11	Extension of Time
	II.12	Suspension of Work
	II.13	Attendees
	II.14	Minutes of Meeting
	II.15	Transmittal for Minutes of Meeting
	II.16	Submittal Form
III	**Engineering Submittal**	
	III.1	Master Schedule
	III.2	Cost Loaded Schedule
	III.3	Material Approval
	III.4	Specification Comparison Statement
	III.5	Product Data
	III.6	Product Sample
	III.7	Workshop Drawings
	III.8	Builders Drawings
	III.9	Composite Drawings
	III.10	Method Statement
	III.11	Request for Information

(*Continued*)

TABLE 1.30 Continued
List of Project Control Documents

Serial Number	Document Name	
	III.12	Request for Modification
	III.13	Variation Order (Proposal)
	III.14	Request for Alternative or Substitution
IV	**PCS Reporting Forms**	
	IV.1	Contractor's Submittal Status Log E-1
	IV.2	Contractor's Procurement Log E-2
	IV.3	Contractor's Shop Drawing Status Log
	IV.4	Daily Progress Report
	IV.5	Weekly Progress Report
	IV.6	Lookahead Schedule
	IV.7	Monthly Progress Report
	IV.8	Progress Photographs
	IV.9	Daily Checklist Status
	IV.10	Progress Payment Request
	IV.11	Payment Certificate
	IV.12	Submittal Schedule
	IV.13	Schedule Update Report
V	**Management Plans**	
	V.1	Quality Control Plan
	V.2	Safety Plan
	V.3	Environmental Protection Plan
VI	**Quality Control Forms**	
	VI.1	Checklist (Request for Inspection)
	VI.2	Checklist for Form Work
	VI.3	Notice for Daily Concrete Casting
	VI.4	Checklist for Concrete Casting
	VI.5	Quality Control of Concreting
	VI.6	Report on Concrete Casting
	VI.7	Notice for Testing at Lab
	VI.8	Concrete Quality Control Form
	VI.9	Checklist for Mechanical Work
	VI.10	Checklist for Electrical Work
	VI.11	Checklist for Finishing
	VI.12	Checklist for External Work
	VI.13	Checklist for Landscape
	VI.14	Remedial Note
	VI.15	Non-Conformance/Compliance Report
	VI.16	Material Inspection Report
	VI.17	Safety Violation Notice
	VI.18	Notice of Commencement of New Activity
	VI.19	Removal of Rejected Material
	VI.20	Testing and Commissioning

(*Continued*)

TABLE 1.30 Continued
List of Project Control Documents

Serial Number	Document Name	
VII	**Closeout Forms**	
	VII.1	As-Built Drawings
	VII.2	Substantial Completion Certificate
	VII.3	Handing Over Certificate
	VII.4	Taking Over Certificate
	VII.5	Manuals
	VII.6	Handing Over of Spare Parts
	VII.7	Defect Liability Certificate

Prior to the start of execution/installation of work, the contractor has to submit specified material/product/system, and shop drawings to the A/E/(consultant), construction/project manager, as per project specification requirements, for approval, review, or information. The contractor, while preparing the submittal for the shop drawing has to consider the following:

1. Review contract specifications.
2. Review contract drawings.
3. Determine and verify field/site measurements.
4. Installation information about the material to be used.
5. Installation details relating to the axis or grid of the project.
6. Dimensions of the product, equipment to be installed.
7. Roughing in requirements.
8. Coordination with other trade (disciplines) requirements.
9. Clearly marking the changes, deviations to the contract drawings.

The consultant reviews the submittal to verify that the proposed product/sample/shop drawing comply with the contract specifications and returned the transmittal to the contractor mentioning one of the following actions on the transmittal:

- **A:** Approved
- **B:** Approved as Noted
- **C:** Revise and Resubmit OR Not Approved
- **D:** For Information OR More Information Required

In case of deviation from the specified items, the contractor has to submit a schedule of such deviation(s) listing all the points that do not conform to the specifications.

Figure 1.75 illustrates a site transmittal form for material approval, Figure 1.76 illustrates a specification comparison form, and Figure 1.77 illustrates a site transmittal form for shop drawing approval.

Project Name

Consultant Name

SITE TRANSMITTAL

Request for Material Approval

CONTRACT No. : TRANSMITTAL NO. ___________ REV. _____

CONTRACTOR :

TO :

WE REQUEST APPROVAL OF THE FOLLOWING MATERIALS/GOODS/PRODUCTS/EQUIPMENT

ITEM NO.	DWG., SPEC. OR BOQ. REF	DESCRIPTION	SUBMITTAL CODE *	ACTION CODE **
		SAMPLE FORM		

DETAILS OF INFORMATION,LITERATURE, CATALOG CUTS, AND THE LIKE ATTACHED ARE:

SAMPLES:

Enclosed ☐ Submitted under separate cover ☐ Not applicable ☐

N.B: We certify that above items have been reviewed in detail & and are correct & in strict performance with the Contract Drawings & Specification except as otherwise stated.

CONTRACTOR'S REP. : ____________________ DATE : ____________

RECEIVED BY CONSULTANT : ____________________ DATE : ____________

cc: Owner Rep.

Resident Engineer to enter ACTION CODE and REMARKS

R.E.'s REMARKS :

Initials ____________ Date ________

Corrections or comments made relative to submittals during this review do not relieve Contractor from compliance with the requirements of the Drawings and Specifications. This check is only for review of general conformance with the design concept of the project and general compliance with the information given in the Contract Documents. Contractor is responsible for confirming and correlaing all quantities and dimensions, selecting fabrication process and techniques of construction; coordinating his work with that of other trades, and performing his work in a safe and satisfactory manner.

Resident Engineer : ____________________ DATE : ____________

Received by Contractor : ____________________ DATE : ____________

cc: Owner Rep.

* SUBMITTAL CODE:	** ACTION CODE:	
1: Submitted for Approval	A: Approved	C: Not Approved

FIGURE 1.75 Site transmittal for material.

1.3.2.8.2 Manage Communication

The contract document specifies the number of original (paper print) and copies to be transmitted to A/E (consultant) for review and approval. Figure 1.78a illustrates an example submittal process (paper-based) and Figure 1.78b illustrates an example submittal process (electronic).

Figure 1.79 illustrates a sample submittal transmittal form.

With the advent of the electronic submittal transmittal system, electronic documents, such as Portable Document Format (PDF) and Building Information Model (BIM), are used for submittal purposes. The contractor, A/E (consultant), or owner may use an Internet-based project management software having transmission, tracking, and email features., however utilization of an electronic documentation system should be specified in the contract documents.

1.3.2.8.2.1 Manage Submittals There are different types of logs used in construction projects to monitor the submission of material, shop drawings, and other submittals. Figure 1.80 illustrates a contractor's submittal status log (Report E-1) normally called Log E-1 and Figure 1.81 illustrates a contractor's shop drawing status log.

1.3.2.8.2.2 Conduct Meetings Project meeting refers to a face-to-face communication method to exchange information among team members and stakeholders.

In construction projects, there are many types of meetings held during all the stages/phases of the project. Each meeting has its own purpose and structure. The meetings are used to distribute information, discuss issues, make proposals, suggest solutions, share information, and contribute ideas for improvement and successful completion of the project. The following types of meetings are normally held in construction projects:

1. Kickoff meeting.
2. Planning meeting.
3. Pretender meeting.
4. Preconstruction meeting.
5. Coordination meeting.
6. Progress meeting.
7. Change control meeting.
8. Quality meeting.
9. Safety meeting.

The frequency of meetings depends on the project stage/phase. The frequency of meetings in the construction phase is normally specified in the contract documents. To conduct a project meeting, it is advisable to prepare and circulate the agenda well in advance. In case of a progress meeting during the construction phase, the resident engineer prepares the agenda and circulates it to the participants expected to attend the meeting. The contractor informs the resident engineer in advance about the points the contractor would like to discuss. These points are also included in the agenda. Figure 1.82 illustrates a typical agenda format for a meeting. Figure 1.83 is a sample form to list the meeting attendees, Figure 1.84 illustrates the format for

Project Name
Consultant Name

SPECIFICATION COMPARISON STATEMENT (SCS)

Contractor: ______________________ Date : ____________

Contract No. ______________________ A/S No.: ____________

Submittal No. : ____________ Revision: ______ Transmittal Ref.: ________

Submittal Title: ____________ Specification Ref : ________

S No.	SPECIFICATION REQUIREMENTS	CONTRACTOR'S PROPOSAL	REMARKS

SAMPLE FORM

FIGURE 1.76 Specification comparison statement.

preparation of the minutes of the meeting, and Figure 1.85 is a sample transmittal form for distribution of the minutes of the meeting.

1.3.2.8.2.3 Manage Documents In construction projects, all the related documents are sent and received (exchanged) through the use of a transmittal form. These forms are generally issued to the contractor along with other contract documents. Project team members are required to follow the procedures specified in the contract.

For any communication with external stakeholders, such as regulatory bodies, a company letterhead is used to communicate the matter.

1.3.2.8.3 Control Documents

Contract conditions specify the time allowed to process the transmittal and other contract-related communication. The contractor, consultant, and construction/project manager maintain logs for all incoming and outgoing documents. Follow-up is also done among internal project team members to expedite the required action to be taken against the transmittal.

Table 1.31 illustrates the logs maintained by the consultant during site supervision.

1.3.2.9 Project Risk Management

Risk is the probability that the occurrence of an event may turn into an undesirable outcome (loss, disaster). It is virtually anything that threatens or limits the ability of an organization to achieve its objectives. It can be unexpected and unpredictable events that have the potential to damage the functioning of the organization in terms of money or in the worst scenario it may cause the business to close.

Project Name
Consultant Name
SITE TRANSMITTAL
Request for Shop Drawings Approval

CONTRACT No.: TRANSMITTAL NO. ___________ REV. _____

CONTRACTOR :

TO :

WE REQUEST APPROVAL OF THE FOLLOWING ENCLOSED DRAWINGS

ITEM NO.	DWG., SPEC. OR BOQ. REF	DRAWING TITLE	DWG. NOS.	Rev.	SUBMITTAL CODE *	ACTION CODE **
	SAMPLE FORM					

N.B: We certify that above items have been reviewed in detail & and are correct & in strict performance with the Contract Drawings & Specification except as otherwise stated.

CONTRACTOR'S REP. : ______________________ DATE : ______________

RECEIVED BY CONSULTANT : ______________________ DATE : ______________

cc: Owner Rep.

Resident Engineer to enter ACTION CODE and REMARKS

R.E.'s REMARKS :

Initials ____________ Date ________

Corrections or comments made relative to submittals during this review do not relieve Contractor from compliance with the requirements of the Drawings and Specifications. This check is only for review of general conformance with the design concept of the project and general compliance with the information given in the Contract Documents. Contractor is responsible for confirming and correlating all quantities and dimensions, selecting fabrication process and techniques of construction; coordinating his work with that of other trades, and performing his work in a safe and. satisfactory manner.

Resident Engineer : ______________________ DATE : ______________

Received by Contractor : ______________________ DATE : ______________

cc: Owner Rep.

cc: Project Manager	**** ACTION CODE:**
1: Submitted for Approval	A: Approved C: Not Approved
2: Submitted for your Information	B: Approved as Noted D: For Information
3:	

FIGURE 1.77 Site transmittal for shop drawings.

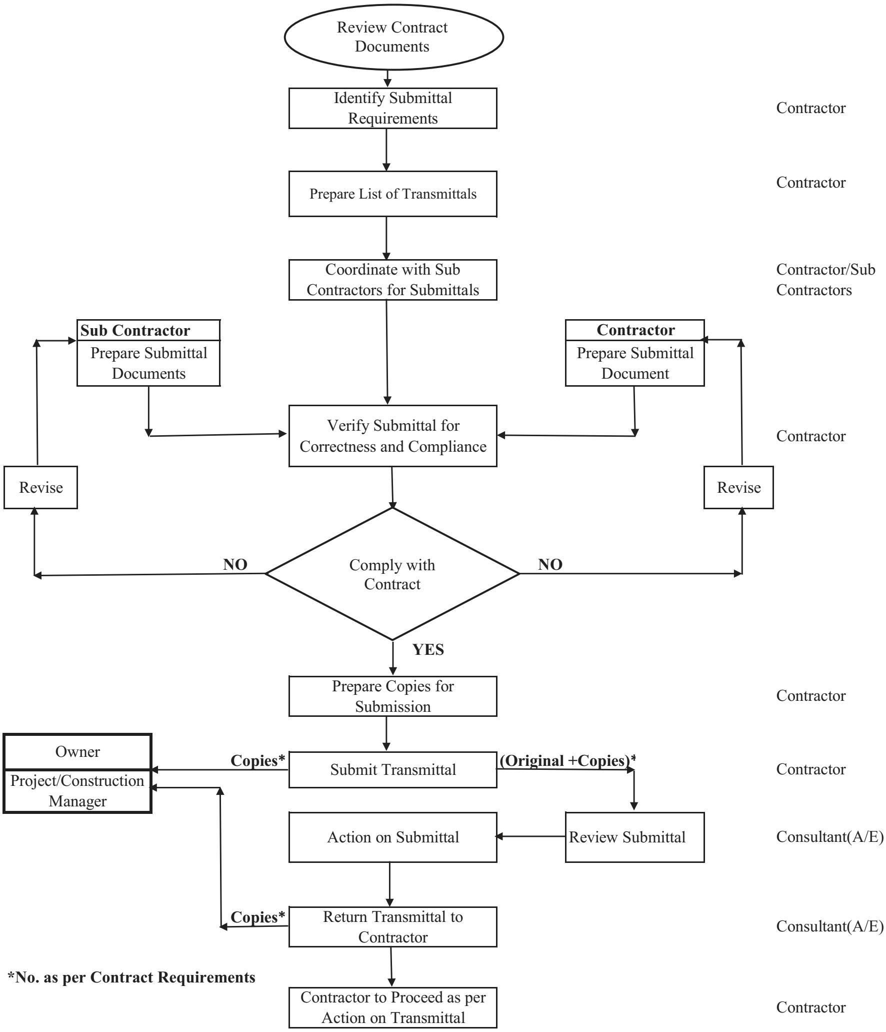


FIGURE 1.78A Submittal process paper-based.

Risk is any unexpected event that may occur suddenly and thus affect the organization's strategic and operational objectives. Risk is the possibility of events or activities impeding the achievement of an organization's strategic and operational objectives.

Risk management is a set of coordinated activities to direct and control the risk. Risk management is the process of identifying, analyzing, assessing, and prioritizing different kinds of risks, responding to any risk by planning risk mitigation, implementing mitigation plans, and controlling the risks. It is a process of thinking systematically about the possible risks, problems, or disasters before they happen and setting up the procedure that will avoid the risk, minimize the impact, or cope with

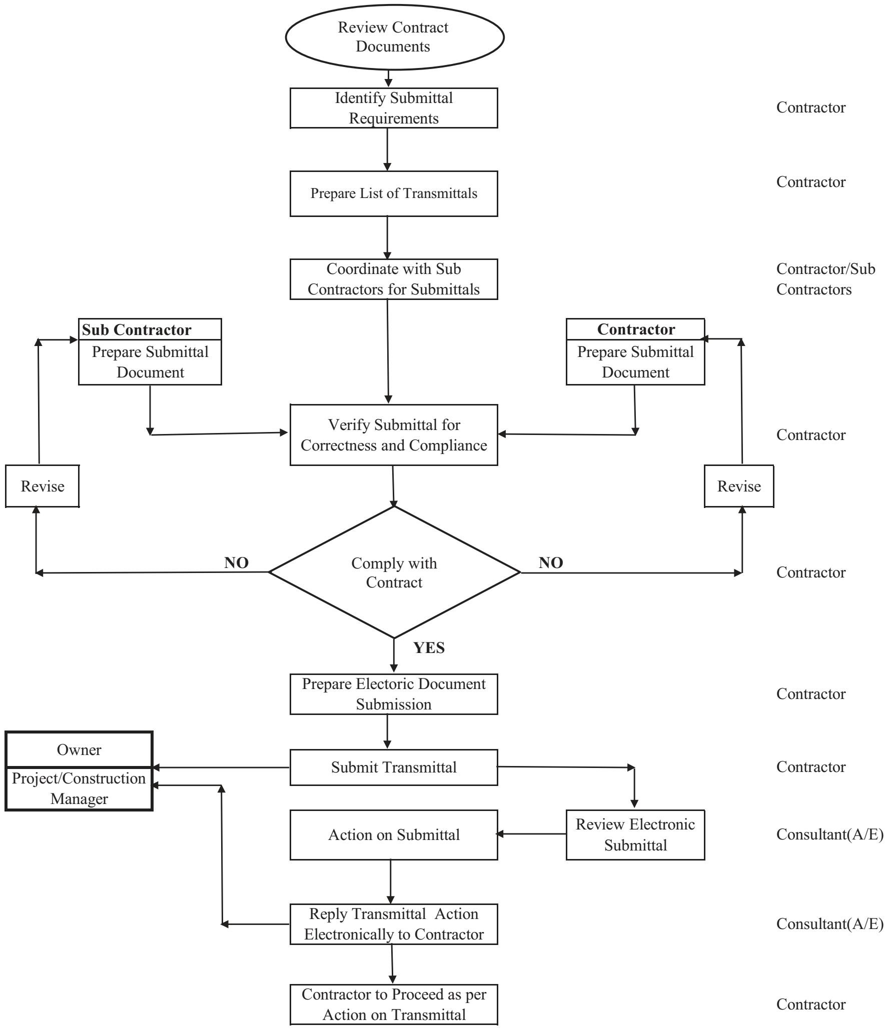


FIGURE 1.78B Submittal process electronic.

the impact. The objectives of project risk management are to increase the probability and impact of positive events and decrease the probability and impact of events adverse to the project objectives.

1.3.2.9.1 ISO 31000 Risk Management Standard

ISO 31000 is an international standard published in 2009 that provides principles and guidelines for effective risk management. It outlines a generic approach to risk management that can be applied to different types of risks (financial, safety, project risks) and used by any type of organization. The standard provides a uniform vocabulary and concepts for discussing risk management. It provides guidelines and principles

Project Name			
Consultant Name			
SUBMITTAL TANSMITTAL FORM			
Contractor Name :			
Contract No. :			
To.	**Resident Engineer**		
Transmittal No.:		**Date :**	

Submittal Type:		**Action Requested:**	
DG	Shop Drawings	1	For Approval
SK	Sketches	2	For Review and Comment
PR	Material/Product/System	3	For Information
MD	Manufacturer's Data	4	For Construction
SM	Sample	5	For Incorporation Within the Design
MM	Minutes of Meeting	6	For Costing
RP	Reports	7	For Tendering
LG	Logs	SAMPLE FORM	
OT	Others (please specify)		

We are sending herewith the following:

ENCLOSURES

Item	Qty	Ref. No.	Description	Type	Action

Comments:

Issued by:	**Received by:**
Signature:	Signature:
Date:	Date:

FIGURE 1.79 Submittal transmittal form.

that can help to undertake a critical review of your organization's risk management process. ISO 31000 is intended to serve as a guide for the design, implementation, and maintenance of risk management. ISO 31000:2009 describes a systematic and logical process, during which organizations manage risk by identifying it, analyzing, and then evaluating whether the risk should be modified by risk treatment in order to satisfy their risk criteria.

ISO standards are updated periodically. ISO 31000:2009 was revised in 2018. The book discusses the guidelines intended to streamline risk management for

Project Name
Consultant Name

CONTRACTOR'S SUBMITTAL STATUS LOG (REPORT E-1)

CONTRACT NO. : ____________________ NO. : ________
CONTRACTOR : ____________________ DATE : ________

Type of Submittal: Shop Drawing (SD), Samples (SM), Guarantee (GT), Mf's Dats (MF), Mt's Dats (MT), Certificates (CT), Test (TT), Otr (OT)

Action Code :
A = Approved as submitted
B = Approved as noted
C = Not Approved
D = For Information

Document Specification or BOQ Page	Submittal Sequence No.	Rev	Description	SD	SM	GT	MF	MT	CT	TT	OT	Planned Sub. date	Submitted By Contrac.	Returned By A/E	Action	Approval Needed By	Required On Job	Notes

SAMPLE FORM

FIGURE 1.80 Contractor's submittal status log E-1.

Project Name

Consultant Name

CONTRACTOR'S SHOP DRAWINGS STATUS LOG

CONTRACT NO. :		NO. :	
CONTRACTOR :		DATE :	

Document Specification or BOQ Page	Item No.	Submittal Sequence No.						Drawing No.	Description	Submittal Type	Action Code : A = Approved as submitted B = Approved as noted BR = Approved as noted, Resubmit C = Not Approved D = For Information						Remarks
		Div	Sec	Typ	Sr.	Rev	Ser			SD	Planned Sub. date	Submitted By Contrac.	Returned By A/E	Action	Approval Needed By	Required On Job	

SAMPLE FORM

FIGURE 1.81 Contractor's shop drawing status log.

PROJECT NAME

Contract Number:			
Type of Meeting:		**Date of Meeting:**	
Place of Meeting:		**Time of Meeting:**	
Owner:			
Project/Construction Manager			
A/E (Consultant)			

AGENDA

SAMPLE FORM

1.Points to be discussed:

1.1 …………………………………

1.2 ………………………………….

1.3 ………………………………….

1.4 …………………………………..

…………………………………………….

…………………………………………….

2. Any other Issues:

Signed by: ………………………. Position: …………………………

Deate: …………………………..

FIGURE 1.82 Agenda format for meeting.

organizations and the clauses described in ISO 31000:2018. Table 1.32 lists the clauses of ISO 31000:2018

Risk is involved in any activity of an organization. Risk management can be applied to an entire organization, at its many areas and levels, at any time, as well as to specific functions, projects, and activities.

Risk management is application-specific. In some circumstances, it can therefore be necessary to supplement the vocabulary in this guide. Where terms related to the management of risk are used in a standard, it is imperative that their intended meanings within the context of the standard are not misinterpreted, misrepresented, or

PROJECT NAME
Construction/Project Manager Name
CONSULTANT(A/E) NAME

ATTENDEES

Meeting Type: ____________________ Meeting No.: ____________

Location: ____________

Project Phase: ____________________ Date: ____________

Time: ____________

S No.	NAME	POSITION	COMPANY	SIGNATURE
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

FIGURE 1.83 Meeting attendees.

misused. ISO 31000 focuses on best practice principles for implementing, maintaining, and improving a framework for risk management.

ISO 31000 is a set of guidelines, not requirements, whereas ISO 9001 and ISO 14001 are requirements, which means they compose a strict set of specifications that can be certified to. ISO 31000 is not for certification purposes. It's simply a set of best practice guidelines.

ISO 31000 is an effort to acknowledge that business operations always contain a degree of uncertainty, and therefore, risk. No matter what our business goals, there's always a chance that things might go wrong.

PROJECT NAME

Minutes of Meeting

Contract NO.:	
Owner Name:	
Project/Construction Manager:	
Contractor Name:	

Meeting Type:		Minutes Number:	
		Date:	
Meeting Location:		Time:	

SAMPLE FORM

Attendees

Number	**Name**	**Position**	**Company**

ITEM	DESCRIPTION OF DISCUSSION	STATUS	PRIORITY	ACTION			
				By	Due	Started	Completed

Distribution	Owner	PM/CM	Engineer's Representative	Contractor	Other
Original Copies	☐ ☐	☐ ☐	☐ ☐	☐ ☐	☐ ☐

FIGURE 1.84 Minutes of meeting.

ISO 31000 family consists of:

1. ISO 31000:2018 (Principles and Guidelines on Implementation) ISO/IEC
2. ISO 31010:2009 (Risk Assessment Techniques)
3. ISO Guide 73:2009 (Risk Management Vocabulary)

PROJECT NAME

Transmittal for Minutes of Meeting

Transmittal Number:		**Date:**	
Contract Number:		**Contractor:**	
Owner:			
Project/Construction Manager	SAMPLE FORM		
A/E (Consultant)			

Meeting Type:		Minutes Number:	
		Date:	
Meeting		Time:	

ATTENDEES			
NO	NAME	POSITION	COMPANY

Your Use	☐	For Review and Comment	☐
Your Approval	☐	As Requested	☐

Engineer's Representative

Name	Signature	Date

The attached minutes constitutes our understanding of the points discussed and conclusions reached. All participants are requested to review these minutes and inform Engineer's Representative of their comments, if any, latest in 72 hours of the date of receiving these minutes.

FIGURE 1.85 Minutes of meeting transmittal.

ISO 31000 aims to simplify risk management into a set of clearly understandable and actionable guidelines, that should be straightforward to implement, regardless of the size, nature, or location of a business.

Risk management is an ongoing process that continues throughout the lifecycle of a project. Managing risk is based on principles, framework, and process outlined under Clauses 4, 5, and 6 of ISO 31000 Risk Management System. These activities

TABLE 1.31
List of Logs

Section	Log
1	Incoming and Outgoing Letters (Owner, Contractor)
2	Staff Approval
3	Subcontractor Approval
4	Transmittal for Shop Drawing
5	Material Source Approval
6	Transmittal for Material
7	Transmittal for Sample
8	Request for Alternative
9	Request for Information
10	Request for Modification
11	Job Site Instruction
12	Variation Order
13	Request for Substitution
14	Non-Compliance Report
15	Remedial Note
16	Payment Request/Certificate
17	Daily Report
18	Checklist
19	Daily Checklist Status
20	Checklist for Concrete Casting
21	Material Delivered at Site
22	Material Inspection Report
23	Concrete Test Report
24	Weekly Progress Report
25	Monthly Progress Report
26	Photographs
27	Notice of Meeting
28	Minutes of Meeting
29	Safety Violation Report
30	Accident Report
31	Request for Proposal
32	Construction Schedule
33	Safety Management Plan
34	Quality Control Plan
35	Authority Approved Drawings
36	Correspondence with Authorities
37	Issue Log
38	Inter Office Memo
39	Video Recording

TABLE 1.32
ISO 31000:2018 Sections (Clauses)

Section (Clause) No.	Relevant Clause in 31000:2018	Description
1	**Scope**	
2	**Normative References**	
3	**Terms and References**	
	3.1	Risk
	3.2	Risk Management
	3.3	Stakeholder
	3.4	Risk Source
	3.5	Event
	3.6	Sequence
	3.7	Likelihood
	3.8	Control
4	**Principles**	
	4.1	Integrated
	4.2	Structured and Comprehensive
	4.3	Customized
	4.4	Inclusive
	4.5	Dynamic
	4.6	Best Available Information
	4.7	Human and Cultural Factors
	4.8	Continual Improvement
5	**Framework**	
	5.1	General
	5.2	Leadership and Commitment
	5.3	Integration
	5.4	Design
		5.4.1 Understanding the organization and its context.
		5.4.2 Articulating risk management commitment.
		5.4.3 Assisting organizational roles, authorities, responsibilities, and accountabilities.
		5.4.4 Allocating resources.
		5.4.5 Establishing communication and consultation.
	5.5	Implementation
	5.6	Evaluation
	5.7	Improvement
		5.7.1 Adapting.
		5.7.2 Continually improving.
6	**Process**	
	6.1	General
	6.2	Communication and Consultation

(*Continued*)

TABLE 1.32 Continued
ISO 31000:2018 Sections (Clauses)

Section (Clause) No.	Relevant Clause in 31000:2018	Description
	6.3	Scope, Context, and Criteria
		6.3.1 General.
		6.3.2 Defining the scope.
		6.3.3 External and internal context.
		6.3.4 Defining risk criteria.
	6.4	Risk Assessment
		6.4.1 General.
		6.4.2 Risk identification.
		6.4.3 Risk analysis.
		6.4.4 Risk evaluation.
	6.5	Risk Treatment
		6.5.1 General.
		6.5.2 Selection of risk treatment options.
		6.5.3 Preparing and implementing risk treatment plans.
	6.6	Monitoring and Review
	6.7	Recording and Reporting

have a coordinated relationship. Figure 1.86 shows the relationship between these activities.

1.3.2.9.2 Risk Management Principles

As per ISO 31000, there are eight principles of risk management. The purpose of risk management principles is for value creation and protection. Figure 1.87 illustrates the eight principles of risk management.

These principles provide guidance on the characteristics of effective and efficient risk management, communicating its value, and explaining its intention and purpose. The principles are the foundation for risk management and should be considered for establishing the risk management framework and processes.

These principles are further explained as follows:

1. Integrated
   The organization should integrate its risk management efforts into all parts and activities of the organization.
   Risk management should be considered a company-wide activity.
2. Structured and Comprehensive
   A structured and comprehensive approach that leads to the most consistent, effective, and desirable risk management outcomes.

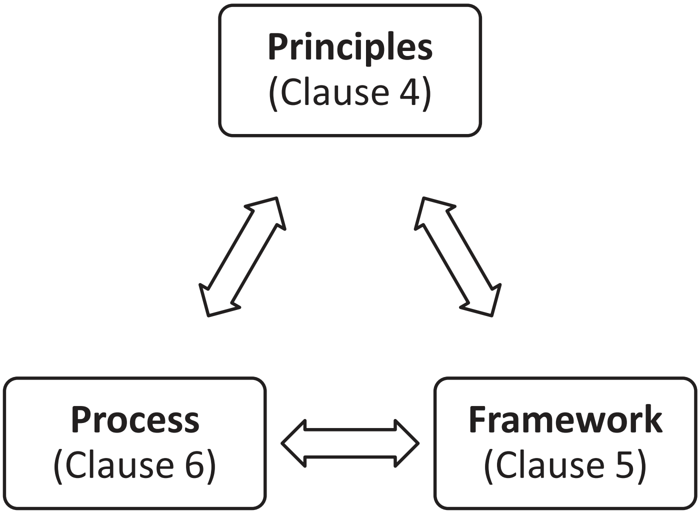


FIGURE 1.86 Risk management clauses relationship.

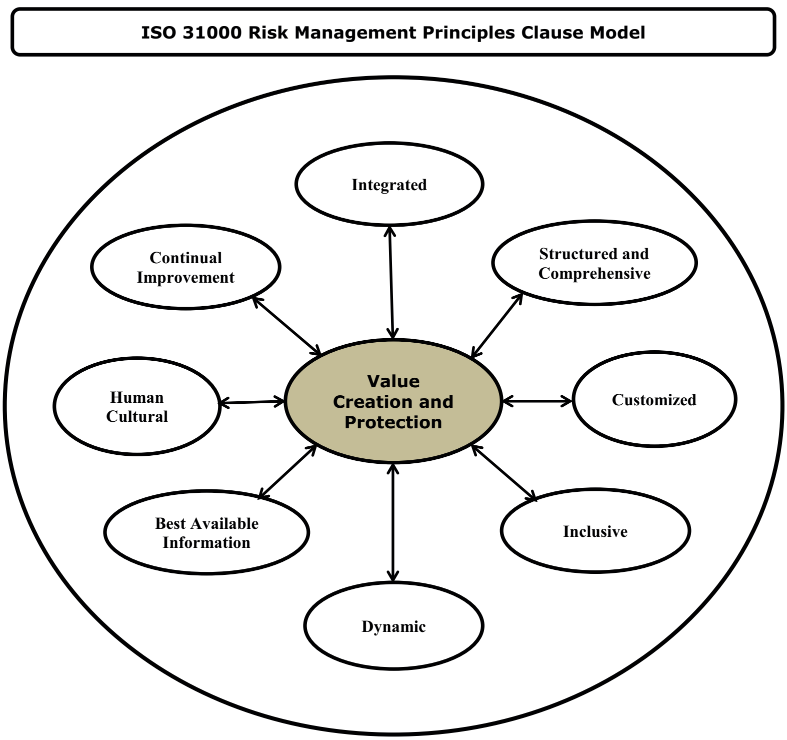


FIGURE 1.87 Risk management principles clause model.

3. Customized
   The risk management framework and process should be customized and proportionate to meet the organization's external and internal context related to achieving the goals and objectives of the organization.
4. Inclusive
   The risk management process should encourage timely involvement and participation of all stakeholders to make the process most effective. The risk management process should encourage the use of reliable information, views, and perceptions of all stakeholders and be implemented into risk management efforts.
5. Dynamic
   Risk management should be dynamic and capable of managing organizational changes, including its external and internal context, and adapting to the changes. A risk management process should help the organization anticipate, identify, acknowledge, and respond to the changes and expectations in an appropriate and timely manner.
6. Best Available Information
   Consider the information from the historical, present, and future expectations. Risk management should explicitly take into account any limitations and uncertainties associated with such information and expectations. Information should be timely, clear, and available to relevant stakeholders in a timely and clear manner.
7. Human and Cultural Factors
   Human and cultural factors significantly influence all aspects of risk management at each level and stage. Ensure that the risk management process considers human and cultural factors.
8. Continual Improvement
   Continually improve the risk management process through lessons learned and experience.

1.3.2.9.3 Risk Management Plan

A risk management plan identifies how risks associated with the project will be identified, analyzed, managed, and controlled. Risk management is an integral part of project management as the risks are likely to occur at any stage of the project. Therefore, the risk has to be continually monitored and response actions to be taken immediately. The risk management plan outlines how risk activities will be performed, recorded, and monitored throughout the life cycle of the project. It is intended to maximize the positive impact for the benefit of the project and decrease/minimize or eliminate the impact of events adverse to the project. The risk management must commence early in the project development stage (study stage) and proceed as the project evolves and more and more information about the project in available. The project plan should:

- Define risk management strategy/approach.
- Define project objectives, goals related to risk management.
- Identify risk owners and team members.
- Define risk decisions.

- Detail about risk resources.
- Include risk management process.
    - Methods of risk identification.
    - Methods of risk assessment.
    - Level of risk.
    - Response to risk.
    - Management of risk.
    - Control of risk.
- Process of integrating risk management activities into project scope, schedule, cost, and quality.
- Documenting and recording of risks.
- Communication procedure for risk reporting.
- Update of risk management plan.

1.3.2.9.4 Risk Management Process

The risk management process involves the systematic application of policies, procedures, and practices to the activities of communicating and consulting, establishing the context, and assessing, treating, monitoring, reviewing, recording, and reporting risk. Figure 1.88 illustrates the organizational structure of the ISO 31000 process clause.

The risk management process is an integral part of management and decision-making and integrated into the structure, operation, and processes of the organization. It can be applied at strategic, operational, program, or project levels.

ISO 31000 risk management process clause consists of the following elements:

1. General
2. Communication and Consultation
3. Scope, Context, and Criteria
4. Risk Assessment
5. Risk Treatment
6. Monitoring and Review
7. Recording and Reporting

1.3.2.9.4.1 General

The risk management process is an iterative process. Therefore, the risk management process has to be developed as an iterative process. It is an ongoing process that continues throughout the lifecycle of the process. The activities are sequential but iterative and monitored at each stage.

1.3.2.9.4.2 Communication and Consultations The purpose of communication and consultation is to keep informed the relevant stakeholders, both internal and external, to understand the risk, the basis on which decisions are made and the reasons why particular action is required. The communication method is to be clearly defined based on the standard policies and procedures of the organization. Communication seeks to promote awareness and understanding of risk, whereas

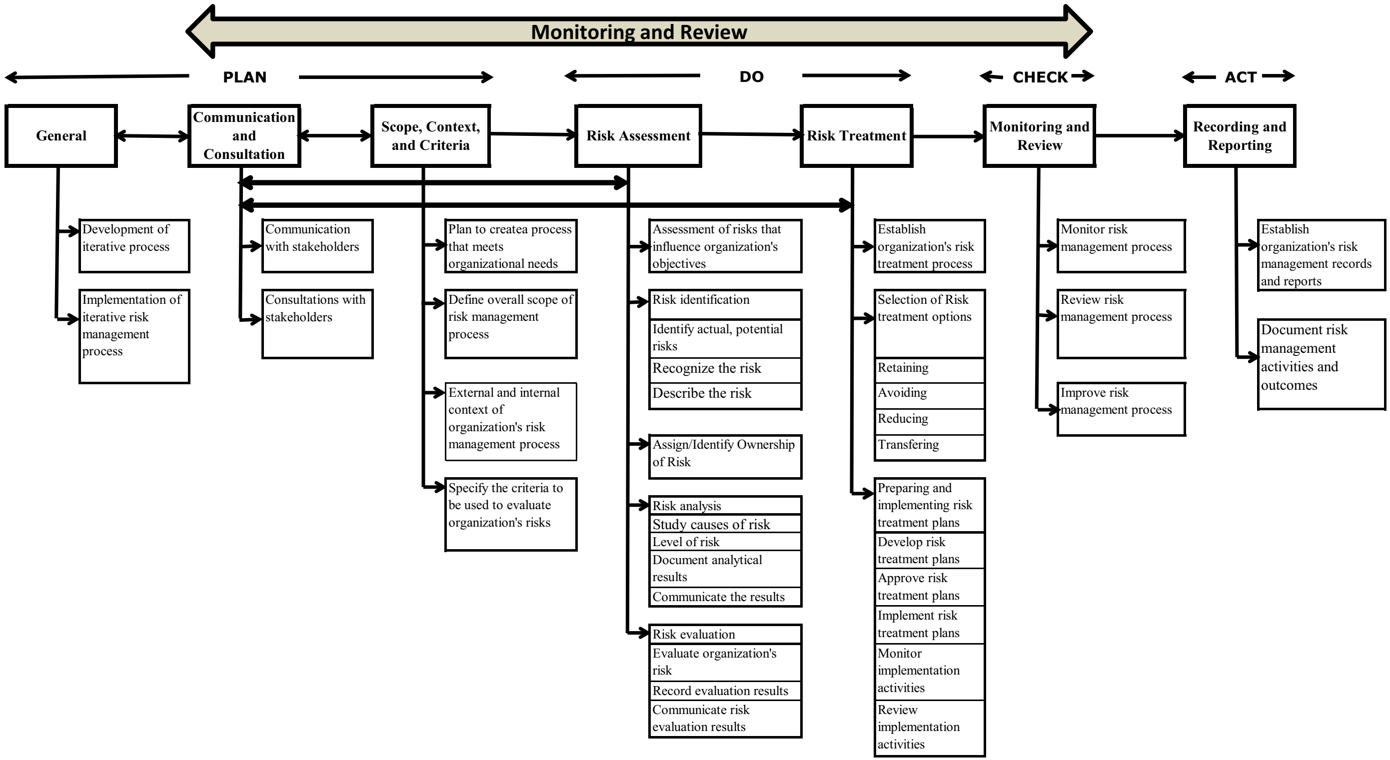


FIGURE 1.88 Organizational structure of ISO 31000 risk management process clauses.

consultation involves obtaining feedback and information from the relevant stakeholders to make decisions. Communication and consultations are to be coordinated closely in order to facilitate factual, timely, relevant, accurate, and understandable exchange of information among the relevant stakeholders taking into consideration the confidentiality and integrity of the information as well as the privacy rights of individuals. Communication and consultations with relevant stakeholders, both internal and external, should take place within and throughout all the stages of the risk management process.

The purpose of communication and consultation is to:

- Bring together experts from different areas to participate at each step of risk management process.
- Involve internal and external stakeholders at each step of risk management process.
- Ensure that different views from experts are considered while defining risk criteria and when evaluating the risk.
- Provide sufficient information to facilitate risk oversight and decision-making.
- Build a sense of inclusiveness and ownership among those affected by the risk.

1.3.2.9.4.3 Scope, Context, and Criteria The purpose of establishing scope, context, and criteria is to plan and create customized risk management processes to meet organizational needs. The following activities are to be considered while creating a process that meets the organization's customized needs.

- The organization should define the scope of the risk management activities.
- The organization to clearly specify the scope of the organization's risk management activities.
- The organization to clarify the external and internal context of the organization's risk management process. The external and internal context is the environment in which the organization seeks to define and achieve its objectives.
- The organization specifies the criteria that the organization plans to use to evaluate the organization's risks.
- The organization should specify the amount and type of risks that the organization may or may not take to achieve its objectives.

1.3.2.9.4.4 Risk Assessment Risk assessment is the act of determining the probability that risk will occur and the impact that event would have, should it occur. Risk assessment is designed to reduce or eliminate the risk of certain kinds of events happening (occurring) or having an impact on the project. Risk assessment consists of the following major elements:

1. Risk identification.
2. Risk analysis.
3. Risk evaluation.

Risk assessment should be conducted systematically, iteratively, and collaboratively, drawing on the knowledge and views of stakeholders. It should use the best available information collected through communication and consultation among the stakeholders, supplemented by further inquiry as necessary.

Risk Identification

The purpose of risk identification is to find, recognize, and register the risks that might help or prevent an organization from achieving its objectives. It is a process of research, recognition, and registration of risk. Risk identification involves determining the source and type of risk that may affect the project. It is also to determine how often (frequency) it occurs.

The organization can use a range of techniques for identifying uncertainties that may affect one or more objectives. The following tools and techniques are used to identify risks.

1. Benchmarking.
2. Brainstorming.
3. Delphi technique.
4. Interviews.
5. Past database, historical data from similar projects.
6. Questionnaires.
7. Risk breakdown structure.
8. Workshops.
9. Root cause analysis.
10. SWOT analysis.
11. Risk register.

The risk register is a document recording details of all the identified risks at the beginning of the project and during the life cycle of the project in a format that consists of comprehensive lists of significant risks along with the actions and costs estimated with the identified risks. The risk register is updated every time a new risk is identified or relevant actions are taken. Table 1.33 illustrates an example risk register.

Risk Analysis

Risk analysis is the process of analyzing the listed risks. The purpose of risk analysis is to comprehend the nature of risk and its characteristics including, where appropriate, the level of risk. Table 1.34 illustrates risk probability levels normally assumed for a probability impact matrix. The percentage of probability of occurrence shown in the table is indicative. The organization can determine the probability level as per the nature of the business.

Risk analysis involves a detailed consideration of uncertainties, risk resources, consequences, likelihood, events, scenarios, controls, and their evidence. There are two methods of analyzing risks. These are:

1. Qualitative analysis.
2. Quantitative analysis.

TABLE 1.33
Risk Register

Project Name

Risk Register

Serial Number	Risk Identification Number (Risk ID)	Description of RiskOwner of Risk	Estimated Likelihood of Risk	Impact	Estimated Severity	Prioritization	List of Activities Influenced	Leading Indicators for Risk	Risk Mitigation Plan	Risk Mitigation Plan on Leading Indicator	Timeline for Mitigation Action	Tracking of Leading Indicators	Date of Review/Update	Forecating Risk Happenings	Action to be Taken in Future.

TABLE 1.34
Risk Probability Levels

Serial Number	Value	Definition	Meaning	% Probability of Occurrence
1	Level 5	Very High (Frequent)	• Almost certain that the risk will occur. • Frequency of occurrence is very high.	40–80
2	Level 4	High (Likely)	• It's likely to happen. • Frequency of occurrence is less.	20–40
3	Level 3	Moderate (Occasional)	• Its occurrence is occasional.	10–20
4	Level 2	Low (Unlikely)	• It's unlikely to happen.	5–10
5	Level 1	Very Low (Rare)	• The probability to occur is rare.	0–5

Qualitative Analysis

Qualitative analysis is a process to assess the probability of occurrence (likelihood) of the risk and its impact (consequence). This process prioritizes risks according to their potential effect on project objectives. Qualitative risk analysis requires that the probability and consequences of the risks be evaluated using established qualitative analysis methods and tools.

The following tools and techniques are used for qualitative analysis:

- Failure Mode and Effects Analysis (FMEA)
- Group Discussion (Workshop)
- Pareto Diagram
- Probability and Impact Assessment
- Probability Levels
- Risk Categorization

Quantitative Analysis

Quantitative analysis is a process to quantify the probability of risk and its impact based on numerical estimation. The quantitative risk analysis process aims to analyze numerically the probability of each risk and its consequences on project objectives, as well as the extent of overall project risk.

The following tools and techniques are used for quantitative analysis:

- Event tree analysis.
- Probability analysis.
- Sensitivity analysis.
- Simulation techniques (Monte Carlo Simulation).

These techniques:

- Determine the probability of achieving a specific project objective.
- Quantify the risk exposure for the project, and determine the size of schedule and cost contingency reserves that may be needed.
- Identify the risk requiring the most attention by quantifying its relative contribution to project risk.
- Identify realistic and achievable scope, schedule, and cost targets.

Risk analysis should consider factors such as:

- The likelihood of events and consequences.
- The nature and magnitude of consequences.
- Complexity and connectivity.
- Time-related factors and volatility.
- The effectiveness of existing controls.
- Sensitivity and confidence level.

Similarly, the risk impact is analyzed for each of the identified risks that may be classified into different levels such as:

- Very High
- High
- Substantial
- Possible
- Slight

Based on the impact level, the probability and impact matrix is prepared. Table 1.35 is a sample risk probability and impact matrix.

Risk analysis provides input to risk evaluation, to decisions on whether risks need to be treated and how, and on the most appropriate risk treatment strategy and methods. The results provide insights for decisions, where choices are being made, and options involve different types of levels of risk.

Risk Evaluation

The purpose of risk evaluation is to support decisions. Risk evaluation involves comparing the results of the risk analysis with the established risk criteria to determine where additional action is required. This can lead to a decision to:

- Do nothing further.
- Consider risk treatment options.
- Undertake further analysis to better understand the risk.
- Maintain existing controls.
- Reconsider objectives.

TABLE 1.35
Risk Probability and Impact Matrix

Probability / Severity			Probability				
			Level 5	**Level 4**	**Level 3**	**Level 2**	**Level 1**
			Very High (Frequent)	**High (Likely)**	**Moderate (Occasional)**	**Low (Unlikely)**	**Very Low (Rare)**
Impact/Severity	**Level 5**	Very High					
	Level 4	High					
	Level 3	Substantial					
	Level 2	Possible					
	Level 1	Slight					

SAMPLE FORM

Risk Assessment Matrix for: Scope/Schedule/Cost/Quality

Decisions should take account of the wider context and the actual and perceived consequences to external and internal stakeholders. The outcome of risk evaluation should be recorded, communicated, and then validated at appropriate levels of the organization.

The results of risk assessment/evaluation are used to prioritize risks to establish very high to very low ranking. Prioritization of risks depends on the following factors:

1. Probability (Occurrence)
2. Impact (Consequences)
3. Urgency
4. Proximity
5. Manageability
6. Controllability
7. Responsiveness
8. Variability
9. Ownership Ambiguity

The prioritization list helps the project manager to plan actions and assign the resources to mitigate the realization of high-value probability. Table 1.36 illustrates an example of risk assessment for material delivery loading and unloading of material.

1.3.2.9.4.5 Risk Treatment The purpose of risk treatment is to select and implement options for addressing risk.

Risk treatment involves an iterative process of:

- Formulating and selecting risk treatment options.
- Planning and implementing risk treatment.
- Assessing the effectiveness of that treatment.
- Deciding whether the remaining risk is acceptable.

If not acceptable, take further treatment.

Selecting the most appropriate risk treatment option(s) involves balancing the potential benefits derived in relation to the achievement of the objectives against the costs, effort, or disadvantages of implementation.

Plan Risk Response

Plan risk response is a process that determines what action (if any) will be taken to address the identified and assessed risks that are listed under the risk register on a prioritization basis. The risk response process is used for developing options and actions to enhance opportunities and reduce the threats to the identified risk activities in the project.

For each identified risk, a response must be identified. The risk owner and project team have to select the risk response for each of the identified risks.

The probability of the risk event occurring, and the impacts (threats) are the basis for evaluating the degree to which the response action is to be evolved. Based on the risk probability impact matrix, a risk response strategy for scope, schedule, cost, quality, and HSE can be listed as per Table 1.37.

TABLE 1.36
Example of Risk Assessment

RISK ASSESSMENT

OWNER NAME

PROJECT NAME

ACTIVITY = MATERIAL DELIVERY—LOADING AND UNLOADING OF MATERIALS

Sl. No.	Basic Job Activity/ Hazard	Hazard	Initial Risk Rating Probability x	Severity	Risk Factor	Control Measures in Placement/Mitigation Actions	Final Risk Rating Probability x	Severity	Residual Risk Factor	Risk Acceptable
1	Uncontrolled movement of the load.	Cause injury to the person. Damage to the property	4	2	8	1) Ensure that the personnel are not positioned in corners where emergency movement is restricted. 2) Beware of pinch points. 3) Wear PPE. 4) Do not place any part of the body below the hoisted load. 5) Use tag lines to guide the load. 6) Manual guiding should be avoided. Preplan the lift. 7) Adopt proper signaling method and ensure proper communication and coordination. 8) Adopt proper rigging method based on packing dimensions. 9) Provide padding for the materials at sharp corners and delicate portions. 10) Ensure proper guiding of the load to avoid jerks and swaying of the load. 11) Ensure the access is clear for the transportation of the load.	2	1	2	**Low**

(Continued)

TABLE 1.36 Continued
Example of Risk Assessment

RISK ASSESSMENT

OWNER NAME

PROJECT NAME

ACTIVITY = MATERIAL DELIVERY—LOADING AND UNLOADING OF MATERIALS

Sl. No.	Basic Job Activity/ Hazard	Hazard	Initial Risk Rating		Risk Factor	Control Measures in Placement/Mitigation Actions	Final Risk Rating		Residual Risk Factor	Risk Acceptable
			Probability x Severity				Probability x Severity			
2	Failure of slings while lifting the materials.	May cause serious injury to the personal. Damage to the property.	4	3	12	1) Use tested slings. 2) Do not exceed SWL. 3) Ensure the slings used are suitable for the purpose intended. 4) Ensure padding wherever the slings come in contact with sharp corners. 5) Adopt proper rigging method. 6) Examine the conditions of the sling prior to use.	3	1	3	**Low**

Source:

RPN-Risk Priority Number

8–16	**High Risk**
4–6	**Medium Risk**
1–3	**Low Risk**

TABLE 1.37
Risk Response Strategy

Potential Risk		Probability Level	Impact/Severity Level	Risk Response Strategy
Scope	1			
	2			
Schedule	1			
	2			
Cost	1			
	2			
Quality	1			
	2			
HSE	1			
	2			

SAMPLE TABLE

Generally, risk response strategies for impact (consequences) on the project fall into one of the following categories:

1. Avoidance
2. Transfer
3. Mitigation (Reduction)
4. Acceptance (Retention)

Avoidance
Avoidance is changing the project scope, objectives, or plan to eliminate the risk or to protect the project objectives from the impact (threat).

Transfer
Transfer is transferring the risk to someone else who will be responsible for managing the risk. Transferring the threat does not eliminate the threat, it still exists, however, it is owned and managed by another party.

Mitigation
Mitigation is a reduction in the probability and/or impact to an acceptable threshold. It is done by taking a series of control actions.

Acceptance

It is acceptance of consequences after response actions and understanding the risk impact should it occur.

Risk treatment options are not necessarily mutually exclusive or appropriate in all circumstances. Options for treating risk may involve one or more of the following:

- Avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk.
- Taking or increasing the risk in order to pursue an opportunity.
- Removing the risk source.
- Changing the likelihood.
- Changing the consequences.
- Sharing the risk (e.g., through contracts, buying insurance).
- Retaining the risk by informed decision.

Justification for risk treatment is broader than solely economic considerations and should take into account all of the organization's obligations, voluntary commitments, and stakeholder views. The selection of risk treatment options should be made in accordance with the organization's objectives, risk criteria, and available resources.

Approve Risk Response

When selecting risk treatment options, the organization should consider the values, perceptions, and potential involvement of the stakeholders and the most appropriate ways to communicate and consult with them. Though equally effective, some risk treatments can be more acceptable to some stakeholders than to others.

Risk treatments, even if carefully designed and implemented, might not produce the expected outcomes and could produce unintended consequences. Monitoring and review need to be an integral part of the risk treatment implementation to give assurance that the different forms of treatment become and remain effective.

Risk treatment can also introduce new risks that need to be managed.

If there are no treatment options available or if treatment options do not sufficiently modify the risk, the risk should be recorded and kept under ongoing review.

Decision makers and other stakeholders should be aware of the nature and extent of the remaining risk after risk treatment. The remaining risk should be documented and subjected to monitoring, review, and, where appropriate, further treatment.

Implementing of Risk Treatment Plan

The purpose of risk treatment plans is to specify how the chosen treatment options will be implemented, so that arrangements are understood by those involved, and progress against the plan can be monitored. The treatment plan should clearly identify the order in which risk treatment should be implemented.

Treatment plans should be integrated into the management plans and processes of the organization, in consultation with appropriate stakeholders.

The information provided in the treatment plan should include:

- The rationale for the selection of the treatment options, including the expected benefits to be gained.

- Those who are accountable and responsible for approving and implementing the plan.
- The proposed actions.
- The resources required, including contingencies.
- The performance measures.
- The constraints.
- The required reporting and monitoring.
- When actions are expected to be undertaken and completed.

1.3.2.9.4.6 Monitoring and Reviewing The purpose of monitoring and reviewing is to assure and improve the quality and effectiveness of process design, implementation, and outcomes. Ongoing monitoring and periodic review of the risk management process and its outcomes should be a planned part of the risk management process, with responsibilities clearly defined.

It is a systematic process of tracking identified risks, monitoring residual risks, identifying new risks, execution of risk response plan, and evaluating the effectiveness of implementation of actions against established levels of risk in the area of scope, time, cost, and quality throughout the life cycle of the project. It involves timely implementation of risk response to identified risks to ensure the best outcome for a risk to a project. It is an ongoing process for the life cycle of the project.

Monitoring and review should take place in all stages of the process. Monitoring and review include planning, gathering, and analyzing information, recording results (update risk register), and providing feedback.

The risk monitoring process provides information that assists with making effective decisions in advance of the risk occurring. Communication with all project stakeholders is needed to assess periodically the acceptability of the level of risk on the project. It helps monitor status and trends continually (scope, schedule, cost estimates, quality of product, etc.).

The results of monitoring and review should be incorporated throughout the organization's performance management, measurement, and reporting activities.

Risk monitoring processes help to determine if:

- Risk treatment, risk responses have been implemented as planned.
- Risk treatment/response actions are effective as expected, or if a new treatment plan should be developed.
- Project assumptions are still valid.
- Risk exposure has changed from its prior state, with analysis of trends.
- A risk trigger has occurred.
- Proper policies and procedures are followed.
- Risks have occurred or arisen that were not previously identified.

1.3.2.9.4.7 Recording and Reporting The risk management process and its outcomes should be documented and reported through appropriate mechanisms. Recording and reporting aims to:

- Communicate risk management activities and outcomes across the organization.
- Provide information for decision-making.

- Improve risk management activities.
- Assist interaction with stakeholders, including those with responsibility and accountability for risk management activities.

Decisions concerning the creation, retention, and handling of documented information should take into account, but not be limited to, their use, information sensitivity, and the external and internal context.

Reporting is an integral part of the organization's governance and should enhance the quality of dialogue with stakeholders and support top management and oversight bodies in meeting their responsibilities. Factors to consider for reporting include, but are not limited to:

- Differing stakeholders and their specific information needs and requirements.
- Cost, frequency, and timeliness of reporting.
- Method of reporting.
- Relevance of information to organizational objectives and decision-making.

Table 1.38 illustrates the risk monitoring and control form.

Figure 1.89 illustrates a typical flowchart for risk monitoring process.

Figure 1.90 illustrates a typical flowchart for risk management procedure.

1.3.2.9.5 Risks in Construction Projects

Construction projects have many varying risks. Risk management throughout the life cycle of the project is important and essential to prevent unwanted consequences

TABLE 1.38
Monitoring Control Form

Serial Number	Description	Action			
1	Risk ID				
2	Description of Risk				
3	Response	Sample Form			
4	Strategy of Response	Avoidance	Transfer	Mitigation	Acceptance
5	Monitoring and Control	Risk Owner	Review Date	Critical Issue	
6	Estimated Impact on the Project				
7	Actual Impact on the Project				
8	Revised Response				
9	Record Update Date				
10	Communication to Stakeholders				

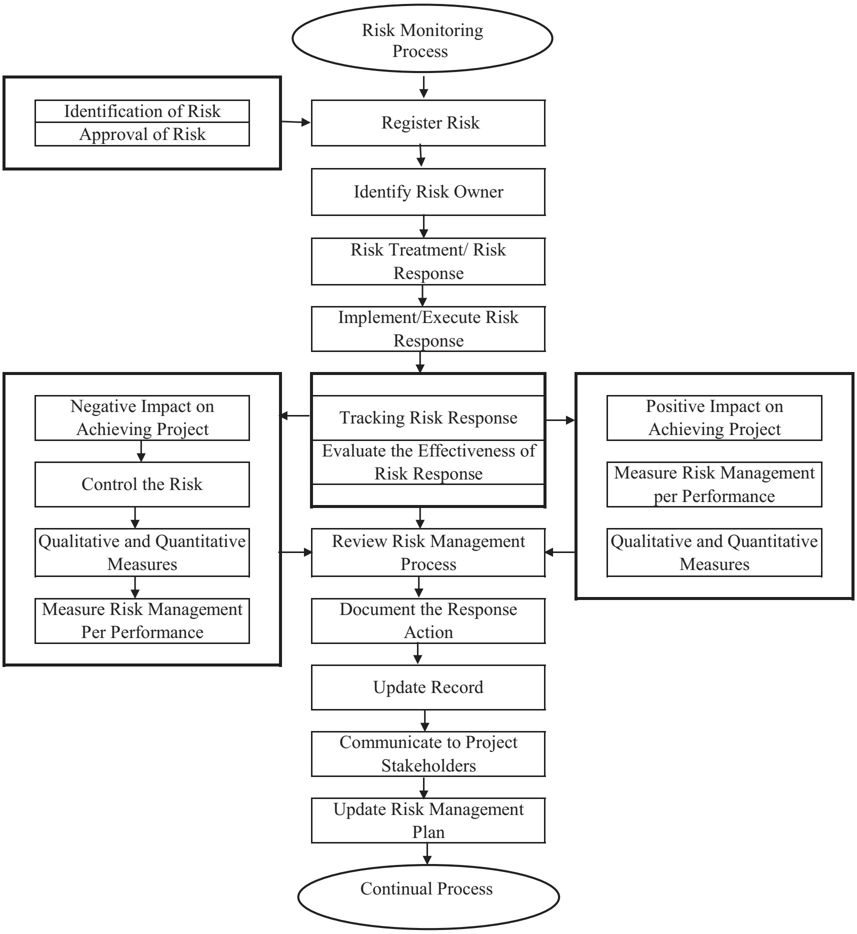


FIGURE 1.89 Typical flowchart for risk monitoring process.

and effects on the project. Construction projects have involvement of many stakeholders such as project owners, developers, design firms (consultants), contractors, banks, and financial institutions funding the project who are affected by the risk. Each of these parties have involvement with certain portion of the overall construction project risk, however, the owner has a greater share of risks as the owner is involved from the inception until completion of the project and beyond. The owner must take initiatives to develop risk consciousness and awareness among all the parties emphasizing the importance of explicit consideration of risk at each stage of the project as the owner is ultimately responsible for the overall project. Traditionally:

1. Owner/client is responsible for the investment/finance risk.
2. Designer (consultant) is responsible for design risk.
3. Contractors and subcontractors are responsible for construction risk.

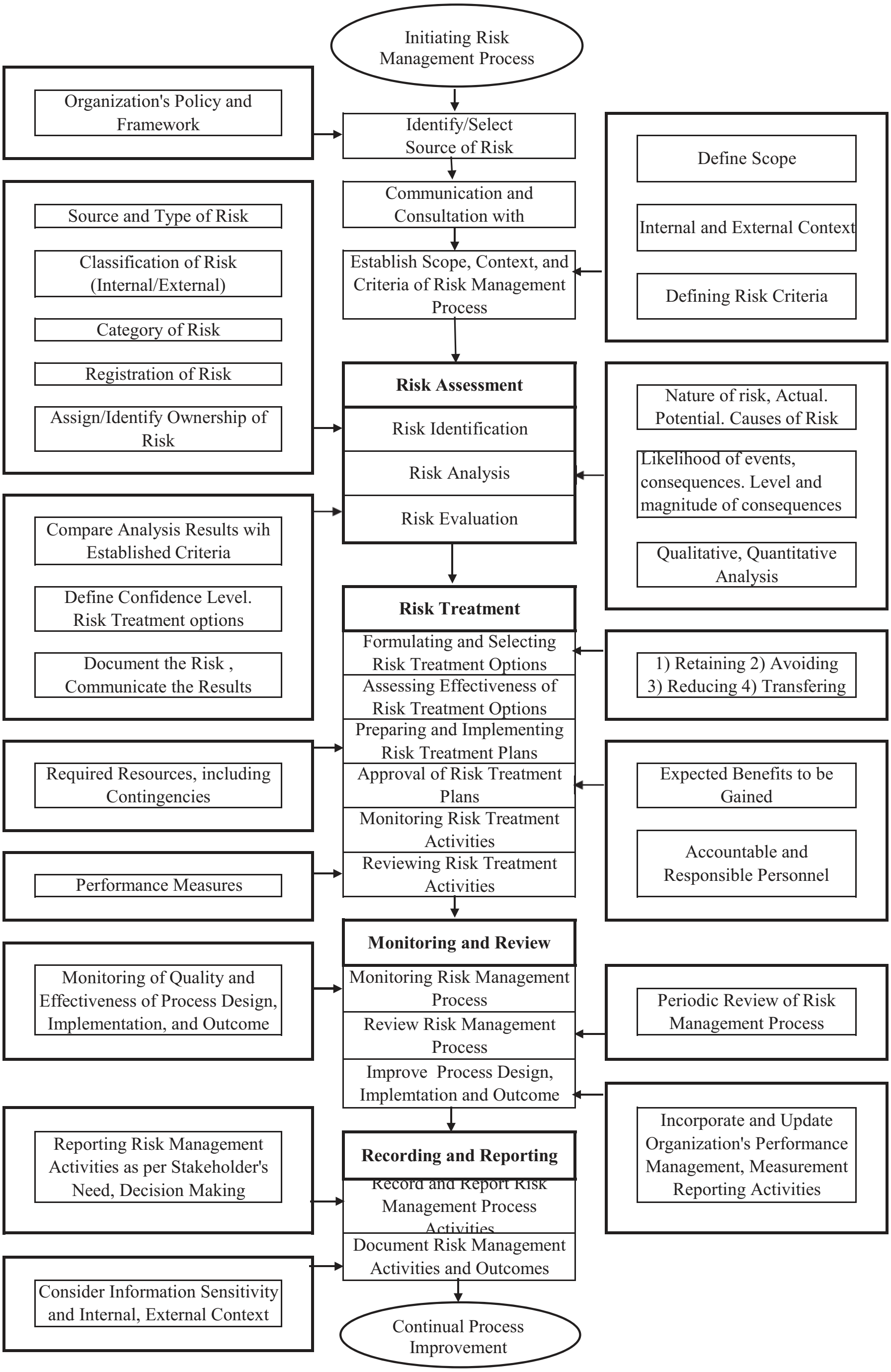


FIGURE 1.90 Typical flowchart for risk management procedure.

Construction projects are characterized as very complex projects, where uncertainty comes from various sources. Construction projects involve a cross-section of many different participants. They have varying project expectations. Those both influence and depend on each other in addition to the "other players" involved in the construction process. The relationships and the contractual groupings of those who are involved are also more complex and contractually varied. Construction projects often require a large number of materials and physical tools to move or modify these materials. Most items used in construction projects are normally produced by other construction-related industries/manufacturers. Therefore, the risk in construction projects is multifaceted. Construction projects inherently contain a high degree of risk in their projection of cost and time as each is unique. No construction project is without any risk. Risk management in construction projects is mainly focused on delivering the project with:

1. What was originally accepted (as per defined **Scope**).
2. Agreed upon time (as per **Schedule** without any delay).
3. Agreed upon budget (no overruns to accepted C**ost**).

Risk management is an ongoing process. In order to reduce the overall risk in construction projects, the risk assessment (identification, analysis, and evaluation) process must start as early as possible to maximize project benefits. There are a number of risks that can be identified at each stage of the project. Early risk identification can lead to better estimation of the cost in the project budget, whether through contingencies, contractual, or insurance. Risk identification is the most important function in construction projects.

Risk factors in construction projects can be categorized in a number of ways according to the level of detail or selected viewpoints. These are categorized based on various risk factors and sources of risk. The contractor has to identify related risks affecting the construction, analyze these risks, evaluate the effects on the contract, and evolve the strategy to counter these risks, before bidding for a construction contract. Construction project risks mainly relate to the following:

- Scope and change management.
- Schedule/time management.
- Budget/cost management.
- Quality management.
- Resources and manpower management.
- Communication management.
- Procurement/contract management.
- Health, safety, and environmental management.

Table 1.39 illustrates typical categories of risk in construction projects.

The risk in construction projects starts from the inception of the project and is traced until completion of the project and beyond. In order to achieve a successful

TABLE 1.39
Typical Categories of Risk in Construction

Sr. No.	Category	Types
1	Management	Selection of project delivery and contracting system.
		Selection of project management consultant.
		Selection of designer.
		Selection of contractor/EPC contractor.
2	Contract (Project)	Scope/design changes.
		Schedule.
		Cost.
		Conflict resolution.
		Delay in change order negotiations.
3	Statutory	Statutory/regulatory delay.
4	Technical	Incomplete design.
		Incomplete scope of work.
		Design changes.
		Design mistakes.
		Errors and omissions in contract documents.
		Incomplete specifications.
		Ambiguity in contract documents.
		Inconsistency in contract documents.
		Inappropriate schedule/plan.
		Inappropriate construction method.
		Conflict with different trades.
		Improper coordination with regulatory authorities.
		Inadequate site investigation data.
5	Technology	New technology.
6	Construction	Delay in mobilization.
		Delay in transfer of site.
		Different site conditions to the information provided.
		Changes in scope of work.
		Resource (labor) low productivity.
		Equipment/plant productivity.
		Insufficient skilled workforce.
		Union and labor unrest.
		Failure/delay of machinery and equipment.
		Quality of material.
		Failure/delay of material delivery.
		Delay in approval of submittals.
		Extensive subcontracting.
		Subcontractor’s subcontractor.
		Failure of project team members to perform as expected.
		Information flow breaks.
7	Physical	Damage to equipment.
		Structure collapse.

(*Continued*)

TABLE 1.39 Continued
Typical Categories of Risk in Construction

Sr. No.	Category	Types
		Damage to stored material.
		Leakage of hazardous material.
		Theft at site.
		Fire at site.
8	Logistic	Resources availability.
		Spare parts availability.
		Consistent fuel supply.
		Transportation facility.
		Access to worksite.
		Unfamiliarity with local conditions.
9	Health, Safety, and Environment	Injuries.
		Health and safety rules.
		Environmental protection rules.
		Pollution rules.
		Disposal of waste.
10	Financial	Inflation.
		Recession.
		Fluctuations in exchange rate.
		Availability of foreign exchange (certain countries).
		Availability of funds.
		Delays in payment.
		Local taxes.
11	Economical	Variation of construction material price.
		Sanctions.
12	Commercial	Import restrictions.
		Custom duties.
13	Legal	Permits and licenses.
		Professional liability.
		Litigation.
14	Political	Change in laws and regulations.
		Constraints on employment of expatriate workforce.
		Use of local agent and firms.
		Civil unrest.
		War.
15	Natural/Environmental	Flood.
		Earthquake.
		Cyclone.
		Sandstorm.
		Landslide.
		Heavy rains.
		High humidity.

(*Continued*)

TABLE 1.39 Continued
Typical Categories of Risk in Construction

Sr. No.	Category	Types
		Fire.
16	Geological	Estimation of accessible reserves.
17	Supply and Demand	Financial crises and macroeconomic factors.
18	Operational	Availability of skilled workers.

TABLE 1.40
Major Risk Factors Affecting Owner

Serial Number	Risk Factor	
1	**Study**	
	1.1	Incomplete/Improper feasibility study.
	1.2	Long procedure for authority approval and permits.
	1.3	Delay in raising the funds to proceed with the work.
	1.4	Change in law.
	1.5	Late internal approval process from the owner team.
	1.6	Selection of project delivery system.
	1.7	Errors in estimated schedule.
	1.8	Errors in estimated cost.
2	**Design**	
	2.1	Incompetent consultant.
	2.2	Incomplete design scope.
	2.3	Inadequate or ambiguous specification.
	2.4	Delays in authority approval.
	2.5	Delay in completion of design.
3	**Tendering**	
	3.1	Inadequate tendering price if estimate is wrong.
4	**Construction**	
	4.1	Contractor has lack of knowledge and experience in similar types of construction.
	4.2	Delay in site transfer.
	4.3	Impractical planning and scheduling.
	4.4	Omissions in design and specifications.
	4.5	Inflation.
	4.6	Fluctuation in exchange rate.
	4.7	Increase in material cost.
	4.8	Coordination problems.
	4.9	Ineffectiveness and lack of supervision by consultant.
	4.10	Delays in approval of transmittals.
	4.11	Contracting system.
	4.12	Lack of coordination between project participants.
	4.13	Unpredicted contingencies, force majeure.
	4.14	Political disturbances.

TABLE 1.41
Major Risk Variables for Feasibility Study

Serial Number	Risk Variables
1	Marketing aspect.
2	Investment risk in next ten years.
3	Financial aspect (payback).
4	Economic aspect.
5	Technical and technological risk.
6	Environmental and spatial plan aspect.
7	Regulations and policy aspect.
8	Political.
9	Social and cultural.

project, the risk management processes are to be performed during each of the following main stages of the construction project:

1. Study
2. Design
3. Bidding and Tendering
4. Construction

Construction projects have the involvement of many participants. Each of the participants has their own risk at each stage/phase of the project life cycle. Therefore, it is necessary to:

1. Identify and record the risks that affect the project at each stage.
2. Assess the likelihood of each risk occurring in the future and the impact on the project should this happen.
3. Plan cost-effective management actions with clearly identified responsibilities, to avoid, eliminate, or reduce any significant risk identified.
4. Monitor and report the status of these risks and the effectiveness of planned risk management action.

Risk identification is the most important function in the construction project. There are various risk factors in each of the project stages affecting the construction projects. Table 1.40 illustrates major risk factors that may affect the owner at different stages of the project while Table 1.41 lists major risk variables to be considered while conducting a feasibility study of a project.

Table 1.42 illustrates major risks affecting the designer (consultant) and Table 1.43 illustrates major risks affecting the contractor.

TABLE 1.42
Major Risk Factors Affecting Designer (Consultant)

Serial Number	Risk Factor
1	**Concept Design**
	1.1 Lack of owner input.
	1.2 Incomplete requirements and specifications.
	1.3 Lack of information or information transfer with wrongly estimated objectives of the proposal.
	1.4 Project objectives not defined clearly.
	1.5 Changing requirements and specification.
	1.6 Selected alternatives not suitable for final solution.
	1.7 Environmental considerations.
2	**Detailed Design**
	2.1 Project performance specifications.
	2.2 Technical specifications.
	2.3 Follow-Up of codes and standards.
	2.4 Difficulties in dealing specifications and standards concerning existing conditions and clients' requirements.
	2.5 Lack of knowledge about the technical conditions.
	2.6 Incomplete design.
	2.7 Prediction of possible changes in design during construction phase.
	2.8 Environmental considerations.
	2.9 Regulatory requirements.
	2.10 Constructability.
	2.11 Impractical project schedule.
	2.12 Incorrect cost estimation.
	2.13 Design completion schedule.

TABLE 1.43
Major Risk Factors Affecting Contractor

Serial Number	Risk Factor
1	**Bidding and Tendering**
	1.1 Low bid.
	1.2 Poor definition of scope of work.
	1.3 Overall understanding of project.
	1.4 BOQ material not verifying with contract (construction) drawings.
	1.5 Errors in resource estimation.
	1.6 Errors in resource productivity.
	1.7 Errors in resource availability.
	1.8 Errors in material price.

(*Continued*)

TABLE 1.43 Continued
Major Risk Factors Affecting Contractor

Serial Number		Risk Factor
	1.9	Improper schedule.
	1.10	Quality standards.
	1.11	Exchange rate.
	1.12	Unenforceable conditions or contract clauses.
2	**Construction**	
	2.1	Delay in transfer of site.
	2.2	Different site conditions to the information provided.
	2.3	Delay in mobilization.
	2.4	Changes in scope of work.
	2.5	Resource (Labor) low productivity.
	2.6	Equipment/plant productivity.
	2.7	Insufficient skilled workforce.
	2.8	Union and labor unrest.
	2.9	Failure/Delay of machinery and equipment.
	2.10	Quality of material.
	2.11	Failure/Delay of material delivery.
	2.12	Delay in approval of submittals.
	2.13	Incompetent subcontractor.
	2.14	Failure of project team members to perform as expected.
	2.15	Improper communication system.
	2.16	Conflict with different trades.
	2.17	Inappropriate construction method.
	2.18	Damage to equipment.
	2.19	Structure Collapse.
	2.20	Damage to stored material.
	2.21	Theft at site.
	2.22	Fire at site.
	2.23	Resources availability.
	2.24	Spare parts availability.
	2.25	Consistent fuel supply.
	2.26	Transportation facility.
	2.27	Access to worksite.
	2.28	Injuries.
	2.29	Health and Safety rules.
	2.30	Environmental protection rules.
	2.31	Disposal of waste.
	2.32	Inflation.
	2.33	Delays in payment.
	2.34	Variation in construction material price.
	2.35	Delay in permit and licenses.
	2.36	Change in laws and regulations.
	2.37	Constraints in employment of expatriate workforce.
	2.38	New technology.
	2.39	Force majeure.

1.3.2.10 Project Contract Management

Project procurement/contract management in construction projects is an organizational method, process, and procedure to obtain the required construction products. It includes the process to acquire construction facilities complete with all the related products/materials, equipment, and services from outside contractors/companies to the satisfaction of the owner/client/end user.

Conventional notions of the procurement/purchasing cycle, which is normally applied in batch production, mass production, or in merchandising, are less appropriate to the realm of construction projects. The procurement of construction projects also involves commissioning professional services and creating a specific solution. The process is complex, involving the interaction of the owner/client, project/construction manager, designer/consultant, contractor(s), suppliers, and various regulatory bodies. Generally, a construction project comprises building materials (civil), electromechanical items, finishing items, and equipment. Construction involves the installation and integration of various types of materials/products, equipment, systems or other components to complete the project/facility to ensure that the facility is fully functional to the satisfaction of the owner/end user. Contract management involves:

- Identification of:
- What are the services in-house available?
- What services to be procured from outside agencies/organizations?
- How to procure (direct contract, competitive bidding)?
- How much to procure?
- How to select a supplier/contractor?
- How to arrive at appropriate prices, terms, and conditions?
- Signing of contract.
- Timely delivery.
- Receiving right type of material/system.
- Timely execution of work.
- Inspection of work to maintain quality of the project.
- Completion of project within agreed-upon schedule.
- Completion of project within agreed-upon budget.
- Documenting reports and plans.

1.3.2.10.1 Plan Procurement Management Process

In construction projects, the involvement of outside companies/parties starts at the early stage of the project development process. The owner/client has to decide what work is to be procured, or constructed by others. Every organization has their procurement system to procure services, contracts, and products from others. Figure 1.91 illustrates the stages at which an outside agency (contractor) is selected as per the procurement strategy for a particular type of project delivery system. At each of these stages, the procurement management process (bidding and tendering process) takes place. Figure 1.92 illustrates the procurement management process life cycle to select the contractor (outside agency).

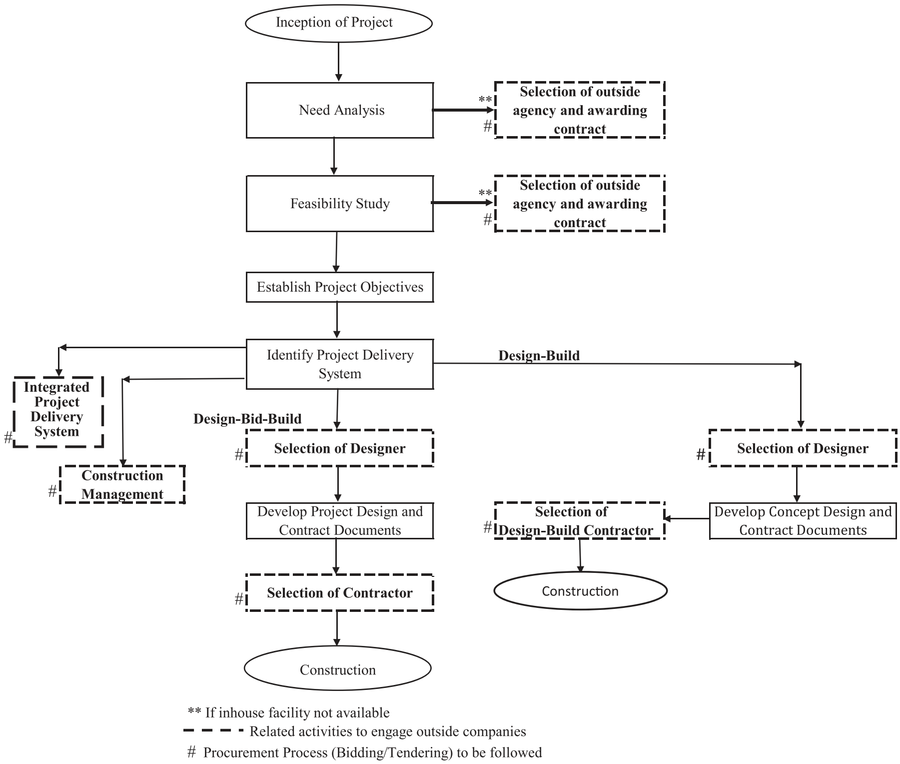


FIGURE 1.91 Procurement process stages in construction projects.

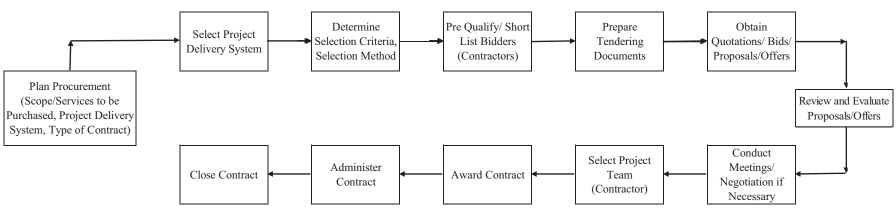


FIGURE 1.92 Contract management process.

Also, the owner has to determine the type of contract/pricing methods to select the contractor (outside agency).

1.3.2.10.2 Select Project Delivery System

Construction project delivery system is an organizational relationship of three elemental parties, owner, designer (consultant), and contractor, the roles and responsibilities of the parties and the general sequence of activities to be performed to deliver the project. The roles and responsibilities of these parties vary considerably under different project delivery systems. The following are the main categories of project delivery systems:

1. Traditional System
2. Integrated System
3. Management-Oriented System
4. Integrated Project Delivery System

Each category is further classified and sub-classified to various project delivery systems into various types of project delivery systems, advantages, and disadvantages of each of these systems.

The selection of a project delivery system mainly depends on the project size, complexity of the project, innovation, uncertainty, urgency, and the degree of involvement of the Owner.

1.3.2.10.3 Select Project Team (Contractor)

In construction projects, the owner engages outside agencies such as construction/ project manager, designer, consultant, and contractor to do the following work:

1. Feasibility Studies (if in-house facility is not available or inadequate)
2. Project Management, Construction Management
3. Project Design
4. Construction

The selection of the project team (contractor) is mainly done as follows:

1. Screening of Qualified Contractors (Prequalification of Contractor)
2. Selecting Contractor Using Contracting Methods such as:
    a. Competitive Bidding
    b. Competitive Negotiations
    c. Direct Negotiations
3. Awarding Contract

While engaging an outside agency (contractor), the following selection criteria to be considered as a minimum to prequalify the agency (contractor):

- Available skill level.
- Relevant/past performance on similar types of work.
- Reputation about their work.
- Number of projects (work) successfully completed.
- Technical competence.
- Knowledge about the type of projects (work) for which likely to be engaged.
- Available resources.
- Commitment to creating best value.
- Commitment to containing sustainability.

- Rapport/behavior.
- Communication.

The aforementioned information is gathered through a request for information, request for prequalification, or prequalification questionnaires from the prospective agency, consultant, and contractor.

After short listing of contractors, bid documents are distributed to submit the proposal. The following are the most common contracting methods for selection of project team:

1. Low Bid
2. Best Value
   a. Total Cost
   b. Fees
3. Qualification Based Selection (QBS)

1.3.2.10.3.1 Perform Short Listing (Prequalification) Process The first stage in the selection of the project team (contractor) is by short listing the prospective contractors. The information is gathered through:

- Request for Information
- Request for Qualification
- Prequalification Questionnaires

Prequalification of Feasibility Study Consultant

Normally the consultants are selected on quality-based selection method.

Prequalification of Construction Manager

The construction manager is a professional firm or individual having expertise in the management of construction processes. There are two types of construction managers (construction management systems). These are:

1. Agency CM
2. CM at Risk

While selecting the construction manager, the owner has to ensure that the CM has the professional expertise in managing the following main areas of the project:

- Scope
- Schedule
- Cost
- Monitoring and Control
- Quality
- Safety

The owner has to consider regulatory requirements (licensing) while selecting the CM. Table 1.44 lists prequalification questionnaires (PQQ) to select a construction manager.

Prequalification of Designer (A/E)

The designer (A/E) consists of architects, engineer s, or consultants. They are the owner's appointed entity accountable to convert the owner's conception and need into the specific facility with detailed directions through drawings and specifications within the economic objectives. They are responsible for the design of the project and in certain cases supervision of the construction process. Table 1.45 lists PQQ to select the designer (A/E).

Prequalification of Contractor (Design-Build)

Table 1.46 lists PQQ to select a contractor (design-build).

Prequalification of Contractor (Design-Bid-Build)

Table 1.47 lists Prequalification Questionnaire (PQQ) to select contractor.

Evaluation of Prequalification Documents

Upon receiving the information relating to the qualification data, the documents are evaluated as per the selection criteria determined earlier by the project owner. Table 1.48 is an evaluation criteria to qualify the designer to participate in the tender.

1.3.2.10.4 Manage Construction Documents

The construction documents reviewed and approved by the owner are organized by the consultant for bidding purposes. Necessary information is inserted on these documents prior to release for distribution to quailed bidders.

1.3.2.10.5 Conduct Bidding and Tendering

Regardless of the type of project delivery system, the contract arrangement between the owner and the contractor has to be established. The following are the most common types of contract/compensation methods used in construction projects:

1. Firm fixed price or lump sum contract.
2. Cost reimbursement contract.
3. Re-Measurement contract.
4. Target price contract.
5. Time and cost contract.
6. Guaranteed Maximum Price (QMP) contract.

Tendering and bidding documents are prepared based on the strategy to procure the contract. Bidding/tendering documents are distributed to shortlisted contractors. Figure 1.93 illustrates the bidding process to select the contractor as per the procurement method in accordance with the contractor selection strategy for the selection of a contractor.

1.3.2.10.5.1 Evaluate Bids The submitted bids are reviewed and evaluated by the contractor selection committee members for full compliance to the tender requirements.

TABLE 1.44
Prequalification Questionnaires (PQQ) for CM

Serial Number	Question	Answer
1	Name of the Organization and Address	
2	Organization's Registration and License Number	
3	ISO Certification	
4	Total Experience (Years)	
	4.1 Agency Construction Manager	
	4.2 CM at Risk	
5	Size of Project (Maximum Amount Single Project)	
	5.1 Agency Construction Manager	
	5.2 CM at Risk	
6	List Similar Type (Type to be Mentioned) of Projects Completed	
	6.1 Agency Construction Manager	
	6.2 CM at Risk	
7	Type of Services Provided as Agency CM/CM for Aforementioned Projects	
	7.1 During Project Study	
	7.2 During Design	
	7.3 During Bidding/Tendering	
	7.4 During Construction	
	7.5 During Start-Up	
8	Total Experience in Green Building Construction	
9	Total Management Experience	
	9.1 Project Scope	
	9.2 Project Planning and Scheduling	
	9.3 Project Costs	
	9.4 Project Quality	
	9.5 Technical and Financial Risk	
	9.6 HSE	
	9.7 Stakeholder Management	
	9.8 Project Monitoring and Control	
	9.9 Conflict Management	
	9.10 Negotiations	
	9.11 Information Technology	
10	Experience in Conducting Value Engineering	
11	Resources	
	11.1 Management	
	11.2 Engineering	
	11.3 Technician	
	11.4 Construction Equipment	
12	Total Turnover for Last Five years	

(*Continued*)

TABLE 1.44 Continued
Prequalification Questionnaires (PQQ) for CM

Serial Number	Question	Answer
13	Submit Audited Financial Reports for Last Three Years	
14	Experience in Training of Owner's Personnel	
15	Knowledge About Regulatory Procedures	
16	Litigation (Dispute, Claims) on Earlier Projects	

TABLE 1.45
Prequalification Questionnaires (PQQ) for Designer (A/E)

Serial Number	Question	Answer
1	Name of the Organization and Address	
2	Organization's Registration and License Number	
3	ISO Certification	
4	LEED or Similar Certification	
5	Total Experience (Years) in Designing Following Type of Projects	
	5.1 Residential	
	5.2 Commercial (Mixed Use)	
	5.3 Institutional (Governmental)	
	5.4 Industrial	
	5.5 Infrastructure	
	5.6 Design-Build (Specify Type)	
6	Size of Project (Maximum Amount Single Project)	
	6.1 Residential	
	6.2 Commercial (Mixed Use)	
	6.3 Institutional (Governmental)	
	6.4 Industrial	
	6.5 Infrastructure	
	6.6 Design-Build (Specify Type)	
7	List Successfully Completed Projects	
	7.1 Residential	
	7.2 Commercial (Mixed Use)	
	7.3 Institutional (Governmental)	
	7.4 Industrial	
	7.5 Infrastructure	
	7.6 Design-Build	
8	List Similar Type (Type to be Mentioned) of Projects Completed	
	8.1 Project Name and Contracted Amount	
	8.2 Project Name and Contracted Amount	
	8.3 Project Name and Contracted Amount	

(*Continued*)

TABLE 1.45 Continued
Prequalification Questionnaires (PQQ) for Designer (A/E)

Serial Number	Question	Answer
	8.4 Project Name and Contracted Amount	
	8.5 Project Name and Contracted Amount	
9	Total Experience in Green Building Design	
10	Joint Venture with any International Organization	
11	Resources	
	11.1 Management	
	11.2 Engineering	
	11.3 Technical	
	11.4 Design Equipment	
	11.5 Latest Software	
12	Design Production Capacity	
13	Design Standards	
14	Present Work Load	
15	Experience in Value Engineering (List Projects)	
16	Financial Capability (Turnover for Last Five Years)	
17	Financial Audited Report for Last Three Years	
18	Insurance and Bonding Capacity	
19	Organization Details	
	19.1 Responsibility Matrix	
	19.2 CVs of Design Team Members	
20	Design Review System (Quality Management during Design)	
21	Experience in Preparation of Contract Documents	
22	Knowledge About Regulatory Procedures and Requirements	
23	Experience in Training of Owner's Personnel	
24	List of Professional Awards	
25	Litigation (Dispute, Claims) on Earlier Projects	

TABLE 1.46
Prequalification Questionnaires (PQQ) for Design-Build Contractor

Serial Number	Question	Answer
1	Name of the Organization and Address	
2	Organization's Registration and License Number	
3	ISO Certification	
4	Registration/Classification Status of the Organization	
5	Joint Venture with any International Contractor	
6	Total Turnover Last Five Years	
7	Audited Financial Report for Last Three Years	
8	Insurance and Bonding Capacity	
9	Total Experience (Years) as Design-Build Contractor	
10	Total Experience (Years) as Contractor	

(*Continued*)

TABLE 1.46 Continued
Prequalification Questionnaires (PQQ) for Design-Build Contractor

Serial Number	Question	Answer
Design-Build Contracts information		
11	Total Experience (Years) in Construction of Following Type of Projects	
	11.1 Residential	
	11.2 Commercial (Mixed Use)	
	11.3 Institutional (Governmental)	
	11.4 Industrial	
	11.5 Infrastructure	
12	Size of Project (Maximum Amount Single Project)	
	12.1 Residential	
	12.2 Commercial (Mixed Use)	
	12.3 Institutional (Governmental)	
	12.4 Industrial	
	12.5 Infrastructure	
13	List Successfully Completed Projects	
	13.1 Residential	
	13.2 Commercial (Mixed Use)	
	13.3 Institutional (Governmental)	
	13.4 Industrial	
	13.5 Infrastructure	
14	List Similar Type (Type to be Mentioned) of Projects Completed	
	14.1 Project Name and Contracted Amount	
	14.2 Project Name and Contracted Amount	
	14.3 Project Name and Contracted Amount	
	14.4 Project Name and Contracted Amount	
	14.5 Project Name and Contracted Amount	
15	Resources	
	15.1 Management	
	15.2 Engineering	
	15.3 Technical	
	15.4 Foreman/Supervisor	
	15.5 Skilled Manpower	
	15.6 Unskilled Manpower	
	15.7 Plant and Equipment	
16	Quality Management Policy	
17	Health, Safety, and Environment Policy	
	17.1 Number of Accidents during Last Three Years	
	17.2 Number of Fires at Site	
18	Current Projects	
19	Staff Development Policy	
20	List of Delayed Projects	
21	List of Failed Contract	

(*Continued*)

TABLE 1.46 Continued
Prequalification Questionnaires (PQQ) for Design-Build Contractor

Serial Number	Question	Answer
Designer's Information		
22	Total Years of Experience in Design-Build Type of Projects	
23	Size of Project (Maximum Value)	
24	List Similar Type of Successfully Completed Projects	
25	List Successful Design-Build Projects	
26	Resources	
	26.1 Architect	
	26.2 Structural Engineer	
	26.3 Civil Engineer	
	26.4 HVAC Engineer	
	26.5 Mechanical Engineer	
	26.6 Electrical Engineer	
	26.7 Low Voltage Engineer	
	26.8 Interior Designer	
	26.9 Landscape Engineer	
	26.10 CAD Technicians	
	26.11 Quantity Surveyor	
	26.12 Equipment	
	26.13 Design Software	
27	LEED or Similar Certification	
28	Total Experience in Green Building Design	
29	Design Philosophy/Methodology	
30	Quality Management System	
31	HSE Consideration in Design	
32	List of Professional Awards	
33	Litigation (Dispute, Claims) on Earlier Projects	

TABLE 1.47
Prequalification Questionnaires (PQQ) for Contractor (Design-Bid-Build)

Serial Number	Question	Answer
1	Name of the Organization and Address	
2	Organization's Registration and License Number	
3	ISO Certification	
4	Registration/Classification Status of the Organization	
5	Joint Venture with any International Contractor	
6	Total Turnover Last Five years	
7	Audited Financial Report for Last Three years	
8	Insurance and Bonding Capacity	

(*Continued*)

TABLE 1.47 Continued
Prequalification Questionnaires (PQQ) for Contractor (Design-Bid-Build)

Serial Number	Question	Answer
9	Total Experience (Years) in Construction of Following Type of Projects	
	9.1 Residential	
	9.2 Commercial (Mixed Use)	
	9.3 Institutional (Governmental)	
	9.4 Industrial	
	9.5 Infrastructure	
10	Size of Project (Maximum Amount Single Project)	
	10.1 Residential	
	10.2 Commercial (Mixed Use)	
	10.3 Institutional (Governmental)	
	10.4 Industrial	
	10.5 Infrastructure	
11	List Successfully Completed Projects	
	11.1 Residential	
	11.2 Commercial (Mixed Use)	
	11.3 Institutional (Governmental)	
	11.4 Industrial	
	11.5 Infrastructure	
12	List Similar Type (Type to be Mentioned) of Projects Completed	
	12.1 Project Name and Contracted Amount	
	12.2 Project Name and Contracted Amount	
	12.3 Project Name and Contracted Amount	
	12.4 Project Name and Contracted Amount	
	12.5 Project Name and Contracted Amount	
13	List of Subcontractors	
14	Resources	
	14.1 Management	
	14.2 Engineering	
	14.3 Technical	
	14.4 Foreman/Supervisor	
	14.5 Skilled Manpower	
	14.6 Unskilled Manpower	
	14.7 Plant and Equipment	
15	Current Projects	
16	Quality Management Policy	
17	Health, Safety, and Environment Policy	
	17.1 Number of Accidents during Last Three Years	
	17.2 Number of Fires at Site	
18	Staff Development Policy	
19	List of Delayed Projects	
21	List of Failed Contract	
22	List of professional Awards	
23	Litigation (Dispute, Claims) on Earlier Projects	

TABLE 1.48
Designer's (A/E) Selection Criteria

Serial Number	Evaluation Criteria		Weightage	Notes
1	**General Information**			
	a. Company Information			
2	**Business**		**10%**	
	a. LEED or Similar Certification	5%		
	b. ISO Certification	5%		
3	**Financial**		**20%**	
	a. Turnover	5%		
	b. Financial Standing	5%		
	c. Insurance and Bonding Limit	10%		
4	**Experience**		**30%**	
	a. Design Experience	10%		
	b. Similar Types of Projects	10%		
	c. Current Projects	10%		
5	**Design capability**		**10%**	
	a. Design Approach	5%		
	b. Design Capacity	5%		
6	**Resources**		**20%**	
	a. Design Team Qualification	10%		
	b. Design Team Composition	5%		
	c. Professional Certification	5%		
7	**Design Quality**		**5%**	
8	**Safety Consideration in Design**		**5%**	

Note: The weightage mentioned in the table is indicative only. The percentage can be determined as per the owner's strategy.

The main purpose of bid evaluation is to determine that the bid responses are complete in all respects in accordance with the evaluation and selection methodology specified in the tender documents.

Most government and public sector projects follow the low bid selection method. There are three international bidding procedures which may be selected by the project owner to suit the nature of project procurement. These are:

1. Single Stage: One Envelope: In this procedure, the bidders submit bids in one envelope containing both technical and financial proposals. The bids are evaluated by the selection committee, which sends their recommendation to the owner. Following the review and concurrence by the owner, the contract is awarded to the lowest bidder.
2. Single Stage: Two Envelopes: In this procedure, the bidders submit two envelopes, one containing a technical proposal and the other a financial proposal. Initially, technical proposals are evaluated without referring to the price. Bidders whose proposal does not conform to the requirements may be

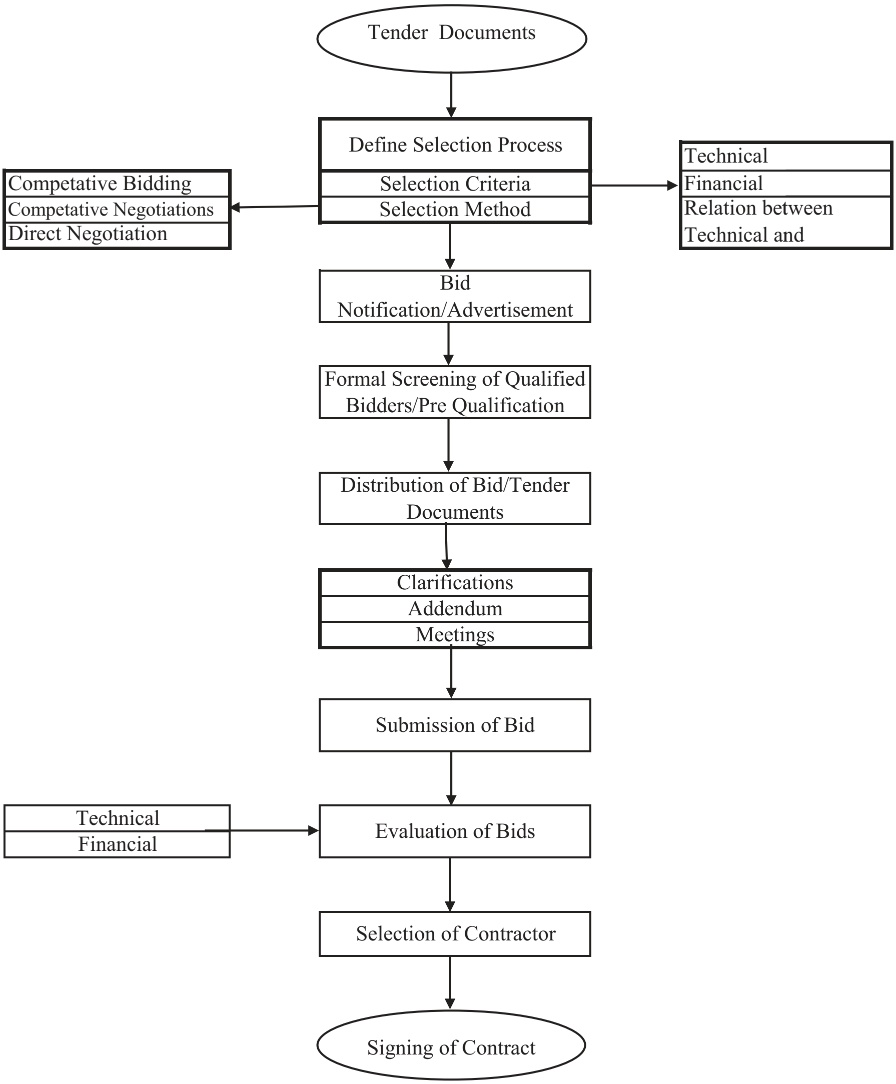


FIGURE 1.93 Bidding/tendering (procurement) process.

rejected/not accepted. Following the technical proposal evaluation, the financial proposals of technically responsive bidders are reviewed. Upon review and concurrence by the owner, the contract is awarded to the lowest bidder.

3. Two Stages: In this procedure, during the first stage, the bidders submit their technical offers on the basis of operating and performance requirements, but without price. The technical offers are evaluated by the selection committee. Any deviations to the specified performance requirements are discussed with the bidders who are allowed to revise or adjust the technical offer and resubmit the same.

During the second stage, the bidders, whose technical offers are accepted, are invited to submit the final technical proposal and financial proposal. Both proposals are reviewed by the selection committee and, following review and concurrence by the owner, the contract is awarded to the lowest bidder. This procedure is mainly applicable for turnkey projects, complex plants.

Table 1.49 lists the items to be reviewed prior to the evaluation of bid documents.

1.3.2.10.5.2 Select Contractor After the bids have been reviewed and evaluated by the consultant, they are sent to the owner for approval and further action. In certain cases, the bids are reviewed by a tender-approving agency. The comments raised by the agency are to be taken care of before the finalization of the bid. In most cases, the bidder with the lowest bid amount wins the contract. In case the bid amount is more than the approved project budget, the owner has to update the budget amount or negotiate with the contractor to meet the owner's expectations. Upon approval from the relevant agency, the owner awards the contract to one bidder

1.3.2.10.6 Administer Contract

Contract administration is the process of formal governance of contracts and changes to the contract document. It is concerned with managing contractual relationships between various participants to successfully complete the facility to meet the owner's objectives. It includes tasks such as:

- Administration of project requirements.
- Administration of project team members.
- Communication and management reporting.
- Execution of contract.
- Monitoring contract performance (scope, cost, schedule, quality, risk).
- Inspection and quality.
- Variation order process.
- Making changes to the contract documents by taking corrective action as needed.
- Payment procedures.

It is required that the contract administration procedure is clearly defined for the success of the contract and that the parties to the contract understand who does what, when, and how. The following are some typical procedures that should be in place for management of the contract management activities:

1. Contract document maintenance and variation.
2. Performance review system.
3. Resource management and planning.
4. Management reporting.
5. Change control procedure.
6. Variation order procedure.
7. Payment procedure.

Table 1.50 lists the contents of the contract management plan.

TABLE 1.49
Checklist for Bid Evaluation

Serial Number	Description	Yes	No	Notes
A: Documents				
A.1	Bid submitted before closing time on the date specified in the bid documents.			
A.2	Bidders' identification is verified.			
A.3	Bid is properly signed by the authorized person.			
A.4	Bid bond is included.			
A.5	Required certificates are included.			
A.6	Bidders' confirmation of the validity period of bid.			
A.7	Confirmation to abide by the specified project schedule.			
A.8	Bid documents have no reservation or conditions (limitation or liability).			
A.9	Preliminary method statement.			
A.10	List of equipment and machinery.			
A.11	List of proposed core staff as listed in the tender documents.			
A.12	Complete responsiveness to the commercial terms and conditions.			
A.13	All the required information is provided (completeness of information).			
A.14	All the supporting documents required to determine technical responsiveness is submitted.			
B: Financial				
B.1	All the items are priced.			
B.2	Bid Amount clearly mentioned.			
B.3	Prices of provision items.			

1.3.2.10.7 Close Contract

It is a process of completing the contract, verification of completed activities, acceptance of all the deliverables, takeover of project, and issuance of a substantial completion certificate. Normally, the contract documents stipulate all the requirements to be completed to close the contract. Table 1.51 illustrates the lists of all the activities required to be recorded to close the contract.

1.3.2.11 Health, Safety, and Environment Management

(This section is contributed by Mr. Edward Taylor and Mr. Jitendra C. Patel)

Safety is the cornerstone of a successful project. Accidents cause needless loss of human and physical capital. These losses can only be detrimental to the project schedule and cost. Safety, long neglected, is increasingly being recognized for its value as contractors and owners strive to avoid the increasing cost of injuries and fatalities. In 2021, the National Safety Council estimated the direct and indirect costs of a single fatality at $1.3 million. Another source computes the average direct and

TABLE 1.50
Contents of Contract Administration Plan

Serial Number	Topics
1	Contract summary, deliverables. and scope of work.
2	Type of contract.
3	Contract schedule.
4	Contract cost.
5	Project team members with roles and responsibilities.
6	Core staff approval procedure.
7	Contract communication matrix/management reporting.
8	Coordination process.
9	Liaison with regulatory authorities.
10	Material/product/system review/approval process.
11	Shop drawing review/approval process.
12	Project monitoring and control process.
13	Contract change control process: a. Scope b. Material c. Method d. Schedule e. Cost
14	Review of variation/change requests.
15	Project holdup areas.
16	Quality of performance.
17	Inspection and acceptance criteria.
18	Risk identification and management.
19	Progress payment process.
20	Claims, disputes, conflict, and litigation resolution.
21	Contract documents and records.
22	Post contract liabilities.
23	Contract closeout and independent audit.

indirect costs of a strain or sprain injury at more than $64,000. Numerous researchers have demonstrated the business case for safety through benefit-cost analyses. In one such analysis, the US Occupational Safety and Health Administration's Office of Regulatory Analysis has stated "our evidence suggests that companies that implement effective safety and health can expect reductions of 20% or greater in their injury and illness rates and a return of $4 to $6 for every $1 invested."

The trend toward improved safety seems gradual but recognizable. As in other fields, technological advances continually provide better materials, methods, and equipment. Increasingly prefabricated materials and modular construction reduce worker exposure to more hazardous construction activities found with older conventional methods. In recent years, researchers have found that incorporating safety in the design phase has huge potential to impact exposures to hazardous situations. A concept called Prevention through Design (PtD) is well established in

TABLE 1.51
Contract Closeout Checklist

Sr. No.	Description	Yes/No
Project Execution		
1	Contracted work completed.	
2	Site work instructions completed.	
3	Job site instructions completed.	
4	Remedial notes completed.	
5	Non-Compliance reports completed.	
6	All services connected	
7	All the contracted work inspected and approved.	
8	Testing and commissioning carried out and approved.	
9	Any snags?	
10	Is project fully functional?	
11	All other deliverable completed.	
12	Spare parts delivered.	
13	Is waste material disposed?	
14	Whether safety measures for use of hazardous material established?	
15	Whether the project is safe for use/occupation?	
16	Whether all the deliverable accepted?	
Project Documentation		
17	Authorities' approval obtained.	
18	Record drawings submitted	
19	Record documents submitted.	
20	As-Built drawings submitted.	
21	Technical manuals submitted.	
22	Operation and maintenance manuals submitted.	
23	Equipment/material warrantees/guarantees submitted.	
24	Test results/test certificates submitted.	
Training		
25	Training to owner/end user's personnel imparted.	
Negotiated Settlements		
26	Whether all the claims and dispute negotiated and settled.	
Payments		
27	All payments to subcontractors/specialist suppliers released.	
28	Bank guarantees received.	
29	Final payment released to main contractor.	
Handing Over/Taking Over		
30	Project handed over/taken over.	
31	Operation/maintenance team taken over.	
32	Excess project material handed over/taken over.	
33	Facility manager in action.	

Europe and gaining a foothold in the United States. With PtD, safety is "designed in" a project. For instance, steel columns can receive shop-drilled holes for the easy attachment of safety lanyards during steel erection. This almost insignificant additional effort can save a life. Innovative concepts such as PtD require strong advocates to demonstrate their safety value and make a business case to the industry.

Though safety gains have been made, the situation remains critical. The 2022 US annual construction fatality rate was 13.0 per 100,000 full-time workers. In contrast, the 2022 US fatality rate for all occupations was 3.7 per 100,000. Sadly, construction workers incur occupational fatality risk that is 3.5 times greater than the general working population. How can construction be made safer? The process is detailed but the solution can be simply summarized as in Figure 1.94.

1.3.2.11.1 Safety Management Framework (By Edward Taylor)

Strive to incorporate safety into the project as early as possible. A safety-conscious contractor can provide valuable input in the early stages of design. As seen in Figure 1.95, early processes offer the most potential to affect safety.

Prior to construction, the contractor needs to compile a coordinated, comprehensive site plan. Although the details of a comprehensive safety management plan are beyond the scope of this text, we can certainly illustrate some critical elements using our PLAN, PROVIDE, TRAIN framework.

PLAN: Each site is unique and requires a specific plan. In creating a plan, here are some important items.

- Secure emergency contact information from:
  - Hospitals.

FIGURE 1.94 Safety framework.

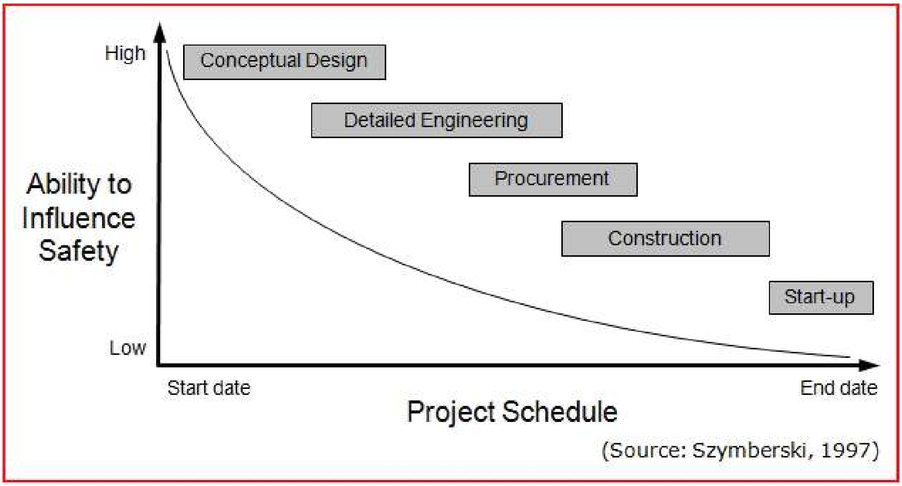


FIGURE 1.95 The ability to influence safety.

- Fire and rescue squad.
- First aid medical treatment facilities.
- Locate buried and overhead utilities.
- Notify utilities requiring relocation or de-energizing.
- Coordinate the project schedule with utility relocations.
- Provide safe access and egress from the site for:
- Typical material and equipment deliveries.
- Oversized loads.
- Other miscellaneous.
- Conduct regular safety inspections and site training.
- Plan for traffic control.
- Plan for emergency response scenarios.

The aforementioned contains only a few critical items. A complete and comprehensive safety plan should incorporate sufficient detail to address all hazards, including those that are site specific.

PROVIDE: Workers have the right to expect their employer will provide them with the proper equipment, tools, and training to complete all tasks safely. A few basic expectations for employers include:

- Provide well-maintained equipment (e.g., cranes, backhoes, etc.).
- Require periodic safety inspections.
- Keep maintenance logs.
- Furnish operating manuals and load charts.
- Utilize certified crane operators.
- Require safety assurance checks.
- Inspect chains, slings, and hoists daily.

- Replace hand tools with damaged cords or missing guards.
- Provide the basic safety gear: hardhats, safety glasses, gloves, and hearing protection.
- Provide fall protection for workers at heights of six feet or more.
- Designate a company safety officer.

Providing workers with well-maintained equipment not only enhances safety and improves productivity but boosts morale. Poorly functioning tools and equipment create hazards, diminish productivity, and damage worker morale.

TRAIN: Even the best plan and top-notch equipment require well-trained employees. In developed countries, construction training is commonly available through unions, trade associations, individual company programs, and even the Internet. In fiscal year 2023, approximately 550,000 workers in the US construction workforce received a standardized OSHA ten-hour training course in construction safety. In fact, some localities require such training for all workers on public projects. This is an excellent example of informed owners realizing that increased safety can provide long-term benefits by reducing costs. More extensive safety training courses, beyond the basic ten-hour course, appropriate for supervisors, are also widely available.

Typical basic construction safety training might include:

- Four most common fatal hazards (i.e., falls, electrocutions, struck by, and caught in\between).
- Material handling.
- Hazard communication.
- Lockout/tag out procedures.
- Vehicular safety.
- Personal protective equipment.

Training is not a one-and-done endeavor. Employee turnover, job reassignments, and changing technology necessitate that training be ongoing and frequently updated.

1.3.2.11.2 Major Causes of Site Accidents (By Edward Taylor)

The results of site accidents range from minor injuries such as cuts and bruises to major ones such as broken limbs and paralysis, and the worst accidents may result in fatalities. Thankfully, specific injury severity and its frequency tend to be inversely related. The following focuses primarily on the causes of fatalities, but the causes of accidents resulting in minor and major injuries are often remarkably similar because there is an element of randomness in injury outcomes. A few inches may be the only difference between a near miss and a fatality.

Almost 60% of construction fatalities are caused by four primary means. These hazards, mentioned previously, are commonly known as the “Fatal Four.” They consist of falls, electrocutions, struck by incidents, and caught in\between incidents. Preventing these is the core of any construction safety program.

Falls alone constitute one-third of all construction fatalities in the US. Types of falls include those from roofs, scaffolding, ladders, equipment, through openings, etc. Though falls occur in a multitude of ways, they are all preventable. A national campaign in the US sponsored by a consortium of construction stakeholders and safety emphasized the ability to prevent falls using the theme outlined previously. PLAN. PROVIDE. TRAIN. Properly trained workers with fall protection systems in place should never become fall fatalities. Common fall protection systems include guardrails, safety nets, and body harnesses. A typical body harness is shown in Figure 1.96.

Electrocutions, another leading fatality cause, are responsible for almost 10% of construction deaths. Primary causes of electrocution are:

- Contact with overhead power lines.
- Contact with energized sources.
- Improper use of extension and flexible cords.

Safety countermeasures are:

- Maintain a safe distance from overhead lines*.
- Use ground fault circuit interrupters (GFCI).
- Inspect portable tools and extension cords for damage.

*Ten feet is considered the minimum safe clearance for power lines up to 50 kV. For a 200 kV line, the minimum clearance doubles to 20 feet.

FIGURE 1.96 Personal fall arrest system.

When impact alone creates the injury, this is considered a struck-by event. Workers can be struck by flying, falling, swinging, or rolling objects. These events may be minimized by staying clear of lifted loads, maintaining awareness and respect for the swing radius of cranes, backhoes, etc., and providing equipment operators protection from falling debris.

Struck by and caught in between events are somewhat similar. When crushing between two objects or being pulled into or caught in running machinery occurs, this is considered caught in\between. Some common causes of this type are structural collapse, trench cave-in, or becoming trapped between equipment and a stationary object. A safe worksite will have bracing for unstable structures as well as sloping, benching, or shielding for trenching operations. Workers should be trained to maintain awareness of moving equipment, stay clear when possible, and avoid pinch points.

Thus far, the focus has been on accidents that cause fatalities and serious injuries. Any safety discussion should also include common causes of less serious injuries. Most construction work is physically challenging. Strains, sprains, bumps, bruises, and cuts are common. The inevitable bumps and scrapes can be minimized with Personal Protective Equipment (PPE). Using hard hats, gloves, safety glasses, and hearing protection must become second nature. To avoid strains, use two people to lift heavy loads and avoid awkward working positions.

Harsh environments are another challenge. Nature's elements can create a variety of problems. Rain, wind, cold, and heat each present special challenges. Heat illness is a major concern in the summer months. When temperatures are high, workers should take special care to keep hydrated, work in the shade when possible, and complete higher-effort tasks in the cooler morning hours.

Less obvious and often overlooked, a cluttered and dirty worksite is one common and easily preventable cause of accidents. Site cleanliness and orderliness cannot be overemphasized. Scattered tools, materials, and construction debris invite slips, trips, and falls. Loose nails create cuts and punctures. A strong correlation exists between cleanliness and safety.

Another less obvious cause of accidents is the inability to recognize potential hazards on the job site. Young workers are particularly vulnerable because they lack experience. Immigrant workers comprise another vulnerable group. Poor language skills make recognition training and awareness more difficult. Since the lack of ability to recognize potential hazards is frequently found in both groups, they may require specialized training to build recognition and teach avoidance. Mentoring and close supervision are also recommended to reduce their risk of injury.

1.3.2.11.3 Safety in Construction Projects and Process Industries (By Jitendra C. Patel)

Loss prevention philosophy makes process industries, construction projects, and other industries believe that protection of its resources, including employees and physical assets, against human distress and financial loss resulting from accidental occurrences can be controlled. Disasters have taught us an improved loss control through a professional management system. The paper sets out approaches to loss prevention that may be adopted by any industry and not limited to the process industry. It discusses the major elements and methodology of the overall program. These elements include policy declaration, employee training, permit-to-work procedures, safety inspections, predictive maintenance, safety meetings, safety talks, safety suggestions, loss prevention compliance reviews, executive management safety reviews, safe operations committee, contractor safety program, non-operating personnel safety orientation, emergency drills, disaster control plan, and employee incentive schemes.

Fundamental concepts and methodology of the program are to identify all loss exposures, evaluate the risk of each exposure, plan how to handle each risk, and, manage according to plan. People are the first source of losses. These could be managers, engineers, or workers who plan, design, build, operate, and maintain the plants. Also, the general public may be subjected to the hazards! Secondly, equipment—whether fixed plant, machines, tools, protective gear, or vehicles. Thirdly, materials such as processed substances, supplies, and products that have physical and chemical hazards affecting people, equipment, and environment. Fourth is surroundings, which include buildings, surfaces, and sub-surfaces, atmosphere, lighting, noise, radiation, hot or cold weather, and social or economic conditions that can affect safe performance of people, equipment, and materials.

Human sufferings and economic aspects of costs lost and work delays or property damage vary from minor to major. As we all know, a loss is the effect of an undesired event that could result in injury, property damage, and production upset. Root causes of accidents in the process industry are 30% due to design failure, operational error, or equipment failure, and 20% attributed to maintenance and inspection deficiencies, 45% by inadequate supervision and training, and 5% due to natural phenomena and external influences.

1.3.2.11.3.1 Policy Declaration It is important that the highest authority of the corporation/company and his/her management considers no phase of operation or administration as being of greater importance than accident prevention. It should be the policy of management to provide and maintain safe, healthy working conditions to follow operating practices that will safeguard employees, result in safe working conditions and efficient operations. A policy declaration should be developed and displayed for the knowledge of employees and its implementation is ensured by the management.

1.3.2.11.3.2 Training Safety training should be conducted for all employees, including operations, maintenance, engineering, and other administration personnel.

New employees assigned to work, including clerical staff, are given an introduction to general activities of the industry with an emphasis on loss prevention. As a part of this training program, new employees should receive training on first aid/CPR, firefighting, and usage of personal protective equipment, hazardous chemical handling, and work permit procedures. Over and above the normal work-related training, regular employees should also be given refresher safety training on a set, frequently scheduled basis. The employees' supervisor usually determines the training requirements.

1.3.2.11.3.3 Work Permit Procedures Management should have a certification program for the employees to issue and receive work permits for good control and safe execution of tasks to be performed by other than normal operating personnel within the defined hazardous areas. Professionals from the loss prevention/safety department should assist with the work permit procedure certification. Validity of this certification should be decided by the management based on the nature of activities, number of employees, and other relevant criteria such as employees' knowledge, ability, attitude, and behavior. During this certification period, employees should undergo a refresher program to update and upgrade themselves on work permit procedures, which may be organized by in-house operations/maintenance training groups.

Generally, process industries have work permits for hot and cold work and a permit for entry into confined space. Other work permits include precautionary permits for the potential for accidental release of hydrocarbons, steam condensate, or any other toxic or reactive injurious materials during the course of any activity, excavation permits, permits to work on higher elevations or under water, and so on. The functioning of the work permit system and its strict adherence to the procedural requirements should be monitored by performing field surveys by dedicated management representatives and should be backed by spot-check reviews by loss prevention/safety professionals.

1.3.2.11.3.4 Safety Inspections Over and above all daily, weekly, and monthly regular work level inspections, the process industry should make a commitment that all facilities, such as operating plants, maintenance shops, offices, and other workplaces be inspected as spot checks by the management at least once every quarter to identify and eliminate hazards and to provide safe working conditions.

A typical operating plant safety inspection team should consist of members from operations, maintenance, process engineering, loss prevention/safety, and fire protection. An operations superintendent should lead the team from an unaffected division along with the process and maintenance engineers of the division to be surveyed and a representative each from loss prevention and fire protection. The team should review procedures and related software and conduct a walk-through inspection of the operating plants to not only verify satisfactory completion of previous items but also to make a note of other additional observations. The findings should be discussed at a subsequent critique meeting and should be consolidated in a report. The operations management should follow-up on the corrective actions taken on the findings.

Similar quarterly safety inspections should also be conducted on maintenance facilities such as machine shops, welding shops, sheet metal shops, relief valve shops, instrumentation shops, offices, material warehouses, etc.

1.3.2.11.3.5 Other Predictive Maintenance Inspections Some other inspections, certifications, and predictive maintenance programs that have proved beneficial in process industries are as follows:

On Stream Inspection Program

This records thickness measurements for all pressure vessels, equipment, and selected process line circuits. The OSI program involves various survey points in the plant on a pre-planned schedule.

Relief Valve Inspection Program

This program should normally monitor relief valves through a relief valve coordinator or a specialist from the inspection group. The program is to forecast valves to be removed, to revise test intervals, and to evaluate specific problems.

Rotating Equipment Monitoring Program

Rotating equipment should be monitored on a biweekly/monthly/quarterly cycle based on the critical nature of the equipment by dedicated maintenance specialists using state-of-the-art sophisticated vibration analysis equipment.

Crane/Heavy Equipment Inspection

All cranes (mobile and fixed) used in the process industry should be inspected and certified by a crane inspection specialist. The crane/heavy equipment operators and riggers should also be certified for a particular crane/load during lifting operations.

Safety Meetings

Safety meetings and talks are considered vital in communicating loss prevention/safety topics, motivating employees, and acknowledging contributions in the loss prevention/safety program.

Operations Safety Meetings

Every operations unit should organize a safety meeting at least once in two months. These meetings should be chaired by the plant foreman and attended by the plant operation supervisors, lead operators, and a representative from loss prevention/safety if available. Various issues related to operations safety, observations during quarterly plant safety inspections and near misses/incidents having lesson learning potential should be discussed during these meetings.

Maintenance Safety Meetings

The maintenance department should organize safety meetings more frequently, preferably at least once every two weeks. Due to the nature of their work, often the maintenance employees are exposed to unsafe conditions or commit unsafe acts. These meetings, usually chaired by the maintenance foreman, are organized based on crafts and held at the workplaces. During these meetings, a loss prevention/safety representative should also deliver a safety talk on specialized topics. Safety films, as visual training aids, should be shown during these meetings.

Safety Talks

Frequent—weekly/monthly/quarterly safety talks are conducted by the industry line organizations. The appropriate management should recognize the best safety talk. Discussions on related operating instructions as well as recent incidents/accidents involving losses, should be included as topics of safety talks. The inmate discussion concept is the best and most effective way to educate and update the employees with relevant information to help increase and improve their safety awareness both at work and at home.

Safety Suggestion Program

A safety suggestion program should be introduced that encourages employee involvement in loss prevention. Employees whose suggestions are accepted by the management should be recognized for their contributions. Implementation of accepted safety suggestions should receive greater prioritized attention for early benefits. Process industry history shows that the implementation of many of these suggestions has resulted in significant improvements in plant and personal safety.

Loss Prevention Compliance Reviews

Loss prevention compliance reviews of the facility should be performed on a selective basis to monitor adherence with the industry/company loss prevention/safety policy. These independent reviews provide objective feedback on the effectiveness of the loss prevention/safety effort and should be performed by specialists such as the operations/maintenance/engineering representatives from the proponent organization, other expertise from electrical/instrumentation, rotating equipment, on stream inspector, crane/heavy equipment inspector, loss and fire prevention, and industrial hygiene/health/environmental. Guidelines for performing reviews should be tailored to the size and type of review undertaken. Management should follow the team's recommendations for timely corrective actions taken.

Executive Management Safety Reviews

It is good industry practice to conduct an overall safety review of the facility by corporate executive management at least once a year. Participants should review the status of implementation of all items reported during the previous tour. They should also review new constructions and modifications to equipment with respect to loss prevention factors. These executives should allow time for presentations on items requiring capital budgetary approval, which could improve process safety and personnel safety.

Safe Operations Committee

The safe operations committee should be chartered to evaluate the company organization's loss prevention program and recommend ways and means for improvement. The management-level company/organization representative should chair the committee. Generally, members of the committee should include managers/superintendents of operations, maintenance, and engineering representatives from training, loss prevention, and fire protection. Key issues that should be addressed in such committees are analysis of deficiencies, effectiveness of programs, compliance with corporate general and engineering standards, review and follow-up of corrective actions taken on safety problems identified by safety inspection or other reviews, examine levels of priority given to various safety problems, and discuss employee involvement in various on or off the job activities. Review of the incidents/accidents/near misses should be given greater importance for lesson learning potentials and recommendations.

Contractor Safety Program

Special care and attention should be given to activities performed by the contractors. Safe execution of any tasks within the processing facility is the sole responsibility of the proponent organization management regardless of contractor involvement. The proponents must ensure that the contractors have a good workable safety program that is well-communicated and fully implemented. The program should ensure that contractors meet their responsibilities to protect personnel, equipment, and plant facilities. Contractual obligations are reviewed at pre-contract meetings and during regular site inspections while work is in progress. Finally, an evaluation report should be prepared for future reference to determine whether the contractor is worthy of being considered again.

Contractor Safety Orientation Program

It is important that company management recognizes the hazards and the needs of non-operating personnel who are not familiar with the process plant facilities and the procedures to follow in case of emergency. They should organize a safety program for all such employees, especially contractor employees working inside their facility. During the program, a safety awareness presentation should be made on various hazards in the facility, work permits procedural requirements, safety policy, and general functional procedures for their operations and emergency/evacuation procedures.

Fire/Emergency Drills

In industry, announced and unannounced fire/emergency drills have been found of great value to tune employees to face any real in-plant emergencies. A written scenario should be prepared for each drill that sufficiently describes the role of operating personnel, location and magnitude of fire/emergency, equipment affected, source of a release, direction of flow, etc. A team consisting of representatives from operations, maintenance and process engineering, fire protection, and loss prevention/safety should review these drills by making observations. A meeting should be conducted after such drills to evaluate the opportunities for improvement.

Disaster Control Plan

Every process industry/organization should develop a disaster control plan that should define the procedures for obtaining assistance from inside or outside the company support organizations during disasters and detail the functions of essential personnel assigned to control the disaster. At least two drills per annum, one of which is preferably unannounced, are recommended to evaluate the effectiveness of the plan and readiness of the people and corrective actions are taken on any deficiencies noted.

Incentive Programs

Company/organizations should develop good safety promotional incentive programs such as safety competitions of employees and also for the contracting firms who may be involved in major project construction and/or maintenance/repair jobs. Employees' individual and team performance should be recognized by the company to encourage and motivate employees to think and execute safety at all times, and reduce losses that could occur due to injury, property damage, or operations/production upsets.

1.3.2.11.4 Safety Hazards during Summer (By Jitendra C. Patel)

During summer, people suffer from fatigue, exhaustion, heat-related illnesses, tornadoes, lightning storms, stinging insects, allergies, wildfires, poisonous plants, poisonous animals, and kids drowning are reported each week in hot areas. Vehicle safety is also the most important as a killer. Don't ever leave children unattended inside a vehicle, not even for a split second! The temperature inside a car reaches well over 120 degrees F in less than one hour. Also, do not keep perfumes, cologne, hair sprays, or aerosol cans of any kind inside a car to avoid car explosions! Remove them quickly if you have them now!

As the temperature rises, the body's stress also rises. There are two critical actions that can help to battle the heat. Acclimatization to the heat is to get accustomed and used to heat and consume a lot of water. The human body is a good regulator of heat. It reacts to heat by circulating blood and raising skin temperature. Excess heat is then released by sweating. Sweating maintains a stable body temperature if the humidity level is low enough to permit evaporation and also if the body fluids and salts you lose are adequately replaced. Many factors can cause the body to unbalance its ability to handle heat, for example, age, weight, fitness, medical condition, diet, etc.

When the heat is combined with other stresses such as physical work, loss of body fluids, fatigue, or some medical conditions, it may lead to heat-related illnesses, disability, and even death. Therefore, caution everyone, including workers and children, that this can happen to anybody, even to young and fit people.

Heat stress is a serious hazard. When body temperature rises even a few degrees above normal, that is, 98.6 degrees F, we can experience tiredness, irritability, inattention, muscle cramps, become weak, disoriented, and dangerously ill. Heat Stress reduces our work capacity and efficiency. People who are overweight, physically unfit, suffer from heart conditions, drink too much alcohol, and are not used to summer temperatures, are at greater risk and should seek medical advice. First aid for heat stress is nutritious food, getting acclimatized to heat, and drinking lots of water.

Heat rash is when people are constantly exposed to hot and humid air; heat rash can substantially reduce the ability to sweat and the subsequent body's tolerance to heat. First aid for heat rash is: Clean the affected areas thoroughly and dry them completely. Calamine or other soothing lotion may help relieve the discomfort.

Heat cramps are the final warning for heat stress. This may occur after prolonged exposure to heat. They are painful intermittent spasms of the abdomen and other muscles. First aid for heat cramps varies. The best care is rest, move the victim to a cool environment. Give him/her plenty of water. Do not give pops, sparkling water, or alcohol.

Heat exhaustion may result from physical exertion in hot environments. Heat exhaustion develops when a person fails to replace body fluids and salt that are lost through sweating. You experience extreme weakness, fatigue, nausea, or a headache as heat exhaustion progresses. First aid for heat exhaustion is to rest in a shade or cool place, Drink plenty of water, loosen clothing to allow the body to cool, and use cool, wet rags to aid cooling.

Heat stroke is a serious medical condition that urgently requires medical attention in which sweating stops, which makes the skin hot and dry. The body temperature is very high (105 degrees F and rising). Symptoms of heat stroke are mental confusion, delirium, that is, disordered speech, chills, dizziness, strong fast pulse, loss of consciousness, convulsions or coma, a body temperature of 105 degrees F or higher, and hot, dry skin that may be red or bluish. Remember, first aid for heat stroke is a medical emergency since brain damage and death are possible. Until medical help arrives, move the victim to a cool place. Call emergency telephone numbers for help such as 999 or 110 or 911. You must use extreme caution when soaking clothing or applying water to a victim. Shock may occur if done too quickly with very cold water. Use a fan or ice packs. Douse or sprinkle the body continuously with a cool liquid and summon medical help.

Other sun-related health problems

Exposure to UV radiation can lead to the most common skin cancers. Getting one or two sunburn blisters before the age of 18 doubles the risk of developing melanoma. This is important for children.

Long exposure to sunlight can lead to eye problems later in life, such as cataracts. Another one is a "burning" of the eye surface, called "snow blindness" from sunlight, which may lead to complications later in life.

Repeated exposure to the sun can cause premature aging effects. Sun-induced skin damage causes wrinkles, easy bruising, and brown spots on the skin. For anyone, avoid being exposed to the sun. It is not too late!

Furthermore, sunburn can alter the distribution and function of disease-fighting white blood cells for up to 24 hours after exposure to the sun. Repeated over-exposure to UV radiation can cause more damage to the body's immune system. Mild sunburn can directly suppress the immune functions of human skin where the sunburn occurs, even in people with dark or brown skin. This means that it applies to all of us of Indian origin.

The sting of the summer: With increased temps, insects become very active. Insects are a nuisance and can cause many health-related problems. Common stinging insects are bees, wasps, hornets, yellow jackets, fire ants, etc. Over two million people are allergic to stinging insects. An allergic reaction to an insect sting can occur within minutes, or even hours after the sting. Stinging insects are especially attracted to sweet fragrances of perfumes, colognes, hair sprays, picnic food, open soda or beer cans, and garbage areas. Avoid these attractants in order to lessen a person's chance of being stung.

Symptoms of an allergic reaction are itching and swelling in areas other than the sting site, tightness in the chest and difficulty in breathing, hoarse voice, dizziness, and unconsciousness or cardiac arrest. The treatment for an allergic reaction is the use of epinephrine and other treatments. Epinephrine can be self-injected if directions are followed or administered by a doctor. Intravenous fluids, oxygen, and other treatments may also be needed. It is very important to call for medical assistance immediately, even if a person says, "I am okay" after administering epinephrine.

To remove the stinger, scrap with a credit card or other object. DO NOT pinch and pull out the stinger, this will inject more venom. If breathing difficulties develop, DIAL the emergency telephone, for example, 999 or 110, or 911 for prompt medical care. Wash the stung area with soap and water. If stung on a finger or hand, remove jewelry in case swelling may occur. Apply a cold compress.

Snakes, scorpions, disease-carrying mosquitoes, desert flies, and ticks are also prevalent during the summer months.

Ticks can carry a wide variety of diseases since they contract the diseases from the host they attach to. Other than medical help, there are over 150 natural repellents to protect from ticks. The most common ones are: Citronella, eucalyptus, lemon leaves, peppermint, lavender, cedar oil, canola, rosemary, pennyroyal, and cajuput, etc. Generally, these are considered safe to use in low dosages, but their effectiveness is limited to 30 minutes.

How can we have fun in the summer? Like anything else, moderation is best. Avoid those beehives and hornet nests. Keep waste, beverages, and food in enclosed containers. Wear protective clothing from ticks and mosquitoes. Wear proper sunscreen. Wear sunglasses to protect your eyes from UV light. If you are sensitive to sunburn, avoid being in the sun when the sun is at its peak. Consume lots of water to stay hydrated. Cool down in air-cooled rooms or near fans. Wear light-colored, natural fiber clothing to help your body repel heat absorption and cool easier. Avoid strenuous activities.

Control the heat at its source using insulating and reflective barriers on walls and windows of your home and keep blinds or curtains drawn. Keep doors and windows closed. Switch off lights behind you when done; also, switch off your car engines radiating heat. Lower the shower temperatures. Reduce physical demands of work using mechanical assistance instead of lifting manually, use a wheeled trolley. Increase the frequency and length of rest breaks if you are doing hard work. Schedule jobs to cooler times either early mornings or late evenings. Drink one cup of water every 20 minutes or so. Salt your food well, particularly while acclimatizing to a hot job. Low salt diet, people having blood pressure problems should consult with their doctor. Properly acclimatized to heat. Recognize symptoms of heat stress utilizing a "buddy" system

1.3.2.11.5 Loss Prevention during Construction (By Edward Taylor)

There are various controls utilized to prevent losses during construction activity. The standard hierarchy of controls is seen in Figure 1.97.

Eliminate the hazard when possible. This can be extremely simple. For example, using modular components assembled at ground level can eliminate exposure to falls. Other hazards associated with placing conventional reinforcing steel and cast-in-place concrete can be avoided with the use of precast components manufactured off-site in a controlled environment. No other means of control will be as effective as elimination.

However, elimination is not always feasible. The next best options are substitution and implementation of engineering controls. For example, a contractor might substitute scaffolding for ladders to reduce the danger of falls. After elimination and substitution, seek engineering controls to control the hazard at its source. Isolation and guarding, such as limiting access to hazardous areas and removing defective equipment from service, are examples.

Next in the hierarchy, administrative controls such as a written safety and health plan do not eliminate hazards but build the ability to recognize and avoid them. Though less effective than the previous mitigation tools, this aspect of loss prevention should not be neglected. To complement the written plan, employees should receive initial and refresher training in fall protection, electrical safety, lockout/tagout procedures, proper use of PPE, etc. Small firms often utilize a professional safety consultant to develop and implement training. Larger firms might invest in a full-time safety officer for training and troubleshooting. General knowledge training is vital for administrative controls to be effective.

In addition to general knowledge training, employees should receive site-specific training since each site has its own peculiarities and special concerns. Also, site conditions are constantly changing. These changing conditions and other areas of special emphasis should be addressed in weekly jobsite safety meetings, sometimes referred to as toolbox talks.

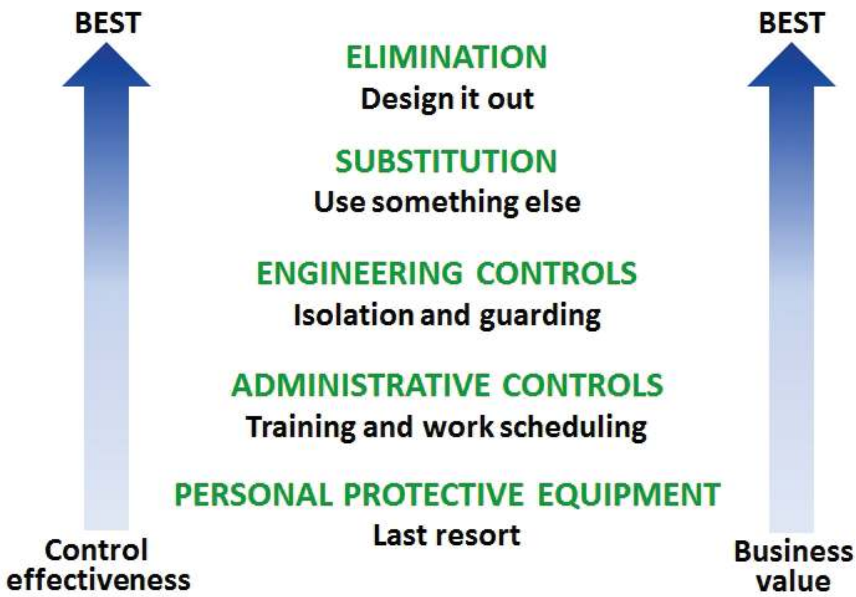


FIGURE 1.97 Hierarchy of controls.

When other more effective controls are infeasible, the last line of defense is personal protective equipment. Types of PPE include hard hats, safety glasses, gloves, hearing protection, respirators, etc. These items should be furnished by the employer with strict attention to compliant utilization by all. PPE will go far in eliminating many common injuries.

1.3.2.11.6 OSHA (By Edward Taylor)

The Occupational Safety and Health Administration (OSHA), a division of the US Department of Labor, was formed in 1970 to assure healthful and safe working conditions. It has been greatly successful in reducing workplace accidents. However, construction remains among the most dangerous industries with disproportionate injury rates. In 2022, construction occupations incurred about 15% of all workplace fatalities with only about 5% of the total workforce.

OSHA's construction industry regulations are found in document 29 CFR Part 1926. Not surprisingly, there are major sections for fall protection (Subpart M) and electrical (Subpart K) since falls and electrocutions annually rank in the top three causes of construction fatalities. Because of their less specific nature, the other Fatal Four areas (caught in\between and struck by) are addressed within multiple provisions in the OSHA 1926 standard.

To enforce its regulations, OSHA conducts job site investigations using Compliance Safety and Health Officer (CSHO) staff members. These investigations may be random, complaint-driven, or targeted to a special initiative such as fall protection. Like most enforcement agencies, OSHA's resources limit its ability to enforce. Only a very small percentage of active projects undergo an investigation. Given its scarce resources, OSHA continually faces the question of how to optimize its efforts for maximum worker safety.

Knowing that prevention trumps enforcement and punishment, OSHA actively promotes and certifies construction training for supervisors and workers. Though prevention is preferred and the most effective use of effort, the issuance of citations and levying punishment are frequently necessary. At this writing, in 2023, OSHA has the power to issue citations with penalties of more than $15,625 for serious violations discovered during investigations or after accidents (with fatalities or serious injuries) and an additional $15,625 per day beyond a deadline to abate the hazard. These penalty amounts are adjusted annually for inflation.

1.3.2.11.7 Conclusion (By Edward Taylor)

Safety is always the best option. Each construction fatality is someone's child. Though economic loss can be compensated, a human being can never be replaced. Construction firms have a paramount obligation to return each worker to their family safely every day. Increasingly owners are becoming more involved in promoting a safe working environment. It is now common for owners to require that contractors meet safety benchmarks for bidding prequalification thus eliminating unsafe contractors from the bidding process.

Safety breaches occur for a variety of reasons. For example, safety can be compromised by too much emphasis on the speed of construction when sound safety procedures are neglected in favor of riskier shortcuts. This short-sighted approach neglects losses in productivity from the disruptive effects of accidents on completion schedules. Construction's macho culture, another compromising factor, creates problems by undervaluing safe work practices. It's disheartening to know that fall fatalities occur when fall protection is available but unused.

To achieve safety improvements, the industry must assume its moral obligation to workers, put aside its macho attitudes, and embrace the cultural change that can produce safety. Workers often understand how to work safely but fail to be compliant. Changing culture is a process and requires commitment from management, strong supervisory leadership, and positive role models. Change is incremental and hard-fought when habits are deeply embedded. Safety is no accident. PLAN. PROVIDE. TRAIN.

The application of loss prevention measures discussed can produce favorable results in the field of accident prevention in construction and process industries. The trend of this decade is toward improved safety awareness and performance in all categories of functions. Healthy action plans have proved successful in meeting the aforementioned challenges and the results are encouraging.

1.3.2.12 Project Financial Management

Construction projects are mainly capital investment projects that have the involvement of three main parties.

1. Owner
2. Designer (Consultant)
3. Contractor

The owner is responsible for financing the project to procure the services of the designer (A/E), contractor, and other parties and has to compensate for their services for which the owner has contracted with these parties to construct the facility/project. Other parties may include the project manager, construction manager, specialists, material/equipment suppliers, and many other players, as per the procurement strategy adopted by the owner. The relationship between the owner and these parties is a buyer-seller relationship and is bound by the contract signed between the owner and these parties. The capital funding required for a construction project mainly includes:

1. Land acquisition cost.
   There is not much to manage the finances for land acquisition costs which are normally known as per market conditions.
2. Cost related to license fees, permits, regulatory taxes, insurance, and project-related owner's overhead cost.
   The cost for each of these items is fixed and known and does not have major effects or variations to be managed and controlled.
3. Construction project cost.
   The overall cost expended during the life cycle of the construction project consists of:
   Designer (A/E) fee.
   Construction supervisor (consultant, project manager, construction manager).
   Construction costs normally include supply, installation/execution, testing and commissioning, and maintenance for a period of one or two years (depending on the contract).

The construction cost is generally 80–85 % of the construction project cost (construction phase). Balance is the fee for the designer and supervision.

Construction projects cannot proceed unless adequate funds are arranged by the owner. These funds are arranged by either public financing or private financing.

Finance management is a process bringing together project planning, scheduling, budgeting, procurement, accounting, disbursement, control, auditing, reporting, and physical performance (progress) of the project with the aim of managing project resources and achieving the owner's objectives. Finance management is an important aspect of project/construction management functions. Finance management has a great impact on both the owner as well as the contractor. Timely and relevant financial information provides a basis for better decisions, thus speeding the progress of the project.

1.3.2.12.1 Develop Financial Management Plan

A financial plan is:

- Estimating the total funds required to complete the project.
- Identifying the source of funds (financial means to cover the project requirement).
- Preparing project cash flow (usage of funds).
- Making sure that the needed finance is available at the right time.

- Identifying the alternate process of securing the funds to mitigate risk or contingencies.

Most construction projects begin with the recognition of a new facility or refurbishment/repair of the existing facility. In either case, the owner has to arrange the funds to develop/refurbish the facility. Once the need is identified, and a feasibility study is conducted, the project cost is estimated based on rough order of magnitude. This estimate helps the owner for initial commitment, in principle, for project funding, and manages the financial resources to build the facility. As the project phase advances to the next stage, the level of accuracy is refined. Depending on the type of project delivery system and contract methods, a more accurate and definitive estimate is evolved. At every stage, the funding requirements for construction are reviewed with the earlier stage and adjusted, if needed. The contracted amount is considered as project cost baseline for both the owner and contractor. However, both owner and contractor have to consider reserves while estimating the financial resources. These reserves, contingencies, and management are included in a cost estimate to mitigate cost risk by allowing for future situations that are difficult to predict.

Figure 1.98 illustrates the process to develop a financial management plan and Table 1.52 lists the contents of the owner's financial plan.

1.3.2.12.2 Control Finance

In construction projects, fund requirements for the project and the availability of funds are reviewed, compared, managed, and controlled at each stage of the project life cycle. Generally, the initial cost estimates are based on analogous (rough order of magnitude). These estimates are further refined as project development stages progress and a greater understanding of the project scope, schedule, quality, and resources are evolved. The contract price agreed between the owner and contractor is the cost the owner has to pay to the contractor for the services rendered to construct/build the project/facility as specified in the contract and to complete as per agreed-upon schedule and quality.

The bid price (or negotiated price) is the contracted amount that is paid by the owner to the contractor as per the terms of the contract. The contractor based its expenses and cash flow on this figure. The bidding price includes:

- Direct Cost
- Material
- Labor
- Equipment
- Indirect Cost
- Overhead Cost
- Risks and Profit

The contractor has to plan, manage, and control all the construction activities within the contracted amount.

The owner, however, adds contingency and management reserve to the base cost estimate to mitigate the risks. The major components of a project budget for the owner are:

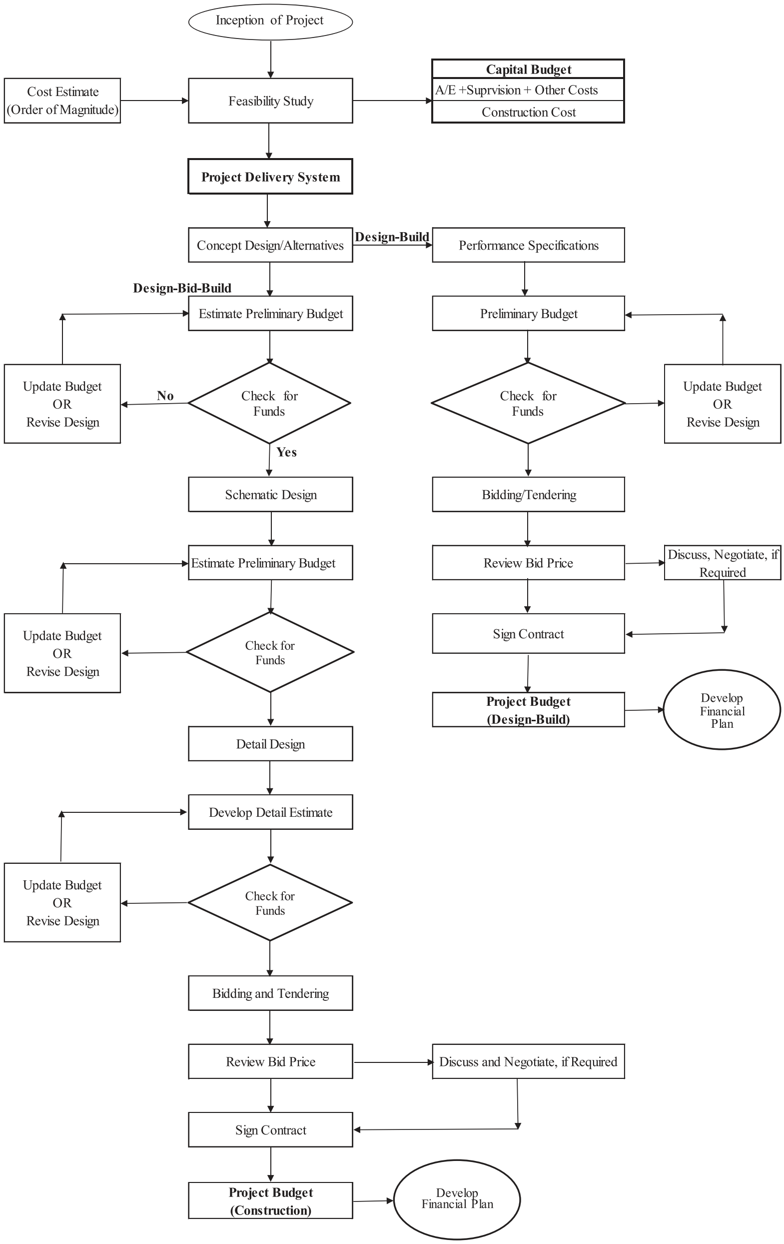


FIGURE 1.98 Process for developing a financial plan.

- Base cost estimate (definitive cost at the end of detailed design or bid amount).
- Contingency: It is the amount set aside to allow for responding to identified risks. Sometimes it is known as a known unknown.

TABLE 1.52
Contents of Contractor's Financial Plan

Section	Topic
1	Description of Project
2	Finance Management Organization
3	Estimated Cost of Project
4	Project Schedule
5	Type of Contracting Method
6	Source of Funds
7	Payment (Receivable) Schedule Breakdown
	7.1 Advance Payment
	7.2 Monthly Progress Payment
8	Accounts Payable Schedule Breakdown
	8.1 Insurance, Bonds
	8.2 Staff Salaries
	8.3 Labor Payment
	8.4 Material Purchases
	8.5 Equipment Purchases
	8.6 Equipment Rent
	8.7 Subcontractor Payment
	8.8 Consumables
	8.9 Taxes
9	Retention
10	Cash Flow
11	Project Risk and Response Strategy
12	Contingency Plan to Secure Funds from Alternate Source
13	Internal Control
	13.1 Accounting System
	13.2 Accounts Auditing
	13.3 Track Changes in Budget
14	Records Management
	14.1 Project Expenses
	14.2 Finance Closure Report

- Management Reserve: It is the amount set aside to allow for future situations that are unpredictable or could not have been foreseen. This includes changes to the scope of work or unidentified risks.

Monitoring and control of project costs is essential for both parties. Normally, an S-Curve is used as a reference to track the progress of the project over time. It also helps monitor cash flow and determine the slippage in the project schedule and cost baseline. The contractor uses a cost-loaded schedule for determining the contract payments during the project against the approved progress of work. The contractor can plan the project expenses against the expected payments and has to control the finances toward:

- Labor salaries.
- Staff salaries.
- Material purchases.
- Equipment purchases.
- Taxes and other regulatory expenses.
- Retention.

The owner has to arrange funds to make progress payments on a regular basis. Funds required to pay the changes to the scope of work or approved claims can be managed from the reserves. The contractor's monthly expenses are different from the actual progress payment expected from the owner. During the initial stage of project execution, the contractor's expenses are much higher than the progress payment. To meet these expenses the contractor has to arrange funding from other sources. In certain projects, the contractor receives advance payment from the owner. However, it is necessary that the contractor plan and control the finances for smooth and uninterrupted execution of the project. Figure 1.99 is an example of an expense (accumulated cost) and payment (accumulated net sale) schedule for a project. Plotting of cost versus sale helps the contractor to control the project finances.

The schedule is updated regularly to reflect ongoing changes in the progress of work and forecasted payments. Normally, it takes considerable time between the expenditure on resources and payment to be received from the owner for the work the contractor has done and approved for payment by the owner. The contractor has to secure funds to cover the cash flow difference.

During the execution of the construction project, the owner has to consider payments toward unexpected changes such as:

- More work done (progress of work) than planned.
- Claims.
- Failure to adjust extra payments.
- Default from funding agency.

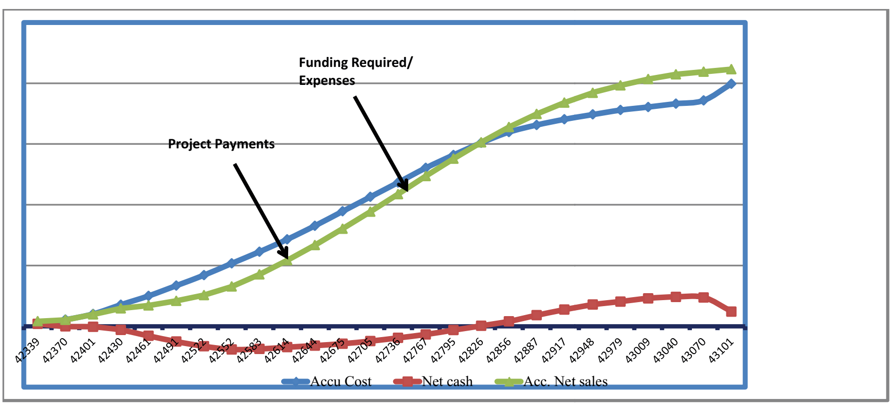


FIGURE 1.99 Expenses and payment schedule.

Similarly, the contractor has to consider following:

- Slow progress of work resulting less payments than expected/planned.
- Productivity is less than estimated.
- Early delivery of material.
- Delay in payment by the owner.
- Resources to do extra (additional) work required by the owner.

1.3.2.12.3 Administer and Record Finance

Project accounting system is required to manage the project needs and expenses and provide the financial information to all the interested stakeholders. Table 1.53 lists different logs maintained by the finance department.

1.3.2.13 Project Claim Management

Claim management is the process to mitigate the effects of the claims that occur during the construction process and resolve them quickly and effectively. If the claims are not managed effectively, it can lead to disputes ending in litigation. Even under most ideal circumstances, contract documents cannot provide full information; therefore, claims do occur in construction projects. In construction projects, a claim is defined as seeking adjustment or consideration by one party against another party with respect to:

TABLE 1.53
Logs Maintained by Finance Department

Section	Log
1	Incoming and Outgoing Correspondence
2	Progress (Interim) Payment
3	Subcontractor Payment
4	Material Purchase
5	Equipment Purchase
6	Procurement (General)
7	Procurement (Consumables)
8	Letter of Credit
9	Freight/Transportation Charges
10	Custom Clearance
11	Equipment Rental
12	Vehicle Rental
13	Insurance, Bonds, Guarantees
14	Regulatory, License Fees
15	Staff Salaries
16	Labor Salaries
17	Office Rent
18	Camp Rent
19	Cash in Hand

- Extension of Time
- Scope
- Method
- Payment

There are mainly three types of claims. These are:

1. Contractual Claims: Claims that fall within the specific clause of the contract.
2. Extra-Contractual Claims: Claims that result from the breach of contract.
3. Ex-Gratia Claims: Claims that the contractor believes the rights on moral grounds.

Table 1.54 lists major causes of claims in construction projects.

The claims in construction projects can be attributed to:

1. Owner
2. Contractor

Figure 1.100 illustrates the claim management process.

1.3.2.13.1 Identify Claims

Claims are a common part of almost every construction project. With utmost care taken to coordinate all the activities and related contract documents, claims in construction projects may arise under any form of construction contracts. Table 1.55 illustrates effects of claim on construction project.

Most construction contracts impose time deadlines for submitting claims. Normally the claims to be made within 30 days after the claim arose and also to be recorded in the monthly progress report that the contractor submits to the owner. Claim identification involves proper interpretation of contract requirements and gathering complete information to substantiate the claim. The identified claim needs to be submitted with all the supporting documents for justification.

1.3.2.13.2 Prevent Claims

Table 1.56 illustrates preventive actions to mitigate effects of claims on construction projects.

1.3.2.13.3 Resolve Claims

All the claims are to be resolved and the contract is to be closed. The method of resolution depends on the type of claim, size of the claim, severity of the claim, effects, and consequences of the claim on the project. The submitted claims are to be resolved in a justifiable manner. The following are the methods used to resolve the claim:

- Negotiation
- Mediation
- Arbitration
- Litigation

In all these cases a comprehensive analysis is necessary to come to an amicable solution. Table 1.57 lists documents required for analysis of construction claims.

TABLE 1.54
Major Causes of Construction Claims

Serial Number	Causes
I	**Owner Responsible**
	I.1 Delay in issuance of notice to proceed.
	I.2 Delay in making the site available on time.
	I.3 Different site conditions.
	I.4 Project objectives are not well-defined.
	I.5 Inadequate specifications: a. Design Errors b. Omissions
	I.6 Scope of work not well-defined.
	I.7 Conflict between contract documents.
	I.8 Change/modification of design.
	I.9 Change in schedule.
	I.10 Addition of work.
	I.11 Omission of work.
	I.12 Delay in approval of subcontractor.
	I.13 Delay in approval of materials.
	I.14 Delay in approval of shop drawings.
	I.15 Delay in response to contractor's queries.
	I.16 Delay in payment to contractor.
	I.17 Lack of coordination among different contractors directly under the control of owner.
	I.18 Interference and change by the owner.
	I.19 Delay in owner supplied material.
	I.20 Acceleration.
II	**Contractor Responsible**
	II.1 Delay to meet milestone dates.
	II.2 Non-compliance with specifications.
	II.3 Changes in specified process/methodology.
	II.4 Substitution of material.
	II.5 Non-compliance to regulatory requirements.
	II.6 Charges payable to outside party due to cancelation of certain items/products.
	II.7 Material not meeting the specifications.
	II.8 Workmanship not to the mark.
	II.9 Suspension of work.
	II.10 Termination of work.
III	**Miscellaneous**
	III.1 New regulations.
	III.2 Weather conditions.
	III.3 Unforeseen circumstances.

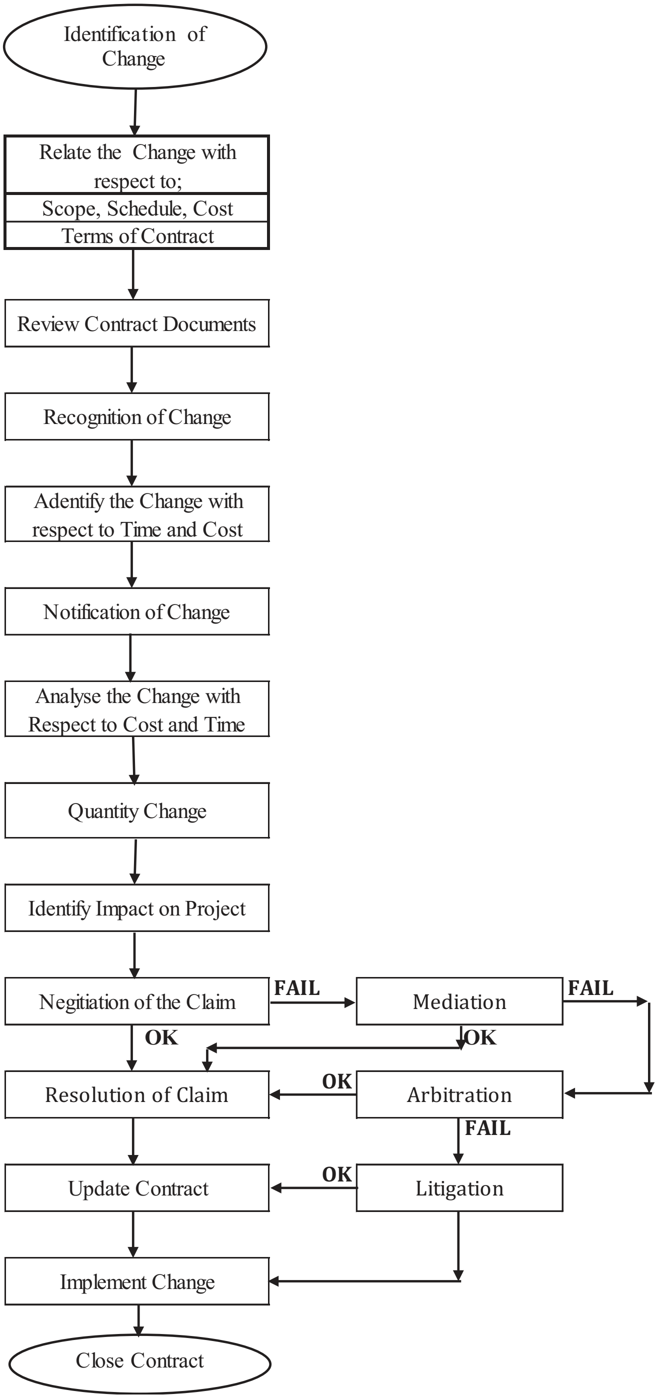


FIGURE 1.100 Claim management process.

TABLE 1.55
Effects of Claim on Construction Projects

Serial Number		Causes	Effects on Project
I	**Owner Responsible**		
	I.1	Delay in issuance of notice to proceed.	• Delay in completion of project.
	I.2	Delay in making the site available on time.	• Delay in completion of project.
	I.3	Different site conditions.	• Delay in completion of project. • Change in project cost.
	I.4	Project objectives are not well-defined.	• Delay in completion of project. • Change in project cost.
	I.5	Inadequate specifications: a. Design Errors b. Omissions	• Delay in completion of project. • Change in project cost.
	I.6	Scope of work not well-defined.	• Delay in completion of project. • Changes in project cost.
	I.7	Conflict between contract documents.	• Changes in schedule.
	I.8	Change/modification of design.	• Change in project cost.
	I.9	Change in schedule.	• Change in project cost.
	I.10	Addition of work.	• Change in project cost. • Change in completion of project.
	1.11	Omission of work.	• Change in project cost.
	1.12	Delay in approval of subcontractor.	• Delay in completion of project.
	I.13	Delay in approval of materials.	• Delay in completion of project.
	I.14	Delay in approval of shop drawings.	• Delay in completion of project.
	I.15	Delay in response to contractor's queries.	• Delay in completion of project.
	I.16	Delay in payment to contractor.	• Delay in completion of project.
	I.17	Lack of coordination among different contractor directly under the control of owner.	• Changes in schedule.
	I.18	Interference and change by the owner.	• Delay in completion of project. • Change in project cost.
	I.19	Delay in owner supplied material.	• Delay in completion of project.
	I.20	Acceleration.	• Change in project cost.
II	**Contractor Responsible**		
	II.1	Delay to meet milestone dates	• Delay in completion of project.
	II.2	Non-Compliance with specifications.	• Changes in project cost.
	II.3	Changes in specified process/ methodology.	• Changes in project cost. • Changes in project schedule.
	II.4	Substitution of material.	• Changes in project cost.
	II.5	Non-Compliance to regulatory requirements.	• Changes in project cost.
	II.6	Charges payable to outside party due to cancelation of certain items/products.	• Changes in project cost.
	II.7	Material not meeting the specifications.	• Changes in project cost.

(*Continued*)

TABLE 1.55 Continued
Effects of Claim on Construction Projects

Serial Number		Causes	Effects on Project
	II.8	Workmanship not to the mark.	• Changes in project cost.
	II.9	Suspension of work.	• Changes in project cost.
	II.10	Termination of work.	• Changes in project cost.
III	**Miscellaneous**		
	III.1	New regulations.	• Delay in project completion. • Possible changes in cost.
	III.2	Weather conditions.	• Delay in project completion.
	III.3	Unforeseen circumstances.	• Delay in project completion.

TABLE 1.56
Preventive Actions to Mitigate Effects of Claims on Construction Projects

Serial Number		Causes	Preventive Actions
I	**Owner Responsible**		
	I.1	Delay in issuance of notice to proceed.	• Complete all the required documentation, permits before signing of contract.
	I.2	Delay in making the site available on time.	• Obtain legal documents and title deeds in time.
	I.3	Different site conditions.	• Conduct predesign study/survey through specialist consultant/contractor. • Collect historical data prior to start of design. • Proper site investigations and if any existing utility services under the site. • Ensure that the contractor is aware of geographic/geological conditions of the area.
	I.4	Project objectives are not well-defined.	• Business case to be properly defined. • Designer to collect all required data and clarification from the owner.
	I.5	Inadequate specifications: a. Design Errors b. Omissions	• Review of design drawings by the designer. • Review of specifications by the designer. • Designer to ensure design drawings are reviewed and coordinated. • Designer to ensure clear and complete bill of quantities. • Specifications and documents are properly prepared as per standard format. • Quality management system during design phase. • Allow reasonable time to designer to prepare complete and clear drawings and specifications.

(*Continued*)

TABLE 1.56 Continued
Preventive Actions to Mitigate Effects of Claims on Construction Projects

Serial Number	Causes	Preventive Actions
I.6	Scope of work not well-defined.	• Construction documents are accurate and all the items/activities are properly defined. • Review all the documents. • Prepare clear and unambiguous documents.
I.7	Conflict between contract documents.	• Review documents and design drawing and coordinate with all the trades.
I.8	Change/modification of design.	• Resolve issue without major effects on schedule.
I.9	Improper schedule.	• Designer to check schedule for all activities and precedence. • Check for constraints and consistency.
I.10	Change in schedule.	• Keep to contracted schedule for completion of project.
I.11	Addition of work.	• Review scope of work to ensure all the requirements are included. • Establish proper mechanism to process changes.
I.12	Omission of work.	• Negotiate and resolve without any impact on the project.
I.13	Delay in approval of subcontractor.	• Take action within specified time to response the transmittals. • Ensure that review period for transmittals is appropriate.
I.14	Delay in approval of materials.	• Take action within specified time to response the transmittals. • Ensure that review period for transmittals is appropriate.
I.15	Delay in approval of shop drawings.	• Take action within specified time to response the transmittals. • Ensure that review period for transmittals is appropriate.
I.16	Delay in response to contractor's queries.	• Take action within specified time to response the transmittals. • Ensure that review period for transmittals is appropriate.
I.17	Delay in payment to contractor.	• Arrange funds to pay the progress payments as per specified time in the contract documents.
I.18	Lack of coordination among different contractor directly under the control of owner.	• Division of work and packages are properly coordinated and clearly identified for each contractor. • Develop cooperative and problem-solving attitudes for successful completion of project.
I.19	Interference and change by the owner.	• Avoid interference and define clearly the roles and responsibilities of each part. • Follow change order procedure specified in the contract documents.
I.20	Delay in owner supplied material.	• Owner to ensure timely delivery of material suitable for installation.
I.21	Acceleration.	• Study contractual consequences before issuance of instruction to accelerate or fast-track the activities.

(*Continued*)

TABLE 1.56 Continued
Preventive Actions to Mitigate Effects of Claims on Construction Projects

Serial Number	Causes		Preventive Actions
II	**Contractor Responsible**		
	II.1	Delay to meet milestone dates.	• Check the milestone activities and perform as included in the schedule. • Identify constraints to complete milestone activities. • Establish strategy to deal with tight schedule.
	II.2	Non-Compliance with specifications.	• Ensure compliance to the specifications. • Establish proper quality management system.
	II.3	Bill of quantities not matching with design drawings.	• Contractor to check quantities while bidding.
	II.4	Changes in specified process/methodology.	• Follow specified method. • Request for change if recommended by the manufacturer. • Submit and get approval on method of statement for installation of work.
	II.5	Substitution of material.	• Follow relevant sections of contract specifications.
	II.6	Non-Compliance to regulatory requirements.	• Study and keep track of regulatory requirement for execution of work.
	II.7	Charges payable to outside party due to cancelation of certain items/products.	• Settle the matter amicably.
	II.8	Material not meeting the specifications.	• Submit request for substitution and follow the contract requirements for substitution.
	II.9	Workmanship not to the mark.	• Use skilled manpower.
	II.10	Suspension of work.	• Follow contract conditions.
	II.11	Termination of work.	• Follow contract conditions.
III	**Miscellaneous**		•
	III.1	New regulations.	• Follow change order procedures for such conditions.
	III.2	Weather conditions.	• Follow change order procedures for such conditions.
	III.3	Unforeseen circumstances.	• Follow change order procedures for such conditions.

TABLE 1.57
Documents Required for Analysis of Construction Claims

Serial Number	Name of Document
1	Contract Documents
	1.1 Tender Documents (related to claim, if required)
	1.2 Conditions of Contract (general conditions, specific conditions)
	1.3 Particular Specifications
2	Drawings
	1.1 Contract Drawings
	1.2 Approved Shop Drawings
3	Construction Schedule
	1.1 Contract Schedule
	1.2 Approved Construction Schedule
4	Reports
	4.1 Daily Report
	4.2 Monthly Report
	4.3 Test Reports
	4.4 Non-Compliance Report
	4.5 Material Delivered at Site
5	Minutes of Meetings
	5.1 Progress Meetings
	5.2 Coordination Meetings
	5.3 Safety Meetings
	5.4 Quality Meetings
6	Submittal Logs
	6.1 Material, Sample
	6.2 Shop Drawings
	6.3 Request for Information
	6.4 Request for Substitution (Alternative)
7	Job Site Instruction
8	Variation Order
9	Site Progress Records
	9.1 Photographs
	9.2 Videos
10	Payment Request
11	Check Lists
12	Correspondence with Regulatory Authorities

2 Construction Management Principles for Construction Management Phases

Abdul Razzak Rumane

2.1 CONSTRUCTION PROJECT PHASES

Most construction projects are custom-oriented, having specific needs and customized designs. Construction projects are constantly increasing in technological complexity. The relationship and the contractual grouping of those who are involved are also complex and contractually varied. There are innumerable processes that make up the construction project. It is always the owner's desire that his/her project should be unique. Further, it is the owner's goal and objective that the facility is completed on time and within agreed-upon budget. Systems engineering approach to construction projects helps understand the entire process of project management and to manage and control its activities at different levels of various phases to ensure timely completion of the project with economical use of resources to make the construction project most qualitative, competitive, and economical.

Though it is difficult to generalize the number of phases of the project life cycle, the number of phases depends on considering the innumerable processes that make up the construction process, the technologies, processes, and complexity of construction projects. Duration of each phase may vary from project to project.

Generally, construction projects have five common phases. These are:

1. Conceptual Design
2. Schematic Design
3. Detailed Design
4. Construction
5. Testing, Commissioning, and Handover

As per *Construction Extension to the PMBOK® Guide*, third edition,

> Most Construction projects can be viewed in Five Phases, although they are sometimes shortened to four, each one of these phases can be treated like a project itself, with all of the process groups operating as they do for the overall

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project. These phases are concept, planning (and development), detail design, construction, and start-up and turnover.

However, in major projects, preparation of the construction (contract) documents, their review and approval, and the process of bidding and tendering take considerable time. Thus, for a major construction project, it is ideal to divide the construction project life cycle into seven phases. These are:

1. Conceptual Design
2. Schematic Design
3. Detailed Design
4. Construction (Contract) Documents
5. Bidding and Tendering
6. Construction
7. Testing, Commissioning, and Handover

The methodology applied in this book is based on seven phases of construction projects. These phases are listed in Table 2.1.

Table 1.2 discussed under Section 1.2 of Chapter 1 (Volume 1) illustrates subdivided activities, components of construction project life cycle phases.

Each of these phases is treated as a project itself with all five process groups operating as they do for the overall project and each phase is composed of activities, elements having functional relationships to achieve a common objective for a useful purpose.

Figure 2.1 illustrates the construction project life cycle for the design-bid-build type of project delivery system, whereas Figure 2.2 illustrates the construction project life cycle for the design-build type of project delivery system.

Design-Bid-Build type of project delivery system has a sequential relationship whereas in the case of the design-build, the construction phases commence while the design development process is still in progress. The construction phase overlaps the design phases.

TABLE 2.1
Phases of Construction Projects

Phase	Construction Extension PMBOK® Guide, Third Edition Methodology	Phase	Most Common Phases for Major Projects (Methodology in This Book)
1	Concept	1	Concept Design
2	Planning (and Development)	2	Schematic Design
3	Detailed Design	3	Design Development
		4	Construction Documents
		5	Bidding and Tendering
4	Construction	6	Construction
5	Start-Up and Turnover	7	Testing, Commissioning, and Handover

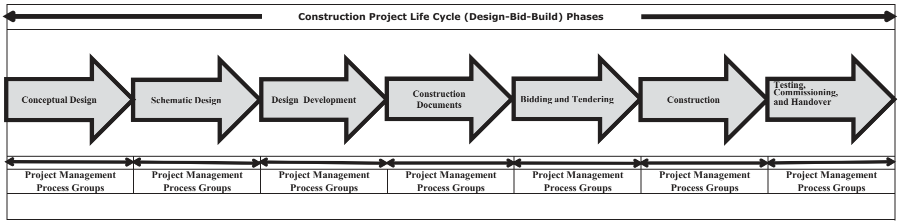


FIGURE 2.1 Construction project life cycle for design-bid-build type of PDS.

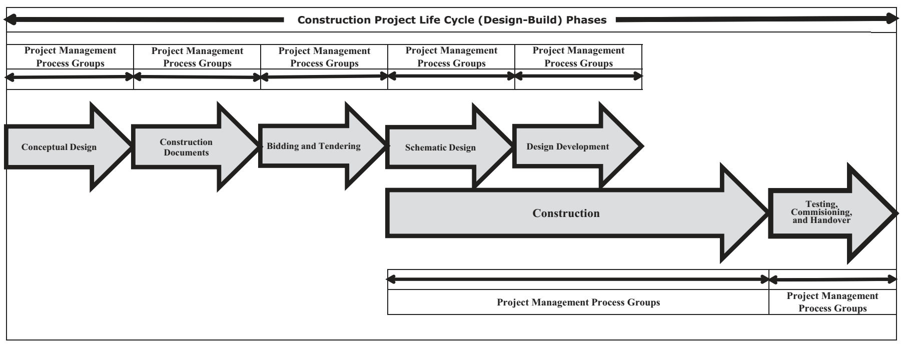


FIGURE 2.2 Construction project life cycle for design-build type of PDS.

In the agency construction management type of management system, the construction manager is normally commissioned by the project owner once project objectives and goals are established by the owner/client. The construction manager takes up the responsibility to act as an adviser to the client and manage the project over the entire life cycle of the project or a specific phase/stage of the project.

2.2 CONCEPTUAL DESIGN PHASE

Conceptual design is the first phase of the construction project life cycle. This phase/stage is concerned with the preparation of concept design. Conceptual design is often viewed as most critical to achieving outstanding project performance. Most important decisions about planning, organization, and type of contract take place during this phase. This phase is also called/known as:

- Programming phase.
- Definition phase.
- Predesign phase.

The conceptual design phase commences once the need is recognized. In this phase, the idea is conceived and given an initial assessment. During the conceptual phase, project goals and objectives are established, the preliminary project plan is prepared, alternatives are analyzed and a preferred alternative is selected, the environment is examined, forecasts are prepared, objectives cost, and time objectives of the project are performed. Conceptual phase includes:

- Identification of need by the owner, and establishment of main goals.
- Feasibility study that is based on owner's objectives.
- Identification of project delivery system.
- Identification of project team by selecting other members and allocation of responsibilities.
- Identification of alternatives.
- Selection of preferred alternative.
- Financial implications and resources, based on estimation of life cycle cost of the favorable alternative.
- Time schedule.
- Development of concept design.

Table 2.2 illustrates the major activities relating to the concept design phase processes developed based on the project management process group's methodology.

The most significant impacts on the quality of the project begin during the conceptual phase. This is the time when specifications, statement of work, contractual agreements, and initial design are developed. Initial planning has the greatest impact on a project because it requires the commitment of processes, resource schedules, and budgets. A small error that is allowed to stay in the plan is magnified several times through subsequent documents that are second or third in the hierarchy. Figure 2.3 illustrates a logic flow diagram for the conceptual design phase.

2.2.1 Development of Project Charter

The project charter defines the objectives, scope, deliverables, and overall approach for the new project. In a construction project, the project charter is the document prepared by the owner/client or by the project manager on behalf of the owner, describing the project objectives and requirements to deliver the project. Project charter is also known as:

- Client Brief
- Definitive Project Brief
- Terms of Reference

Terms of reference are developed based on the need statement, which is further analyzed for the feasibility of the project. The outcome of the feasibility report is used to prepare the project brief (project goals and objectives). Alternatives are identified, and the preferred alternative is selected after evaluation/analyzing the alternatives. Thereafter, the project delivery system is selected based on the complexity of the project and the strategy to be followed by the owner. The TOR is developed to proceed with the design and construction of the project.

TABLE 2.2
Major Activities Relating to Conceptual Design Phase Processes

An elongated right arrow with the text "Conceptual Design Phase" written inside it.

Management Processes	Project Management Process Groups				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Integration Management	Problem Statement/ Need Statement	Preliminary Project Management Plan	Development of Alternatives	Monitor Concept Design Progress	Concept Design Deliverables
	Feasibility Study		Development of Concept Design	Manage Owner Need, Changes	
	Project Goals and Objectives		Implement Changes	Review of Concept Design	
	Project Terms of Reference		Concept Drawings, Reports, Models		
Stakeholder Management	Project Delivery System	Responsibility Matrix	Design Performance Report	Design Progress	
	Project Team Members	Establish Stakeholders Requirements		Design Status	
	Regulatory Authorities				
Scope Management		Identification of Alternatives		Evaluation and Approval of Alternative	
		Concept Design Scope		Aesthetics, Constructability	
		Data Collection		Sustainability, Economy, Environmental Compatibility	
		Owner's Requirements		Authorities Approval	
		Design Deliverables		Compliance to Owner's Need	
				Stakeholder's Approval of Concept Design	

(*Continued*)

TABLE 2.2 Continued
Major Activities Relating to Conceptual Design Phase Processes

An elongated right arrow with the text "Conceptual Design Phase" written inside it.

Management Processes	**Project Management Process Groups**				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Schedule Management		Preliminary Schedule		Concept Design Submission Schedule Approval of Project Schedule	
Cost Management		Conceptual Estimate		Control Project Cost	
Quality Management		Quality Codes and Standards, Regulatory Requirements	Design Compliance to Codes, Standards, and Regulatory Requirements	Conformance to Technical and Functional Capability, Energy Efficiency	
Resource Management		Assign Project Design Team Roles and Responsibilities of Team Members	Manage Team Members from Different Disciplines	Performance of Team Members	Assign New Phase/Project
Communication Management		Design Progress Information	Liaison and Coordination with All Parties Coordination Meetings	Design Status Information	
Risk Management		Management of Design Risk		Control Design Risk	
Contract Management		Project Delivery System Contracting System	Design to Comply Contract Type/ Pricing	Administer Project Delivery System Requirements	Demobilize Team Members

(*Continued*)

TABLE 2.2 Continued
Major Activities Relating to Conceptual Design Phase Processes

An elongated right arrow with the text "Conceptual Design Phase" written inside it.

Management Processes	Project Management Process Groups				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
		Selection of Consultant for Feasibility Study			
		Selection of Design Team (Consultant)		Check for Contracting System	
HSE Management		Safety Consideration in Design	HSE Consideration is Design	Check for Regulatory Requirements	
Financial Management		Designer/ Consultant Payment		Cost Effectiveness Over the Project Life Cycle (Economy)	Designer/ Consultant Payment
Claim Management		Management of Owner's Need Changes		Control Changes/ Claims	Settle Claims by Designer

Note: These activities may not be strictly sequential, however, the breakdown allows implementation of project management functions to be more effective and easily manageable at different stages of the project phase.

2.2.1.1 Identification of Need

Most construction projects begin with the recognition of a new facility. The need for the project is created by the owner. The owner of the facility could be an individual, a public/private sector company or a governmental agency. The need should be based on real (perceived) requirements or deficiencies. The owner's needs must be well-defined describing the minimum requirements of quality, performance, project completion date, and approved budget for the project. Table 3.2 and Table 3.3 discussed in Section 3.3.1 of Volume 1 list major points to be considered for need analysis of a construction project and need statement, respectively.

2.2.1.2 Feasibility Study

A feasibility study is defined as an evaluation or analysis of the potential impact of the identified need of the proposed project. A feasibility study takes its starting point from the output of project identification needs. Once the owner's need is identified,

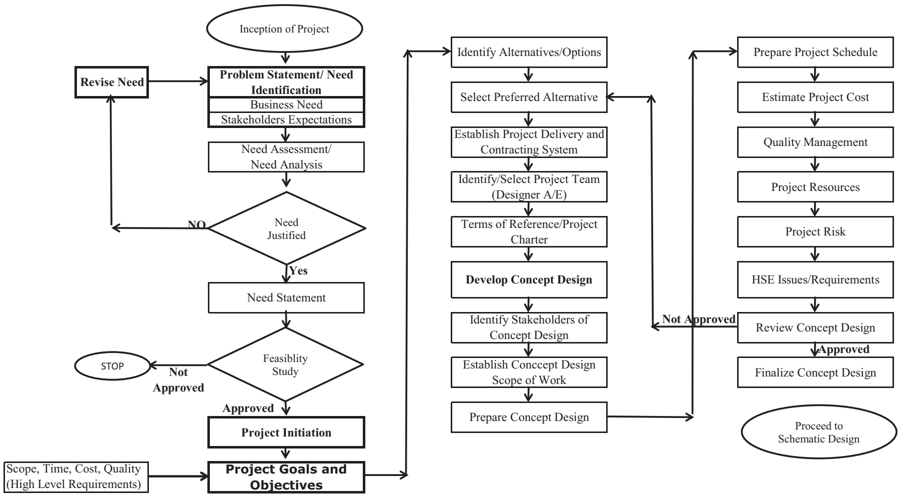


FIGURE 2.3 Logic flow process for concept design phase.

the traditional approach is pursued through a feasibility study or an economic appraisal of the owner's needs for benefits. A feasibility study is performed to more clearly define the viability and form of the project that will produce the best or most profitable results. The feasibility study assists decision makers (investors/owners/clients) in determining whether or not to implement the project. The feasibility study may be conducted in-house if the capability exists. However, the services of a specialist or Architect/Engineer (A/E) are usually commissioned by the owner/client to perform such study. Since the feasibility study stage is a very crucial stage in which all kinds of professionals and specialists are required to bring many kinds of knowledge and experience into the broad-ranging evaluation of feasibility, it is required to engage a firm having expertise in the related fields. The feasibility study establishes the broad objectives for the project and so exerts an influence throughout subsequent stages. The successful completion of the feasibility study marks the first of several transition milestones and is, therefore, most important to determine whether or not to implement a particular project or program. The feasibility study decides the possible design approaches that can be pursued to meet the need.

After completion of the feasibility study, it is possible to define the project objectives. The project objective definition will usually include the following information:

1. Project scope and project deliverables.
2. Preliminary project schedule.
3. Preliminary project budget.
4. Specific quality criteria the deliverables must meet.
5. Type of contract to be employed.
6. Design requirements.
7. Regulatory requirements.
8. Potential project risks.

9. Environmental considerations.
10. Logistic requirements.

Completion of feasibility study is the starting point for the project by the owner/client, if the project/objective is approved. Thus, the project goals and objectives are established.

2.2.1.3 Identification of Alternatives

Once the owner/client defines the project objectives, a project team (in-house or outside agency) is selected to start the development of alternatives. In certain cases, the owner assigns the designer (consultant) to develop conceptual alternatives, evaluation of conceptual alternatives, and selection of preferred alternatives in consultation with the owner and is included in the terms of reference.

The project goals and objectives serve as a guide for the development of alternatives. The team develops several alternative schemes and solutions. Each alternative is based on a predetermined set of performance measures to meet the owner's requirements. In the case of construction projects, it is mainly the extensive review of development options that is discussed between the owner and the team members. The team provides engineering advice to the owner to enable him/her to assess the feasibility and relative merits of various alternative schemes to meet his/her requirements.

2.2.1.4 Analyze Alternatives

Quantitative comparison and evaluation of identified alternatives is carried out by considering the advantages and disadvantages of each item systematically. Social, economic, and environmental impacts, functional capability, safety, and reliability should be considered in the development of alternatives. Each alternative is compared by considering the advantages and disadvantages of each systematically to meet a predetermined set of performance measures and the owner's requirements. The team makes a brief presentation to the owner and the project is selected based on preferred conceptual alternatives.

The following elements are considered to analyze and evaluate each of the identified alternatives:

1. Suitability to the purpose and objectives.
2. Performance parameters.
3. Economy.
4. Cost efficiency.
5. Life cycle costing.
6. Sustainable (environmental, social, economic).
7. Environmental impact.
8. Environment-Preferred material and products.
9. Physical properties, thermal comfort, insulation, fire resistance.
10. Utilization of space.
11. Accessibility.
12. Ventilation.
13. Indoor air quality.

14. Water efficient.
15. Power consumption (energy saving measures—renewable energy and alternative energy).
16. Daylighting.
17. High-Performance lighting.
18. Green building concept.
19. Aesthetic.
20. Safety and security.
21. Statutory/regulatory requirements.
22. Codes and standards.
23. Any other critical issues.

2.2.1.5 Select Preferred Alternative

Based on the analysis of identified alternatives, the preferred alternative that satisfies the project goals and objectives is selected. Figure 2.4 illustrates the evaluation and analysis of alternative methods for the selection of preferred alternatives.

With approval of a preferred alternative by the owner, the project proceeds toward the next stage of the project development process.

2.2.1.6 Develop Terms of Reference

Terms of reference is a written document stating what will be done by the designer (consultant) to develop the project/facility. It is issued to the designer (consultant) by the owner to develop project design and construction documents. The TOR generally requires the designer (consultant) to perform the following:

- Development of Concept Design
- Preparation of Detailed Design and Contract Documents for Tendering Purposes
- Preparation of Preliminary Design, Budget, and Schedule and Obtaining Authorities' Approval

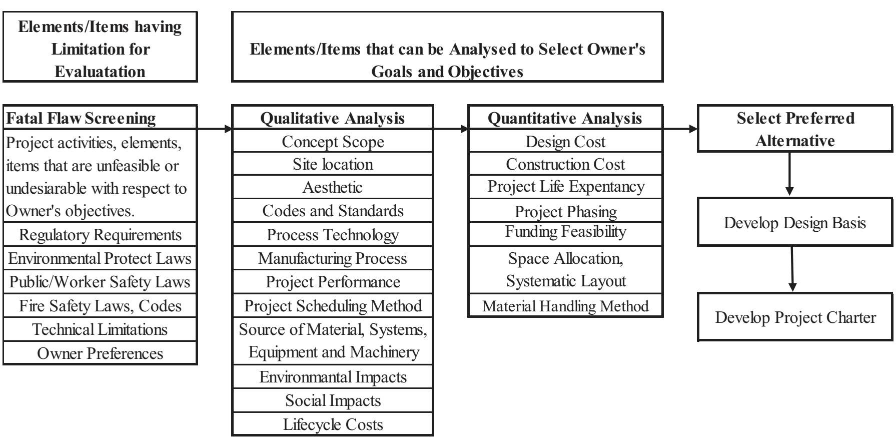


FIGURE 2.4 Evaluation and analysis of alternative methods for selection of preferred alternative.

Table 4.24 discussed earlier in Chapter 4 (Volume I) illustrates an example of the contents of the TOR documents for a building construction project.

2.2.2 Develop Preliminary Project Management Plan

The designer prepares a preliminary project management plan. It should document key management and oversight tasks and will be updated throughout the project. The plan should include a definition of the owner's goals and objectives, technical requirements, schedules, budget, resources, quality plan and standards, risk plan, and financial plan.

2.2.3 Identify Project Stakeholders

The following stakeholders have direct involvement in the project during conceptual design:

- Owner
- Consultant
- Designer
- Regulatory Authorities
- Project/Construction Manager (if the owner decides to engage during this phase)

2.2.3.1 Determine Project Delivery System

During this phase, the owner has to decide the procurement method and contract strategy. The selection of a project delivery system mainly depends on the project size, complexity of the project, innovation, uncertainty, urgency, and the degree of involvement of the owner. (Section 2.4 of Volume 1 details the selection of the project delivery system.)

2.2.3.2 Select Design Team

The owner is the first member of the project team. The relationship and responsibilities with other team members depend on the type of deliverable system the owner would prefer to go with.

For design-bid-build type of contract system, the first thing the owner has to do is to select design professionals/consultants. Generally, the owner selects the designer/consultant on the basis of qualifications (Qualifications Based System (QBS)) and prefers to use the one he/she has used before and with that, he/she has had a satisfactory result. Figure 2.5 illustrates a logic flow diagram for the selection of a designer (A/E).

Upon selection of a designer (A/E), an agreement is made between the owner and designer (A/E). The following are typical contents of the contract between the owner and designer (A/E).

1. Project Definition
2. Project Schedule

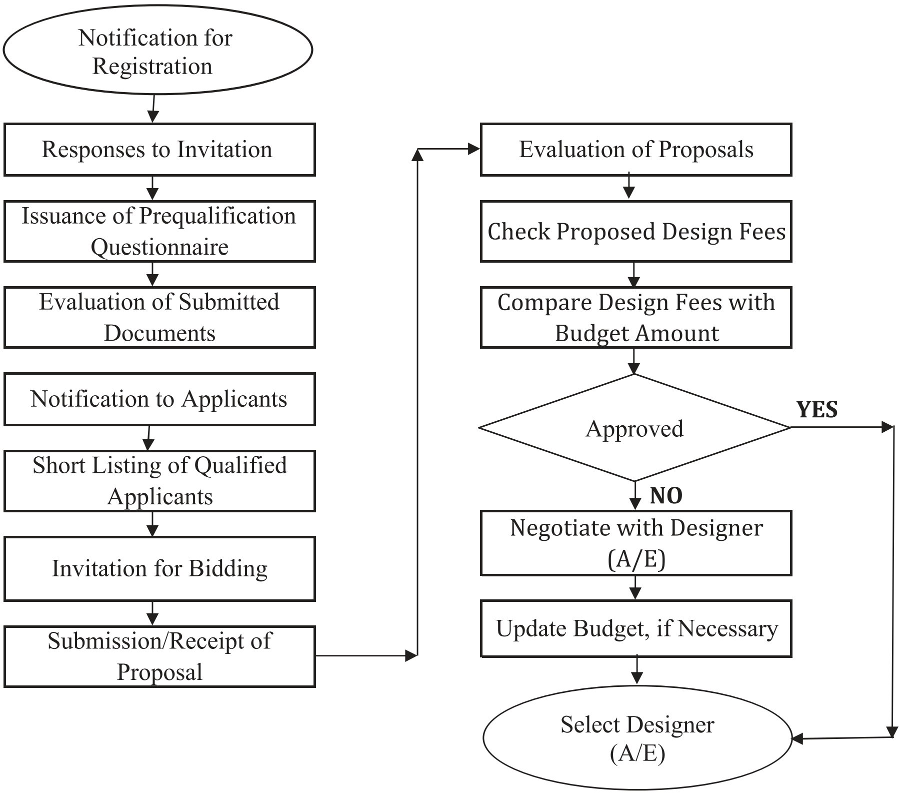


FIGURE 2.5 Logic flow diagram for selection of designer (A/E).

3. Scope of Work
4. Design Deliverables
5. Owner Responsibilities
6. Fees for Services
7. Variation Order
8. Penalty for Delay
9. Liability toward Design Errors
10. Insurance
11. Arbitration/Dispute Resolutions
12. Taxes
13. Appointment of Subconsultant
14. Selection of Team Members
15. Duties (Responsibilities)
16. Compliance with Authorities' Requirements
17. Suspension of Contract
18. Termination
19. Glossary

2.2.3.3 Establish Stakeholders' Requirement

A distribution matrix listing key project activities and stakeholders who are involved in advice, monitoring, reviewing, and/or approving various activities, documents, or deliverables is prepared. All related documents are distributed to these stakeholders for appropriate action.

2.2.3.4 Develop Responsibility Matrix

Upon signing a contract with the client to design the project and offer other services, the designer (consultant) assigns a project manager to execute the contract and is responsible to manage the development of design and contract documents to meet the client's needs and objectives. The project manager coordinates with other departments and acquires design team members to develop the project design. A project team leader, along with respective design engineer(s), quality engineer, and AutoCAD technician from each trade, is assigned to work on the project. The project team is briefed by the project manager about the project objectives and the roles, responsibilities, and authorities of each team member. The quality manager also joins the project team to ensure compliance with the organization's quality management system. Figure 2.6 illustrates the project design organization structure, and Table 2.3 illustrates the responsibilities of various participants during the conceptual phase of the construction project life cycle.

2.2.4 Develop Concept Design Scope

The Terms of Reference is a guideline to prepare concept design deliverables.

2.2.4.1 Identify Concept Design Deliverables

The following are the concept design deliverables:

1. Concept Design Report (Narrative/Descriptive Report)
   a. Space program.
   b. Building exterior.
   c. Building interior.
   d. Structural system.
   e. MEP system.
   f. Fire safety.
   g. Conveyance system.
   h. Information and Communication Technology (ICT).
   i. Landscape.
   j. HSE issues.
   k. Traffic plan (if applicable).
2. Drawings
   a. Overall site plan.
   b. Floor plan.
   c. Elevations.
   d. Sketches.
   e. Sections (indicative to illustrate overall concept).

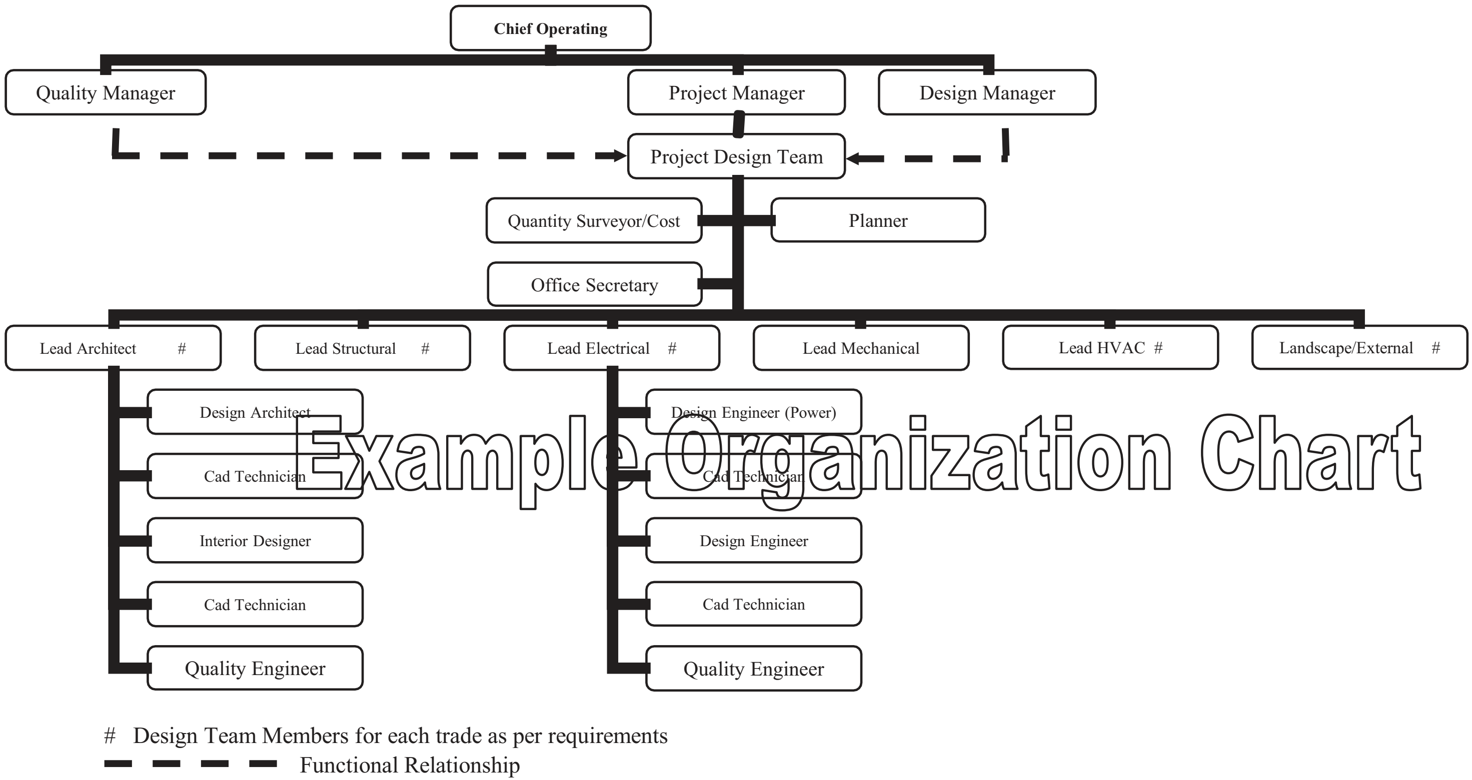


FIGURE 2.6 Project design team organization chart.

TABLE 2.3
Responsibilities of Various Participants (Design-Bid-Build Type of Contracts) during Concept Design Phase

Phase	Responsibilities		
	Owner	Designer	Regulatory
Conceptual Design	• Identification of need. • Selection of alternatives. • Selection of team members. • Approval of time schedule. • Approval of budget. • TOR.	• Feasibility. • Development of alternatives. • Schedule. • Cost estimates. • Development of concept design.	• Approval of project submittals.

3. Data Collection, Studies Reports
4. Existing Site Conditions
5. Concept Schedule of Material and Finishes
6. Sustainability Requirements
7. Lighting/Daylight Studies
8. LEED Requirements
9. Facility Management Requirements
10. Preliminary Project Schedule
11. Preliminary Cost Estimate
12. Regulatory Approvals
13. Models
14. Evaluation Criteria of the Alternatives (if Part of TOR)

2.2.5 Develop Concept Design

Selected preferred alternative is the base for the development of concept design.

While developing the concept design, the designer must consider the following:

1. Project goals.
2. Usage.
3. Technical and functional capability.
4. Latest technology equipment and systems suitable for networking through the Internet of Things (IOT).
5. Aesthetics.
6. Constructability.
7. Sustainability (environmental, social, and economical).
8. Health and safety.
9. Reliability.
10. Environmental compatibility.
11. Fire protection measures.

12. Provision for facility management requirements.
13. Supportability during maintenance/maintainability.
14. Cost-Effective over the entire life cycle (economy).

It is the designer's responsibility to pay greater attention to improving the environment and of achieving sustainable development. Numerous UN meetings, such as:

- The first United Nations Conference on Human Development held in Stockholm in 1972.
- The Brundtland Commission on Environment and Development in 1987 emphasized "sustainability." Whether it be a sustainable environment, sustainable economic development, sustainable agricultural and rural development, and so on.

Sustainable development as defined by the Brundtland Commission is "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

- The 1992 Earth Summit in Rio de Janeiro
- The 2002 Earth Summit in Johannesburg
- The 2005 World Summit
- The UN 2012 Sustainable Development Conference, Rio de Janeiro, Brazil
- The UN 2015 Sustainable Development Summit in New York
- The 2021 COP26 (Conference of Parties) in the UK

Accordingly, the designer has to address environmental and social issues and comply with local environmental protection codes. A number of tools and rating systems have been created by LEED (USA), BREEAM (UK), and HQE (France) in order to assess and compare the environmental performance of buildings. These initiatives have a great impact on how the buildings are designed, constructed, and maintained. Therefore, while developing building projects, the following need to be considered:

1. Accretion with natural environment by using natural resources such as sunlight, solar energy, and ventilation configuration.
2. Energy conservation by energy-efficient measures to diminish energy consumption (energy efficient construction).
3. Environmental protection to reduce environmental impact.
4. Use material having harmony with the environment.
5. Aesthetic harmony between a structure and its surrounding nature and built environment.
6. Good air quality.
7. Comfortable temperature.
8. Comfortable lighting.
9. Comfortable sound.
10. Clean water.
11. Less water consumption.
12. Integration with social and cultural environment.

During the design stage, the designer must work jointly with the owner to develop details on the owner's needs and objectives and give due consideration to each part of the requirements. The owner on his/her part, should ensure that the project objectives are:

1. Specific
2. Measurable
3. Agreed upon by all the Team Members
4. Realistic
5. Possible to Complete with in Definite Time
6. Within Budget

2.2.5.1 Collect Data/Information

The purpose of data collection is to gather all the relevant information on existing conditions, both on the project site and surrounding area that will impact the planning and design of the project. The data related to the following major elements is required to be collected by the designer:

1. Certificate of title.
   a. Site legalization.
   b. Historical records.
2. Topographical survey.
   a. Location plan.
   b. Site visits.
   c. Site coordinates.
   d. Photographs.
3. Geotechnical investigations.
4. Field and laboratory test of soil and soil profile.
5. Existing structures in/under the project site.
6. Existing utilities/services passing through the project site.
7. Existing roads, structure surrounding the project site.
8. Shoring and underpinning requirements with respect to adjacent area/structure.
9. Requirements to protect neighboring area/facility.
10. Environmental studies.
11. Daylighting requirements.
12. Wind load, seismic load, dead load, and live load.
13. Site access/traffic studies.
14. Applicable codes, standards, and regulatory requirements.
15. Usage and space program.
16. Design protocol.
17. Scope of work/client requirements.

2.2.5.2 Collect Owner's Requirements

Based on the scope of work/requirement mentioned in the TOR, a detailed list of requirements is prepared by the designer (consultant). The project design is developed taking into consideration the owner's requirements and all other design criteria.

Table 2.4 is a checklist for the owner's preferred requirements related to architectural work.

TABLE 2.4
Checklist for Owner's Preferred Requirements (Architectural)

Owner's Preferred Requirements (Architectural)				
Sr. No.	**Description**	**Yes**	**No**	**Notes**
1	Building Type			
	a. Commercial			
	b. Residential			
	c. Public			
	d. Other Type (specify)			
2	Multi Story			
3	Basement			
	Floor number:			
	a. Mezzanine			
	b. Ground			
	c. Typical Number			
4	Type of Façade System			
	a. Curtain Wall—Glass			
	b. Fair Face Concrete			
	c. Painting Plaster			
	d. Stone			
	e. Ceramic			
	f. Aluminum Composite Panels			
	g. Precast panels			
	h. Brick			
	i. GRG			
	j. Louvers			
	k. Façade Cleaning System			
5	Type of roof			
	a. Space Frame			
	b. Brick			
	c. Skylight			
	d. Louvers			
	e. Canopies			
6	Type of Partition			
	a. Block Work			
	b. Concrete			
	c. Gypsum Board			
	d. Demountable Partition			
	e. Operable Partition			
	f. Glass Partition			
	g. Wood Partition			
	h. Sandwich Panels			
7	Type of Doors			
	a. Wooden			
	b. Steel			

(*Continued*)

TABLE 2.4 Continued
Checklist for Owner's Preferred Requirements (Architectural)

Owner's Preferred Requirements (Architectural)				
Sr. No.	**Description**	**Yes**	**No**	**Notes**
	c. Aluminum			
	d. Glazing			
	e. Fire Rated			
	f. Rolling Shutter			
	g. Sliding			
8	Type of Windows			
	a. Wooden			
	b. Aluminum			
	c. Metal			
9	Wall Finishes			
	a. Wood cladding			
	b. Painting Plaster			
	c. Stone			
	d. Ceramic			
	e. Curtain Glass			
	f. Mirror			
	g. Wallpaper			
	h. Polished Plaster			
10	Type of Ceiling			
	a. Acoustic			
	b. Wooden			
	c. Metallic			
	d. Plain Gypsum Panels			
	e. Curve Light			
	f. Metal Tiles			
	g. Gypsum Tiles			
	h. Perforated Tiles			
	i. GRG Tiles			
	j. Spider Glass			
11	Floor Finishes			
	Stone			
	Carpet			
	Wood parquet			
	Ceramic			
	Epoxy			
	Terrazzo			
	Rubber			
	Raised floor			
12	Toilet			
	Wash basin			
	Solid surface			
	Mirror			
	WC			
	Accessories			

(*Continued*)

TABLE 2.4 Continued
Checklist for Owner's Preferred Requirements (Architectural)

	Owner's Preferred Requirements (Architectural)			
Sr. No.	**Description**	**Yes**	**No**	**Notes**
13	Bathroom			
	Wash basin			
	Mirror			
	Solid surface			
	WC			
	Shower			
	Accessories			
14	Kitchen			
	Rough carpentry			
	Solid surface			
	Sink type			
	Accessories			
15	Staircase			
16	Elevator			
17	Entrance			
	Front			
	Rear			
	Service			
18	Terraces			
	Indoor			
	Outdoor			
19	Landscape Garden			
20	Parking			
	Car shade			
	Open Area			
21	Swimming Pool			
	Indoor			
	Outdoor			
22	Other Services			

Table 2.5 is a checklist for the owner's preferred requirements related to structural work.

Table 2.6 is a checklist for the owner's preferred requirements related to mechanical work.

Table 2.7 is a checklist for the owner's preferred requirements related to heating ventilation and cooling (HVAC) work.

Table 2.8 is a checklist for the owner's preferred requirements related to electrical work.

TABLE 2.5
Checklist for Owner's Preferred Requirements (Structural)

Owner's Preferred Requirements (Structural)				
Sr. No.	**Description**	**Yes**	**No**	**Notes**
1	Building Type			
	a. Commercial			
	b. Residential			
	c. Other Type (specify)			
2	Multistory			
3	Basement			
4	Type of Construction			
	a. Reinforced Cast *in situ*			
	b. Reinforced Precast			
	c. Steel Structure			
5	Type of Roof			
	a. Concrete			
	b. Steel			
	c. Other Type (specify)			
6	Type of Basement			
	a. Heated and Cooled			
	b. Unconditioned			
7	Type of Partition Walls			
	a. Block			
	b. Concrete			
	c. Other Type			

TABLE 2.6
Checklist for Owner's Preferred Requirements (Mechanical)

Owner's Preferred Requirements (Mechanical)				
Sr. No.	**Description**	**Yes**	**No**	**Notes**
1	Equipment Type—Pumps			
	a. Normal			
	b. Standby Unit			
	c. Preferential Country of Origin			
2	Water Storage Tank			
3	Water System Type			
	a. Cold Water Only			
	b. Cold/Hot water			
4	Type of Pipe Water Supply			
	a. Metallic			

(*Continued*)

TABLE 2.6 Continued
Checklist for Owner's Preferred Requirements (Mechanical)

Owner's Preferred Requirements (Mechanical)				
Sr. No.	**Description**	**Yes**	**No**	**Notes**
	b. Non-Metallic			
5	Type of Pipe Drainage			
	a. Metallic			
	b. Non-Metallic			
6	Boiler System			
	a. Central			
	b. Individual Unit			
	c. Preferential Type of Boiler			
7	Preferential Fittings and Accessories			
8	Water Pumps on Emergency			
9	Fuel Storage Type			
10	Interface with BMS			

TABLE 2.7
Checklist for Owner's Preferred Requirements (HVAC)

Owner's Preferred Requirements (HVAC)				
Sr. No.	**Description**	**Yes**	**No**	**Notes**
1	Equipment Type			
	a. Normal			
	b. Special			
	c. Preferential Country of Origin			
2	Standby Unit			
3	System Type			
	a. Cooling Only			
	b. Cooling/Heating			
4	BMS System			
	a. Manual Operation			
	b. Automatic			
	c. Addressable			
	d. Web-Based			
5	Power for Equipment			
	a. Normal			
	b. Emergency			
6	Thermostat Type			
	a. Analog			
	b. Digital			

TABLE 2.8
Checklist for Owner's Preferred Requirements (Electrical)

Owner's Preferred Requirements (Electrical)				
Sr. No.	**Description**	**Yes**	**No**	**Notes**
1	Lighting Type			
	a. Normal			
	b. LED			
	c. Optic Fiber			
2	Lighting Switching			
	a. Normal Switching			
	b. Central Switching			
	c. Smart Building			
	d. Dimming			
3	Power			
	a. Normal			
	b. Emergency			
	c. Through UPS			
4	Diesel Generator Set			
5	UPS			
6	Capacitor Bank			
7	Fire Alarm System			
	a. Analog			
	b. Addressable			
8	Communication System			
	a. Analog			
	b. Digital			
	c. IP Telephony			
9	IT System			
	a. Passive Network			
	b. Active components			
10	Security System			
	a. Analog Cameras			
	b. Digital Cameras			
	c. IP Cameras			
	d. Analog System			
	e. Digital System			
	f. IP Integration			
	g. Guard Tour System			
	h. X-Ray Machine			
	j. Metal Detectors			
	k. Other Requirements			
11	Access Control System			

(*Continued*)

TABLE 2.8 Continued
Checklist for Owner's Preferred Requirements (Electrical)

Owner's Preferred Requirements (Electrical)				
Sr. No.	**Description**	**Yes**	**No**	**Notes**
12	Parking Control System			
13	Road Blocker			
14	Public Address System			
	a. Analog			
	b. Digital			
	c. IP			
15	Audio Visual System			
16	Conference System			
17	Satellite Antenna System			
	a. Digital			
	b. IP			
18	Central Clock System			
19	System Integration			
20	Provision for Integration with Alternate Energy			
21	Any Other System			

2.2.5.3 Prepare Concept Design

The designer can use techniques such as quality function deployment (QFD) to translate the owner's needs into technical specifications. Figure 2.7 illustrates a house of quality for a college building project based on certain specific requirements by the customer.

While preparing concept design, the designer has to consider various available options/systems to ensure project economy, performance, and operation. The concept design should be suitable for further development.

2.2.5.3.1 Concept Design Drawings

Table 2.9 lists the elements that comprise the concept design drawings of various trades (disciplines).

2.2.5.3.2 Concept Design Report

Concept design reports should be concise, covering all the related information about concept design considerations. Reports are prepared for each of the trades mentioned in the TOR. The following is the example a table of contents of concept design report for architectural work and civil/structural work for building projects.

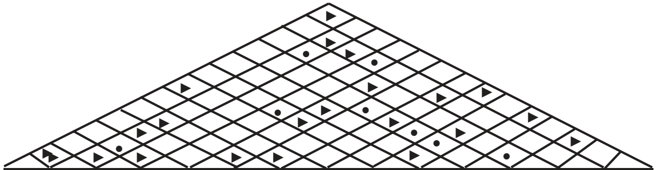
A. Table of Contents for Architectural Work

1. Introduction
   1.1 Project Goals and Objectives
2. Owner's Schedule Requirements

Correlation
- ▶ Strong Positive
- ● Positive
- ◊ Negative

Priorities Ranking Maximum:10

Relationship
- ■ Strong
- □ Medium
- ♦ Weak



Customer Needs \ Tech. Specs	Priorities	Structural Design	Partitioning	Internal Finishes	Furnishings	Lighting Control	HVAC	Mechanical Works	Conveying System	Structured Cabling	Switches Servers	Fire Alarm System	Low Voltage System	Specialities	Generator
No. of Class Rooms	10	■	■		■				■	■			■		
Laboratory	9	■	■	□			□			■				■	
Library	7	■		□		□				□			□	■	
Workshops	8	■		■	■		□	■						■	
Auditorium	7	■		■	■	□	□			□			□	■	
Tele Confrencing System	9									■			■		□
Audio Visual System	9									■	□		■		□
Cafeteria	7	■		■	■	□						□	□	■	□
Gymnasium	6	■											□	■	
Play Grounds	5					□		□			□		□	■	
IT Facility	9									■	■				□
Paging/Public Address	8									□	□	□	■		□
Administrative Area	7	■	■	■	■	□	□	□	□	□	□	□	□		□
Teachers' Room	7	■	■	■						□		□	□		□
Circulation Area	7	■			■	□	□	□	□			□	□		□
HVAC	8					□	■	□				□	□		□
Lighting	8					■				□					■
Voice Evacuation System	9									□		■	□		
Sanitation	7							■							
Security	9									■	□		□		
Elevators/Escalators	7								■						□
Emergency Power	8														■
Parking Area	7	■			□	□		□					□	□	

Technologically advance college building

Better Education Facility

Latest Architectural Design
Modern College Fcilities
Modern Class Rooms

FIGURE 2.7 House of quality for college building project.

TABLE 2.9
List of Elements Comprising Concept Design Drawings

Serial Number	Elements to be Included in Drawing
1	Architectural
1.1	Overall site plans: a. Existing site plan. b. Location of building, roads, parking, access, and landscape. c. Project boundary limits. d. Site utilities. e. Water supply, drainage, stormwater lines. f. Zoning. g. Reference grids and axes. h. Demolition plan, if any.
1.2	Floor plans: a. Floor plans of all floors. b. Structural grids. c. Vertical circulation elements. d. Vertical shafts. e. Partitions. f. Doors. g. Windows. h. Floor elevations. i. Designation of rooms. j. Preliminary finish schedule. k. Services closets. l. Raised floor, if required.
1.3	Roof plans: a. Roof layout. b. Roof material. c. Roof drains and slopes.
2	Structural
2.1	a. Building structure. b. Floor grade and system. c. Foundation system. d. Tentative size of columns, beams. e. Stairs. f. Roof and general sections.
3	Elevator
3.1	a. Traffic studies. b. Elevator/escalator location. c. Equipment room.
4	Plumbing and Fire Suppression a. Sprinkler layout plan. b. Piping layout plan. c. Water system layout plan.

(*Continued*)

TABLE 2.9 Continued
List of Elements Comprising Concept Design Drawings

Serial Number	Elements to be Included in Drawing
4.1	d. Water storage tank location. e. Development of preliminary system schematics. f. Location of mechanical room.
5	HVAC
5.1	a. Ducting lay out plan. b. Piping layout plan. c. Development of preliminary system schematics. d. Calculations to allow preliminary plant selections. e. Establishment of primary building services distribution routes. f. Establishment of preliminary plant location and space requirements. g. Determine heating and cooling requirements based on heat dissipation of equipment, lighting loads, type of wall, roof, glass., etc. h. Estimation of HVAC electrical load. i. Development of BMS schematics showing interface. j. Location of plant room, chillers, cooling towers.
6	Electrical
6.1	a. Lighting layout plan. b. Power layout plan. c. System design schematic without any sizing of cables and breakers. d. Substation layout and location. e. Total connected load. f. Location of electrical rooms and closets. g. Location of MLTPs, MSBs, SMBs, EMSB, SEMBs, DBs, EDBs, etc. h. Location of starter panels, MCC panels, etc. i. Location of generator, UPS. j. Raceway routes. k. Riser requirements. l. Information and communication technology (ICT): i. Information technology (computer network). ii. IP telephone system (telephone network). iii. Smart building system. m. Loss prevention systems: i. Fire alarm system. ii. Access control security system layout. iii. Intrusion system. n. Public address, audiovisual system layout. o. Schematics for FA and other loss prevention systems. p. Schematics for ICT system, and other low voltage systems. q. Location of LV equipment.
7	Landscape
7.1	a. Green area layout. b. Selection of plants. c. Irrigation system.

(*Continued*)

TABLE 2.9 Continued
List of Elements Comprising Concept Design Drawings

Serial Number	Elements to be Included in Drawing
8	External
8.1	a. Street/road layout. b. Street lighting. c. Bridges (if any). d. Security system. e. Location of electrical panels (feeder pillars). f. Pedestrian walkways. g. Existing plans.
9	Narrative Description

3. Project Directory
4. Architecture
   4.1 Applicable Codes and Standards
   4.2 International Codes
   4.3 Local Codes
   4.4 Building Height
   4.5 Projections
   4.6 Fire Safety Requirements
   4.7 Usage of Building
   4.8 Stairways
5. Project Requirements
   5.1 Basement
   5.2 Ground Floor
   5.3 Other Floors
6. Existing Site Conditions
   6.1 Location Maps
   6.2 Project Site and Surrounding Area Survey Reports
7. Data Collection
   7.1 Site Analysis
   7.2 Traffic Study
   7.3 Existing Site Views
8. Design Options
9. Building Structure
   9.1 Design Loads
   9.2 Wind Loads
   9.3 Deflection Criteria
10. Design Program Software
11. Geographical Investigation
12. Shoring
13. Dewatering
14. Drawings

B. Table of Contents for Structural/Civil Work

1. Introduction
   1.1 Project Goals and Objectives
   1.2 Existing Site Conditions
2. Codes and Standards
3. Regulatory Compliance
4. Design criteria
5. Design systems
   5.1 Design System Alternatives
   5.2 Key Construction Elements
   5.3 Environmental Risk Assessment
   5.4 Geotechnical Investigation and Foundation Design
   5.5 Analysis Model
   5.6 Material
   5.7 Durability
   5.8 Fire Safety
   5.9 Design Loads
   5.10 Lateral Loads
   5.11 Structural Movement Criteria
   5.12 System Suitability for Structure
   5.13 Shoring and Dewatering
   5.14 Retaining Wall and Lateral Stability System
   5.15 Substructure
   5.16 Design Program/Software
6. Testing Systems
7. Risk Assessment

C. Table of Contents for Mechanical Work

1. Introduction
2. Codes and Standards
3. Regulatory Compliance
4. Incoming Services Routes and Regulatory Requirements
5. Fire Suppression Work
   5.1 Design Criteria
   5.2 Sprinkler System
   5.3 Smoke Ventilation System
   5.4 Firefighting Pumps
   5.5 Piping System
   5.6 Fire Suppression System for Diesel Generator Room
   5.7 Fire Suppression for Low Voltage Equipment Room
6. Mechanical (Plumbing) Work
   6.1 Design Criteria
   6.2 Water Supply System
      6.2.1 Cold Water
      6.2.2 Hot Water
   6.3 Water Distribution Network
   6.4 Water Storage System

6.5 Plumbing Fittings and Fixtures
6.6 Plant Room (Pumps, Heaters) Location
6.7 Storm Water Drainage System
6.8 Sewage System
6.9 Irrigation Water System
6.10 Piping for Mechanical Work

D. Table of Contents for Heating Ventilation Air Conditioning (HVAC) Work

1. Introduction
2. Codes and Standards
3. Regulatory Compliance
4. HVAC System Design Criteria
5. Environmental Conditions
6. HVAC Equipment Selection
   6.1 Chiller
   6.2 Cooling System
   6.3 Air Handling Unit
   6.4 Energy Recovery Equipment
   6.5 Direct Digital Control system
   6.6 Pumps
   6.7 Fans and Ventilation
   6.8 Ducting
   6.9 Duct Insulation
   6.10 Piping
   6.11 Risers
   6.12 Piping Insulation
   6.13 Acoustic and Vibration
7. Location of Plant Room
8. Building Management System (BMS)

E. Table of Contents for Electrical Work

1. Introduction
2. Codes and Standards
3. Regulatory Compliance
4. Design Criteria
   4.1 Safety and Protection
5. Electrical Substation
6. Cables and Wires
7. Main Electrical Supply
   7.1 Main Distribution System
   7.2 Secondary Distribution System
   7.3 Distribution Equipment (Panels, Boards, Switchgear)
   7.4 Circuits
8. Internal and External Lighting
   8.1 Light Fixtures

8\. Power Receptacles
9\. Emergency Power System
10\. Earthing (Grounding) System

11. Lightning Protection System
12. Alternate Energy (Solar) System
13. Fire Alarm and Voice Evacuation System
14. Audiovisual System
15. Security System (CCTV, Access Control)
16. Communication System

2.2.6 Prepare Preliminary Schedule

The duration of the construction project is finite. It has a definite beginning and a definite end, therefore during the conceptual phase, the expected time schedule for the completion of the project/facility is worked out. The expected time schedule is important for both the financial and acquisition of the facility by the owner/end user. It is the owner's goal and objective that the facility is completed in time for occupancy/usage. During this phase, limited information and details about project activities are available, and have a wide accuracy range. The project schedule is developed using top-down planning using key events. It is also known as Class 4 schedule or Schedule Level 1 (please refer to Table 1.20 and Table 1.21).

Figure 2.8 illustrates a typical project schedule (life cycle) for a construction project. (The example schedule is a construction of three branches for a bank.)

2.2.7 Estimate Conceptual Cost

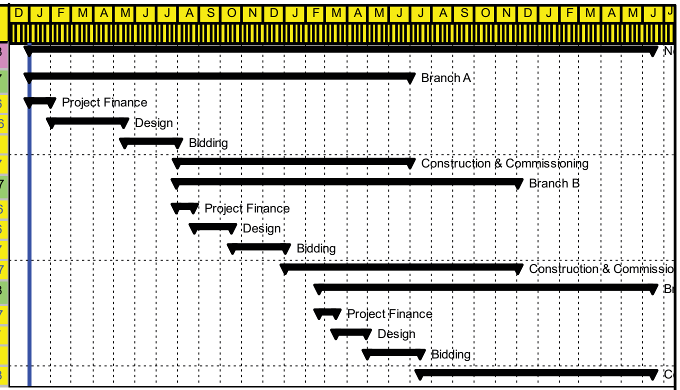
A cost estimate during the concept design is required by the owner to know the capital cost of construction. This is required by the owner to arrange the financial resources. Conceptual cost is also known as budgetary cost. Parametric cost estimation methodology is used to estimate conceptual cost (please refer to Table 1.23). The designer has to ensure that the conceptual cost does not exceed cost estimated during feasibility stage. The accuracy and validity of conceptual cost estimation are related to the level of information available while developing concept design. The designer has to properly estimate the resources required for the successful completion of a project. Table 2.10 illustrates a quality check for cost estimation.

2.2.8 Establish Quality Requirements

During this phase, the designer has to plan and establish quality criteria for the project. This includes the following:

- Owner's requirements.
- Quality standards and codes to be complied.
- Regulatory requirements.
- Conformance to owner's requirements.
- Conformance to requirements listed under TOR.
- Design review procedure.
- Drawings review procedure.
- Document review procedure.
- Quality management during all the phases of project life cycle.

Activity ID	Activity Name	Original Duration	Start	Finish
New Branch Offices for XYZ Bank		896	01-Jan-16	14-Jun-18
Branch A		547	01-Jan-16	30-Jun-17
Project Finance		31	01-Jan-16	31-Jan-16
Design		105	01-Feb-16	15-May-16
Bidding		77	16-May-16	31-Jul-16
Construction & Commissioning		334	01-Aug-16	30-Jun-17
Branch B		491	30-Jul-16	02-Dec-17
Project Finance		25	30-Jul-16	23-Aug-16
Design		55	24-Aug-16	17-Oct-16
Bidding		77	18-Oct-16	02-Jan-17
Construction & Commissioning		334	03-Jan-17	02-Dec-17
Branch C		480	20-Feb-17	14-Jun-18
Project Finance		25	20-Feb-17	16-Mar-17
Design		44	17-Mar-17	29-Apr-17
Bidding		77	30-Apr-17	15-Jul-17
Construction & Commissioning		334	16-Jul-17	14-Jun-18



Remaining Work
Summary
Milestone

Page 1 of 1

FIGURE 2.8 Typical schedule (project life cycle).

TABLE 2.10
Quality Check for Cost Estimate during Concept Design

Serial Number	Points to be Checked	YES/NO
1	Check for use of historical data.	
2	Check if estimate factors are used to adjust historical data.	
3	Check the estimate is updated with revision or update of concept.	
4	Check if the updates/revisions are chronologically listed and cost estimate updated.	
5	Whether scope of work is descriptive/narrative, well enough for estimation purposes?	
6	Whether estimate is updated, taking into consideration feedback from each trade?	
7	Is the estimate based on area schedule provided by the architect?	
8	Is the cost estimate clearly identifying the quantities and associated work?	
9	Whether all the assumptions are as per current market data?	
10	Is cost estimates from all the relevant trades included in the final sum?	
11	Does the estimate include all the requirements of specialist consultants?	
12	Whether the total estimate is reviewed and verified.	

2.2.9 Estimate Resources

The designer has to estimate the resources required to complete the project. This includes the estimation of manpower required during construction phase, testing, commissioning, and handover phase. The designer also has to estimate the manpower required during design and tendering stages of the construction project.

2.2.10 Manage Risk

The designer has to identify the risks that will affect the successful completion of a project. The following are typical risks that normally occur during conceptual design phase:

- Lack of input from the owner about the project goals and objectives.
- Project objectives not defined clearly.
- Feasibility study not done properly.
- Alternative selection is not suitable for further development.
- The related project data and information collected are incomplete.
- The related project data and information collected are likely to be incorrect and wrongly estimated.
- Environmental consideration.
- Regulatory requirements.
- Errors are in estimating the project schedule.
- Errors in cost estimation.

The designer has to take into account aforementioned mentioned risk factors while developing the concept design.

Further, the designer has to consider the following risk while planning the duration for completion of conceptual phase.

- Impractical conceptual design preparation schedule.
- Delay in obtaining authorities' approval.
- Delay in environmental approval.
- Delay in data collection.
- Delay in deciding project delivery system.

2.2.11 Monitor Work Progress

The designer has to prepare a work schedule to prepare and submit the design to the owner for review and approval. The concept design progress has to be monitored to meet the submission schedule. Regular meetings to monitor the progress and coordination among different trades are required to ensure timely submission of the concept design package.

2.2.12 Review Concept Design

Table 2.11 illustrates major points for analysis of concept design.

TABLE 2.11
Major Points for Analysis of Concept Design

Serial Number	Description	Yes	No	Notes
A: Concept Design				
A.1	Does the design support the owner's project goals and objectives?			
A.2	Does the design meet all the elements specified in TOR?			
A.3	Does the design meet all the performance requirements?			
A.4	Whether constructability has been taken care.			
A.5	Whether technical and functional capability considered.			
A.6	Whether design confirms with fire and egress requirements.			
A.7	Whether health and safety requirements in the design are considered.			
A.8	Whether environmental constraints considered.			
A.9	Whether design risks been identified, analyzed, and responses planned for mitigation.			
A.10	Was energy conservation is considered?			
A.11	Was sustainability considered in design?			
A.12	Whether cost effectiveness over the entire project life cycle is considered.			
A.13	Whether the design meets LEED requirements.			
A.14	Whether accessibility is considered.			
A.15	Does the design meet ease of maintenance?			
A.16	Does the design have provision for inclusion of facility management requirements?			

(*Continued*)

TABLE 2.11 Continued
Major Points for Analysis of Concept Design

Serial Number	Description	Yes	No	Notes
A.17	Whether all reasonable alternative options/systems are considered for design.			
A.18	Whether all reasonable alternative options are considered for project economy.			
A.19	Whether all the regulatory/statutory requirements taken care.			
A.20	Does the design support proceeding to the next design development stage?			
B: Financial				
B.1	Project cost is properly estimated.			
C: Schedule				
C.1	Project schedule is practically achievable.			
D: Reports				
D.1	Whether the reports are complete and include adequate information about the project.			
D.2	Whether the reports are prepared for all the trades mentioned in TOR.			
D.3	Whether the report is properly formatted and has table of contents for each report.			
E: Drawings, Sketches				
E.1	Whether drawings, sketches for all trades prepared as per TOR.			
F: Models				
F.1	Whether the models meet the design objectives.			
G: Submittals				
G.1	Whether number of sets prepared as per TOR.			

2.2.13 Finalize Concept Design

Final designs are prepared incorporating the comments, if any, found during analysis and review of the drawings and documents for submission to the owner/client

2.2.14 Submit Concept Design Package

Normally, the following are submitted to the owner for their review and approval in order to proceed with development of schematic drawings:

1. Outline specifications.
2. Concept design drawings.
3. Concept design reports.
4. Project schedule.
5. Cost estimate.
6. Model.

2.3 SCHEMATIC DESIGN PHASE

Schematic design is mainly a refinement of the elements in the conceptual design phase. Schematic design is also known as **preliminary design**. It is a design intent document that quantifies functional performance expectations and parameters for each system to be commissioned. It is traditionally labeled as 30% design. Schematic design adequately describes information about all proposed project elements in sufficient detail for obtaining regulatory approvals, necessary permits, and authorization. At this phase, the project is planned to the level where sufficient details are available for initial cost and schedule. This phase also includes the initial preparation of all documents necessary to build the facility/construction project. Table 2.12 illustrates the major activities relating to the schematic design phase developed based on the project management process group's methodology.

TABLE 2.12
Major Activities Relating to Schematic Design Phase Processes

Management Processes	Project Management Process Groups				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Integration Management	Concept Design Deliverables	Preliminary Project Management Plan	Develop General Layout of Project (Site Plans)	Building Code Requirements	Schematic Design Deliverables
	Concept Design Comments		Architectural Plans	Concept Design Comments	
	TOR Requirements		Structural Scheme Plans	Existing Conditions	
	Authorities' Requirements		Electromechanical Services	Design Calculations	
			Landscape and Infrastructure	Compliance to Regulatory/ Authorities' Requirements	
			Develop Schematic Design	Constructability	
Stakeholder Management	Identify Project Team	Stakeholders Requirements	Owner's Need Considerations	Stakeholders Requirements	

(*Continued*)

TABLE 2.12 Continued
Major Activities Relating to Schematic Design Phase Processes

Schematic Design Phase

Management Processes	Project Management Process Groups				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
	Identify Design Team				
Scope Management		Site Conditions		Authorities Approval	
		Energy Conservation Requirements		Compliance to Owner's Needs	
		Technical and Functional Capability		Stakeholders Approval	
		Outline Specifications			
		System Schematics			
		Value Engineering			
		Design Deliverables			
Schedule Management		Project Schedule (CPM/Bar Chart)	Preliminary Schedule	Project Schedule	
Cost Management		Cost of Activities	Preliminary Cost	Project Cost Estimate	
		Cost of Resources			
		Preliminary Estimate			
Quality Management		Design Criteria	Design Coordination with All Disciplines	Compliance to Codes, Standards, and Authorities	
		Codes and Standards			

(*Continued*)

TABLE 2.12 Continued
Major Activities Relating to Schematic Design Phase Processes

Schematic Design Phase

Management Processes	Project Management Process Groups				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
		Authorities Requirements			
Resource Management		Assign Project Design Team	Manage Team Members of Different Disciplines	Performance of Team Members	Assign New Phase/Project
		Estimate Resources			
Communication Management		Design Progress Information	Liaison and Coordination with All Parties	Design Status Information	
			Coordination Meetings		
Risk Management		Management of Design Risk		Control Design Risk	
Contract Management		Contract Terms and Conditions	Preliminary Contract Documents	Check for Contracting System	
HSE Management		Safety Considerations in Design	Environmental Requirements	Life Safety in Design Requirements	
Financial Management		Designer/ Consultant Payment			Designer/ Consultant Payment
Claim Management		Design Change Payments		Control Changes	Settle Claim by Designer

Note: These activities may not be strictly sequential, however, the breakdown allows implementation of project management function more effectively and easily managed at different stages of the project phase.

2.3.1 Develop Schematic Design Requirements

The central activity of preliminary design is the architect's design concept of the owner's objective which can help in making detailed engineering and design for the required facility. Preliminary design is a subjective process of transforming ideas and information into plans, drawings, and specifications of the facility to be built. Component/equipment configurations, material specifications, and functional performance are decided during this stage. Design is a complex process. Before design is started, scope must adequately define deliverables, that is what will be provided. These deliverables are design drawings, contract specifications type of contracts, construction inspection record drawings, and reimbursable expenses.

For the development of the preliminary design phase, the designer has to:

- Make investigations of site conditions.
- Collect and analyze the required data.
- Analyze building code requirements.
- Analyze energy conservation requirements.
- Study fire and other regulatory codes and requirements.

Based on the evaluation and analysis of the required data, the designer can proceed with the development of preliminary design by considering the following major points:

1. Concept design deliverables.
2. Calculations to support the design.
3. System schematics for electromechanical system.
4. Coordination with other members of the project team.
5. Authorities' requirements.
6. Availability of resources.
7. Constructability.
8. Health and safety.
9. Reliability.
10. Energy conservation issues.
11. Environmental issues.
12. Selection of systems and products that support functional goals of the entire facility.
13. Selection of equipment and systems to conform to the latest technology and suitable for networking through IOT.
14. Sustainability.
15. Requirements of all stakeholders.
16. Optimized life cycle cost (value engineering).

2.3.1.1 Identify Schematic Design Requirements

In order to identify requirements to develop a schematic design, the designer has to gather comments made by the owner/project manager on the submitted concept design, collect TOR requirements, regulatory requirements, and other related data to ensure that the developed design is error-free and has minimum omissions.

2.3.1.1.1 Gather Concept Design Comments

The objective of the schematic design is to refine and develop a clearly defined design based on the client's requirements. While developing the schematic design, the designer has to review the submitted concept design drawings, reports, and take into consideration the comments, if any, made on the concept design. The designer can discuss in detail with the owner/project manager and incorporate all their requirements to develop a schematic design.

2.3.1.1.2 Identify TOR Requirements

Normally the TOR lists the requirements guidelines to develop the schematic design. It mainly consists of the following:

1. Complete Schematic Drawings for the Selected/Approved Concept Design
2. Schematic Design Report
3. Preliminary Models

The TOR details that during schematic design phase, the following items to be developed taking into consideration the approved concept design and comments on the design:

1. Drawings
    - 1.1 Site Plan
    - 1.2 Architectural Design
    - 1.3 Interior Design
    - 1.5 Structural Design
    - 1.6 Mechanical Design
        - 1.6.1 Public Health
        - 1.6.2 Fire Suppression
    - 1.7 HVAC Design
    - 1.8 Electrical Design
    - 1.9 Smart Building Systems
    - 1.10 Special Systems
    - 1.11 Landscape Design
    - 1.12 External Works
2. Outline Specifications
3. Preliminary Contract Documents
4. Project Schedule (Preliminary)
5. Cost Estimate (Preliminary)
6. Authorities Approvals
7. Value Engineering Report
8. Preliminary Model

2.3.1.1.3 Collect Owner's Requirements

The owner requirements discussed under Section 2.2.5.2 are further developed in detail in order to be considered in the schematic design.

2.3.1.1.4 Collect Regulatory Requirements

During this phase, the schematic design drawings are submitted to the regulatory bodies for their review and approval for compliance with the regulations, codes, and licensing procedures. Any comments on the drawings are incorporated into the drawings and are resubmitted if required. Normally, for building projects, the following schematic drawings are submitted for approval by the concerned authorities:

1. Architectural drawings approval by municipality.
2. Fire department:
   a. Escape route (stairs).
   b. Fire alarm system.
   c. Fire suppression (sprinkler) system.
   d. Smoke ventilation system.
   e. Inflammable material and fuel system.
   f. Conveyance system (elevator).
   g. Exit and emergency lighting system.
3. Public works for utilities connections such as water supply.
4. Public works for stormwater, sanitary, and drainage system.
5. HVAC system for compliance to energy conservation.
6. Electricity agency for approval of total connected load (electrical).
7. Electrical substation location.
8. Fuel point for building.

For infrastructure and road work, the following approvals are required:

1. Environmental impact.
2. Sanitary, stormwater, drainage system discharge.
3. Landscape.
4. Traffic signage and markings.
5. Right-Of-Way.
6. Street lighting.
7. Substation for streetlights.

The requirements differ depending on the particular country's applicable rules and regulations.

2.3.1.1.5 Collect LEED Requirements

Leadership in Energy and Environmental Design (LEED) is an internationally recognized green building certification system, providing verification by a third party that the building is designed and constructed to the standards and requirements outlined by the LEED rating system. The design team and contractor have to integrate all the required features in their design to ensure that the building is more durable, healthy and more energy efficient.

In order to construct a building that merits LEED certification, the designer has to consider the following:

- Optimize site selection.
- Orientation of building to make maximum advantages of sunlight.
- Water efficiency.
- Use of energy as efficiently as possible.
- Use of water as efficiently as possible.
- Indoor environmental quality:
- Indoor air quality.
- Ventilation.
- Outdoor airflow monitoring.
- Maximum use of alternate (renewable) energy.
- Minimize wastewater.
- Sustainable material selection.
- Regional priority.
- Innovation in design.

2.3.1.2 Establish Schematic Design Requirements

The schematic design requirements are developed considering all the items discussed under Section 2.3.1.1. These are mainly as follows:

1. Gathering of comments on concept design deliverables.
2. Collection of owner's preferred requirements.
3. Collection of regulatory requirements.
4. Collection of sustainability requirements.
5. TOR requirements.
6. Provision for facility management system/equipment.

2.3.2 Develop Preliminary Project Management Plan

Preliminary project management plan is updated based on additional information collected during schematic design phase. Typical contents of a project management plan are as follows:

1. Project Description
2. Project Objectives
3. Project Organization
   - 3.1 Organization chart
   - 3.2 Responsibility Matrix
   - 3.3 Project Directory
4. Project (Scope) Deliverables
5. Project Schedule
6. Project Budget

7. Project Quality Plan
8. Project Resources
9. Risk Management
10. Communication Matrix
11. Contract Management
12. HSE Management
13. Project Finance Management
14. Claim Settlement

2.3.3 Identify Project Stakeholders

During schematic design phase, the following are stakeholders having direct involvement in the project:

- Owner
- Consultant
- Designer
- Regulatory Authorities
- Project/Construction Manager (if the owner decides to engage during this phase, depending on the type of project delivery system)

2.3.3.1 Identify Project Team Members

During this phase, most project team members, such as the owner's representative, project manager (design), and other design personnel, are selected and identified.

2.3.3.2 Identify Design Team Members

Design team members are selected based on the organizational structure and suitable skills required to perform the job. Normally, the design team consists of:

1. Project Manager
2. Design Managers (One for each Trade)
3. Quality Manager
4. Team Leader (Principal Engineer)—Each Trade
5. Team Members (Engineers, CAD Technicians for Each Discipline)
6. Quantity Surveyor (Cost Engineer)

Figure 2.9 illustrates an example structural/civil engineering design team organization chart.

2.3.3.3 Establish Stakeholders' Requirement

A distribution matrix based on the interest and involvement of each stakeholder is prepared and the appropriate documents are sent for their action/information as per the agreed-upon requirements.

2.3.3.4 Develop Responsibility Matrix

Table 2.13 illustrates responsibilities of various participants during schematic design phase.

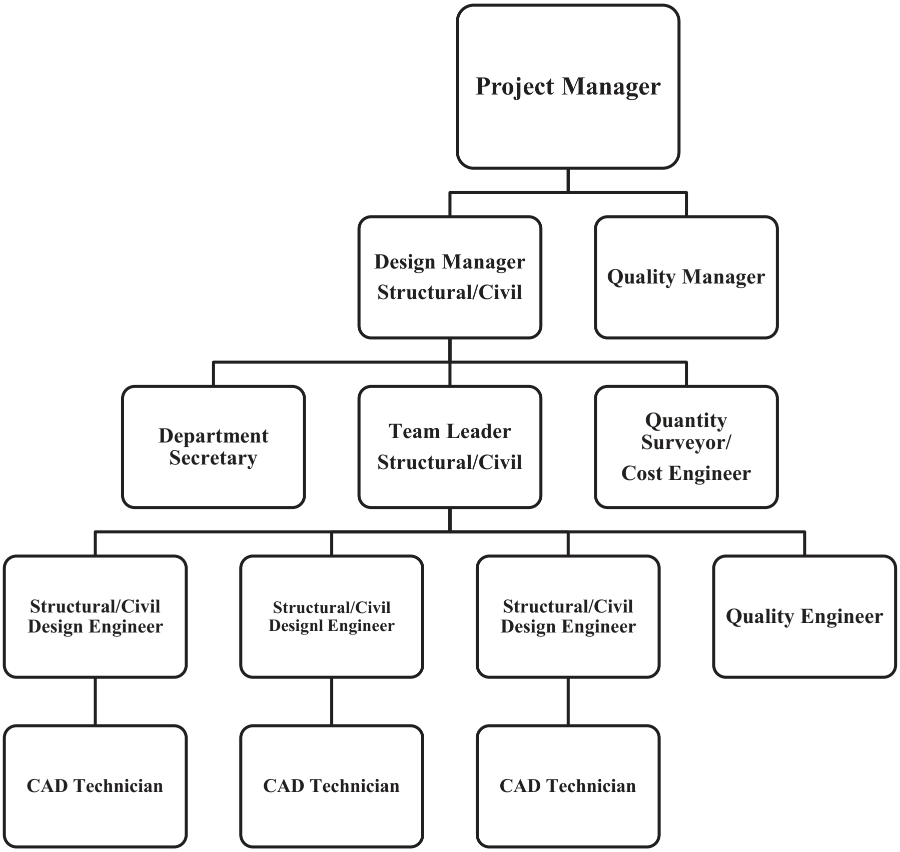


FIGURE 2.9 Structural/civil engineering design team organization chart.

TABLE 2.13
Responsibilities of Various Participants (Design-Bid-Build Type of Contracts) during Schematic Design Phase

Phase	Responsibilities		
	Owner	Designer	Regulatory Authorities
Schematic Design	• Approval of Preliminary (Schematic) Design	• Develop general layout/ scope of facility/project. • Regulatory approval. • Schedule. • Budget. • Contract terms and conditions. • Value engineering.	• Approval of project submittals.

2.3.4 Develop Schematic Design Scope

Schematic design scope is developed taking into consideration the requirements established under Section 2.3.1.2. These are as follows:

- TOR requirements.
- Owner's preferred requirements.
- Approved concept design documents.
- Approved preliminary project schedule.
- Approved preliminary cost estimate.
- Regulatory requirements.
- Codes and standards.

The purpose of development of schematic design is to provide sufficient information to identify the work to be performed and to allow the detailed design to proceed without significant changes that may affect the project schedule and budget. The scope of work during the schematic design phase mainly comprises:

- Preparation of Schematic Drawings
- Outline Specifications
- Preliminary Schedule
- Preliminary Cost Estimate
- Authorities' Approvals
- Narrative Reports

2.3.4.1 Identify Schematic Design Deliverables

Based on the scope of schematic design, the following are the deliverables to be developed:

1. Design Drawings
   1.1 Architectural
   1.2 Structural
   1.3 Conveying System
   1.4 Mechanical (public health and fire suppression)
   1.5 HVAC
   1.6 Electrical
   1.7 Landscape
   1.8 External
2. Outline Specifications
3. Narrative Reports
4. Preliminary Schedule
5. Preliminary Cost Estimate
6. Regulatory Approvals
7. Value Engineering
8. Models

Table 2.14 lists the schematic design deliverables to be developed during the schematic design phase.

TABLE 2.14
Schematic Design Deliverables

Serial Number	Deliverables
1	General
1.1	a. Preliminary/outline specifications.
	b. Zoning.
	c. Permits and regulatory approvals.
	d. Energy code requirements.
	e. Construction methodology narration.
	f. Descriptive report of environmental, health, and safety requirements.
	g. Estimate construction period (preliminary schedule).
	h. Estimated cost.
	i. Value engineering suggestions and resolutions.
	j. Life safety requirements.
	k. Sketches/perspective
	i. Interior
	ii. Exterior
	m. Graphic presentation.
2	Preliminary Design Drawings
2.1	Architectural.
2.1.1	Overall site plans:
	a. Existing site plans.
	b. Location of building, roads, parking, access, and landscape.
	c. Project boundary limits.
	d. Site utilities.
	e. Water supply, drainage, stormwater lines.
	f. Zoning.
	g. Reference grids and axis.
2.1.2	Floor plans:
	a. Floor plans of all floors.
	b. Structural grids.
	c. Vertical circulation elements.
	d. Vertical shafts.
	e. Partitions of various types.
	f. Doors.
	g. Windows.
	h. Floor elevations.
	i. Designation of rooms.
	j. Preliminary finish schedule.
	k. Door schedule.
	l. Hardware schedule.
	m. Ceiling plans.
	n. Service closets.
	o. Raised floor, if required.

(*Continued*)

TABLE 2.14 Continued
Schematic Design Deliverables

Serial Number	Deliverables
2.1.3	Roof plans:
	a. Roof layout.
	b. Roof material.
	c. Roof drains and slopes.
2.1.4	Elevations:
	a. Wall cladding.
	b. Curtain wall.
	c. Stones cladding.
	d. Exterior insulation and finishing system (EIFS).
	e. Sections at various locations.
2.2	Structural:
	a. Building structure.
	b. Floor grade and system.
	c. Foundation system.
	d. Tentative size of columns, beams.
	e. Stairs.
	f. Elevations and sections through various axis.
	g. Roof.
2.3	Elevator:
	a. Traffic studies.
	b. Elevator/escalator location.
	c. Equipment room.
2.4	Plumbing and fire suppression:
	a. Sprinkler layout plan.
	b. Piping layout plan.
	c. Water system layout plan.
	d. Water storage tank location.
	e. Development of preliminary system schematics.
	f. Location of mechanical room.
2.5	HVAC:
	a. Ducting lay out plan.
	b. Piping layout plan.
	c. Development of preliminary system schematics.
	d. Calculations to allow preliminary plant selections.
	e. Establishment of primary building services distribution routes.
	f. Establishment of preliminary plant location and space requirements.
	g. Determine heating and cooling requirements based on heat dissipation of equipment, lighting loads, type of wall, roof, glass, etc.
	h. Estimation of HVAC electrical load.
	i. Development of BMS schematics showing interface.
	j. Location of plant room, chillers, cooling towers.
2.6	Electrical:
	a. Lighting layout plan.
	b. Power layout plan.

(*Continued*)

TABLE 2.14 Continued
Schematic Design Deliverables

Serial Number	Deliverables
	c. System design schematic without any sizing of cables and breakers.
	d. Substation layout and location.
	e. Total connected load.
	f. Location of electrical rooms and closets.
	g. Location of MLTPs, MSBs, SMBs, EMSB, SEMBs, DBs, EDBs, etc.
	h. Location of starter panels, MCC panels, etc.
	i. Location of generator, UPS.
	j. Raceway routes.
	k. Riser requirements.
	l. Information and communication technology (ICT):
	i. Information Technology (Computer Network)
	ii. IP Telephone System (Telephone Network)
	iii. Smart Building System
	m. Loss prevention systems:
	i. Fire Alarm System
	ii. Access Control Security System Layout
	iii. Intrusion System
	n. Public address, audiovisual system layout.
	o. Schematics for FA and other loss prevention systems.
	p. Schematics for ICT system, and other low voltage systems.
	q. Location of LV equipment.
2.7	Landscape:
	a. Green area layout.
	b. Selection of plants.
	c. Irrigation system.
2.8	External:
	a. Street/road layout.
	b. Street lighting.
	c. Bridges (if any).
	d. Security system
	e. Location of electrical panels (feeder pillars).
	f. Pedestrian walkways.

2.3.5 Develop Schematic Design

The primary goal of this phase is to develop a clearly defined design based on the client's requirements. Figure 2.10 illustrates logic flowchart process for schematic design phase.

In order to develop a schematic design, the designer has to collect related data/information and perform site investigations.

2.3.5.1 Collect Data/Information

The following data to be collected to develop a schematic design for a building project:

- Needs of the owner.
- Building/project usage.

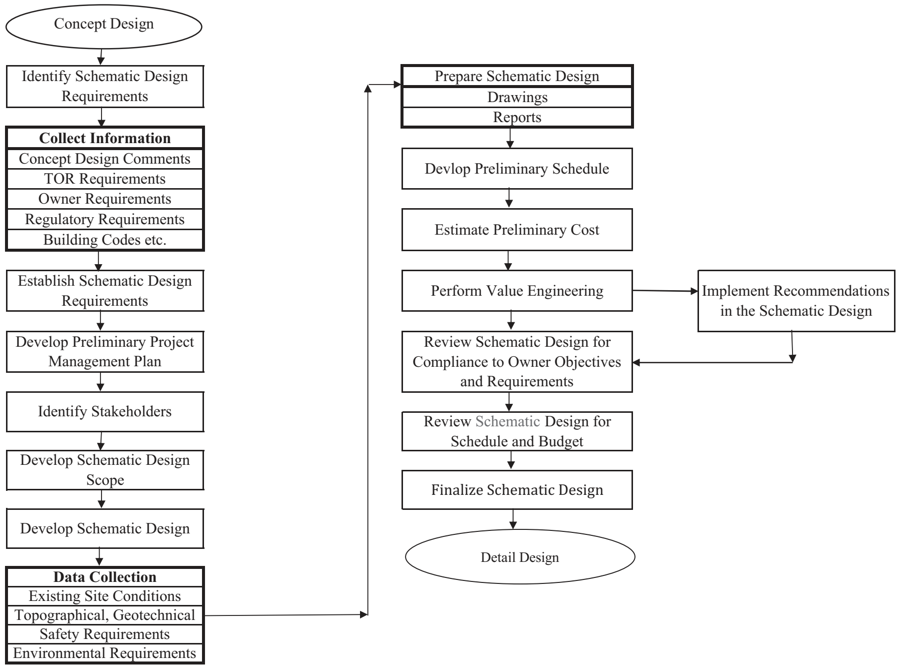


FIGURE 2.10 Logic flow process for schematic design phase.

- Space program.
- Technical and functional capability requirements.
- Zoning requirements.
- Aesthetics requirements.
- Fire protection requirements.
- Indoor air quality.
- Lighting/daylighting requirements.
- Conveying system traffic analysis.
- Health and safety features.
- Environmental compatibility requirements.
- Energy conservation requirements.
- Sustainability requirements.
- Facility management requirements.
- Regulatory/authority requirements (permits).
- Codes and standards to be followed.
- Social responsibility requirements.
- Project constraints.
- Ease for constructability.
- Number of drawings to be produced.
- Milestone for development of each phase of design.
- Disabled (special needs) access requirements.

2.3.5.2 Perform Site Investigations

- Soil profile and laboratory test of soil.
- Topography of the project site.
- Hydrological information.
- Wind load, seismic load, dead load, and live load.
- Existing services passing through the project site.
- Existing roads, structures surrounding the project site.
- Shoring and underpinning requirements with respect to adjacent area/structure.

2.3.5.3 Prepare Schematic Design

During this phase, several alternative schemes are reviewed and one scheme that meets the owner's objectives is selected.

2.3.5.3.1 Schematic Design Drawings

The following schematic drawings for building projects are generally prepared during this phase:

- Architectural.
  - Overall site plans.
  - Floor plans.
  - Roof plans.
  - Sections.
  - Elevations.
- Structural.
  - Building structure.
  - Foundation system.
  - Stairs.
  - Roof.
- Conveying system.
  - Elevator location.
  - Machine room.
- MEP.
  - General arrangement of each system.
  - Single line riser diagram.
  - Electrical schematic diagram.
  - Layout of equipment rooms.
  - Layout of electrical substation.
  - Electrical rooms.
  - Vertical shafts.
- Security system.
- External works.
- Landscape plans.

The designer can use the BIM tool for designing the project.

- Building Information Modeling

BIM is an innovative process of generating a digital database for collaboration and managing building data during its life cycle and preserves the information for reuse and additional industry-specific applications. Building Information Modeling is Autodesk's strategy for the application of information technology to the building industry. It helps with better visualization and clash detection. It is an excellent tool to develop project staging plans, study phasing and coordination issues during construction project life cycle, preparation of as-built, and also during maintenance of the project. (Please refer to Chapter 5 for more details about the use of BIM.)

2.3.5.3.2 Schematic Design Report

The schematic reports mainly identify:

- Systems
- Materials
- Finishes
- Design Features Describing the Selected Option
- Construction Methodology
- Project Risk

2.3.5.3.2.1 Outline Specifications Outline specifications indicating project-specific features of major equipment, systems, materials are prepared during this phase. Normally, specifications are prepared per MasterFormat® contract documents produced jointly by the Construction Specification Institute (CSI) and Construction Specifications Canada (CSC), which are widely accepted as standard practice for preparation of contract documents. (Different types of construction contract documents used by construction industry are discussed under Chapter 6, Volume 1.)

2.3.5.3.2.2 Preliminary Contract Documents Based on the type of contracting arrangements, the owner would like to handle the project, necessary documents are prepared by establishing a framework for execution of the project. Generally, the FIDIC (Federation International des Ingénieurs Conseils) model conditions for international civil engineering contracts are used as a guide to prepare these contract documents. Preliminary documents are prepared in line with model contract documents.

2.3.6 Perform Value Engineering

Value Engineering (VE) studies can be conducted at various phases of construction project life cycle, however, the studies conducted in the early stage of the project tend to provide greatest benefit. In most projects, value engineering studies are performed during the schematic phase of the project. At this stage the design professionals have considerable flexibility to implement the recommendations made by the VE team, without significant impacts to the project schedule or design budget. In certain countries for a project over five million US dollars, a value engineering study must be conducted as part of the schematic design process. The team members to perform a value engineering study depend on client's/owner's requirement. It is advisable that a

SAVE international registered certified value specialist is assigned to lead this study. Figure 2.11 illustrates value engineering process activities.

2.3.7 Prepare Preliminary Schedule

The project schedule is developed using top-down planning using key events. It is also known as Class 3 schedule or Schedule Level 2 (please refer to Table 1.20 and Table 1.21).

Figure 2.12 illustrates a typical preliminary schedule for a construction project. (The example schedule is a construction of three branches for a bank).

2.3.8 Estimate Preliminary Cost

The cost estimate during this phase is based on elemental parametric methodology. It is also known as budgetary (preliminary estimate). (Please refer to Table 1.23.)

2.3.9 Manage Design Quality

In order to minimize design errors, minimize design omissions, and reduce rework during schematic design, the designer has to plan quality (planning of design work), perform quality assurance, and control quality for preparing schematic design. This will mainly consist of the following:

1. **Plan Quality**
   Establish owner's requirements.
   Determine number of drawings to be produced.
   Establish scope of work.
   Identify quality standards and codes to be complied.
   Establish design criteria.
   Identify regulatory requirements.
   Identify requirements listed under TOR.
   Establish quality organization with responsibility matrix.
   Develop design (drawings and documents) review procedure.
   Establish submittal plan.
   Establish design review procedure.
2. **Quality Assurance**
   Collect data.
   Investigate site conditions.
   Prepare preliminary drawings.
   Prepare outline specifications.
   Ensure functional and technical compatibility.
   Coordinate with all disciplines.
   Select material to meet owner objectives.
3. **Control Quality**
   Check design drawings.
   Check specifications/contract documents.
   Check for regulatory compliance.

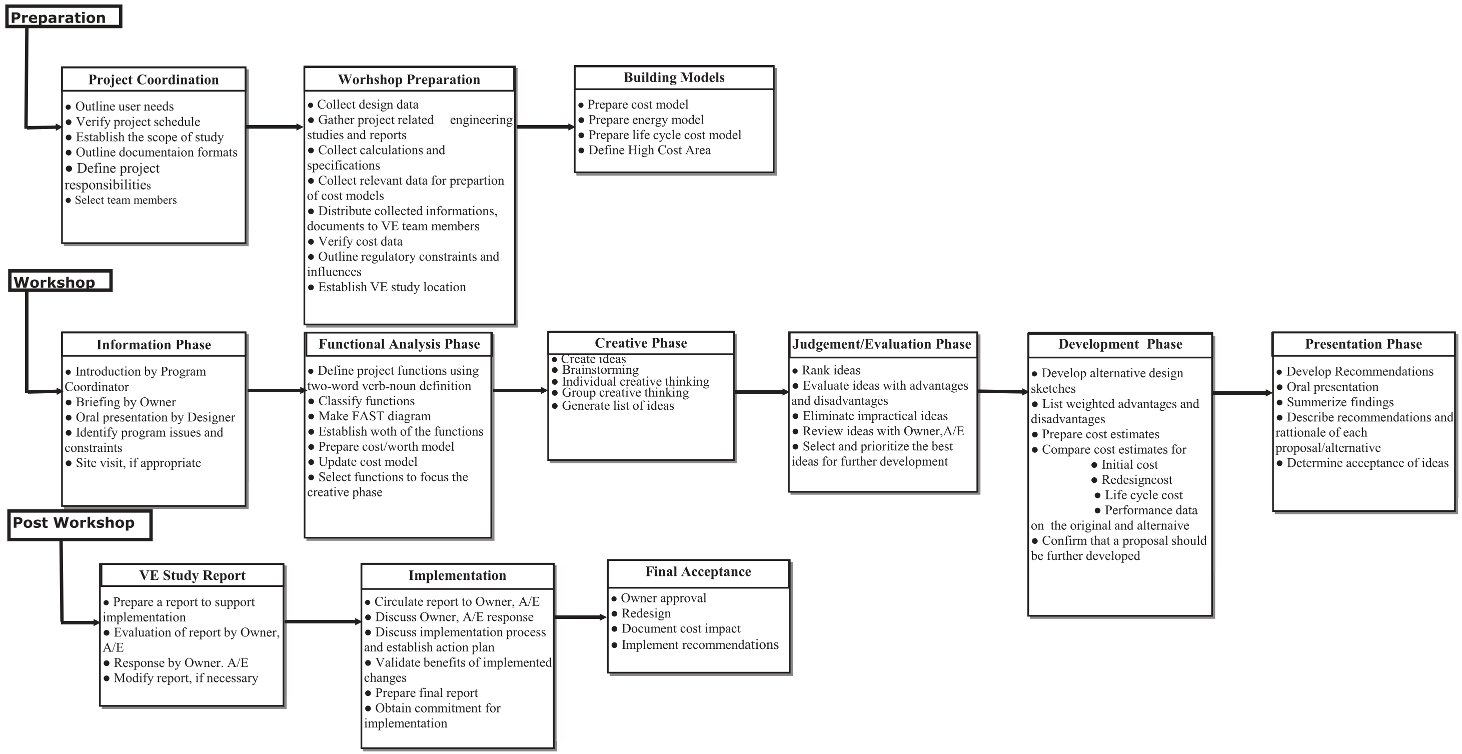
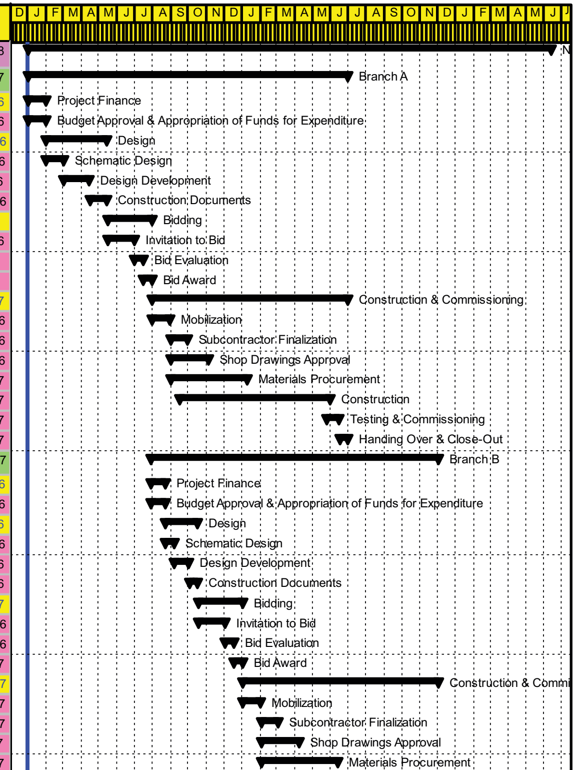


FIGURE 2.11 Value engineering process activities.

Activity Name	Original Duration	Start	Finish
New Branch Offices for XYZ Bank	896	01-Jan-16	14-Jun-18
Branch A	547	01-Jan-16	30-Jun-17
Project Finance	31	01-Jan-16	31-Jan-16
Budget Approval & Appropriation of Funds for Expenditure	31	01-Jan-16	31-Jan-16
Design	105	01-Feb-16	15-May-16
Schematic Design	30	01-Feb-16	01-Mar-16
Design Development	45	02-Mar-16	15-Apr-16
Construction Documents	30	16-Apr-16	15-May-16
Bidding	77	16-May-16	31-Jul-16
Invitation to Bid	46	16-May-16	30-Jun-16
Bid Evaluation	15	01-Jul-16	15-Jul-16
Bid Award	16	16-Jul-16	31-Jul-16
Construction & Commissioning	334	01-Aug-16	30-Jun-17
Mobilization	31	01-Aug-16	31-Aug-16
Subcontractor Finalization	30	01-Sep-16	30-Sep-16
Shop Drawings Approval	65	01-Sep-16	04-Nov-16
Materials Procurement	132	01-Sep-16	10-Jan-17
Construction	259	16-Sep-16	01-Jun-17
Testing & Commissioning	23	25-May-17	16-Jun-17
Handing Over & Close-Out	14	17-Jun-17	30-Jun-17
Branch B	491	30-Jul-16	02-Dec-17
Project Finance	25	30-Jul-16	23-Aug-16
Budget Approval & Appropriation of Funds for Expenditure	25	30-Jul-16	23-Aug-16
Design	55	24-Aug-16	17-Oct-16
Schematic Design	15	24-Aug-16	07-Sep-16
Design Development	25	08-Sep-16	02-Oct-16
Construction Documents	15	03-Oct-16	17-Oct-16
Bidding	77	18-Oct-16	02-Jan-17
Invitation to Bid	46	18-Oct-16	02-Dec-16
Bid Evaluation	15	03-Dec-16	17-Dec-16
Bid Award	16	18-Dec-16	02-Jan-17
Construction & Commissioning	334	03-Jan-17	02-Dec-17
Mobilization	31	03-Jan-17	02-Feb-17
Subcontractor Finalization	30	03-Feb-17	04-Mar-17
Shop Drawings Approval	65	03-Feb-17	08-Apr-17
Materials Procurement	132	03-Feb-17	14-Jun-17



Remaining Work Summary
Milestone

Page 1 of 2

FIGURE 2.12 Typical preliminary schedule.

Check preliminary schedule.
Check cost of project (preliminary cost).

BIM tools can be used to control quality of the project (please refer to Chapter 5 for more information).

2.3.10 Estimate Resources

Designer has to estimate the resources required to complete the project. At this stage, more details about the activities and work to be performed during the construction, testing, and commissioning phase are available, the designer has to update the earlier estimated resources and prepare a manpower histogram. Also, the designer can estimate the total number of design team members to develop design and construction documents.

2.3.11 Manage Risks

Following are typical risks that normally occur during schematic design phase:

- Concept design deliverables and review comments are not taken into consideration while preparing the schematic design.
- Regulatory authorities' requirements are not taken into consideration.
- Schematic design scope of work is incomplete.
- The related project data and information collected are incomplete.
- The related project data and information collected are likely to be incorrect and wrongly estimated.
- Site investigations for existing conditions not carried out.
- Fire and safety considerations.
- Environmental consideration.
- Incomplete design.
- Prediction of possible changes in design during construction phase.
- Inadequate and ambiguous specifications.
- Wrong selection of materials and systems.
- Undersize HVAC equipment selection.
- Incorrect water supply requirements.
- Estimated total electrical load is much lower than expected actual consumption.
- Errors in calculating traffic study for conveying system.
- Errors in estimating the project schedule.
- Errors in cost estimation.
- Number of drawings not as per TOR requirements.

Designer has to take into account the aforementioned risk factors while developing the schematic design.

Further, the designer has to consider the following risks while planning the duration for completion of schematic phase.

- Impractical schematic design preparation schedule.
- Delay to obtain authorities' approval.

- Delay in site investigations.
- Delay in data collection.

2.3.12 Monitor Work Progress

The designer has to prepare a work schedule to prepare a schematic design package in order to submit the same to the owner for review and approval. The schematic design progress has to be monitored to meet the submission schedule. Regular meetings to monitor the progress and coordination among different trades and regulatory authorities are required to ensure timely submission of schematic design packages.

2.3.13 Review Schematic Design

Table 2.15 illustrates the major points for analysis of a schematic design.

2.3.14 Finalize Schematic Design

Final schematic design is prepared incorporating the comments, if any, found during analysis and review of the drawings and documents for submission to the owner/client.

2.3.15 Submit Schematic Design

Normally, the following items are submitted to the owner for their review and approval in order to proceed with development of detail design:

1. Schematic design drawings.
2. Outline specifications.
3. Preliminary contract documents.
4. Preliminary schedule.
5. Budgetary cost estimate.
6. Schematic design reports.
7. Model.

2.4 DESIGN DEVELOPMENT PHASE

Design development is the third phase of construction project life cycle. It follows the preliminary design phase and takes into consideration the configuration and the allocated baseline derived during the preliminary phase. The design development phase is also known as the **detailed design/detailed engineering.** The client approved schematic (preliminary) design is the base for preparation of the design development or development of detailed design. All the comments, suggestions on the schematic design from client, regulatory bodies are reviewed and resolved to ensure that changes will not detract from meeting the project design goals/objectives. Detailed design involves the process of successively breaking down, analyzing, and designing the structure and its components so that it complies with the recognized codes

TABLE 2.15
Major Points for Analysis of Schematic Design

Serial Number	Description	Yes	No	Notes
A: Schematic Design (General)				
A.1	Does the design support the owner's project goals and objectives?			
A.2	Does the design meet all the elements specified in TOR?			
A.3	Whether comments on concept design taken care while preparing schematic design.			
A.4	Whether Regulatory approvals obtained.			
A.5	Does the design meet all the performance requirements?			
A.6	Whether constructability has been taken care.			
A.7	Whether technical and functional capability considered.			
A.8	Whether health and safety requirements in the design are considered.			
A.9	Whether design confirm with fire and egress requirements.			
A.10	Whether design risks have been identified, analyzed, and responses planned for mitigation.			
A.11	Whether environmental constraints considered.			
A.12	Was energy conservation is considered?			
A.13	Was sustainability considered in design?			
A.14	Whether cost effectiveness over the entire project life cycle is considered.			
A.15	Whether the design meets LEED requirements.			
A.16	Whether accessibility is considered.			
A.17	Does the design meet ease of maintenance?			
A.18	Does the design have provision for inclusion of facility management requirements?			
A.19	Does the design support proceeding to next design development stage?			
A.20	Whether all the drawings are numbered.			
B: Architectural				
B.1	Drawings coordinated with another discipline?			
B.2	Whether grid system is established.			
B.3	Whether zoning is taken care.			
B.4	Whether overall site plans show all the major areas.			
B.5	Whether floor plans show overall dimensions.			
B.6	Whether roof plans are shown?			
B.7	Whether preliminary elevations are shown.			
B.8	Whether all the rooms are numbered.			
B.9	Whether entrances, stairways, lobbies, corridors identified.			
B.10	Whether services rooms, equipment rooms, plant rooms identified.			
B.11	Whether finishes schedule/requirements prepared.			

(*Continued*)

TABLE 2.15 Continued
Major Points for Analysis of Schematic Design

Serial Number	Description	Yes	No	Notes
C: Structural				
C.1	Whether preliminary foundation plan shown.			
C.2	Whether structural systems identified.			
C.3	Whether preliminary building structure prepared.			
C.4	Whether preliminary framing plans for all floors and roof.			
C.5	Whether relevant codes regarding seismic zone, wind speed considered for structural load calculations.			
C.6	Whether slab loading for equipment considered.			
D: Elevator				
D.1	Whether traffic analysis performed.			
D.2	Whether elevator locations shown.			
D.3	Whether equipment room location shown.			
E: Mechanical				
E.1	Whether preliminary plans for toilets/rest rooms, pantry shown.			
E.2	Whether main water supply, sanitary, and stormwater system shown.			
E.3	Whether riser diagram/single line diagram for plumbing system shown.			
E.4	Whether plumbing fixtures identified.			
E.5	Whether fire protection system complies with regulatory requirements.			
E.6	Whether single line diagram for fire protection system (sprinkler) prepared.			
E.7	Whether equipment room (plant room) location shown.			
E.8	Whether special fire suppression system for electrical substation, generator room considered.			
F: HVAC				
F.1	Whether single line diagram is prepared for all related systems.			
F.2	Whether shaft locations and approximate pipe sizes, duct size shown.			
F.3	Whether location of plant room considered.			
F.4	Whether approximate load for chiller, pump sizes is considered on available data.			
F.5	Whether gross HVAC zoning and typical individual space zoning are considered while preparing the design.			
G: Electrical				
G.1	Whether preliminary lighting plans prepared.			
G.2	Whether preliminary power layout plans prepared.			
G.3	Whether substation location is shown.			
G.4	Whether electrical room located.			

(*Continued*)

TABLE 2.15 Continued
Major Points for Analysis of Schematic Design

Serial Number	Description	Yes	No	Notes
G.5	Whether cable tray and other raceways route shown.			
G.6	Whether riser shaft for cables, bus ducts considered.			
G.7	Whether system schematic diagram prepared.			
G.8	Whether fire alarm system complies with regulatory requirements.			
G.9	Whether preliminary plans for all low voltage systems (communication, public address, audiovisual, access control, security system) prepared.			
G.10	Whether emergency diesel generator is considered.			
H: Landscape				
H.1	Whether landscape plans prepared.			
H.2	Whether plants selected.			
H.3	Whether irrigation system layout prepared.			
I: External				
I.1	Whether site layout plans showing roads, walkways, parking areas, prepared.			
I.2	Whether street lighting plans prepared.			
I.3	Whether project site boundaries are properly marked and demarcated.			
J: Financial				
J.1	Project cost is properly estimated.			
K: Schedule				
K.1	Is project schedule is practically achievable?			
L: Value Engineering				
L.1	Whether value engineering study performed, and recommendations taken care.			
M: Reports				
M.1	Whether the narrative description complete and include adequate information about the project.			
M.2	Whether outline specifications include all the work.			
M.3	Whether preliminary contract documents have taken care all the TOR requirements.			
N: Drawings, Sketches				
N.1	Whether drawings, sketches for all trades prepared as per TOR.			
O: Models				
O.1	Whether the models meet the design objectives.			
P: Submittals				
P.1	Whether numbers of sets prepared as per TOR.			

and standards of safety, and performance while rendering the design in the form of drawings and specifications that will tell the contractors exactly how to build the facility to meet the owner's need. Table 2.16 illustrates the major activities relating to the design development phase based on the project management process group's methodology.

TABLE 2.16
Major Activities Relating to Design Development Phase Processes

Management Processes	Process Management Groups				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Integration Management	Schematic Design Deliverables Comments on Schematic Design TOR Requirements Authorities' Requirements	Project Management Plan	Data Collection/Site Investigations Detailed Design Drawings Bill of Quantities Model	Design Calculations Interdisciplinary Coordination Compliance to TOR	Detail Design Drawings
Stakeholder Management	Identify Design Team	Identify Stakeholders Stakeholders Requirements Stakeholders Matrix		Design Progress	
Scope Management		Owner's Needs, Project Goals and Objectives Design Development Design Documents Design Deliverables Bill of Quantity	Project Specifications	Authorities Approval Compliance to Owner's Need Stakeholders Approval	
Schedule Management		Activity Duration		Project Schedule	

(*Continued*)

TABLE 2.16 Continued
Major Activities Relating to Design Development Phase Processes

Management Processes	Process Management Groups				
	Initiating Process	Planning Process	Execution Process	Monitoring and Controlling Process	Closing Process
		Precedence Diagram			
		Construction Schedule			
Cost Management		Price Analysis		Project Budget	
		Bill of Quantities			
		Resources			
		Detailed Estimate			
Quality Management		Codes and Standards	Design Coordination with All Disciplines	Design Compliance to Owner's Goals and Objectives	
		Regulatory Requirements	Assure Design Quality	Coordination with all Disciplines	
		Design Criteria		Control Design Quality	
		Well-Defined Specifications			
		Plan Design Quality			
Resource Management		Estimate Project Resources	Manage Team Members from All Disciplines	Performance of Team Project Members	
Communication Management		Communication Matrix	Liaison with All Disciplines	Design Status Information	
			Coordination Meetings		

(*Continued*)

TABLE 2.16 Continued
Major Activities Relating to Design Development Phase Processes

Management Processes	Process Management Groups				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Risk Management		Identification of Risk during Bidding, Construction, Testing and Commissioning		Design Risk Control	
Contract Management		Bidding and Tendering Documents		Check for Contracting System	Contract Documents
HSE Management		Safety in Design	Safety Requirements		
		Environmental Compatibility	Environmental Requirements	HSE Compliance in Design	
Financial Management		Designer/ Consultant Payment		Payment to Designer/ Consultant	
Claim Management		Design Change Payment		Control Changes	Settle Designer's Claim

Note: These activities may not be strictly sequential, however, the breakdown allows implementation of project management function more effectively and easily manageable at different stages of the project phase.

2.4.1 Develop Design Development Requirements

Design development is the enhancement of the work carried out during schematic design phase. During this phase, a comprehensive design of work with a detailed work breakdown structure of design, drawings, specifications, and contract documents is prepared. The design development phase is the realm of design professionals, including architects, interior designers, landscape architects, and several other disciplines, such as civil, mechanical, electrical, and other engineering professionals as needed.

During this phase, detailed plans, sections, and elevations are drawn to scale, principal dimensions are noted, and design calculations are checked to confirm the accuracy of design and its compliance with the codes and standards.

2.4.1.1 Identify Design Development Requirements

In order to identify requirements to develop a detailed design, the designer has to gather comments made by the owner/project manager on the submitted schematic design, collect TOR requirements, regulatory requirements, and other related data to ensure that the developed design is accurate to the possible extent, free of errors and minimum omissions. Detailed design activities are similar although more in-depth than the design activities in the preliminary design stage. The size, shape, levels, performance characteristics, technical details, and requirements of all the individual components are established and integrated into the design. Design engineers of different trades have to take into consideration all these as a minimum while preparing the scope of work. The range of design work is determined by the nature of the construction project.

For the development of a detailed design the designer has to consider the following points:

1. Review of comments on the preliminary design by the client (project manager).
2. Review of comments on the preliminary design by the regulatory authorities.
3. Preparation of the detailed design for all the work.
4. Interdisciplinary coordination to resolve conflict.
5. Obtain regulatory approval.
6. Prepare project schedule.
7. Prepare project budget.
8. Prepare bill of quantity.
9. Prepare specifications.

2.4.1.1.1 Gather Schematic Design Comments

The objective of a detailed design is the enhancement of schematic design and to develop a clearly defined design based on the client's requirements. While developing the detailed design, the designer reviews the approved schematic design drawings, reports, and takes into consideration the comments, if any, made on the schematic design.

2.4.1.1.2 Identify TOR Requirements

Normally the TOR lists the requirements guidelines to develop a detailed design. It mainly consists of the following:

1. Detailed Design Drawings for Approved Schematic Design
2. Bill of Quantities
3. Project Specifications
4. Contract Documents
5. Project Schedule
6. Definitive Estimate
7. Format, Scales, and Size of Reports and Drawings

The TOR lists the following items to be developed during the detailed design taking into consideration the approved schematic design and comments:

1. Drawings
   1.1 Project Title

- 1.2 Drawing Index, Legends, and Symbols
- 1.3 Existing Site Condition
- 1.4 Site Plans
- 1.5 Architectural Design
- 1.6 Interior Design
- 1.7 Structural Design
- 1.8 Mechanical Design
  - 1.8.1 Public Health
  - 1.8.2 Fire Suppression
- 1.9 HVAC Design
- 1.10 Electrical Design
- 1.11 Smart Building Systems
- 1.12 Special Systems
- 1.13 Landscape Design
- 1.14 External Works

2. Project Specifications
3. Contract Documents
4. Project Schedule
5. Definitive Cost Estimate
6. Authorities Approvals

2.4.1.1.3 Collect Owner's Requirements

Any additional requirements/changes to those considered during development of schematic design are considered while developing the detailed design. This may include additional systems or changes in the preferred requirements.

2.4.1.1.4 Collect Regulatory Requirements

Government agency regulatory requirements have a considerable impact on pre-contract planning. Some agencies require that the design drawings be submitted for their preliminary review and approval to ensure that the designs are compatible with local codes and regulations. These include:

- Submission of drawings to electrical authorities showing the anticipated electrical load required for the facility.
- Fire alarm and firefighting system drawings.
- Water supply and drainage system.
- HVAC drawings to ensure compliance with energy conservation codes.
- Technical details of conveying system.

2.4.1.2 Establish Detailed Design Requirements

The Detail Design Requirements are developed considering all the items discussed under Section 2.4.1.1.

2.4.2 Develop Project Management Plan

Preliminary project management plan developed during the schematic phase is updated based on additional information collected during the detailed design phase. The contents of the project management plan are the same as that of schematic design, but additional information is added. Typical TOC of the project management plan is:

1. Project Description
2. Project Objectives
3. Project Organization
   3.1 Organization Chart
   3.2 Responsibility Matrix
   3.3 Project Directory
4. Project (Scope) Deliverables
5. Project Schedule
6. Project Budget
7. Project Quality Plan
8. Project Resources
9. Risk Management
10. Communication Matrix
11. Contract Management
12. HSE Management
13. Project Finance Management
14. Claim Settlement

2.4.3 Identify Project Stakeholders

The following stakeholders have direct involvement in the project during the detailed design phase:

- Owner
- Consultant
- Designer
- Regulatory Authorities
- Project/Construction Manager (if the owner decides to engage during this phase, depending on the type of project delivery system)

2.4.3.1 Identify Project Team Members

Generally, the project team members selected to develop schematic design continue during the detailed design phase. Additional design personnel are included to meet the workload to develop a detailed design.

2.4.3.2 Identify Design Team Members

Following are mainly the design members with their major responsibilities:

1. Design Manager
   a. Design criteria.
   b. Design standards.
   c. Design development.
   d. Quality control.

2. Project Manager
   a. Client management.
   b. Contract requirements.
   c. Budget requirements.
   d. Schedule.
   e. Resources.
3. Quality Manager
   a. Quality management plan.
   b. Quality assurance procedures.
   c. Quality control procedures.

Each of the managers has many other team members. These members are selected based on the organizational structure and suitable skills required to perform the job. These include:

1. Team Leader (Principal Engineer)—Each Trade
2. Team Members (Engineers and CAD Technicians for Each Discipline)
3. Quantity Surveyor (Cost Engineer)
4. Owner's Representative
5. End User

2.4.3.3 Establish Stakeholder's Requirement

A distribution matrix based on the interest and involvement of each stakeholder is prepared, and the appropriate documents are sent for their action/information as per the agreed-upon requirements.

2.4.3.4 Develop Responsibility Matrix

Table 2.17 illustrates responsibilities of various participants during the detailed design phase.

TABLE 2.17
Responsibilities of Various Participants (Design-Bid-Build Type of Contracts) during Detailed Design Phase

Phase	Responsibilities		
	Owner	**Designer**	**Regulatory Authorities**
Design Development	• Approval of design. • Approval of time schedule. • Approval of budget.	• Development of detailed design. • Submission for authorities approval. • Detailed plans. • Schedule. • Budget. • BOQ. • Verification of design.	• Review and approval of project submittals.

2.4.4 Develop Design Development Scope

Design development scope is developed taking into consideration requirements established under Section 2.4.1.2 which are as follows:

- Approved schematic design documents.
- TOR requirements.
- Owner's preferred requirements.
- Regulatory requirements.
- Approved preliminary project schedule.
- Approved preliminary cost estimate.
- Codes and standards.

The purpose of the development of a detailed design is to provide sufficient information and detail to ensure that the work to be performed by the contractor is properly identified and correctly addressed taking necessary measures to mitigate errors and omissions in the design. The scope of work during the detailed design phase mainly comprises:

- Design development drawings.
- Technical specifications.
- Bill of quantities.
- Project schedule.
- Detailed cost estimate.
- Authorities' approvals.
- Design development report.

2.4.4.1 Identify Design Deliverables

Based on the scope for design development, the following are the major deliverables to be developed during this phase:

1. Design Drawings
   1.1 Site plans
   1.2 Architectural
   1.3 Interior
   1.4 Structural
   1.5 Conveying System
   1.6 Mechanical (public health and fire suppression)
   1.7 HVAC
   1.8 Electrical
   1.9 Low Voltage System
   1.10 Landscape
   1.11 External
2. Specifications
3. Project Schedule

TABLE 2.18
Detailed Design Deliverables

Serial Number	Deliverables
1	General
1.1	a. Project Specifications
	b. Project Schedule
	c. Project Estimate
	d. Bill of Quantities
	e. Calculations (All Trades)
	f. Site Investigations
	g. Design Report
	h. Model
2	Detailed Design Drawings
2.1	Architectural
2.1.1	Overall Site Plans
2.1.2	Floor Plans
2.1.3	Roof Plans
2.1.4	Elevations
2.2	Structural
2.3	Elevator
2.4	Plumbing and Fire Suppression
2.5	HVAC
2.6	Electrical
2.7	Landscape
2.8	External

4. Definitive Cost Estimate
5. Regulatory Approvals

Table 2.18 lists design development deliverables to be developed during the design development phase.

2.4.5 Develop Detailed Design

Figure 2.13 illustrates design development stages.

The designer has to collect data/information, perform site investigations, and verify the information is same as collected earlier.

2.4.5.1 Collect Data/Information

The designer has to collect all the missing data to ensure that a detailed design is developed without any errors and omissions.

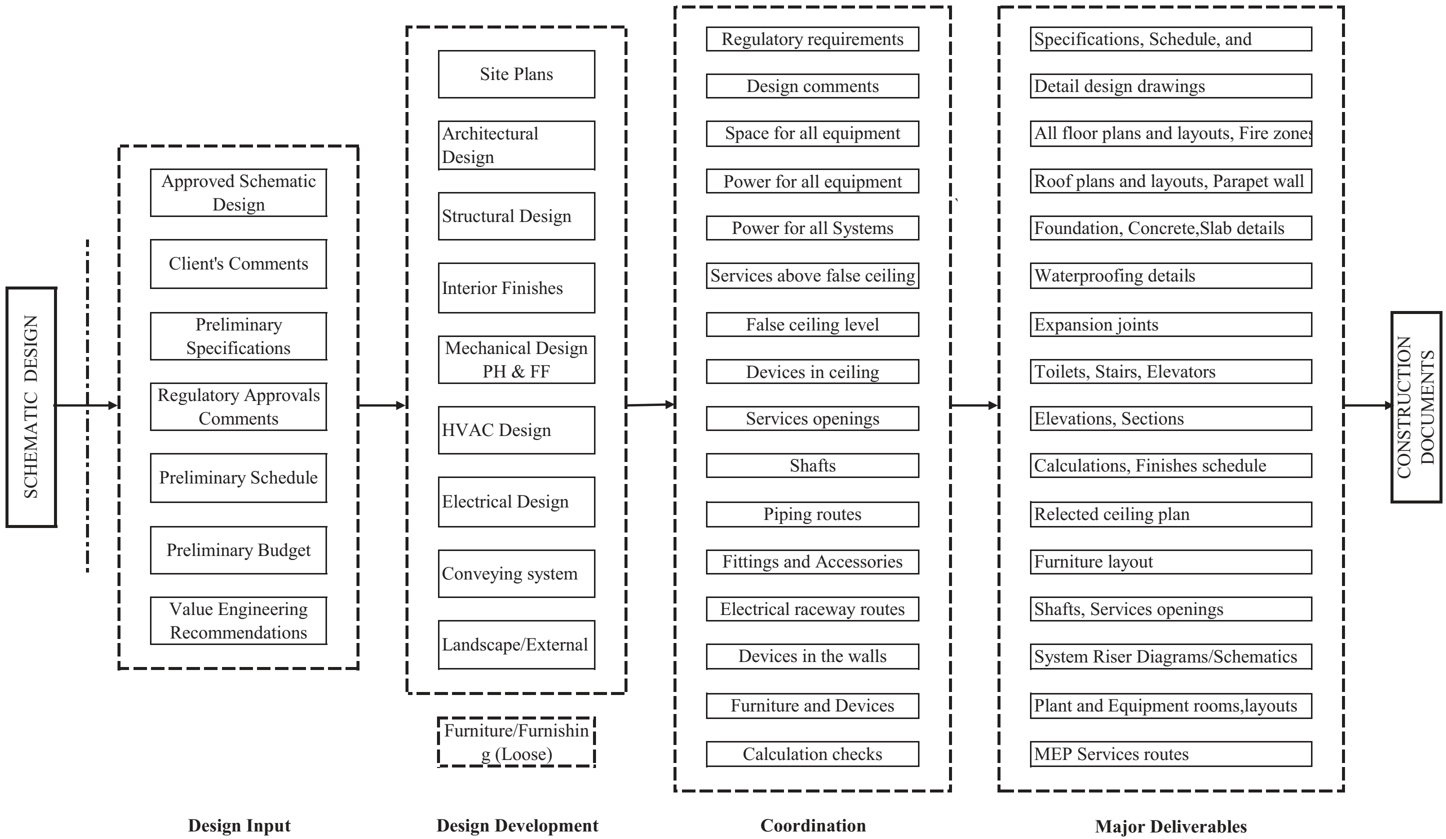


FIGURE 2.13 Design development stages.

2.4.5.2 Perform Site Investigations

The designer has to revisit the site to ensure that there are not many changes to the earlier performed investigations.

2.4.5.3 Prepare Detailed Design

Following detailed drawings for building projects are generally prepared during this phase:

- Architectural
  - Site plans.
  - Floor plans.
  - Roof plans.
  - Partitions.
  - Sections.
  - Elevations.
  - Reflected ceiling plan.
  - Finishes schedule.
  - Door schedule.
  - Typical window details.
  - Furnishings.
- Structural.
  - Building structure.
  - Foundation system.
  - Footings.
  - Stairs.
  - Roof.
  - Sections.
  - Structural floor plans.
- Conveying system.
  - Elevator location.
  - Machine room.
- MEP.
  - General arrangement of each system.
  - Single line riser diagram.
  - Electrical schematic diagram.
  - Layout of equipment rooms.
  - Layout of electrical substation.
  - Electrical rooms.
  - Vertical shafts.
- Security system.
- External work.
- Landscape plans.

2.4.5.3.1 Design Calculations

The designer has to submit the following calculations along with the detailed design:

- Calculation of all structural elements (structural work).
- Calculation of lighting (Isolux calculations).

- Short circuit calculations for cables.
- Lightning protection system.
- Earthing (grounding) system.
- Sound system (audiovisual system).

2.4.5.3.2 Detailed Design of the Work

The following are the aspects of work to be considered by design professionals while preparing the detailed design. These can be considered as a base for the development of design to meet customer requirements and shall help achieve the qualitative project:

1. Architectural Design
   - Intent/use of building/facility.
   - Property limits.
   - Aesthetic look of the building.
   - Environmental conditions.
   - Elevations.
   - Plans.
   - Axes, grids, levels.
   - Room size to suit the occupancy and purpose.
   - Zoning as per usage/authorities' requirements.
   - Identification of zones, areas, rooms.
   - Modules to match with structural layout/plan.
   - Number of floors.
   - Ventilation.
   - Thermal insulation details.
   - Stairs, elevators (horizontal and vertical transportation).
   - Fire exits.
   - Ceiling height and details.
   - Reflected ceiling plan.
   - Internal finishes.
   - Internal cladding.
   - Partition details.
   - Masonry details.
   - Joinery details.
   - Schedule of doors and windows.
   - Utility services.
   - Toilet details.
   - Required electromechanical services.
   - External finishes.
   - External cladding.
   - Glazing details.
   - Finishes schedule.
   - Door schedule.
   - Window schedule.
   - Hardware schedule.

- Special equipment.
- Fabrication of items, such as space frame, steel construction, retaining wall, having special importance for appearance/finishes.
- Special material/product to be considered, if any.
- Any new material/product to be introduced.
- Conveying system core details.
- Maintenance access for equipment/services requirements.
- Ramp details.
- Hard and soft landscape.
- Parking areas.
- Provision for future expansion (if required).

2. Concrete Structure
    - Property limits/surrounding areas.
    - Type of foundation.
    - Energy efficient foundation.
    - Design of foundation based on field and laboratory tests of soil investigation that gives the following information:
        a. Subsurface profiles, subsurface conditions, and subsurface drainage.
        b. Allowable bearing pressure and immediate and long-term settlement of footing.
        c. Co-Efficient of sliding on foundation soil.
        d. Degree of difficulty for excavation.
        e. Required depth of stripping and wasting.
        f. Methods of protecting below-grade concrete members against impact of soil and ground water (water and moisture problems, termite control and radon where appropriate).
        g. Geotechnical design parameters, such as Angle of shear resistance, cohesion, soil density, modulus of deformation, modulus of subgrade reaction, and predominant soil type.
        h. Design loads, such as Dead load, live load, wind load, and seismic load.
    - Footings.
    - Grade and type of concrete.
    - Size of bars for reinforcement and the characteristic strength of bars.
    - Clear cover for reinforcement for:
        a. Raft foundation.
        b. Underground structure.
        c. Exposed to weather structures, such as columns, beams, slabs, walls, and joists.
        d. Not exposed to weather, such as columns, beams, slabs, walls, and joists.
    - Reinforcement bar schedule, stirrup spacing.
    - Expansion joints.
    - Concrete tanks (water).
    - Insulation.
    - Services requirements (shafts, pits).
    - Shafts and pits for conveying system.
    - Location of columns in coordination with architectural requirements.

- Number of floors.
- Height of each floor.
- Beam size and height of beam.
- Openings for services.
- Substructure:
  a. Columns
  b. Retaining Walls
  c. Walls
  d. Stairs
  e. Beams
  f. Slab
- Super structure:
  a. Columns
  b. Stairs
  c. Walls
  d. Beams
  e. Slabs
- Consideration of water proofing requirements for roof slab against water leakage.
- Deflection that may cause fatigue of structural elements, crack or failure of fixtures, fittings, or partitions,. or discomfort of occupants.
- Movement and forces due to temperature.
- Equipment vibration criteria.
- Load sensors to measure deflection.
- Reinforcement bar schedule, stirrup spacing.
- Building services to fit in the building.
- Environmental compatibility.
- Parapet wall.
- Excavation.
- Dewatering.
- Shoring.
- Backfilling.

3. Elevator Work
   - Type of elevator.
   - Loading capacity.
   - Speed.
   - Number of stops.
   - Travel height.
   - Cabin, cabin accessories, cabin finishes, and car operating system.
   - Door, door finishes, and door system.
   - Safety features.
   - Drive, size, and type of motor.
   - Floor indicators, call button.
   - Control system.
   - Cab overhead dimensions.

- Pit depth.
- Hoistway.
- Machine room.
- Operating system.

4. Fire Suppression System

   The fire protection system is mainly to provide protection against fire to life and property. The system is designed taking into consideration local fire codes and NFPA standards. The system includes:
   - Sprinkler system for fire suppression in all areas of the building.
   - Hydrants (landing valve) for professional fighting.
   - Hose reel for public use throughout the building.
   - Gaseous fire protection system for communication rooms.
   - Fire protection system for diesel generator room.
   - Size of fire pumps and controls.
   - Pump size (GPM) based on applicable codes and standards.
   - Fittings and Accessories for pressure drop in the system.
   - Friction loss in the most remote area.
   - Size of elbow or tees fitted on the upstream of fire pump.
   - Space requirements for pumps and other equipment (pump room).
   - Source of water supply for fire pumps.
   - Water storage facility.
   - Interface with other related systems.
5. Plumbing Work
   - Maximum working pressure to have adequate pressure and flow of water supply.
   - Location of pressure relief valves.
   - Maximum design velocity.
   - Maximum probable demand.
   - Demand weight of fixture in fixture unit's public use.
   - Friction loss calculation.
   - Pipe slope.
   - Maximum hot water temperature at fixture outlet.
   - Water heater outlet hot temperature.
   - Providing isolating valves to ensure that the system shall be easy for maintenance.
   - Hot water system.
   - Central water storage capacities.
   - Location of storage tank.
   - Size of pumps and controls.
   - Grounding of equipment and metal piping.
   - Space requirements for pump and other equipment (pump room).
   - Schematic diagram for water distribution system.
6. Drainage System

   While designing the drainage system, schedule of foul drainage demand units and frequency factors for the following items to be considered for sizing of piping system, number of manholes, capacity of sump pit, size of sump pump, and the following:

- Wash basins.
- Showers.
- Urinals.
- Water closets (bathrooms).
- Kitchen sinks.
- Location of vents and traps.
- Location of cleanouts.
- Other equipment such as dishwashers and washing machines.

7. HVAC Work
   - Environmental conditions.
   - Outdoor design conditions.
   - Indoor design conditions.
   - Air conditioning calculations:
     a. Cooling load calculations.
     b. Heating load calculations.
     c. Space temperature and humidity at required set point.
     d. Occupancy load.
     e. Lighting load.
   - Room pressurizing and leakage calculations.
   - Energy consumption calculations.
   - Air conditioning calculations for IT equipment room(s) based on heat emission of equipment.
   - Air distribution system calculations.
   - Smoke extract ventilation calculations.
   - Exhaust ventilation calculations.
   - Ductwork sizing calculations.
   - Selection of the ductwork components such as balancing dampers, constant volume boxes, variable air volume boxes, attenuators, grilles and diffusers, fire dampers, pressure relief dampers, etc.
   - Pipe work sizing calculations.
   - Selection of the inline pipework components, for example, valves, strainers, air vents, commissioning sets, flexible connections, sensors, etc.
   - Selection of boilers, pressurization units, air conditioning calculations.
   - Pipework and ductwork insulation selection.
   - Details of grilles and diffusers, control valves, etc.
   - Selection of the ductwork systems plant and equipment, for example, air handling units, fan coil units, filters, coils, fans, humidifiers, duct heaters, etc.
   - Selection of chillers, cooling towers.
   - Selection of pumps.
   - Selection of fans.
   - Equipment system calculations.
   - Space requirements for chillers, cooling towers, pumps, and other equipment (plant room).

- Mechanical room location and access.
- Preparation of the plan and section layouts, and plant room drawings.
- Electrical load calculations.
- Comparison of electrical consumption with electrical conservation code.
- Preparation of equipment schedules.
- HVAC-related electrical work.
- Control details.
- Starter panels, MCC panels, schematic diagram of MCC.
- Selection of program equipment.
- Preparation of point schedule for building management system.
- Schematic diagram for BMS.

8. Electrical System
    - Lighting calculations for different areas based on illumination level recommended by CIE/CEN/CIBSE and Isolux diagrams.
    - Selection of light fittings, type of lamps.
    - Selection of control gear for light fixtures.
    - Environmental consideration for selection of light fixture and control gear.
    - EXIT/EMERGENCY lighting system.
    - Circuiting references, normal as well as emergency.
    - Sizing of conduits.
    - Power for wiring devices.
    - Power supply for equipment (HVAC, Public Health and Fire Fighting, conveying system, others).
    - Sizing of cable tray.
    - Sizing of cable trunking.
    - Selection (type and size) of wires and cable.
    - Voltage drop calculations for wires and cables.
    - Selection of upstream and downstream breakers.
    - Derating factor.
    - Sensitivity of breakers (degree of protection).
    - Selection of isolators.
    - IP ratings (degree of ingress protection) of panels, boards, isolators.
    - Schedule of distribution boards, switchboards, and main low-tension boards.
    - Cable entry details.
    - Location of distribution boards, switchboards, and low-tension panels.
    - Short circuit calculations.
    - Sizing of diesel generator set for emergency power supply.
    - Sizing of ATS (automatic transfer switch).
    - Generator room layout.
    - Sizing of capacitor bank.
    - Provision for solar system integration.
    - Schematic diagrams.
    - Sizing of transformers.
    - Substation layout.

- Calculations for grounding (earthing) system.
- Grounding system layout.
- Calculations for lightning protection system.
- Lightning protection system layout.

9. Fire Alarm System

   Fire alarm system is designed taking into consideration local fire code and NFPA standards. The system includes:
   - Conduiting and raceways.
   - Type of system—analog/digital/addressable.
   - Type of detectors based on the area and spacing between the detectors and the walls.
   - Break glass/pull station.
   - Type of horns/bells.
   - Voice evacuation system, if required.
   - Type of wires and cables.
   - Mimic panel, if required.
   - Repeater panel, if required.
   - Main control panel.
   - Location of panels.
   - Interface with other systems such as HVAC, elevator.
   - Riser diagram.
10. Information and Communication Technology
    - Structured cabling considering type and size of cable, copper. fiber optic.
    - Racks.
    - Wiring accessories/devices.
    - Access/distribution switches.
    - Internet switches.
    - Core switch.
    - Access gateway.
    - Router.
    - Network management system.
    - Servers.
    - Telephone handsets.
11. Public Address System
    - Conduiting and raceways.
    - Type of system—analog/digital/IP based.
    - Types of wires and cables.
    - Types of speakers.
    - Distribution of speakers.
    - Required noise level in different areas.
    - Calculations for sound pressure level.
    - Zoning of system, if required.
    - Size and type of pre-mixer.
    - Size and type of amplifier.
    - Microphones.
    - Paging system.

- Message recorder/player.
- Interface with other systems.

12. Audiovisual System
    - Conduiting and raceways.
    - Type of system—analog/digital/IP-Based.
    - Types of wires and cables.
    - Racks.
    - Type, size, and brightness of projectors.
    - Type and size of speakers and sound pressure level.
    - Type and size of screens.
    - Microphones.
    - Cameras (visualizers).
    - CD/DVD players-recorders.
    - Control processors.
    - Video switch matrix.
    - Mounting details of equipment.
13. Security System/CCTV
    - Type of system—digital/IP-Based.
    - Conduiting and raceways.
    - Wires and cabling network.
    - Level of security required.
    - Type and size of cameras.
    - Types of monitors/screens.
    - Video/event recording.
    - Video servers.
    - Database server.
    - System software.
    - Schematic diagram.
    - System console.
14. Security System/Access Control
    - Conduiting and raceways.
    - Wires and cabling network.
    - Proximity RFID reader.
    - Fingerprint and proximity combine reader.
    - Magnetic lock.
    - Release button.
    - Door contact.
    - RFID card.
    - Reader control panel.
    - Multiplexers.
    - Monitors.
    - Server.
    - Workstation.
    - Metal detector.
    - Road blocker.
    - Parking control.

15. Landscape

    As a landscape architect, the following points are to be considered while designing the landscape system:
    - Property boundaries.
    - Size and shape of the plot.
    - Shape and type of dwelling.
    - Integration with surrounding areas.
    - Orientation to the sun and wind.
    - Climatic/environmental conditions.
    - Ecological constraints (soil, vegetation, etc.).
    - Location of pedestrian paths and walkways.
    - Pavement.
    - Garage and driveway.
    - Vehicular circulation.
    - Location of sidewalk.
    - Play areas and other social/community requirements.
    - Outdoor seating.
    - Location of services, positions of both under and above utilities, and their levels.
    - Location of existing plants, rocks, or other features.
    - Site clearance requirements.
    - Foundation for paving, including front drive.
    - Top soiling, or topsoil replacement.
    - Soil for planting.
    - Planting of trees, shrubs, and ground covers.
    - Grass area.
    - Sowing grass or turfing.
    - Lighting poles/bollards.
    - Special features, if required.
    - Signage, if required.
    - Surveillance, if required.
    - Installation of irrigation system.
    - Marking out the borders.
    - Storage for landscape maintenance material.
16. External Work (Infrastructure and Road)

    External work is part of the contract requirements of a project that involves construction of a service road and other infrastructure facilities to be connected to the building and to take care of existing services passing through the project boundary line. The designer has to consider the following while designing external work:
    - Grading material.
    - Asphalt paving for road or street.
    - Pavement.
    - Pavement marking.
    - Precast concrete curbs.
    - Curbstones.

- External lighting.
- Cable routes.
- Piping routes for water, drainage, stormwater system.
- Trenches or tunnels.
- Bollards.
- Manholes and hand holes.
- Traffic marking.
- Traffic signals.
- Boundary wall/retaining wall, if required.

17. Bridges

    Designer shall use relevant authorities' design manual and standards and consider the following points while designing the bridges:

    - Soil stability.
    - Alignment with road width, property lines.
    - Speed.
    - Intersections/interchanges.
    - Number of lanes, width.
    - Right-Of-Way lines.
    - Exits, approaches, and access.
    - Elevation datum.
    - Superelevation.
    - Clearance with respect to railroad, roadway, navigation (if applicable).
    - High and low levels of water (if applicable).
    - Utilities passing through the bridge length.
    - Slopes.
    - Number and length of spans.
    - Live loads, bearing capacity.
    - Water load, wind load, earthquake effect (seismic effect).
    - Bridge rails, protecting screening, guard rails, barriers.
    - Shoulder width.
    - Footings, columns, and piles.
    - Abutment.
    - Beams.
    - Substructure.
    - Super structure, deck slab.
    - Girders.
    - Slab thickness.
    - Reinforcement.
    - Supporting components, deck hanger, tied arch.
    - Expansion and fixed joints.
    - Retaining walls, crash wall.
    - Drainage.
    - Lighting.
    - Aesthetic.
    - Sidewalk, pedestrian, and bike facilities.
    - Signage, signals.

- Durability.
- Sustainability.

18. Highways

    The designer shall use relevant authorities' design manual and standards and consider the following points while designing the highways:

    - Type of highway.
    - Soil stability.
    - Speed.
    - Number of lanes, width.
    - Shoulder width.
    - Gradation.
    - Subgrade level.
    - Subbase level.
    - Types of asphalt courses.
    - Pavement details.
    - Type of pavement and thickness.
    - Right-Of-Way lines.
    - Exits, approaches, access, and ramp.
    - Superelevation.
    - Slopes, curvature, turning.
    - Median, barriers, curb.
    - Sidewalks, driveways.
    - Pedestrian accommodation.
    - Bridge roadway width.
    - Drainage.
    - Gutters.
    - Special conditions such as snow, rain.
    - Lighting.
    - Substation to feed streetlights.
    - Signage, markings.
    - Signals.
    - Trees, plants.
    - Parking area.
    - Rest area.
    - Toll station, if any.
    - Speed detectors, if applicable.
    - Durability.
    - Sustainability.

19. Furnishings/Furniture (Loose)

    In building construction projects, loose furnishings/furniture are tendered as a special package and are normally not part of the main contract. In order to express all the features of the furnishing/furniture products in the specification the descriptive feature of the product is not enough. In order to give enough information and understanding of the product, the product specifications are accompanied bya pictorial view/cut-out sheet/photo of the product and the furniture layout.

20. Solar System

    The designer should consider the following points while developing a solar power system:

    - Avoid shading from trees, buildings, etc. (especially during peak sunlight hours).
    - Check the proposed plan for the proposed site to ensure that future, neighboring construction will not cast shade on the array.
    - Determine where solar array can be placed (roof, carport, façade, curtain wall, boundaries, double skin, or elsewhere.
    - Keep the south-facing section obstruction-free, if possible, If the roof is sloped, the south-facing section will optimize the system performance.
    - Minimize rooftop equipment to maximize available open area for solar collector placement.
    - Ensure that the design of the type of roof will have adequate space to install solar system at later stage to optimize cost of installing solar system at later stage.
    - Ensure the roof is capable of carrying the load of solar equipment.
    - Analyze wind loads on rooftop solar equipment in order to ensure that the roof structure is sufficient.
    - Add additional safety equipment for solar equipment access and installation.

2.4.5.3.3 Develop Documents

The designer/consultant is responsible for preparing detailed specifications and contract documents that meet the owner's needs and specify the required level of quality, schedule, and budget.

2.4.5.3.3.1 Prepare Specifications Specifications of work quality are an important feature of construction project design. Specifications of required quality and components represent part of the contract documents and are detailed under various sections of particular specifications. Generally, the contract documents include all the details as well as references to generally accepted quality standards published by international standards organizations. Proper specifications and contract documentation are extremely important as these are used by the contractor as a measure of quality compliance during the construction process.

Particular specifications consist of many sections related to specific topics. Detailed requirements are written in these sections to enable contractors to understand the product or system to be installed in the construction project. The designer has to interact with project team members and the owner while preparing the contract documents.

Generalized writing of these sections is as follows:

Section No. Title

Part 1 General

1.01 General Reference/Related Sections

1.02 Description of Work

1.03 Related Work Specified Elsewhere in Other Sections
1.04 Submittals
1.05 Delivery, Handling, and Storage
1.06 Spare Parts
1.07 Warranties

In addition to the aforementioned, a reference is made for items such as preparation of mock-up, quality control plan, and any other specific requirement related to the product or system specified herein.

Part 2 Product

2.01 Materials
2.02 Manufacturer's Qualification/List of Recommended Manufacturers

Part 3 Execution

3.01 Installation
3.02 Site Quality Control

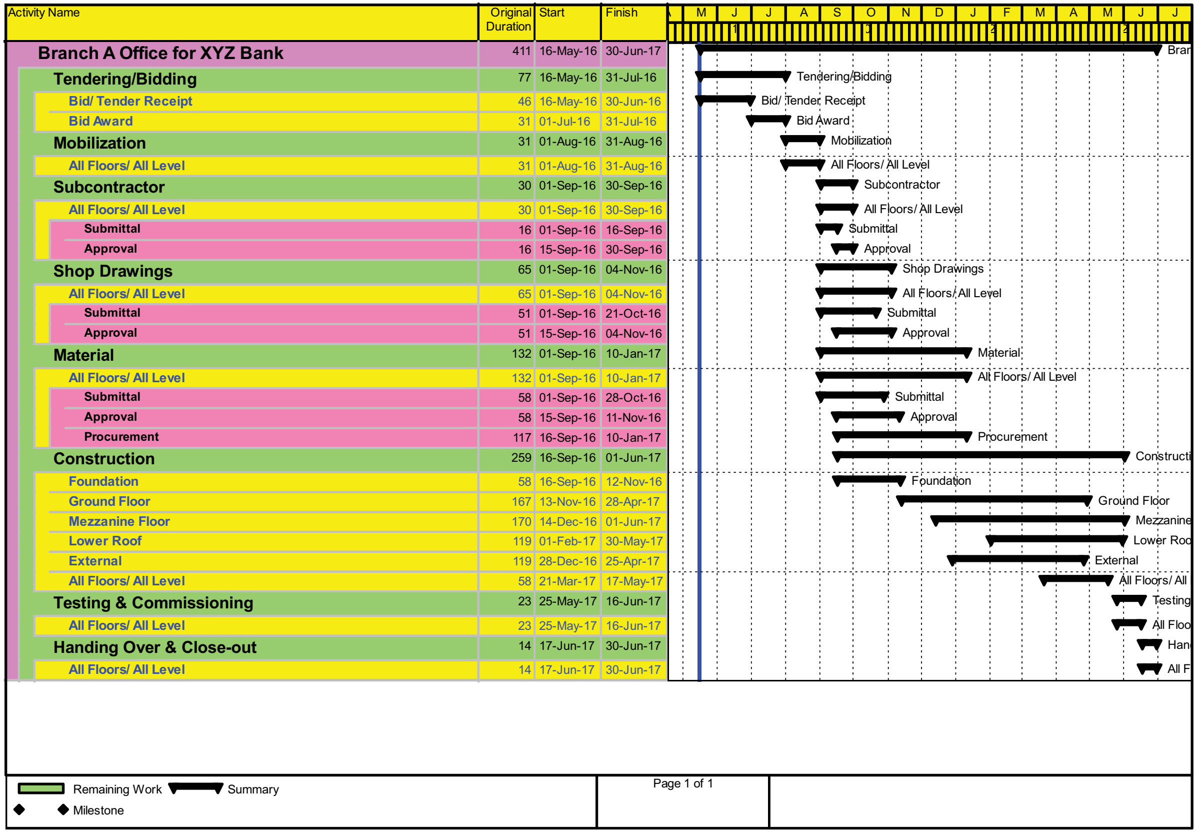
2.4.5.3.3.2 Prepare Contract Documents Preparation of detailed documents and specifications as per MasterFormat® is one of the activities performed during this phase of the construction project. The contract documents must specify the scope of work, location, quality, and duration for completion of the facility. As regards the technical specifications of the construction project, master format specifications are included in the contract documents. Normally, construction documents are prepared as per MasterFormat® contract documents produced jointly by the Construction Specification Institute (CSI) and Construction Specifications Canada (CSC) are widely accepted as standard practice for preparation of contract documents.

MasterFormat® is a master list of section titles and numbers for organizing information about construction requirements, products, and activities into a standard sequence. MasterFormat® is a uniform system for organizing information in project manuals, for organizing cost data, for filling in product information and other technical data, for identifying drawing objects, and for presenting construction market data. MasterFormat® 2014 Edition consists of 48 divisions (division 49 is reserved). (For more information, please refer to Chapter 6 in Volume 1.)

2.4.6 Prepare Schedule

The project schedule is developed using bottom-up planning details using key events. It is also known as Class 1 Schedule or Schedule Level 3 (please refer to Table 1.20 and Table 1.21).

Figure 2.14 illustrates a typical time schedule for a construction project. (The example schedule is the construction of a branch for a bank.)



Activity Name	Original Duration	Start	Finish
Branch A Office for XYZ Bank	411	16-May-16	30-Jun-17
Tendering/Bidding	77	16-May-16	31-Jul-16
Bid/ Tender Receipt	46	16-May-16	30-Jun-16
Bid Award	31	01-Jul-16	31-Jul-16
Mobilization	31	01-Aug-16	31-Aug-16
All Floors/ All Level	31	01-Aug-16	31-Aug-16
Subcontractor	30	01-Sep-16	30-Sep-16
All Floors/ All Level	30	01-Sep-16	30-Sep-16
Submittal	16	01-Sep-16	16-Sep-16
Approval	16	15-Sep-16	30-Sep-16
Shop Drawings	65	01-Sep-16	04-Nov-16
All Floors/ All Level	65	01-Sep-16	04-Nov-16
Submittal	51	01-Sep-16	21-Oct-16
Approval	51	15-Sep-16	04-Nov-16
Material	132	01-Sep-16	10-Jan-17
All Floors/ All Level	132	01-Sep-16	10-Jan-17
Submittal	58	01-Sep-16	28-Oct-16
Approval	58	15-Sep-16	11-Nov-16
Procurement	117	16-Sep-16	10-Jan-17
Construction	259	16-Sep-16	01-Jun-17
Foundation	58	16-Sep-16	12-Nov-16
Ground Floor	167	13-Nov-16	28-Apr-17
Mezzanine Floor	170	14-Dec-16	01-Jun-17
Lower Roof	119	01-Feb-17	30-May-17
External	119	28-Dec-16	25-Apr-17
All Floors/ All Level	58	21-Mar-17	17-May-17
Testing & Commissioning	23	25-May-17	16-Jun-17
All Floors/ All Level	23	25-May-17	16-Jun-17
Handing Over & Close-out	14	17-Jun-17	30-Jun-17
All Floors/ All Level	14	17-Jun-17	30-Jun-17

FIGURE 2.14 Typical time schedule.

2.4.7 Estimate Cost

The cost estimate during this phase is based on elemental parametric methodology. It is also known as detailed costing (detailed estimate) (please refer to Table 1.23).

2.4.8 Manage Design Quality

In order to reduce errors and omissions, it is necessary to review and check the design for quality assurance by the quality control personnel from the project team through itemized review checklists to ensure that design drawings fully meet the owner's objectives/goals. It is also required to review the design with the owner to ensure a mutual understanding of the build/construction process. The designer has to ensure that the installation/execution specification details are comprehensively and correctly described and the installation quality requirements for systems are specified in detail.

The designer has to plan quality (planning of design work), perform quality assurance, and control quality for preparing detailed designs. This will mainly consist of the following:

1. Plan Quality
   - Review comments on schematic design.
   - Determine number of drawings to be produced.
   - Establish scope of work for preparation of detailed design.
   - Identify requirements listed under TOR.
   - Identify quality standards and codes to be complied.
   - Establish design criteria.
   - Identify regulatory requirements.
   - Identify environmental requirements.
   - Establish quality organization with responsibility matrix.
   - Develop design (drawings and documents) review procedure.
   - Establish submittal plan.
   - Establish design review procedure.
2. Quality Assurance
   - Collect data.
   - Investigate site conditions.
   - Prepare design drawings.
   - Prepare detailed specifications.
   - Prepare contract documents.
   - Prepare bill of quantities.
   - Ensure functional and technical compatibility.
   - Ensure the design is constructible.
   - Ensure operational objectives are met.
   - Ensure drawings are fully coordinated with all disciplines.
   - Ensure the design is cost-effective.
   - Ensure selected/recommended material meets the owner's objectives.
   - Ensure that design fully meets the owner's objectives/goals.
3. Control Quality
   - Check quality of design drawings.

TABLE 2.19
Checklist for Design Drawings

Serial Number	Items to be Checked
1	Whether design meets owner requirements and complete scope of work (TOR).
2	Whether designs were prepared using authenticated and approved software.
3	Whether design calculation sheets are included in the set of documents.
4	Whether design is fully coordinated for conflict between different trades.
5	Whether design has taken into consideration relevant collected data requirements.
6	Whether reviewer's comments responded.
7	Whether regulatory approval obtained and comments, if any, incorporated and all review comments responded.
8	Whether design has environmental compatibility.
9	Whether energy efficiency measures are considered?
10	Whether design constructability is considered.
11	Whether design matches with property limits.
12	Whether legends match with layout.
13	Whether design drawings are properly numbered.
14	Whether design drawings have owner logo, designer logo as per standard format.
15	Whether the design format of different trades have uniformity.
16	Whether project name and contract reference are shown on the drawing.

- Check accuracy and correctness of design.
- Verify bill of quantities.
- Check specifications.
- Check contract documents.
- Check for regulatory compliance.
- Check project schedule.
- Check project cost.
- Check interdisciplinary requirements.
- Check required number of drawings prepared.

A BIM tool can be used to control the quality of the project (please refer to Chapter 5 of Volume 1 for more information).

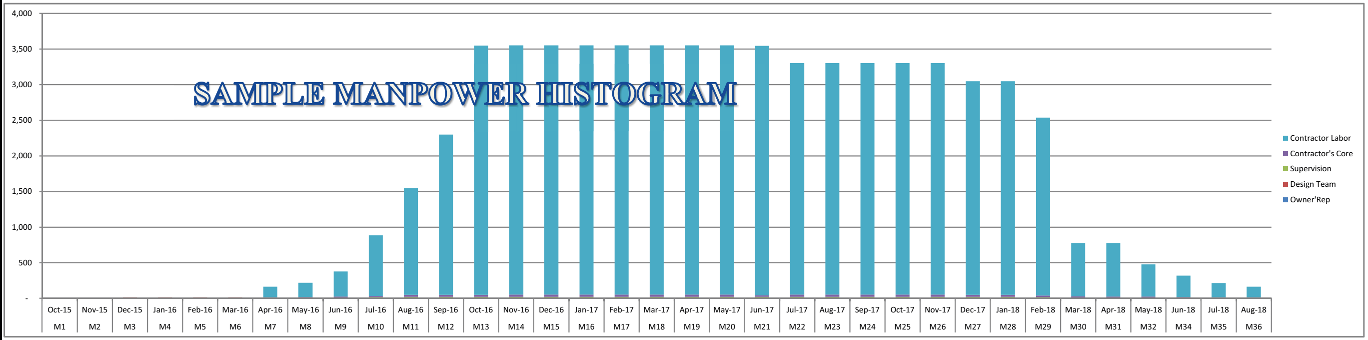
Table 2.19 lists items to be verified and checked internally by the designer before submission to the owner/project manager. (Please refer to Table 4.14 in Volume 1 for mistake proofing.)

2.4.9 Estimate Resources

Designer has to estimate the resources required to complete the project. During the design development phase, detailed information is available to estimate manpower resources during the construction phase. Figure 2.15 illustrates estimated manpower resources during construction and testing, commissioning, and handover phases.

Project Name

MANPOWER HISTOGRAM



Month/ Category	M1 ####	M2 ####	M3 ####	M4 ####	M5 ####	M6 ####	M7 ####	M8 ####	M9 ####	M10 ####	M11 ####	M12 ####	M13 ####	M14 ####	M15 ####	M16 ####	M17 ####	M18 ####
Owner'Rep	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Design Team	5	10	15	15	15	15	3	2	2	2	2	2	2	2	2	2	2	2
Supervision	-	-	-	-	-	-	5	7	9	15	20	20	20	20	20	20	20	20
Contractor's Core	-	-	-	-	-	-	5	10	15	15	25	25	25	30	30	30	30	30
Contractor Labor	-	-	-	-	-	-	150	200	350	850	1,500	2,250	3,500	3,500	3,500	3,500	3,500	3,500
TOTAL	**6**	**11**	**16**	**16**	**16**	**16**	**164**	**220**	**377**	**883**	**1,548**	**2,298**	**3,548**	**3,553**	**3,553**	**3,553**	**3,553**	**3,553**

Month/ Category	M19 ####	M20 ####	M21 ####	M22 ####	M23 ####	M24 ####	M25 ####	M26 ####	M27 ####	M28 ####	M29 ####	M30 ####	M31 ####	M32 ####	M34 ####	M35 ####	M36 ####	Total MM	PEAK
Owner'Rep	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	35	**1**
Design Team	2	2	2	2	2	2	2	2	2	2	2	2	1	-	-	-	-	125	**15**
Supervision	20	20	20	20	20	20	20	20	20	20	15	10	10	10	6	4	3	454	**20**
Contractor's Core	30	30	20	30	30	30	30	30	25	25	20	15	15	15	10	10	10	645	**30**
Contractor Labor	3,500	3,500	3,500	3,250	3,250	3,250	3,250	3,250	3,000	3,000	2,500	750	750	450	300	200	150	64,150	**3,500**
TOTAL	**3,553**	**3,553**	**3,543**	**3,303**	**3,303**	**3,303**	**3,303**	**3,303**	**3,048**	**3,048**	**2,538**	**778**	**777**	**476**	**317**	**215**	**164**	**65,409**	**3,553**

FIGURE 2.15 Manpower resource during construction phase.

2.4.10 Manage Risks

The following are typical risks that normally occur during the design development phase:

- Schematic design deliverables and review comments are not taken into consideration while preparing the detailed design.
- Regulatory authorities' requirements are not taken into consideration.
- Detailed design scope of work not properly established and is incomplete.
- The related project data and information collected is incomplete.
- The related project data and information collected likely to be incorrect and wrongly estimated.
- Site investigations for existing conditioned not verified.
- Fire and safety considerations recommended by the authorities not incorporated in the design.
- Environmental consideration.
- Incomplete design drawings and related information.
- Inappropriate construction method.
- Conflict with different trades.
- Interdisciplinary coordination not done.
- Wrong selection of materials and systems.
- Undersized HVAC equipment selection.
- Incorrect water supply requirements.
- Estimated total electrical load is much lower than expected actual consumption.
- Traffic study for conveying system not verified, taking into consideration final load.
- Prediction of possible changes in design during construction phase.
- Inadequate and ambiguous specifications.
- Project schedule not updated as per detailed data and project assumptions.
- Errors in detailed cost estimation.
- Number of drawings not as per TOR requirements.

Designer has to take into account the aforementioned risk factors while developing the detailed design.

Further, the designer has to consider the following risks while planning the duration for completion of the design development phase.

- Impractical design development preparation schedule.
- Duration to obtain authorities' approval.

2.4.11 Monitor Work Progress

The designer has to prepare a work schedule to prepare a detailed design package in order to submit the same to the owner for review and approval. The detailed design progress has to be monitored to meet the submission schedule. Regular meetings to monitor the progress and coordination among different trades and regulatory authorities are required to ensure the timely submission of detailed design packages.

2.4.12 Review Detailed Design

The success of a project is highly correlated with the quality and depth of the engineering design prepared during this phase. Coordination and conflict resolution are important factors during development of the design to avoid omissions and errors. The designer has to review the detailed design for accuracy of drawings, interdisciplinary coordination, and documents before these are submitted to the owner/project manager for subsequent preparation of construction documents.

2.4.12.1 Review Drawings

Figure 2.16 illustrates design review steps for detailed design drawings.

2.4.12.2 Perform Interdisciplinary Coordination

Table 2.20 illustrates major points to perform interdisciplinary coordination.

2.4.12.3 Review Documents

The designer has to review contract documents and ensure all the requirements listed under TOR are taken care. The contract documents are prepared for the approved type of project delivery system and contract pricing method.

2.4.13 Finalize Detailed Design

Final detailed design is prepared incorporating the comments, if any, found during analysis, review, and interdisciplinary coordination of the drawings and documents for submission to the owner/client

2.4.14 Submit Detailed Design

Normally, the following items are submitted to the owner for their review and approval in order to proceed with development of construction documents for bidding/tendering purposes:

1. Detailed design drawings.
2. Project specifications.
3. Bill of quantities.
4. Contract documents.
5. Project schedule.
6. Detailed cost estimate.
7. Detailed design report.
8. Calculations.
9. Site investigations, survey reports.
10. Model.

2.5 CONSTRUCTION DOCUMENTS PHASE

Construction development phase is the fourth phase of the construction project life cycle. During this phase, the drawings and specifications prepared during the

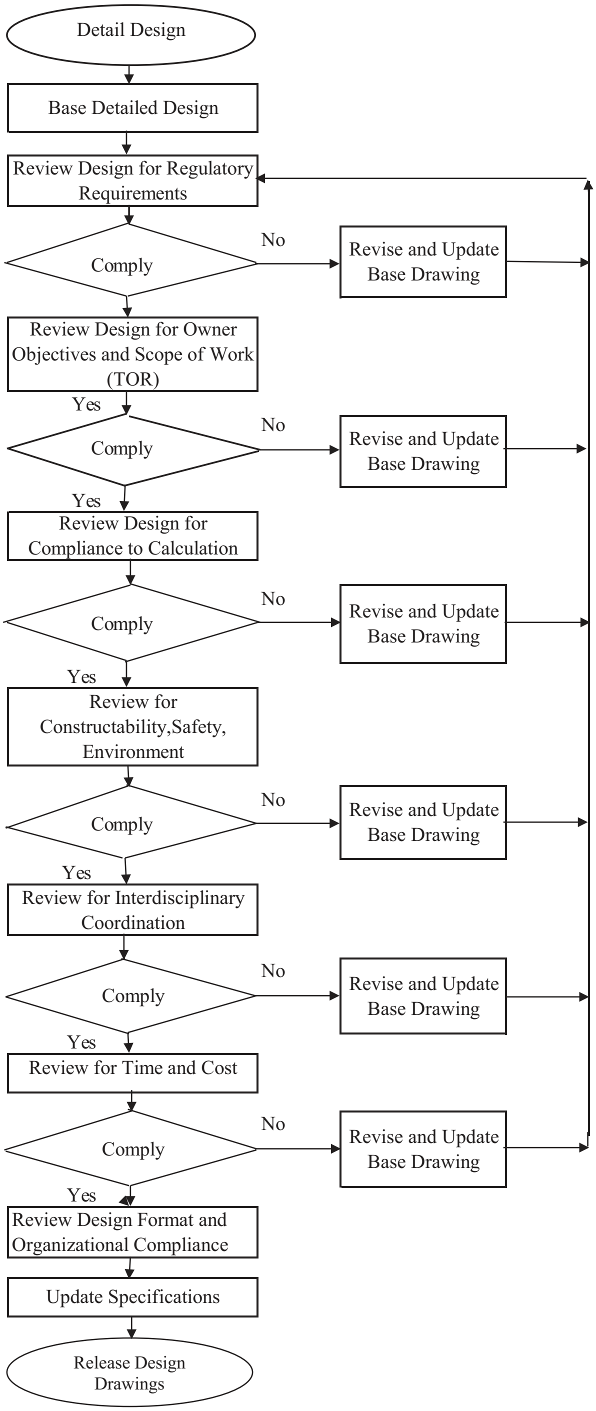


FIGURE 2.16 Design review steps for detailed design.

TABLE 2.20
Interdisciplinary Coordination

Serial Number	Discipline	Discipline					
		Architectural	**Structural**	**Mechanical**	**HVAC**	**Electrical**	**External Work**
1	ARCHITECTURAL		1. Structural Framing Plans	1. Pump Room location and size of room.	1. Plant room location and size.	1. Location and size of substation and door sizing.	1. Property limits.
			2. Axis, Grids, Levels	2. Void above false ceiling for piping.	2. Void above false ceiling for HVAC equipment, duct, and piping.	2. Trenches for cables in substation, electrical room, and generator room.	2. Location of outdoor equipment.
			3. Location of Columns, Beams	3. Sprinkler in false ceiling.	3. Access for maintenance of equipment.	3. Location and size of electrical room and closets.	3. Location of plants.
			4. Modules to Match with Structural Plan	4. Location of sanitary fixtures and accessories.	4. K-Value of thermal insulation, type of external glazing and U-Value.	4. Location of electrical devices.	4. Location of seating/relax area.
			5. Location of Stirs, Fire Exits	5. Location of fire hydrant, cabinet and landing valves.	5. Location of louvers, grills, diffusers.	5. Location of light fittings in the false ceiling.	5. Location of maintenance room/area.
			6. Expansion Joints	6. Location of water tank.	6. Location of thermostat and other devices.	6. Void above false ceiling for cable tray and trunking.	6. Location of manholes.

(*Continued*)

TABLE 2.20 Continued
Interdisciplinary Coordination

Serial Number	Discipline	Discipline: Architectural	Structural	Mechanical	HVAC	Electrical	External Work
			7. Building Dimensions	7. Shaft for water supply, sanitary and drainage pipes.	7. Staircase pressurization system with respect to HVAC.	7. Cable tray, cable trunking route.	7. Location of generator exhaust pipe.
				8. Location of fuel filling point for fuel carrying tanker.	8. Location of HVAC equipment on roof.	8. Location and size of low voltage rooms.	
				9. Location of manholes.	9. HVAC shaft requirement.	9. Location and size of generator room.	
						10. Ventilation of substation and generator room.	
2	STRUCTURAL	Structural Framing Plans		1. Opening for pipe crossing in the walls and slab.	1. Shaft for piping and duct.	1. Base for transformers.	1. Manholes.
		2. Axis, Grids, Levels		2. Shaft for pipe risers (water supply, sanitary, drainage).	2. Openings/sleeves for duct and piping.	2. Base for generator.	2. Foundation for light poles.
		3. Location of Columns, Beams		3. Opening for roof drain.	3. Operating weight of all HVAC equipment.	3. Trenches for electrical cables.	3. Manhole/foundation for electrical panels.

(*Continued*)

TABLE 2.20 Continued
Interdisciplinary Coordination

Serial Number	Discipline	Architectural	Structural	Mechanical	HVAC	Electrical	External Work
		4. Modules to Match with Structural Plan		4. Openings/sleeves for piping.	4. Floor height to accommodate equipment.	4. Openings/sleeves for cable tray, electrical bus duct.	4. Manhole/foundation for feeder pillars.
		5. Location of Stirs, Fire Exits		5. Opening for main circulation drain.	5. Expansion joints requirements.	5. Shaft for cable trays.	5. Underground services tunnel.
		6. Expansion Joints		6. Water tank inlet location.	6. Pump room equipment loads with HVAC equipment.	6. Foundation for light poles.	
		7. Building Dimensions		7. Sanitary manholes.		7. Manhole/ foundation for electrical panels.	
3	MECHANICAL	1. Pump Room Location and Size of Room	1. Opening for pipe crossing in the walls and slab.		1. Make up water requirements for HVAC.	1. Power supply for pumps and other equipment.	1. Irrigation system with external work.
		2. Void Above False Ceiling for Piping	2. Shaft for pipe risers (water supply, sanitary, drainage		2. Connection of chilled water for plumbing work.	2. Location of isolators for power supply.	2. Area drain, road gully with external/ asphalt work.
		3. Sprinkler in False Ceiling	3. Opening for roof drain.		3. Interface with building management system.	3. Interface with fire alarm system.	3. Stormwater manholes with external work.

(*Continued*)

TABLE 2.20 Continued
Interdisciplinary Coordination

Serial Number	Discipline	Discipline: Architectural	Structural	Mechanical	HVAC	Electrical	External Work
		4. Location of Sanitary Fixtures and Accessories	4. Openings/sleeves for piping.		4. HVAC/AHU drain with drainage system.		4. External services to be hooked up with municipality route.
		5. Location of Fire Hydrant, Cabinet, and Landing Valves	5. Opening for main circulation drain.				
		6. Location of Water Tank	6. Water tank inlet location.				
		7. Shaft for Water Supply, Sanitary, and Drainage Pipes	7. Sanitary manholes.				
		8. Location of Fuel Filling Point for Fuel Carrying Tanker					
		9. Location of Manholes					
4	**HVAC**	1. Plant Room Location and Size	1. Shaft for ducts and piping.	1. Make up water requirements for HVAC.		1. Power supply for chillers, pumps, AHUs, and other equipment.	1. Access for underground services.

(*Continued*)

TABLE 2.20 Continued
Interdisciplinary Coordination

Serial Number	Discipline	Discipline					
		Architectural	Structural	Mechanical	HVAC	Electrical	External Work
		2. Void Above False Ceiling for HVAC Equipment, Duct and Piping	2. Opening for ducts and piping in the wall and roof.	2. Connection of chilled water for plumbing work.		2. Location of isolators for power supply.	2. Location of exhaust for underground ventilation system.
		3. Access for Maintenance of Equipment		3. Interface with building management system.		3. Heat dissipation from lighting and other electrical panels.	
		4. K-Value of Thermal Insulation, Type of External Glazing and U-Value		4. HVAC/AHU drain with drainage system.		4. 3-phase/single phase power requirements.	
		5. Location of Louvers, Grills, Diffusers				5. Power supply load during summer/winter.	
		6. Location of Thermostat and Other Devices				6. Electrical power supply for equipment connected to generator.	

(*Continued*)

TABLE 2.20 Continued
Interdisciplinary Coordination

Serial Number	Discipline	Discipline: Architectural	Structural	Mechanical	HVAC	Electrical	External Work
		7. Staircase Pressurization System with Respect to HVAC				7. Interface with fire alarm system.	
		8. Location of HVAC Equipment on Roof				8. Interface with building management system.	
		9. HVAC shaft requirement					
5	ELECTRICAL	1. Location and Size of Substation and Door Sizing	1. Base for transformers.	1. Power supply for pumps and other equipment.	1. Power supply for chillers, pumps, AHUs, and other equipment.		Location of lighting poles.
		2. Trenches for Cables in Substation, Electrical Room and Generator Room	2. Base for generator.	2. Location of isolators for power supply.	2. Location of isolators for power supply.		Location of earth pits.
		3. Location and Size of Electrical Room and Closets	3. Trenches for electrical cables.	3. Interface with fire alarm system.	3. Heat dissipation from lighting and other electrical panels.		Location of electrical manholes, handholes.

(*Continued*)

TABLE 2.20 Continued
Interdisciplinary Coordination

Serial Number	Discipline	Architectural	Structural	Mechanical	HVAC	Electrical	External Work
		4. Location of Electrical Devices	4. Openings/sleeves for cable tray, electrical bus duct.		4. 3-phase/single phase power requirements.		Underground cable routes.
		5. Location of Light Fittings and Other Devices in the False Ceiling	5. Shaft for cable trays.		Power supply load during summer/winter.		Location of bollards.
		6. Void Above False Ceiling for Cable Tray and Trunking	6. Foundation for light poles.		6. Electrical power supply for equipment connected to generator.		Location of electrical panels, feeder pillars.
		7. Cable Tray, Cable Trunking Route	7. Manhole/foundation for electrical panels.		7. Interface with fire alarm system.		
		8. Location and Size of Low Voltage Rooms			Interface with building management system.		
		9. Location and Size of Generator Room					
		10. Ventilation of Substation and Generator Room					

(*Continued*)

TABLE 2.20 Continued
Interdisciplinary Coordination

Serial Number	Discipline	Architectural	Structural	Mechanical	HVAC	Electrical	External Work
6	LAND SCAPE/ EXTERNAL	1. Property Limits	1. Manholes.	1. Irrigation system with external work.	1. Access for underground services.	1. Location of lighting poles.	
		2. Location of Outdoor Equipment	2. Foundation for light poles.	2. Area drain, road gully with external/ asphalt work.	2. Location of exhaust for underground ventilation system.	2. Location of earth pits.	
		3. Location of Plants	3. Manhole/foundation for electrical panels.	3. Stormwater manholes with external work.		3. Location of electrical manholes, handholes.	
		4. Location of Seating/Relax Area	4. Manhole/foundation for feeder pillars.	4. External services to be hooked up with municipality route.		4. Underground cable routes.	
		5. Location of Maintenance Room/Area	5. Underground services tunnel.			5. Location of bollards.	
		6. Location of Manholes				6. Location of electrical panels, feeder pillars.	
		7. Location of Generator Exhaust Pipe				7. Location of generator exhaust pipe.	

design development phase are further developed into the working drawings. All the drawings, specifications, documents, and other related elements necessary for construction of the project are assembled and subsequently released for bidding and tendering. Table 2.21 illustrates the major activities relating to the construction documents phase developed based on the project management process group's methodology and Figure 2.17 illustrates the logic flow process for the construction documents phase.

2.5.1 Develop Construction Documents

The construction document phase provides a complete set of working drawings of all the disciplines, site plans, technical specifications, BOQ, schedule, (except the standards specifications, documents for insertions normally added during the bidding and tendering phase), and related graphic and written information to bid the project. It is necessary that utmost care is taken to develop and assemble all the documents and ensure the accuracy and correctness to meet the owner's objectives.

2.5.1.1 Identify Construction Documents Requirements

In order to identify requirements to assemble contract documents, the designer has to gather the comments on the submitted detailed design by the owner/project manager, collect TOR requirements, regulatory requirements, identify owner requirements, and all other related information to ensure nothing is missed.

2.5.1.1.1 Gather Detailed Design Comments

The designer has to review the comments on the detailed design and coordinate with all the disciplines/trades and incorporate the same while preparing the construction documents.

2.5.1.1.2 Identify TOR Requirement

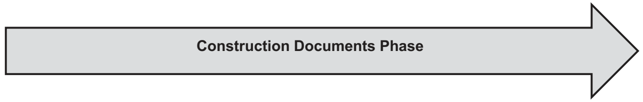
Identify all the requirements listed under TOR. This includes:

- Final Drawings to be prepared to the required scales, format with necessary logo, client name, location map, north orientation, project name, designer name, drawing title, drawing number, contract reference number, date of drawing, revision number, drawing scale, duly signed by the designer.
- Bill of quantities and schedule of rates.
- Contract documents.
- Project schedule.
- Technical specifications.
- Cost estimates.
- Summary report.

2.5.1.1.3 Collect Owner's Requirements

The designer has to discuss with the owner to ascertain there are no changes to the earlier established owner's requirement and if there are any additional requirements or changes then the scope is to be updated and incorporated in the final design, documents before sending for tendering.

TABLE 2.21
Major Activities Relating to Construction Documents Phase Processes



Management Processes	Process Management Group				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Integration Management	Design Development Deliverables	Project Management Plan	Working Drawings	Design Calculations	Working Drawings
	Comments on Design Development		Project Specifications	Interdisciplinary Coordination	
	Authorities' Requirements		Bill of Quantities	Compliance to TOR	
	Environmental Requirements		Tender Documents		
	TOR Requirements				
Stakeholder Management		Project Stakeholders			
		Stakeholders Requirements		Design Progress	
Scope Management		Construction Documents		Authorities Approval	
		Construction Documents Deliverables		Compliance to Owner's Need	
		Tender Documents		Stakeholders Approval	
Schedule Management		Project Schedule		Project Schedule	
		Construction Document Schedule Deliverables		Construction Document Schedule	

(*Continued*)

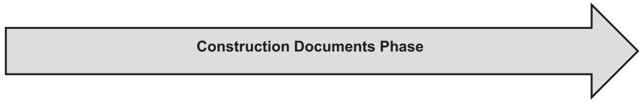
TABLE 2.21 Continued
Major Activities Relating to Construction Documents Phase Processes

Construction Documents Phase

Management Processes	Process Management Group				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Cost Management		Bill of Quantities Price Analysis		Project Budget	
		Definitive Estimate			
Quality Management		Codes and Standards	Design Coordination with All Disciplines	Design Compliance to Owner's Goals and Objectives	
		Regulatory Requirements	Assure Design Quality	Coordination with all Disciplines	
		Design Quality		Control Design Quality	
		Well-Defined Specifications			
		Documents Quality			
Resource Management		Supervision Team Requirements	Manage Team Members from All Disciplines	Performance of Team Project Members	Assign New Project
		Contractor's Core Team			
		Contractor's Manpower			
Communication Management		Communication Matrix	Liaison with All Disciplines	Design Status Information	
			Coordination Meetings		

(*Continued*)

TABLE 2.21 Continued
Major Activities Relating to Construction Documents Phase Processes



Management Processes	Process Management Group				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Risk Management		Identification of Risk during Bidding, Construction, Testing, and Commissioning		Design Risk Control	
Contract Management		Bidding and Tendering Documents		Check for Contracting System	Contract Documents
					Tender Documents
HSE Management		Safety in Design	Safety Requirements		
		Environmental Compatibility	Environmental Requirements	HSE Compliance in Design	
Financial Management		Designer/Consultant Payment		Payment to Designer/Consultant	
Claim Management		Design Change Payment		Control Changes	Settle Designer's Claim

Note: These activities may not be strictly sequential, however, the breakdown allows implementation of project management function more effectively and easily manageable at different stages of the project phase.

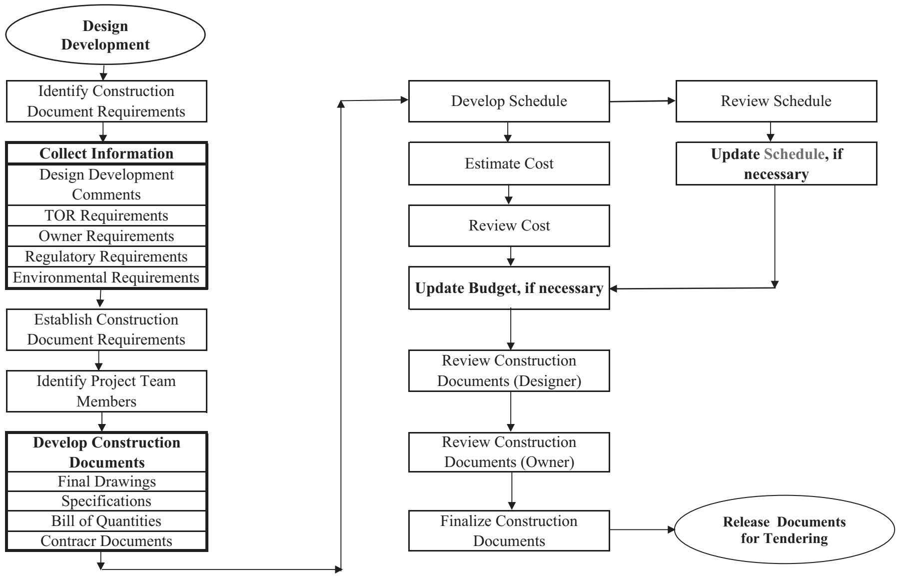


FIGURE 2.17 Logic flow for construction document phase.

2.5.1.1.4 Identify Regulatory Requirements

The designer has to ensure that there are no changes to existing regulatory requirements. If there are updates to regulatory requirements, then the designer has to incorporate the same as any changes during construction have adverse effects on the project.

2.5.1.1.5 Identify Environmental Requirements

Environmental agencies always update their requirements to protect the environment. The designer has to verify that there are no changes to the requirements/assumptions considered during the detailed design development phase.

2.5.1.2 Establish Construction Documents Requirements

The construction documents are developed taking into consideration all the items discussed under Section 2.5.1.1 and any other related information.

2.5.2 Identify Project Stakeholders

The following stakeholders have direct involvement in the construction documents phase:

- Owner
- Consultant
- Designer
- Project/Construction Manager (if the owner decides to engage during this phase, depending on the type of project delivery system)

TABLE 2.22
Responsibilities of Various Participants (Design-Bid-Build Type of Contracts) during Construction Documents Phase

Phase	Responsibilities		
	Owner	**Designer**	**Regulatory Authorities**
Construction Document	• Approval of working drawings. • Approval of tender documents. • Approval of time schedule. • Approval of budget.	• Development of working drawings. • Development of specifications. • Development of contract documents. • Project schedule. • Project budget. • BOQ. • Development of tender documents. • Review of construction documents.	• Review and approval of project submittals.

During this phase quantity surveyor/contract administrator has great responsibilities. His/her team under the leadership of the project manager (design), is responsible for coordinating and assembling all the required documents.

Table 2.22 illustrates responsibilities of various participants during the construction document phase.

2.5.3 Develop Construction Documents Scope

The scope for development of construction documents is prepared taking into consideration requirements established under Section 2.5.1.2 which are as follows:

- Approved design development phase documents.
- TOR requirements.
- Owner's preferred requirements.
- Regulatory requirements.
- Environmental requirements.
- Approved project schedule.
- Approved detailed cost estimate.
- Codes and standards.

The purpose of construction documents is to provide sufficient information and detail to ensure that the bidders will be able to submit the definitive cost for the project. There is no ambiguity in the drawings and specifications and the work to be performed by the contractor is properly identified and correctly addressed, taking necessary measures to mitigate errors and omissions in the design. The scope of work during the construction document phase mainly comprises:

- Preparation of working (final) drawings.
- Technical specifications.
- Bill of quantities.
- Project schedule.
- Definitive cost estimate.
- Authorities' approvals.
- Existing site conditions/site plans.
- Site surveys.
- Design calculations.

2.5.3.1 Identify Construction Documents Deliverables

Table 2.23 lists the construction document deliverables to be developed during this phase.

2.5.4 Develop Construction Documents

The following items are mainly developed during the construction documents phase:

1. Working Drawings
2. Technical Specifications
3. Documents

2.5.4.1 Prepare Final (Working) Drawings

All the drawings prepared during the design development phase are reviewed to ensure all the related information and adjustments are carried out. The following is the list of major disciplines in building construction projects for which working drawings are developed:

1. Architectural Design
2. Concrete Structure
3. Elevator
4. Fire Suppression
5. Plumbing
6. Drainage
7. HVAC Work
8. Electrical System (Light and Power)
9. Fire Alarm System
10. Information and Communication System
11. Public Address System
12. Audiovisual System
13. Security System/CCTV

TABLE 2.23
Construction Documents Deliverables

Serial Number	Deliverables
1	Document I
1.1	Tendering Procedure
	a. Invitation to tender.
	b. Instructions to bidders.
	c. Forms for tender and appendix.
	d. List of equipment and machinery.
	e. List of contractor's staff.
	f. Contractor's certificate of work statement.
	g. List of subcontractor(s) or specialist(s).
	h. Initial bond.
	i. Final bond.
	j. Forms of agreement.
2	Document II
2.1	Conditions of Contract
	a. General conditions. b. Particular conditions. c. Public tender laws.
3	Document III
	a. General specifications.
	b. Particular specifications.
	c. Drawings.
	d. Schedule of rates and bill of quantities.
	e. Analysis of prices.
	f. Addenda.
	g. Tender requirements (if any) and any other instructions issued by the owner.

14. Security System/Access Control
15. Satellite/Main Antenna System
16. Integrated Automation System
17. Landscape
18. External Work (Infrastructure and Road)
19. Furnishings/Furniture (Loose)

Each of these trade drawings shall have:

- Detailed drawings produced at different scales and formats.
- Plans.

- Sections.
- Elevations.
- Schedule.
- Drawing index.

The following information will be included in all the drawings:

- Client name.
- Client logo.
- Location map.
- North orientation.
- Project name.
- Drawing title.
- Drawing number.
- Date of drawing.
- Revision number.
- Drawing scale.
- Contract reference number.
- Signature block.
- Signed by the designer for check and approval.

2.5.4.2 Prepare Specifications

The designer has to prepare comprehensive technical specifications as per the division and section taking into consideration related drawings. It is essential to have close coordination between working drawings and specifications. MasterFormat® specification documents are used to prepare specifications for building projects. These Divisions and sections are divided into a number of volumes for ease of reference. A BOQ for project activities is prepared corresponding to the divisions and sections. (Please refer to Chapter 6 for more information.)

2.5.4.3 Prepare Tender Documents

Following documents are prepared during this phase:

1. Complete set of work (construction) drawings duly coordinated with other disciplines and technical specifications.
2. Detailed bill of quantities.
3. Technical specifications for all the activities shown on the drawings.
4. Schedule.
5. Cost estimate.
6. Legal and contractual information.
7. Contractor bidding requirements.
8. Contract conditions.
9. General specifications.
10. Schedules.
11. Reports.

The previously listed documents are used as guidelines by the designer to prepare the tender documents. These are as follows:

Document I

1. Tendering procedure consisting of:
   a. Invitation to tender.
   b. Instruction to bidders.
   c. Forms for tender and appendix.
   d. List of equipment and machinery.
   e. List of contractor's staff.
   f. Contractor certificate of work statement.
   g. List of subcontractor(s) or specialist(s).
   h. Initial bond.
   i. Final bond.
   j. Form of agreement.
   k. List of tendered documents.

Document II

1. II.1 General Conditions
2. II.2 Particular Conditions
3. II.3 Public Tender Laws

Document III

1. III.1 General Specifications
2. III.2 Particular Specifications (Division 1–49)
3. III.3 Drawings
4. III.4 Schedule of Rates and Bill of Quantities
5. III.5 Analysis of Prices

2.5.5 Estimate Construction Schedule

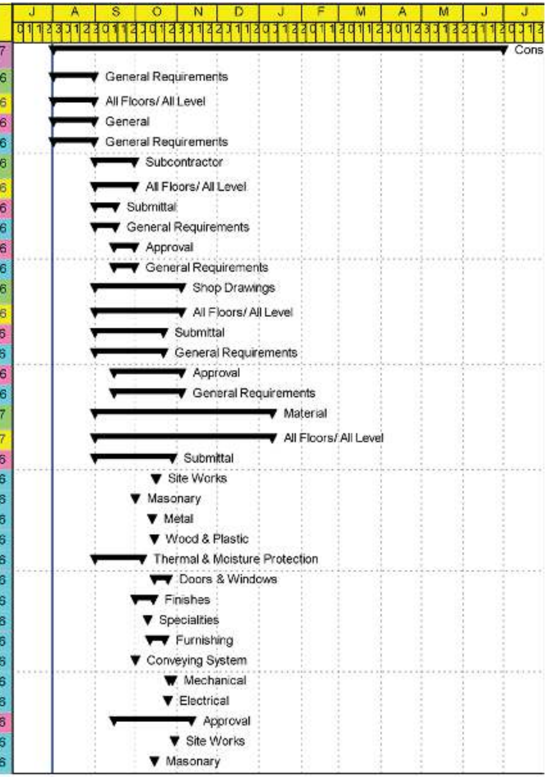
The project schedule is developed using bottom-up planning details using key activities/events. It is also known as Class 1 schedule or Schedule Level 4 (please refer to Table 1.20 and Table 1.22).

Figure 2.18 illustrates a typical construction schedule for a construction project. (The example schedule is the construction of a branch for a bank.)

2.5.6 Estimate Construction Cost

The cost estimate during this phase is based on a detailed costing methodology. During this phase, all the project activities are known, and the detailed bill of

Activity Name	Original Duration	Start	Finish
Construction of a Branch A Office for XYZ Bank	334	01-Aug-16	30-Jun-17
General Requirements	31	01-Aug-16	31-Aug-16
All Floors/ All Level	31	01-Aug-16	31-Aug-16
General	31	01-Aug-16	31-Aug-16
General Requirements	31	01-Aug-16	31-Aug-16
Subcontractor	30	01-Sep-16	30-Sep-16
All Floors/ All Level	30	01-Sep-16	30-Sep-16
Submittal	16	01-Sep-16	16-Sep-16
General Requirements	16	01-Sep-16	16-Sep-16
Approval	16	15-Sep-16	30-Sep-16
General Requirements	16	15-Sep-16	30-Sep-16
Shop Drawings	65	01-Sep-16	04-Nov-16
All Floors/ All Level	65	01-Sep-16	04-Nov-16
Submittal	51	01-Sep-16	21-Oct-16
General Requirements	51	01-Sep-16	21-Oct-16
Approval	51	15-Sep-16	04-Nov-16
General Requirements	51	15-Sep-16	04-Nov-16
Material	132	01-Sep-16	10-Jan-17
All Floors/ All Level	132	01-Sep-16	10-Jan-17
Submittal	58	01-Sep-16	28-Oct-16
Site Works	1	16-Oct-16	16-Oct-16
Masonary	1	01-Oct-16	01-Oct-16
Metal	1	13-Oct-16	13-Oct-16
Wood & Plastic	1	15-Oct-16	15-Oct-16
Thermal & Moisture Protection	36	01-Sep-16	06-Oct-16
Doors & Windows	11	15-Oct-16	25-Oct-16
Finishes	14	01-Oct-16	14-Oct-16
Specialities	1	10-Oct-16	10-Oct-16
Furnishing	11	12-Oct-16	22-Oct-16
Conveying System	1	01-Oct-16	01-Oct-16
Mechanical	3	26-Oct-16	28-Oct-16
Electrical	1	25-Oct-16	25-Oct-16
Approval	58	15-Sep-16	11-Nov-16
Site Works	1	30-Oct-16	30-Oct-16
Masonary	1	15-Oct-16	15-Oct-16

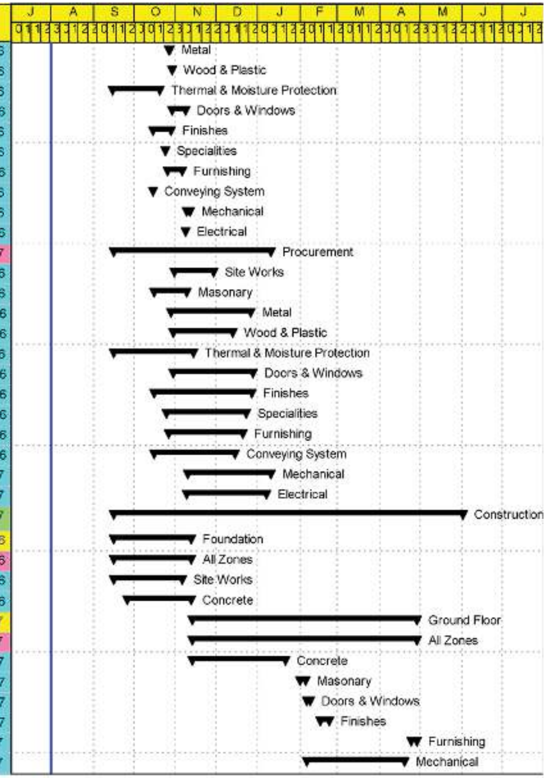


Remaining Work Summary
Milestone

Page 1 of 5

FIGURE 2.18 Typical construction schedule.

Activity Name	Original Duration	Start	Finish
Metal	1	27-Oct-16	27-Oct-16
Wood & Plastic	1	29-Oct-16	29-Oct-16
Thermal & Moisture Protection	36	15-Sep-16	20-Oct-16
Doors & Windows	11	29-Oct-16	08-Nov-16
Finishes	14	15-Oct-16	28-Oct-16
Specialities	1	24-Oct-16	24-Oct-16
Furnishing	11	26-Oct-16	05-Nov-16
Conveying System	1	15-Oct-16	15-Oct-16
Mechanical	3	09-Nov-16	11-Nov-16
Electrical	1	08-Nov-16	08-Nov-16
Procurement	117	16-Sep-16	10-Jan-17
Site Works	30	31-Oct-16	29-Nov-16
Masonary	25	16-Oct-16	09-Nov-16
Metal	60	28-Oct-16	26-Dec-16
Wood & Plastic	45	30-Oct-16	13-Dec-16
Thermal & Moisture Protection	60	16-Sep-16	14-Nov-16
Doors & Windows	60	30-Oct-16	28-Dec-16
Finishes	73	16-Oct-16	27-Dec-16
Specialities	60	25-Oct-16	23-Dec-16
Furnishing	55	27-Oct-16	20-Dec-16
Conveying System	60	16-Oct-16	14-Dec-16
Mechanical	62	10-Nov-16	10-Jan-17
Electrical	60	09-Nov-16	07-Jan-17
Construction	259	16-Sep-16	01-Jun-17
Foundation	58	16-Sep-16	12-Nov-16
All Zones	58	16-Sep-16	12-Nov-16
Site Works	51	16-Sep-16	05-Nov-16
Concrete	48	26-Sep-16	12-Nov-16
Ground Floor	167	13-Nov-16	28-Apr-17
All Zones	167	13-Nov-16	28-Apr-17
Concrete	70	13-Nov-16	21-Jan-17
Masonary	5	01-Feb-17	05-Feb-17
Doors & Windows	3	06-Feb-17	08-Feb-17
Finishes	7	16-Feb-17	22-Feb-17
Furnishing	5	24-Apr-17	28-Apr-17
Mechanical	73	06-Feb-17	19-Apr-17

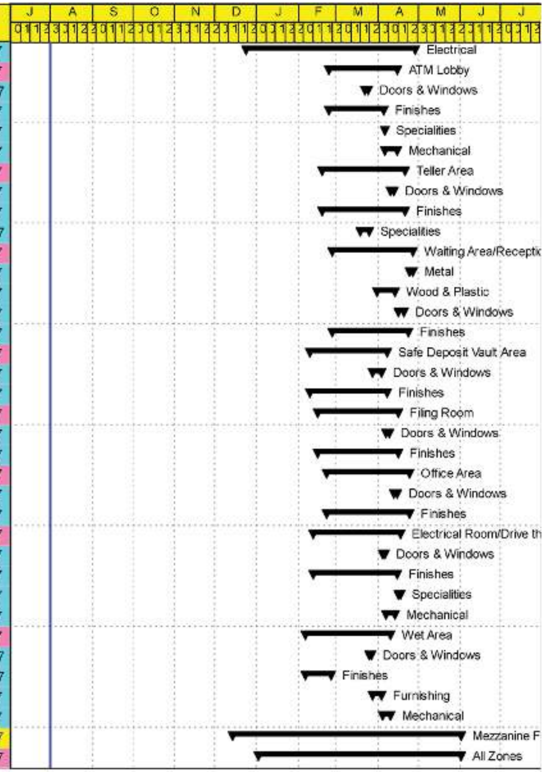


Remaining Work — Summary — Milestone

Page 2 of 5

FIGURE 2.18 Continued

Activity Name	Original Duration	Start	Finish
Electrical	126	24-Dec-16	28-Apr-17
ATM Lobby	52	23-Feb-17	15-Apr-17
Doors & Windows	3	22-Mar-17	24-Mar-17
Finishes	42	23-Feb-17	05-Apr-17
Specialities	1	06-Apr-17	06-Apr-17
Mechanical	10	06-Apr-17	15-Apr-17
Teller Area	63	18-Feb-17	21-Apr-17
Doors & Windows	3	10-Apr-17	12-Apr-17
Finishes	63	18-Feb-17	21-Apr-17
Specialities	7	19-Mar-17	25-Mar-17
Waiting Area/Reception	60	26-Feb-17	26-Apr-17
Metal	3	24-Apr-17	26-Apr-17
Wood & Plastic	14	31-Mar-17	13-Apr-17
Doors & Windows	5	16-Apr-17	20-Apr-17
Finishes	57	26-Feb-17	23-Apr-17
Safe Deposit Vault Area	58	09-Feb-17	07-Apr-17
Doors & Windows	7	28-Mar-17	03-Apr-17
Finishes	58	09-Feb-17	07-Apr-17
Filing Room	61	15-Feb-17	16-Apr-17
Doors & Windows	3	07-Apr-17	09-Apr-17
Finishes	61	15-Feb-17	16-Apr-17
Office Area	62	22-Feb-17	24-Apr-17
Doors & Windows	3	13-Apr-17	15-Apr-17
Finishes	62	22-Feb-17	24-Apr-17
Electrical Room/Drive thru ATM	65	12-Feb-17	17-Apr-17
Doors & Windows	3	04-Apr-17	06-Apr-17
Finishes	63	12-Feb-17	15-Apr-17
Specialities	2	16-Apr-17	17-Apr-17
Mechanical	7	07-Apr-17	13-Apr-17
Wet Area	64	06-Feb-17	10-Apr-17
Doors & Windows	3	25-Mar-17	27-Mar-17
Finishes	20	06-Feb-17	25-Feb-17
Furnishing	7	28-Mar-17	03-Apr-17
Mechanical	7	04-Apr-17	10-Apr-17
Mezzanine Floor	170	14-Dec-16	01-Jun-17
All Zones	151	02-Jan-17	01-Jun-17



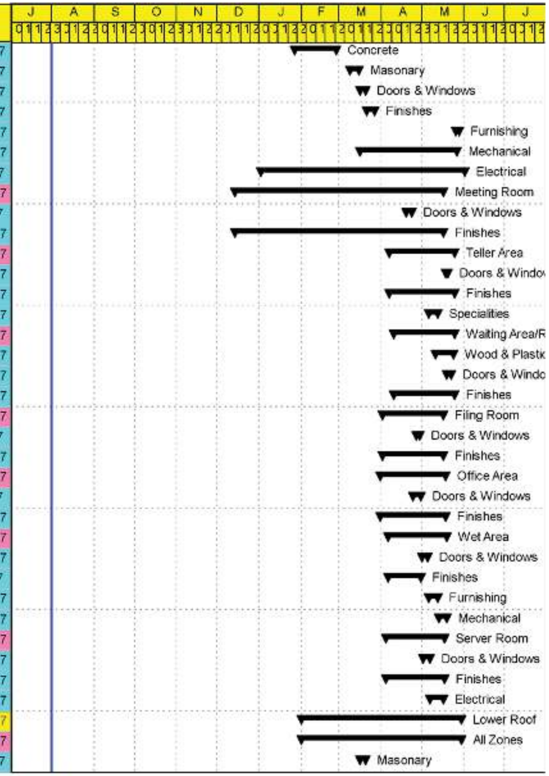
Remaining Work — Summary

◆ Milestone

Page 3 of 5

FIGURE 2.18 Continued

Activity Name	Original Duration	Start	Finish
Concrete	31	27-Jan-17	26-Feb-17
Masonary	7	09-Mar-17	15-Mar-17
Doors & Windows	5	16-Mar-17	20-Mar-17
Finishes	7	21-Mar-17	27-Mar-17
Furnishing	3	26-May-17	28-May-17
Mechanical	72	16-Mar-17	26-May-17
Electrical	151	02-Jan-17	01-Jun-17
Meeting Room	154	14-Dec-16	16-May-17
Doors & Windows	5	19-Apr-17	23-Apr-17
Finishes	154	14-Dec-16	16-May-17
Teller Area	49	07-Apr-17	25-May-17
Doors & Windows	3	18-May-17	20-May-17
Finishes	49	07-Apr-17	25-May-17
Specialities	7	06-May-17	12-May-17
Waiting Area/Reception	46	10-Apr-17	25-May-17
Wood & Plastic	14	11-May-17	24-May-17
Doors & Windows	4	19-May-17	22-May-17
Finishes	46	10-Apr-17	25-May-17
Filing Room	45	02-Apr-17	16-May-17
Doors & Windows	3	27-Apr-17	29-Apr-17
Finishes	45	02-Apr-17	16-May-17
Office Area	49	31-Mar-17	18-May-17
Doors & Windows	7	24-Apr-17	30-Apr-17
Finishes	49	31-Mar-17	18-May-17
Wet Area	44	06-Apr-17	19-May-17
Doors & Windows	5	01-May-17	05-May-17
Finishes	25	06-Apr-17	30-Apr-17
Furnishing	7	06-May-17	12-May-17
Mechanical	7	13-May-17	19-May-17
Server Room	44	04-Apr-17	17-May-17
Doors & Windows	5	02-May-17	06-May-17
Finishes	44	04-Apr-17	17-May-17
Electrical	10	07-May-17	16-May-17
Lower Roof	119	01-Feb-17	30-May-17
All Zones	119	01-Feb-17	30-May-17
Masonary	5	16-Mar-17	20-Mar-17



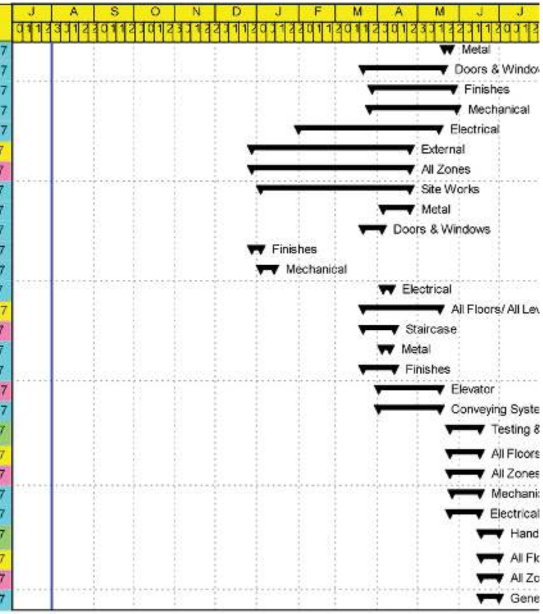
Remaining Work Summary

Milestone

Page 4 of 5

FIGURE 2.18 Continued

Activity Name	Original Duration	Start	Finish
Metal	5	21-May-17	25-May-17
Doors & Windows	61	21-Mar-17	20-May-17
Finishes	61	28-Mar-17	27-May-17
Mechanical	66	26-Mar-17	30-May-17
Electrical	105	01-Feb-17	16-May-17
External	119	28-Dec-16	25-Apr-17
All Zones	119	28-Dec-16	25-Apr-17
Site Works	112	04-Jan-17	25-Apr-17
Metal	21	05-Apr-17	25-Apr-17
Doors & Windows	15	21-Mar-17	04-Apr-17
Finishes	7	28-Dec-16	03-Jan-17
Mechanical	10	04-Jan-17	13-Jan-17
Electrical	7	05-Apr-17	11-Apr-17
All Floors/ All Level	58	21-Mar-17	17-May-17
Staircase	24	21-Mar-17	13-Apr-17
Metal	7	04-Apr-17	10-Apr-17
Finishes	24	21-Mar-17	13-Apr-17
Elevator	46	02-Apr-17	17-May-17
Conveying System	46	02-Apr-17	17-May-17
Testing & Commissioning	23	25-May-17	16-Jun-17
All Floors/ All Level	23	25-May-17	16-Jun-17
All Zones	23	25-May-17	16-Jun-17
Mechanical	21	27-May-17	16-Jun-17
Electrical	22	25-May-17	15-Jun-17
Handing Over & Close-out	14	17-Jun-17	30-Jun-17
All Floors/ All Level	14	17-Jun-17	30-Jun-17
All Zones	14	17-Jun-17	30-Jun-17
General Requirements	14	17-Jun-17	30-Jun-17



Remaining Work Summary
Milestone

Page 5 of 5

FIGURE 2.18 Continued

quantities is available for costing purposes. It is also known as detailed costing (definitive estimate) (please refer to Table 1.23).

2.5.7 Manage Document Quality

In order to reduce errors and omissions, it is necessary to review and check the design for quality assurance by the quality control personnel from the project team through itemized review checklists to ensure that working drawings are suitable for construction. The designer has to ensure that the installation/execution specification details are comprehensively and correctly described and coordinated with working drawings and also the installation quality requirements for systems are specified in detail.

The designer has to plan quality, perform quality assurance, and control quality for preparing contract documents. This will mainly consist of the following:

1. **Plan Quality:**
- Review comments on design development package.
- Determine number of drawings to be produced.
- Establish scope of work for preparation of construction documents.
- Identify requirements listed under TOR.
- Identify quality standards and codes to be complied.
- Identify regulatory requirements.
- Identify environmental requirements.
- Establish quality organization with responsibility matrix.
- Develop review procedure for the produced work drawings.
- Develop review procedure for the specifications and contract documents.
- Establish submittal plan for construction documents.

2. **Quality Assurance:**
- Prepare work drawings.
- Prepare detailed specifications.
- Prepare contract documents.
- Prepare bill of quantities and schedule of rates.
- Ensure functional and technical compatibility.
- Ensure the design is constructible.
- Ensure operational objectives are met.
- Ensure drawings are fully coordinated with all disciplines.
- Ensure the design is cost-effective.
- Ensure selected/recommended material meets the owner's objectives.
- Ensure that design fully meets the owner's objectives/goals.
- Ensure that construction documents match with approved project delivery system.
- Ensure type of contracting/pricing as per adopted methodology.

3. **Control Quality:**
- Check quality of design drawings.
- Check accuracy and correctness of design.
- Verify bill of quantities for correctness as per work drawings.

- Check complete specifications are prepared and coordinated to match work drawings and BOQ.
- Check contract documents as per project delivery system.
- Check for regulatory compliance.
- Check project schedule.
- Check project cost.
- Check calculations.
- Review studies and reports.
- Check accuracy of design.
- Check interdisciplinary requirements.
- Check required number of drawings prepared.

BIM tools can be used to control the quality of the project (please refer to Chapter 5 for more information).

Before the drawings are released for bidding and tendering, it is necessary to check the drawings for formatting, annotation, and interpretation. Table 2.24 lists the items to be checked for a quality check (correctness) of design drawings.

2.5.8 Estimate Resources

At this stage, the designer can estimate resources having accuracy as more details are available to estimate exact resources.

2.5.9 Manage Risks

Following are typical risks that normally occur during the construction document phase:

- Design development deliverables and review comments are not taken into consideration while preparing the construction documents.
- Scope of work to produce construction documents not properly established and is incomplete.
- Documents not matching as per project delivery system.
- Documents not as per type of contract/pricing methodology.
- Regulatory authorities' requirements are not taken into consideration.
- Latest environmental consideration not considered.
- Conflict with different trades.
- Conflict between working drawings and specifications.
- Prediction of possible changes in design during construction phase.
- Inadequate and ambiguous specifications.
- Project schedule not updated as per detailed data and project assumptions.
- Errors in definitive cost estimation.
- Number of drawings not as per TOR requirements.
- It is likely that owner-supplied items, if any, are not included in the documents.

TABLE 2.24
Quality Check for Design Drawings

Serial Number	Points to be Checked	YES/NO
1	Check for use of approved version of AutoCAD.	
2	Check drawing for: • Title frame. • Attribute. • North orientation. • Key plan. • Issues and revision number.	
3	Client name and logo.	
4	Designer (consultant name).	
5	Drawing title.	
6	Drawing number.	
7	Contract reference number.	
8	Date of drawing.	
9	Drawing scale.	
10	Annotation: • Text size. • Dimension style. • Fonts. • Section and elevation marks.	
11	Layer standards including line weights.	
12	Line weights, line type (continuous, dash, dot, etc.).	
13	Drawing continuation reference and match line.	
14	Plot styles (CTB-Color dependent plot style tables).	
15	Electronic CAD file name and project location.	
16	XREF (X reference) attachments (if any).	
17	Image reference (if any).	
18	Section references.	
19	Symbols.	
20	Legends.	
21	Abbreviations.	
22	General notes.	
23	Drawing size as per contract requirements.	
24	List of drawings.	

Designer has to take into account the aforementioned risk factors while developing construction documents.

Further, the designer has to consider the following risks while planning the duration for completion of the construction document phase.

- Impractical construction document preparation schedule.

2.5.10 Monitor Work Progress

The designer has to prepare a work schedule to prepare the construction document package in order to submit the same to the owner for review and approval. The progress to produce construction documents has to be monitored to meet the submission schedule. Regular meetings to monitor the progress and coordination among different trades are required to ensure timely submission of detailed design packages. Any major deviations to the approved drawings and specifications produced during design development should be identified and discussed with the owner/project manager for specific consideration and approval by the client, and accordingly, all the related documents to be updated.

2.5.11 Review Construction Documents

Table 2.25 illustrates items to be reviewed for the constructability of the design.

TABLE 2.25
Constructability Review for Design Drawing

Serial Number	Items to be Reviewed	YES/NO
1	Are there construction elements that are impossible or impractical to build?	
2	Does the design follow industry standards and practices?	
3	Is structural design per site conditions, soil conditions and bearing capacity?	
4	Are the site conditions verified and suitable with respect to access, availability of utility services?	
5	Will all the specified material be available during construction phase?	
6	Is the specified material available from single source or multiple sources and brands?	
6	Is the design suitable for construction using the specified, material, equipment?	
8	Is the design suitable for construction using recommended method statement?	
9	Are the available labor resources capable of building the facility as per contract drawings and contracted methods and practices?	
10	Is the design fully coordinated with technical specifications and CSI Format divisions?	
11	Is the specifications cover the material considered in the design?	
12	Does the design fully meet regulatory requirements?	
13	Are the drawings coordinated with all the trades and cross references are indicated wherever applicable?	
14	Is the design coordinated with adjacent land and its accessibility?	
15	Are requirements of general public and persons of special needs considered?	
16	Are construction schedule and milestone practical to achieve?	

(*Continued*)

TABLE 2.25 Continued
Constructability Review for Design Drawing

Serial Number	Items to be Reviewed	YES/NO
17	Can application of QA/QC requirements be complied with?	
18	Has environmental impact and its mitigation considered?	
19	Is there space for temporary office facilities and parking space for workforce vehicles?	
20	Has availability of storage space for construction material considered?	
21	Is the design sustainable?	

2.5.12 Finalize Construction Documents

Final construction documents package is prepared taking into consideration review comments and identified risks by the designer and comments from the owner/project manager.

2.5.13 Release for Bidding

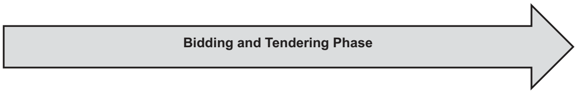
Normally, the following items are submitted to the owner for their review and approval in order to proceed with bidding and tendering phase of the project:

1. Work Drawings
2. Project Specifications
3. Bill of Quantities
   a. Priced
   b. Unpriced
4. Project Schedule
5. Definitive Cost Estimate
6. Project Summary Report
7. Tender Documents Comprising:
   a. Document I Tendering Procedure
   b. Document II Condition of Contract
   c. Document III consisting of:
      III.1 General Specifications
      III.2 Particular Specifications
      III.3 Drawings
      III.4 Bill of Quantities and Schedules of Rates
      III.5 Analysis of Prices
8. Soft Copy of Construction Documents (DVD)

2.6 BIDDING AND TENDERING PHASE

During this phase, tender documents are released for bid, and contract is awarded to successful bidder. Table 2.26 illustrates the major activities relating to bidding and tendering phase developed based on the project management process group's methodology and Figure 2.19 illustrates the logic flow process for

TABLE 2.26
Major Activities Relating to Bidding and Tendering Phase Processes



Management Processes	Process Management Group: Initiating Process	Planning Process	Execution Process	Monitoring and Controlling Process	Closing Process
Integration Management	Construction Documents TOR Requirements Owner's Requirements Authorities Requirements	Organize Tender Documents	Tendering Documents		Award Contract
Stakeholder Management	Identify Bidders		Contractor Selection		
Scope Management		Bidder Selection Procedure Bid Review Procedure	Bid Review	Addendum	
Schedule Management		Bid Period Bid Review Duration		Monitor Bid Duration Monitor Review Duration	
Cost Management		Estimate Bid Price		Control Bid Value	
Quality Management					
Resource Management					
Communication Management		Advertise Tender	Conduct Meetings		
Risk Management			Manage Risk	Control Risk	
Contract Management		Select Bidders	Prepare Construction Contract		Signed Contract
HSE Management					
Financial Management				Update Project Finances	
Claim Management					

Note: These activities may not be strictly sequential, however, the breakdown allows implementation of project management function more effective and easily manageable at different stages of the project phase.

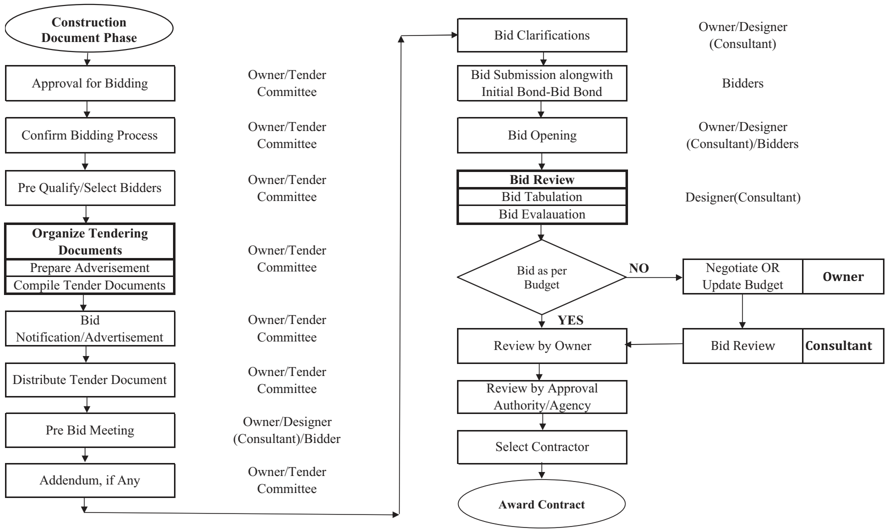


FIGURE 2.19 Logic flow for bidding and tendering phase.

the bidding and tendering phase. This process is to be read in conjunction with Section 1.3.2.10.3.

2.6.1 Organize Tendering Documents

The owner hands over the approved construction documents/tender documents to the tender committee for further action. The bid documents are prepared as per the procurement method and contract strategy adopted during the early stage of the project. Tendering procedure documents submitted by the designer are updated and necessary owner-related information is inserted in the tender documents. The bid advertisement material is prepared, and upon approval from the owner, the bid notification is announced through different media as per the organization's/agency's policy.

2.6.2 Identify Stakeholders

The following stakeholders have direct involvement in the bidding and tendering phase:

- Owner
- Tender Committee
- Designer (Consultant)
- Project/Construction Manager (if the owner decided to engage the during this phase, depending on the type of project delivery system)
- Bidders

Table 2.27 illustrates the responsibilities of various participants during the construction document phase.

TABLE 2.27
Responsibilities of Various Participants (Design-Bid-Build Type of Contracts) during Bidding and Tendering Phase

Phase	Responsibilities		
	Owner/Tender Committee	**Consultant (Designer)**	**Contractor**
Bidding and Tendering	• Advertise Bid • Distribute Bid • Collect Bid (Proposal) • Negotiation • Approve Contractor • Award Contract	• Review/Evaluate Bid • Bid Conference/Meeting • Bid Clarification • Recommend Successful Bidder • Prepare Contract Documents	• Collection of Bid Documents • Preparation of Proposal • Submission of Proposal

2.6.3 Identify Tendering Procedure

The owner has to identify the tendering procedure. Different types of tendering methods are discussed under Sections 2.4.1 (Volume 1) and 1.3.2.10.3.2.

2.6.3.1 Define Bidder Selection Procedure

Owner has to select the bidder selection procedure such as low bid, quality-based. Refer to Sections 2.4.1 (Volume 1), 1.3.2.10.3.2, and 1.3.2.10.3.3 for different types of contracting methods and contractor selection procedures.

2.6.3.2 Establish Bid Review Procedure

The designer (consultant) establishes a bid evaluation procedure in consultation with the owner.

2.6.4 Identify Bidders

Short listing of bidders is done with prequalification questionnaires and their responses. This has already been discussed under Section 1.3.2.10.3.5.

2.6.4.1 Prequalify Bidders

Prequalification of contractor is already discussed under Section 1.3.2.10.3.6.

2.6.5 Manage Tendering Process

The tendering process involves the following activities:

- Bid notification.
- Distribution of tender documents.
- Pre-bid meeting(s).
- Issuing addendum, if any.
- Bid submission.

2.6.5.1 Advertise Tender

The tender is announced in different types of media such as newspapers, magazines, and electronic media, as per the organization's/agency's policy.

2.6.5.2 Distribute Tender Documents

Normally tender documents are distributed to eligible bidders against payment of a fee announced in the bid notification, which is nonrefundable.

2.6.5.3 Conduct Meetings

The owner conducts a pre-bid meeting to provide an opportunity for the contractors bidding the project to review and discuss the construction documents and to discuss:

- General scope of the project.
- Any particular requirements of bidders that may have been difficult to specify.
- Explain details of complex matters.
- Engagement of subcontractors, specialist subcontractors.
- Particular risks.
- Any other matters that will contribute to the efficient delivery of project.

The meeting is attended by the designer (consultant), bidders (contractors), project/construction manager, and tender committee members. Queries from the contractors pertaining to construction documents are noted and the designer (consultant) provides a written response to these queries by clarifying all the points. The bidders have to consider the clarification points and incorporate the requirements while calculating the bid price. The responses recorded in the meeting become part of the contract documents (part of the addendum) that are signed by the owner and successful bidder. Figure 2.20 illustrates a bid clarification form that becomes part of contract documents.

2.6.5.4 Submit/Receive Bids

Bids are received in accordance with the instructions to bidders section of the tender documents. The bid should be accompanied by an initial bond in favor of the owner/tender committee to be valid for a period mentioned in the tendering procedures. All bids received are documented and notified. The tender, which is submitted as a sealed document, is opened as mentioned in tendering procedures.

2.6.6 Manage Risks

Please refer to Table 1.43 under Section 1.3.2.9.3 lists typical risks affecting contractors.

Following are typical risks likely to occur during this phase:

- Not all the qualified bidders taking part in bidding for the project.
- Bidders notice errors and omissions in construction documents resulting delays in submission of bids.
- Amendment to construction documents.
- Addendum.

Project Name
Project Number
Bid Clarification Form

Serial Number	Name of Contractor	Item No. and Clause Reference	Queries	Owner/Condultant's Clarification	Remarks

FIGURE 2.20 Bid clarification form.

- Delay in submission of bids than the notified one.
- Bid value exceeding the estimated definitive cost.
- Successful bidder fails to submit performance bond.

The owner/designer has to consider these risks and plan the phase duration accordingly.

2.6.7 Review Bid Documents

The designer (consultant) reviews the bids for compliance with tender requirements.

2.6.7.1 Evaluate Bids

The designer (consultant) evaluates the bid documents of each of the submitted bids. Please refer to Section 1.3.2.10.3.5.1 for bid evaluation process and Table 1.49 for bid review checklist.

2.6.7.2 Select Contractor

The contractor is selected based on the procurement strategy adopted by the owner.

2.6.8 Award Contract

Figure 2.21 illustrates the contract award process.

2.7 CONSTRUCTION PHASE

Construction is translating the owner's goals and objectives, by the contractor, to build the facility as stipulated in the contract documents, plans, and specifications within budget and on schedule. Construction is the sixth phase of the construction project life cycle and is an important phase in construction projects. A majority of

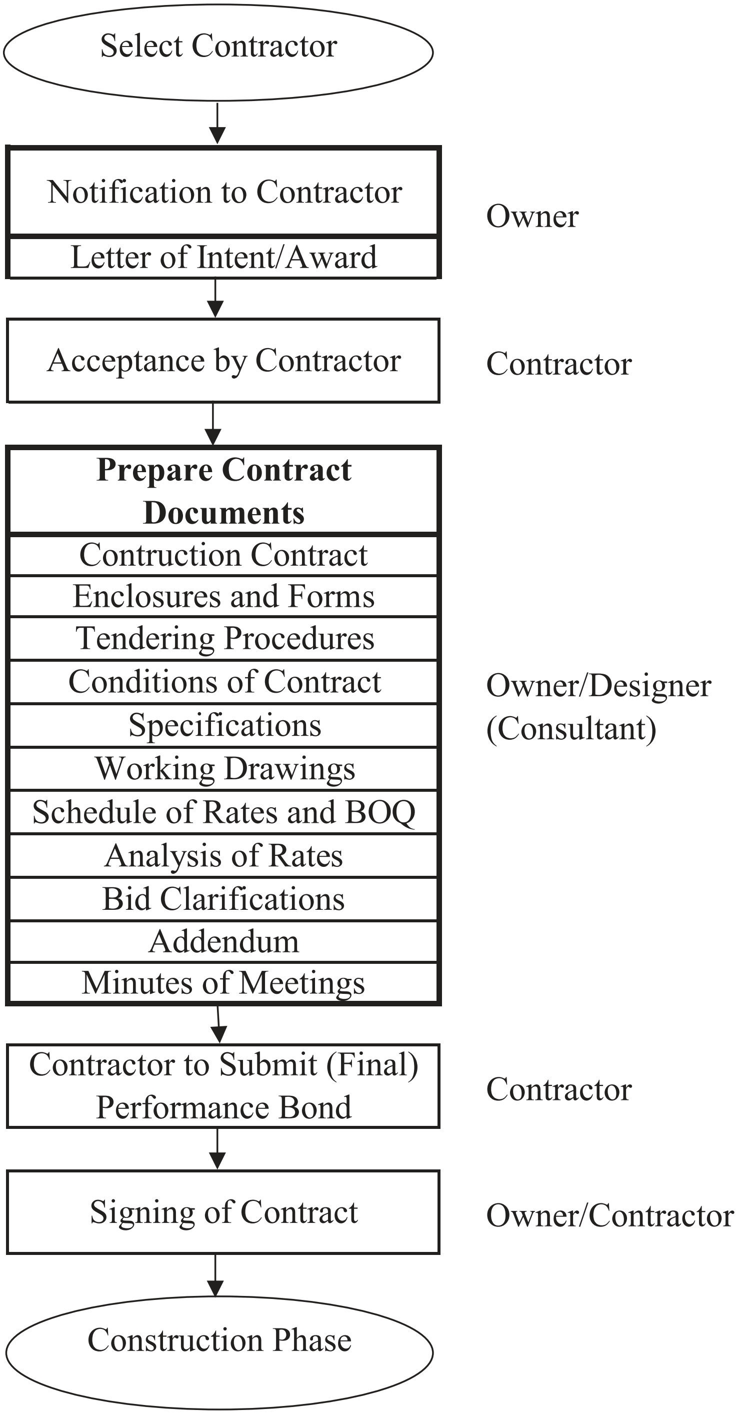


FIGURE 2.21 Contract award procedure.

total project budget and schedule is expended during construction. Similar to costs, the time required to construct the project is much higher than the time required for preceding phases. Construction usually requires a large workforce and a variety of activities. Construction activities involve erection, installation, or construction of any part of the project. Construction activities are actually carried out by the contractor's own workforce or by subcontractors. Construction, therefore, requires more detailed attention of its planning, organization, monitoring, and control of project schedule, budget, quality, safety, and environmental concerns. Table 2.28 illustrates the major activities relating to construction phase developed based on the project management process group's methodology and Figure 2.22 illustrates the logic flow process for the construction phase.

2.7.1 Develop Project Execution Requirements

Once the contract is awarded to the successful bidder (contractor), then it is the responsibility of the contractor to respond to the needs of the client (owner) by building the facility as specified in the contract documents, drawings, and specifications within the budget and time.

2.7.1.1 Identify Contract Requirements

In order to develop contract requirements, the contractor has to review all the construction documents that are part of the contract that the contractor has signed with the owner of the project. This includes:

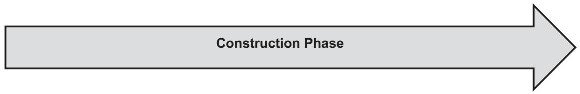
- Working drawings.
- Specification.
- Contract documents.
- Other related documents.

2.7.1.1.1 Review Construction Drawings

The contractor has to review the construction/working drawings to understand the project requirements. Each trade engineer has to review the drawing and understand the construction procedure to be followed to avoid omission and rework. The trade engineers have to:

- Prepare a list of issues to be resolved and information needed from the designer (consultant).
- Prepare a list of conflicting items in the drawings.
- Compare the estimated bid activities and actual materials for proper execution of project.
- Identify high-risk items.
- Check constructability as per the specified method statement.
- Identify the execution process that can be simplified.
- Identify discrepancies between drawings and specifications.
- Identify any missing drawing required to execute the project.
- Identify value engineering change proposal.

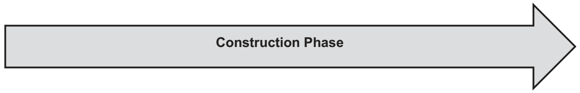
TABLE 2.28
Major Activities Relating to Construction Phase Processes



Management Processes	Project Management Process Group				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Integration Management	Contract Documents	Construction Management Plan	Mobilization	Compliance to Contract Documents	Executed Project
	Tender Documents		Submittals	Change Management	
	Notice to Proceed		Execution Process		
			Construction Work		
Stakeholder Management	Owner's Representative	Responsibility Matrix		Project Status/Performance Report	
	Supervision Team	Stakeholder Requirements		Payments	
	Contractor's Core Staff	Reports		Variation Orders	
	Subcontractor	Meetings		Conflict Resolution	
	Authorities				
Scope Management		Scope Change Management	Design Changes	Authorities Approval	
		Preventive and Corrective Actions		Stakeholders Approval	
				Scope Change Control	
				Alternate Material	
				Site Work Instruction	
				Variation Orders	
				Preventive and Corrective Actions	

(*Continued*)

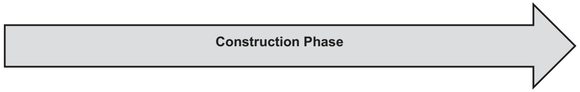
TABLE 2.28 Continued
Major Activities Relating to Construction Phase Processes



Management Processes	Project Management Process Group				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
				Plan Updates	
Schedule Management		Contractor's Construction Schedule		Schedule Monitoring	
				Schedule Control	
				Work Progress Monitoring	
				Submittals Monitoring	
Cost Management		Contracted Value of Project		Cost Control	
		Construction Budget		Cash Flow	
				Progress Payment	
				Variation Orders	
Quality Management		Contractor's Quality Control Plan	Quality Assurance	Quality Control	
			Shop Drawings	Quality Auditing	
			Builders Drawings	Material Inspection	
			Composite Drawings	Work Inspection/Testing	
			Material Approvals	Rework	
			Method Statement	Regulatory Compliance	
Resource Management		Resource Management Plan	Training of Project Team Members	Performance of Team Members	Demobilization of Workforce

(*Continued*)

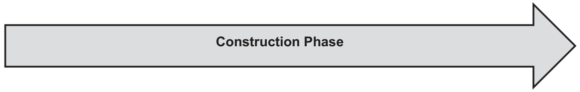
TABLE 2.28 Continued
Major Activities Relating to Construction Phase Processes



Management Processes	Project Management Process Group				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
		Project Manpower	Manage Project Team	Dispute Resolution	
		Subcontractor			
		Material and Equipment		Performance of Workforce	
Communication Management	Kick off Meeting	Communication Plan	Site Administration Matrix	Meetings	
		Submittals			
		Documentation			
		Correspondence			
Risk Management		Risk Management Plan		Control Risk	
		Construction Risks Register		Risk Audit	
Contract Management		Contract Management	Contract Documents	Inspection	Finalize Work Performed
		Plan Purchase of Material/ Equipment	Selection of Subcontractor(s)	Check List	Finalize Material/ Equipment Supplier's Contract
			Material, Systems and Equipment		
HSE Management		Safety Management Plan	Site Safety	Accident Prevention Measures	
		Waste Management Plan	Temporary Fire Fighting	Loss Prevention during Construction	

(*Continued*)

TABLE 2.28 Continued
Major Activities Relating to Construction Phase Processes



Management Processes	Project Management Process Group				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Financial Management		Finance Management Plan	Contractor's Payments	Financial Control	Payment to Consultant
		Contractor Payment	Staff Payment		
		Material and Equipment Payments	Material and Equipment Payments		Payment to Contractor/ Subcontractor
			Progress (Interim Payment) Payment		Material and Equipment Payment
Claim Management		Claim Identification	Claim/Dispute Administration	Claim Prevention	Claim Payments
		Claim Quantification		Conflict Resolution	Settle Claims

Note: These activities may not be strictly sequential, however, the breakdown allows implementation of project management function more effectively and easily manageable at different stages of the project phase.

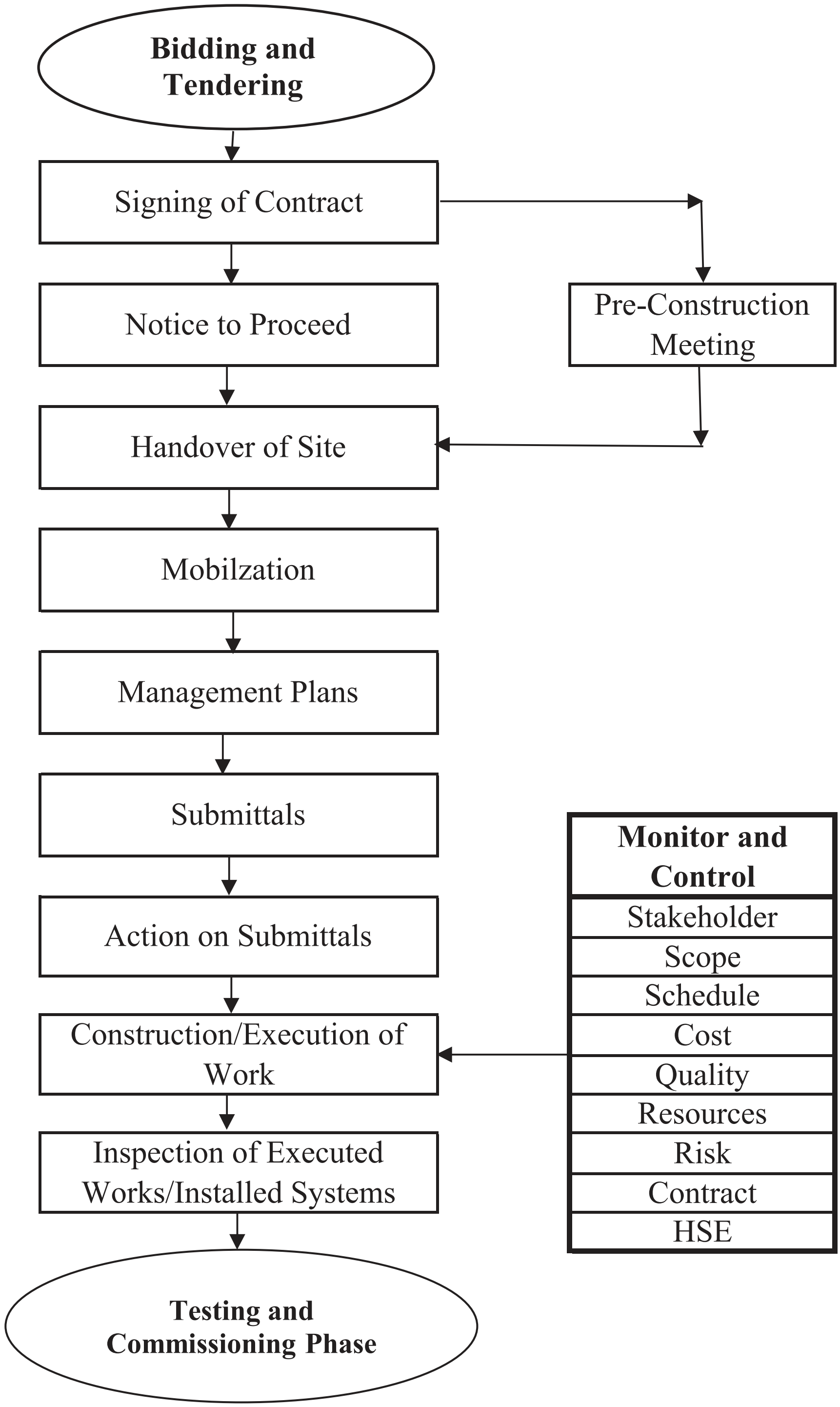


FIGURE 2.22 Logic flow process for construction phase.

- Identify complete scope of work.
- Prepare construction material takeoff.

2.7.1.1.2 Review Specifications

Contractor has to review specifications and check for the following major points:

- Matching of construction drawings and specification requirements.
- Any missing specifications.
- Issues that need to be resolved.
- If there are discrepancies between specifications and drawings.
- Codes and Standards to be followed.
- Submittal requirements.
- Quality requirements.
- Safety requirements.
- Environmental requirements.
- Installation procedure for owner-supplied items.

2.7.1.1.3 Review Contract Documents

Contractor has to carefully study all the clauses of the contract and identify:

- High-risk clauses.
- Items having price difference between bid price and the actual price for the items to be installed for specified performance of work/system.
- Items need to be resolved by raising the RFI.
- Clauses having conflict with regulatory requirements.
- Schedule constraints.
- Ambiguous clauses.
- Clauses that favor the owner.
- Coordination among all the parties involved in the project.
- Any hidden clause that will entitle the owner for compensation claim from the contractor.
- Priorities among various construction documents.
- Discrepancies and conflicting clauses.
- Change order process.
- Claim for extra work.
- Payment procedure.
- Damage and penalty for delay clauses.
- Force majeure clause.

2.7.1.2 Establish Construction Phase Requirements

Contract requirements are established taking into consideration items identified under Section 2.7.1.1. The following are the major requirements:

- Construction of the facility/project as per the specifications.
- Complete the facility within the specified schedule.
- Complete the facility within the contracted amount.
- Complete the facility as per the quality requirements.

2.7.2 Develop Construction Management Plan

Table 2.29 illustrates the contents of the contractor's construction management plan.

2.7.3 Identify Stakeholders

Most stakeholders listed in Figure 1.23 have involvement in the project during the construction phase. These are:

1. Owner
   - Owner's Representative/Project Manager
2. Construction Supervisor
   - Construction Manager (Agency)
   - Consultant (Designer)
   - Specialist Contractor
3. Contractor
   - Main Contractor
   - Subcontractor
   - Supplier
4. Regulatory Authorities
5. End User

2.7.3.1 Identify Owner's Representative/Project Manager

The owner from his/her office deputes or hires from outside, an Owner's Representative (OR) to administer the overall project. The OR should have relevant experience, knowledge about the construction processes of similar nature of project. He/she should be able to manage the project with the help of the supervising team member. In FIDIC terminology, this person is known as the "engineer" who is appointed by the "employer" (owner). (Please refer to Chapter 6 for more information.)

2.7.3.2 Identify Supervision Team

In a traditional type of contract, the client selects the same firm that has designed the project. The firm known as the "consultant" is responsible for supervising the construction process and achieving project quality goals. The firm appoints a representative, who is acceptable and approved by the owner/client, to be on-site and is often called the Resident Engineer (R.E.). The RE, along with supervision team members, is responsible to supervise, monitor, control, and implement the procedure specified in the contract documents and ensure completion of the project within specified time, budget, and per defined scope of work.

In order to ensure a smooth flow of supervision activities, the RE has to follow the organization's supervision manual and contractual requirements. Depending on the type and size of the project, the supervision team usually consists of the following personnel:

1. Resident Engineer
2. Contract Administrator/Quantity Surveyor

TABLE 2.29
Contents of Construction Management Plan

Section	Topic
1	Introduction
	1.1 Project Description
	1.2 Project Scope
	1.3 Key Milestone Dates
2	Construction Management Organization
	2.1 Organization Chart
	2.2 Roles and Responsibilities
	2.3 Coordination and Liaison
3	Quality Management Plan
4	Risk Management Plan
5	Health Safety and Environmental Management Plan
	5.1 Site Safety
	5.2 Hazard Management
	5.3 Waste Management
6	Construction Schedule
7	Change Management
8	Construction Methodology
	8.1 Material Submittals and Approvals
	8.2 Shop Drawing Submittals and Approvals
	8.3 Coordination and Composite Drawings
	8.4 Regulatory Approvals
9	Subcontractor Coordination
	9.1 Selection of Subcontractor
	9.2 Coordination with Subcontractor
10	Resources
	10.1 Workforce
	10.2 Equipment
11	Execution of Work
	11.1 Method Statement
	11.2 Mock-up
	11.3 Work Sequence
	11.4 Site Activities (Installation and Coordination)
	11.5 Inspection of Executed Works
	11.6 Material Storage and Handling
12	Testing and Commissioning
13	Site Administration and Finance Management
14	Site Access and Security

3. Planning/Scheduling Engineer
4. Engineers from Different Trades, Such as Architectural, Structural, Mechanical, HVAC, Electrical, Low Voltage Systems, Landscape, Infrastructure
5. Inspectors from Different Trades
6. Interior Designer
7. Document Controller
8. Office Secretary

The construction phase consists of various activities such as mobilization, execution of work, planning and scheduling, control and monitoring, management of resources/procurement, quality, and inspection. Table 2.30 illustrates the major activities to be performed by the supervisor during the construction phase.

The owner may engage a construction manager (agency) to supervise complex and major projects. CM's role during construction stage is already discussed under Section 3.5.3 (Chapter 3, Volume 1).

TABLE 2.30
Responsibilities of Construction Supervisor (Consultant)

Sr. No.	Description
1	Achieving the quality goal as specified.
2	Review contract drawings and resolve technical discrepancies/errors in the contract documents.
3	Review construction methodology.
4	Approval of contractor's construction schedule.
5	Monitoring and controlling construction time.
6	Monitoring and controlling construction expenditure.
7	Approval of contractor's quality control plan.
8	Regular inspection and checking of executed work.
9	Review and approval of construction materials.
10	Review and approval of shop drawings.
11	Inspection of construction material.
12	Conduct progress and technical coordination meetings.
13	Coordination of owner's requirements and comments related to site activities.
14	Project related communication with contractor.
15	Coordination with regulatory authorities.
16	Evaluating risk and making decisions related to unforeseen conditions.
17	Maintaining project records.
18	Processing of site work instructions for owner's action.
19	Evaluation and processing of variation order/change order.
20	Recommendation of contractor's payment to owner.
21	Approval of contractor's safety management plan.
22	Monitor safety at site and HSE requirements.
23	Supervise testing, commissioning, and handover of the project.
24	Issue substantial completion certificate.

2.7.3.3 Identify Contractor's Core Staff

Contract documents normally specify a list of the minimum number of core staff to be available at site during the construction period. The absence of any of these staff may result in a penalty to be imposed on the contractor by the owner.

The following is a typical list of contractor's minimum core staff needed during construction period for execution of work of a major building construction project.

1. Project Manager
2. Site Senior Engineer for Civil Work
3. Site Senior Engineer for Architectural Work
4. Site Senior Engineer for Electrical Work
5. Site Senior Engineer for Mechanical Work
6. Site Senior Engineer for HVAC Work
7. Site Senior Engineer for Infrastructure Work
8. Planning Engineer
9. Senior Quantity Surveyor/Contract Administrator
10. Civil Work Foreman
11. Architectural Work Foreman
12. Electrical Work Foreman
13. Mechanical Work Foreman
14. HVAC Work Foreman
15. Laboratory Technician
16. Quality Control Engineer
17. Safety Officer

2.7.3.4 Identify Regulatory Authorities

In certain countries there is a regulation to submit electrical, mechanical, and HVAC drawings for review and approval by the authorities. Contractor has to identify which drawings/documents are to be submitted to the authorities during the construction phase. A necessary letter to the regulatory authorities/agencies is issued by the owner upon request for such a letter from the contractor.

2.7.3.5 Identify Subcontractors

In most construction projects, the contractor engages special subcontractors to execute a certain portion of the contracted project work. Areas of subcontracting are generally listed in the particular conditions of the contract document. Generally, the contractor has to submit subcontractors/specialist contractors to execute the following types of work:

1. Precast Concrete Work
2. Metal Work
3. Space Frame, Roofing Work
4. Wood Work
5. Aluminum Work
6. Internal Finishes (such as painting, false ceiling, tiling, cladding)

7. Furnishings
8. Waterproofing and Insulation Work
9. Mechanical Work
10. HVAC Work
11. Electrical Work
12. Low Voltage Systems/Smart Building System
13. Landscape
14. External Work
15. Any Other Specialized Work

The contractor has to submit their names for approval to the owner prior to their engagement to perform any work at the site. Table 2.31 is an example subcontractor selection questionnaire.

TABLE 2.31
Subcontractor Selection Questionnaire

Instructions

Please type or write all your replies legibly. Attach additional sheets if required.

PART I

I.1 Company Information

I.1.1 Name of Organization:

I.1.2 Commercial Registration No.:

I.1.3 Year of Establishment:

I.1.4 Type of Company:

I.1.5 Company Address:

I.1.6 Affiliate Company Name(s) and Address:

I.2 Subcontract Work (Please tick mark all interested)

Sr. No.	Work Description	Detailed Design	Preparation of Shop Drawing	Construction	Inspection/ Auditing
1	Architectural Work				
2	Structural Work				
3	Precast Work				
4	Internal Finishes				
5	External Finishes				
6	Plumbing				
7	Drainage				
8	Fire Fighting				
9	HVAC				
10	Elevator				
11	Escalator				
12	Electrical Work (Power)				
13	Electrical Work (Low Voltage)—Specify				
14	Instrumentation				

(*Continued*)

TABLE 2.31 Continued
Subcontractor Selection Questionnaire

Instructions

15	Building Management System
16	Irrigation
17	Landscape Work
18	Pavements
19	Streets/Roads
20	Waterproofing

PART II

II.1 Financial Information

II.1.1 Provide Copy of Audit Balance Sheet:
II.1.2 Provide Bonding Capacity:
II.1.3 Provide Insurance Capacity:
II.1.4 Provide Bank Reference:

PART III

III.1 Organization Details

III.1.1 Core Business Area:
III.1.2 Organization Chart:
III.1.3 ISO Certification:
III.1.4 Years of Experience:

III.2 Project Details

III.2.1 Project History for Last Ten Years

Sr. No.	Name of Project	Type of Work	Value	Peak Workforce	Start Date	Finish Date
1						
2						
3						
4						

III.2.2 Current Projects

Sr. No.	Name of Project	Type of Work	Value	Peak Workforce	Start Date	Expected Finish Date
1						
2						
3						

PART IV

IV.1 Management StaffI

V.1.1 Provide List of Project Managers, Project Engineers, Engineers

IV.2 Workforce

Sr. No.	Work Description	Technicians	Foreman	Skilled	Unskilled
1	Architectural Work				
2	Structural Work				
3	Precast Work				
4	Internal Finishes				
5	External Finishes				

(*Continued*)

TABLE 2.31 Continued
Subcontractor Selection Questionnaire

Instructions	
6	Plumbing
7	Drainage
8	Fire Fighting
9	HVAC
10	Elevator
11	Escalator
12	Electrical Work (Power)
13	Electrical Work (Low Voltage)—Specify
14	Instrumentation
15	Building Management System
16	Irrigation
17	Landscape Work
18	Pavements
19	Streets/Roads
20	Waterproofing
PART V	
V.1 Quality Management System	
V.1.1 Provide Copy of ISO Certificate	
V.I.2 Person in Charge of QA/QC Activities:	
PART VI	
VI.1 HSE System	
VI.1 Does Company Have HSE Policy	
VI.1.2 Provide Site Accident Records for Last Two Years	

Declaration *We hereby declare that the information provided herein is true to our knowledge. Note:* All relevant documents attached. *Signature of Authorized Person*

2.7.3.5.1 Nominated Subcontractors

In certain projects, the owner/client selects a contractor, known as nominated subcontractor, to carry out certain part of the work on behalf of the owner/client. Normally, the nominated subcontractor is imposed on the main contractor after the main contractor is appointed. The nominated subcontractor may be a specialist supplier, specialist contractor nominated in accordance with the contract to be employed by the contractor for the supply of materials or services, or to execute the project work.

2.7.3.6 Establish Stakeholders' Requirements

A distribution matrix based on the interest and involvement of each stakeholder is prepared and the appropriate documents are sent for their action/information as per the agreed upon requirements. Table 2.32 shows an example matrix for site administration of a building construction project.

TABLE 2.32
Matrix for Site Administration

Sr. No.	Description of Activities	Contractor	Consultant	Owner
1	***General***			
	1.1 Notice to Proceed	-	-	P
	1.2 Bonds and Guarantees	P	R	A
	1.3 Consultant Staff Approval	-	P	A
	1.4 Contractor's Staff Approval	P	R/B	A
	1.5 Payment Guarantee	P	R	A
	1.6 Master Schedule	P	R	A
	1.7 Stoppage of Work	-	P	A
	1.8 Extension of Time	-	P	A
	1.9 Deviation from Contract Documents	P	R	A
	a. Material			
	b. Cost			
	c. Time			
2	***Communication***			
	2.1 General Correspondence	P	P	P
	2.2 Job Site Instruction	D	P	C
	2.3 Site Work Instruction	D	P/B	A
	2.4 Request for Information	P	A	C
	2.5 Request for Modification	P	B	A
3	***Submittals***			
	3.1 Subcontractor	P	B/R	A
	3.2 Materials	P	A	C
	3.3 Shop Drawings	P	A	C
	3.4 Staff Approval	P	B	A
	3.5 Pre-Meeting Submittals	P	D	C
4	***Plans and Programs***			
	4.1 Construction Schedule	P	R	C
	4.2 Submittal Logs	P	R	C
	4.3 Procurement Logs	P	R	C
	4.4 Schedule Update	P	R	C
5	***Monitor and Control***			
	5.1 Progress	D	P	C
	5.2 Time	D	P	C
	5.3 Payments	P	R/B	A
	5.4 Variations	P	R/B	A
	5.5 Claims	P	R/B	A
6	***Quality***			
	6.1 Quality Control Plan	P	R	C
	6.2 Checklists	P	D	C
	6.3 Method Statements	P	A	C
	6.4 Mock-Up	P	A	B
	6.5 Samples	P	A	B
	6.6 Remedial Notes	D	P	C

(*Continued*)

TABLE 2.32 Continued
Matrix for Site Administration

Sr. No.	Description of Activities	Contractor	Consultant	Owner
	6.7 Non-Conformance Report	D	P	C
	6.8 Inspections	P	D	C
	6.9 Testing	P	A	B
7	***Site Safety***			
	7.1 Safety Program	P	A	C
	7.2 Accident Report	P	R	C
8	***Meetings***			
	8.1 Progress	E	P	E
	8.2 Coordination	E	P	C
	8.3 Technical	E	P	C
	8.4 Quality	P	C	C
	8.5 Safety	P	C	C
	8.6 Closeout	-	P	
9	***Reports***			
	9.1 Daily Report	P	R	C
	9.2 Monthly Report	P	R	C
	9.3 Progress Report	-	P	A
	9.4 Progress Photographs	-	P	A
10	***Close Out***			
	10.1 Snag List	P	P	C
	10.2 Authorities Approvals	P	C	C
	10.3 As-Built Drawings	P	D/A	C
	10.4 Spare Parts	P	A	C
	10.5 Manuals and Documents	P	R/B	A
	10.6 Warranties	P	R/B	A
	10.7 Training	P	C	A
	10.8 Handover	P	B	A
	10.9 Substantial Completion Certificate	P	B/P	A

Notes: P: Prepare/Initiate B: Advise/Assist R: Review/Comment A: Approve D: Action E: Attend C: Information

2.7.3.7 Develop Responsibility Matrix

Table 2.33 illustrates the responsibilities of various participants during the construction phase.

2.7.4 Develop Project Execution Scope

Following is the scope of work to be executed during the construction phase:

1. Execution of Work
   - Site work, such as cleaning and excavating of project site.
   - Construction of foundations, including footings and grade beams.

TABLE 2.33
Responsibilities of Various Participants (Design-Bid-Build Type of Contracts) during Construction Phase

Phase	Responsibilities		
	Owner	**Supervisor**	**Contractor**
Construction	• Approve Subcontractor(s) • Approve Contractor's Core Staff • Legal/Regulatory Clearance • SWI • VO • Payments	• Supervision • Approve Plan • Monitor Work Progress • Approve Material • Approve Shop Drawings • Monitor Schedule • Control Budget • Recommend Payment	• Execution of Work • Contract Management • Selection of S ubcontractor(s) • Planning • Resources • Procurement • Quality • Safety

- Construction of columns and beams.
- Forming, reinforcing, and placing the floor slab.
- Laying up masonry walls and partitions.
- Installation of roofing system.
- Finishes.
- Furnishings.
- Conveying system.
- Installation of fire suppression system.
- Installation of water supply, plumbing, and public health systems.
- Installation of heating, ventilating, and air conditioning systems.
- Integrated automation system.
- Installation of electrical lighting and power systems.
- Emergency power supply system.
- Fire alarm system.
- Communication system.
- Electronic security and access control system.
- Landscape work.
- External work.

2. Monitoring and Control during Construction
   - Stakeholder's requirements.
   - Project schedule.
   - Project cost.
   - Project quality.
   - Safety during construction.
3. Inspection of Executed Work

2.7.4.1 Establish Construction Phase Deliverables

The deliverables of construction phase are executed/constructed project complete and duly inspected with the following work:

1. Construction
   a. Structural Work

   b. Architectural
   c. Internal Finishes
   d. External Finishes
   e. Conveying System
   f. MEP Work
   g. Information and Communication
   h. Low Voltage Systems
   i. Landscape Work
   j. External Work
   k. Furnishings
2. Record Drawings/Updated Working Drawings (Shop Drawings)
3. Updated Specifications

2.7.5 Develop Contractor's Construction Schedule

Prior to the start of execution of the project or immediately after the actual project starts, the contractor prepares the project construction plans based on the contracted time schedule of the project. Detailed planning is needed at the start of construction in order to decide how to use the resources such as labor, plants, materials, finance, and subcontractors, economically and safely to achieve the specified objectives. The plan shows the periods for all sections of the work and activities indicating that everything can be completed by the date specified in the contract and ready for use or for installation of equipment by other contractors.

Project planning is a logical process to determine what work must be done to achieve project objectives and ensure that the work of project is carried out:

- In an organized and structured manner.
- Reducing uncertainties to minimum.
- Reducing risk to minimum.
- Establishing quality standards.
- Achieving results within budget and scheduled time.

Depending on the size of the project, the project is divided into multiple zones and relevant activities are considered for each zone to prepare the construction program. While preparing the program the relationships between project activities and their dependency and precedence are considered by the planner. These activities are connected to their predecessor and successor activity based on how the task is planned to be executed. There are four possible relationships that exist between various activities. These are finish-to-start relationship, the start-to-start relationship, the finish-to-finish relationship, and start-to-finish relationship.

Once all the activities are established by the planner and estimated duration of each activity has been assigned, the planner prepares a detailed program fully coordinating all the construction activities.

The first step in preparation of the construction program is to establish the activities, the next step is to establish the estimated time duration of each activity. The deadline for each activity is fixed, but it is often possible to reschedule by changing the sequence in which the tasks are performed while retaining the original estimate.

The activities to be performed during execution are project are grouped into a number of categories. Each of these categories has a number of activities. The following are the major categories of construction project schedules:

A. General Activities
1. Mobilization

B. Engineering
1. Subcontractor Submittal and Approval
2. Materials Submittal and Approval
3. Shop Drawing Submittal and Approval
4. Procurement

C. Site Activities
1. Site Earth Work
2. Dewatering and Shoring
3. Excavation and Backfilling
4. Raft Work
5. Retaining Wall Work
6. Concrete Foundation and Grade Beams
7. Waterproofing
8. Concrete Columns and Beams
9. Casting of Slabs
10. Wall Partitioning
11. Interior Finishes
12. Furnishings
13. External Finishes
14. Equipment
15. Conveying Systems Work
16. Fire Suppression Work
17. Plumbing and Public Health Work
18. HVAC Work
19. Electrical Work
20. Fire Alarm System Work
21. Information and Communication System Work
22. Low Voltage Systems Work
23. Landscape Work
24. External Work

D. Close Out
1. Testing and Commissioning
2. Completion and Handover

The contractor also submits the following along with the construction schedule:

1. Resources (equipment and manpower) schedule.
2. Cost loading (schedule of item's pricing based on bill of quantities).

Figure 2.23 illustrates a logic flow diagram for development of the construction schedule (please also refer to Figure 1.48), and Figure 2.24 illustrates an example of a contractor's construction schedule. (The example schedule is the construction of a branch for a bank.)

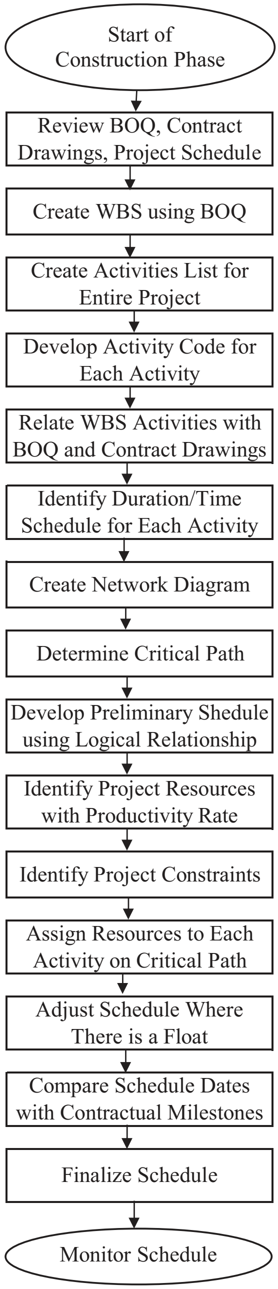
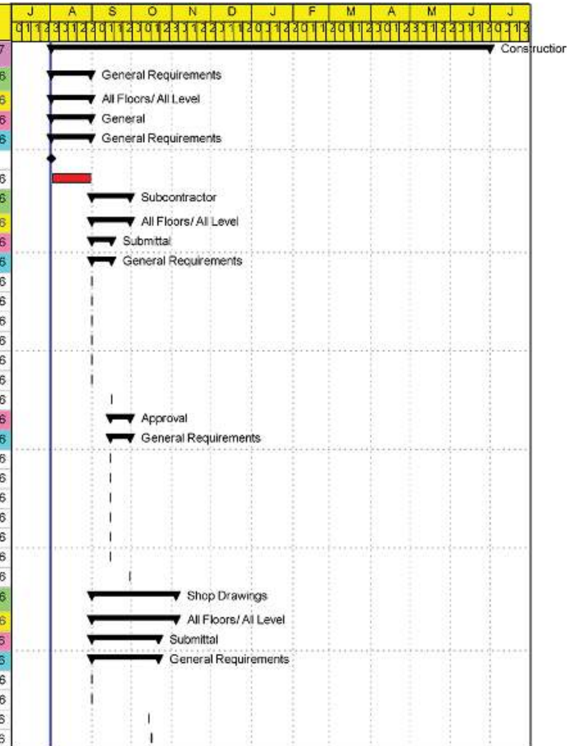


FIGURE 2.23 Logic flow process for development of construction schedule.

Activity Name	Original Duration	Start	Finish
Construction of a Branch A Office for XYZ Bank	334	01-Aug-16	30-Jun-17
General Requirements	31	01-Aug-16	31-Aug-16
All Floors/ All Level	31	01-Aug-16	31-Aug-16
General	31	01-Aug-16	31-Aug-16
General Requirements	31	01-Aug-16	31-Aug-16
Project Start	0	01-Aug-16	
Site Mobilization	30	02-Aug-16	31-Aug-16
Subcontractor	30	01-Sep-16	30-Sep-16
All Floors/ All Level	30	01-Sep-16	30-Sep-16
Submittal	16	01-Sep-16	16-Sep-16
General Requirements	16	01-Sep-16	16-Sep-16
Submit HVAC Subcontractor	1	01-Sep-16	01-Sep-16
Submit Electrical Subcontractor	1	01-Sep-16	01-Sep-16
Submit Plumbing/FF Subcontractor	1	01-Sep-16	01-Sep-16
Submit Wood Work Subcontractor	1	01-Sep-16	01-Sep-16
Submit Alu. & Curtain Wall Subcontractor	1	01-Sep-16	01-Sep-16
Submit Concrete Supplier	1	01-Sep-16	01-Sep-16
Submit Elevator Subcontractor	1	16-Sep-16	16-Sep-16
Approval	16	15-Sep-16	30-Sep-16
General Requirements	16	15-Sep-16	30-Sep-16
Approve HVAC Subcontractor	1	15-Sep-16	15-Sep-16
Approve Electrical Subcontractor	1	15-Sep-16	15-Sep-16
Approve Plumbing/FF Subcontractor	1	15-Sep-16	15-Sep-16
Approve Wood Work Subcontractor	1	15-Sep-16	15-Sep-16
Approve Alu. & Curtain Wall Subcontractor	1	15-Sep-16	15-Sep-16
Approve Concrete Supplier	1	15-Sep-16	15-Sep-16
Approve Elevator Subcontractor	1	30-Sep-16	30-Sep-16
Shop Drawings	65	01-Sep-16	04-Nov-16
All Floors/ All Level	65	01-Sep-16	04-Nov-16
Submittal	51	01-Sep-16	21-Oct-16
General Requirements	51	01-Sep-16	21-Oct-16
Submit Architectural Drawings	1	01-Sep-16	01-Sep-16
Submit Structural Drawings	1	01-Sep-16	01-Sep-16
Submit Counter / Cabinets Drawings	1	14-Oct-16	14-Oct-16
Submit HVAC Drawings	1	16-Oct-16	16-Oct-16

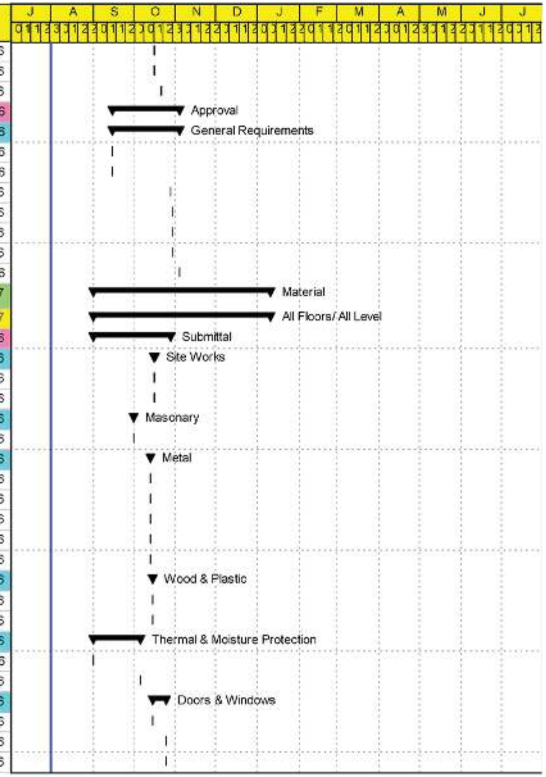


Remaining Work
Critical Remaining Work
◆ Milestone
Summary

Page 1 of 19

FIGURE 2.24 Contractor's construction schedule.

Activity Name	Original Duration	Start	Finish
Submit Plumbing/FF Drawings	1	16-Oct-16	16-Oct-16
Submit Electrical Drawings	1	16-Oct-16	16-Oct-16
Submit Low Voltage Drawings	1	21-Oct-16	21-Oct-16
Approval	51	15-Sep-16	04-Nov-16
General Requirements	51	15-Sep-16	04-Nov-16
Approve Architectural Drawings	1	15-Sep-16	15-Sep-16
Approve Structural Drawings	1	15-Sep-16	15-Sep-16
Approve Counter / Cabinets Drawings	1	28-Oct-16	28-Oct-16
Approve HVAC Drawings	1	30-Oct-16	30-Oct-16
Approve Plumbing/FF Drawings	1	30-Oct-16	30-Oct-16
Approve Electrical Drawings	1	30-Oct-16	30-Oct-16
Approve Low Voltage Drawings	1	04-Nov-16	04-Nov-16
Material	132	01-Sep-16	10-Jan-17
All Floors/ All Level	132	01-Sep-16	10-Jan-17
Submittal	58	01-Sep-16	28-Oct-16
Site Works	1	16-Oct-16	16-Oct-16
Submit Pavers, Kerbstone	1	16-Oct-16	16-Oct-16
Submit Plants	1	16-Oct-16	16-Oct-16
Masonary	1	01-Oct-16	01-Oct-16
Submit Block	1	01-Oct-16	01-Oct-16
Metal	1	13-Oct-16	13-Oct-16
Submit Steel Covers	1	13-Oct-16	13-Oct-16
Submit Handrail & Balustrade	1	13-Oct-16	13-Oct-16
Submit Wooden Cladding Material	1	13-Oct-16	13-Oct-16
Submit External Door Matt (Metal)	1	13-Oct-16	13-Oct-16
Submit Canopy Materials (Roof & Glass)	1	13-Oct-16	13-Oct-16
Wood & Plastic	1	15-Oct-16	15-Oct-16
Submit Counter Wood materials / Accs.	1	15-Oct-16	15-Oct-16
Submit Wooden Material (Wall/Ceiling/Skirting)	1	15-Oct-16	15-Oct-16
Thermal & Moisture Protection	36	01-Sep-16	06-Oct-16
Submit Water Proofing Material	1	01-Sep-16	01-Sep-16
Submit Thermal Insulation b/h Stone Cladding	1	06-Oct-16	06-Oct-16
Doors & Windows	11	15-Oct-16	25-Oct-16
Submit Vault Door	1	15-Oct-16	15-Oct-16
Submit Door (Steel / Wooden / Siding)	1	25-Oct-16	25-Oct-16
Submit Hardware (Doors)	1	25-Oct-16	25-Oct-16



Remaining Work ◆ Milestone
Critical Remaining Work Summary

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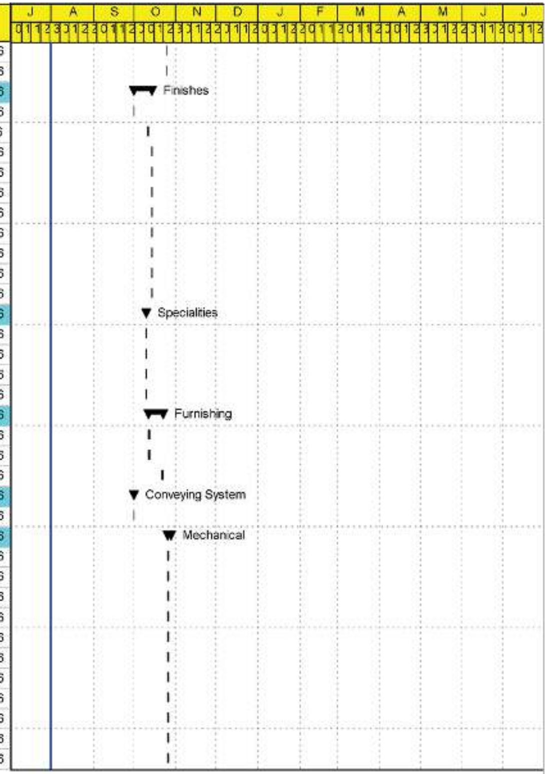
FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Submit Curtain Wall	1	25-Oct-16	25-Oct-16
Submit Aluminum Composite Panel	1	25-Oct-16	25-Oct-16
Finishes	14	01-Oct-16	14-Oct-16
Submit Granite/Marble Flooring	1	01-Oct-16	01-Oct-16
Submit Terrazo Tiles	1	11-Oct-16	11-Oct-16
Submit Gypsum Board Partition	1	14-Oct-16	14-Oct-16
Submit Gypsum Ceiling & Accs	1	14-Oct-16	14-Oct-16
Submit Gypsum Tiles (60x60) & Accs	1	14-Oct-16	14-Oct-16
Submit Ceramic Tiles (Wall & Floor)	1	14-Oct-16	14-Oct-16
Submit Vinyl Tiles & Skirting	1	14-Oct-16	14-Oct-16
Submit Sandstone Cladding -Ext Walls	1	14-Oct-16	14-Oct-16
Submit Carpet	1	14-Oct-16	14-Oct-16
Submit Paints	1	14-Oct-16	14-Oct-16
Specialities	1	10-Oct-16	10-Oct-16
Submit Raised Floor System (Teller/Server)	1	10-Oct-16	10-Oct-16
Submit Toilet Accs	1	10-Oct-16	10-Oct-16
Submit Trash Box (ATM Area)	1	10-Oct-16	10-Oct-16
Submit Rubber Wall Guard (Below ATM)	1	10-Oct-16	10-Oct-16
Furnishing	11	12-Oct-16	22-Oct-16
Submit Curtains	1	12-Oct-16	12-Oct-16
Submit Fixed Furnitures	1	12-Oct-16	12-Oct-16
Submit Kitchen Cabinet	1	22-Oct-16	22-Oct-16
Conveying System	1	01-Oct-16	01-Oct-16
Submit Elevator	1	01-Oct-16	01-Oct-16
Mechanical	3	26-Oct-16	28-Oct-16
Submit Ducting Material & Insulation	1	26-Oct-16	26-Oct-16
Submit Roof Top Package Units	1	26-Oct-16	26-Oct-16
Submit Room Split Units	1	26-Oct-16	26-Oct-16
Submit VCD	1	26-Oct-16	26-Oct-16
Submit Diffusers,Registers,Grilles	1	26-Oct-16	26-Oct-16
Submit Electric Duct Heaters for Package Units	1	26-Oct-16	26-Oct-16
Submit Fans (TEF,KEF,EF)	1	26-Oct-16	26-Oct-16
Submit Condensate Drain Pipes	1	26-Oct-16	26-Oct-16
Submit FP Pipes & Accs	1	26-Oct-16	26-Oct-16
Submit FP Pumps & Accs	1	26-Oct-16	26-Oct-16
Submit Fire Cabinets	1	26-Oct-16	26-Oct-16



Remaining Work ◆ ◆ Milestone
Critical Remaining Work Summary

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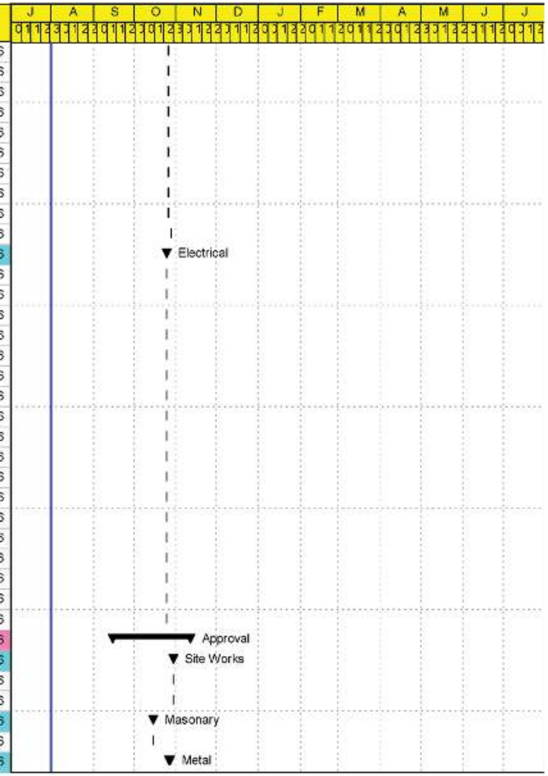
FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Submit Fire Extinguishers	1	26-Oct-16	26-Oct-16
Submit Sprinkler & Spray System	1	26-Oct-16	26-Oct-16
Submit Plumbing Pipes & Accs	1	26-Oct-16	26-Oct-16
Submit SS access cover for Meter Box	1	26-Oct-16	26-Oct-16
Submit Soil & Waste Water Pipes	1	26-Oct-16	26-Oct-16
Submit Sanitary Fixtures	1	26-Oct-16	26-Oct-16
Submit Water Booster Pumps	1	26-Oct-16	26-Oct-16
Submit Electric Water Heater	1	26-Oct-16	26-Oct-16
Submit GRP Water Tank	1	26-Oct-16	26-Oct-16
Submit Air Curtain	1	28-Oct-16	28-Oct-16
Electrical	1	25-Oct-16	25-Oct-16
Submit MSB, SMSB, ATS	1	25-Oct-16	25-Oct-16
Submit Distribution Boards	1	25-Oct-16	25-Oct-16
Submit Cables,Trays,Conduits	1	25-Oct-16	25-Oct-16
Submit AVA Alarm Panel	1	25-Oct-16	25-Oct-16
Submit 50 KVAR Capacitor	1	25-Oct-16	25-Oct-16
Submit Socket,Switches,Jn Box,DP	1	25-Oct-16	25-Oct-16
Submit Trunking	1	25-Oct-16	25-Oct-16
Submit Light Fixtures & Accs	1	25-Oct-16	25-Oct-16
Submit UPS	1	25-Oct-16	25-Oct-16
Submit Data Commun. System	1	25-Oct-16	25-Oct-16
Submit Server Cabinet	1	25-Oct-16	25-Oct-16
Submit Standby Diesel Generator & Fuel Storage Tank	1	25-Oct-16	25-Oct-16
Submit Earthing System	1	25-Oct-16	25-Oct-16
Submit Fire Alarm System	1	25-Oct-16	25-Oct-16
Submit CCTV System	1	25-Oct-16	25-Oct-16
Submit Access Control System	1	25-Oct-16	25-Oct-16
Submit Intrusion Detection System	1	25-Oct-16	25-Oct-16
Submit Queing System	1	25-Oct-16	25-Oct-16
Approval	58	15-Sep-16	11-Nov-16
Site Works	1	30-Oct-16	30-Oct-16
Approve Pavers, Kerbstone	1	30-Oct-16	30-Oct-16
Approve Plants	1	30-Oct-16	30-Oct-16
Masonary	1	15-Oct-16	15-Oct-16
Approve Block	1	15-Oct-16	15-Oct-16
Metal	1	27-Oct-16	27-Oct-16



Remaining Work ◆ ◆ Milestone
Critical Remaining Work Summary

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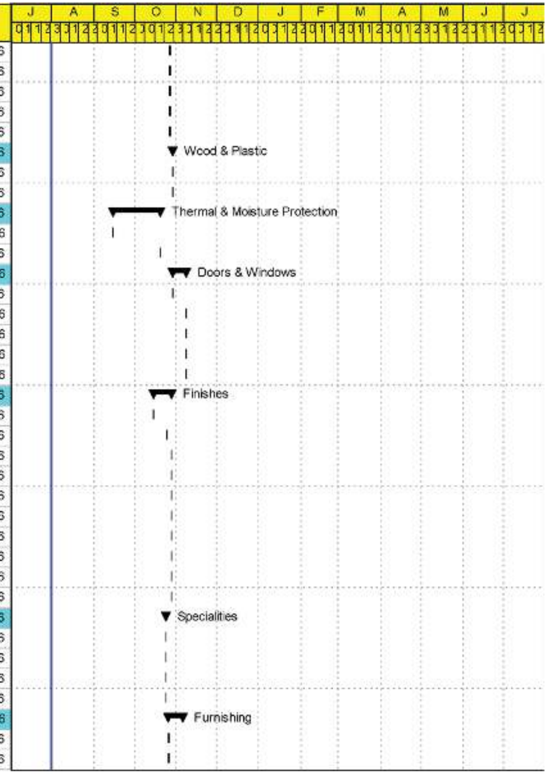
FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Approve Steel Covers	1	27-Oct-16	27-Oct-16
Approve Handrail & Balustrade	1	27-Oct-16	27-Oct-16
Approve Wooden Cladding Material	1	27-Oct-16	27-Oct-16
Approve External Door Matt (Metal)	1	27-Oct-16	27-Oct-16
Approve Canopy Materials (Roof & Glass)	1	27-Oct-16	27-Oct-16
Wood & Plastic	1	29-Oct-16	29-Oct-16
Approve Counter Wood materials / Accs.	1	29-Oct-16	29-Oct-16
Approve Wooden Material (Wall/Ceiling/Skirting)	1	29-Oct-16	29-Oct-16
Thermal & Moisture Protection	36	15-Sep-16	20-Oct-16
Approve Water Proofing Material	1	15-Sep-16	15-Sep-16
Approve Thermal Insulation b/h Stone Cladding	1	20-Oct-16	20-Oct-16
Doors & Windows	11	29-Oct-16	08-Nov-16
Approve Vault Door	1	29-Oct-16	29-Oct-16
Approve Door (Steel / Wooden / Sliding)	1	08-Nov-16	08-Nov-16
Approve Hardware (Doors)	1	08-Nov-16	08-Nov-16
Approve Curtain Wall	1	08-Nov-16	08-Nov-16
Approve Aluminum Composite Panel	1	08-Nov-16	08-Nov-16
Finishes	14	15-Oct-16	28-Oct-16
Approve Granite/Marble Flooring	1	15-Oct-16	15-Oct-16
Approve Terrazo Tiles	1	25-Oct-16	25-Oct-16
Approve Gypsum Board Partition	1	28-Oct-16	28-Oct-16
Approve Gypsum Ceiling & Accs	1	28-Oct-16	28-Oct-16
Approve Gypsum Tiles (60x60) & Accs	1	28-Oct-16	28-Oct-16
Approve Ceramic Tiles (Wall & Floor)	1	28-Oct-16	28-Oct-16
Approve Vinyl Tiles & Skirting	1	28-Oct-16	28-Oct-16
Approve Sandstone Cladding -Ext Walls	1	28-Oct-16	28-Oct-16
Approve Carpet	1	28-Oct-16	28-Oct-16
Approve Paints	1	28-Oct-16	28-Oct-16
Specialities	1	24-Oct-16	24-Oct-16
Approve Raised Floor System (Teller/Server)	1	24-Oct-16	24-Oct-16
Approve Toilet Accs	1	24-Oct-16	24-Oct-16
Approve Trash Box (ATM Area)	1	24-Oct-16	24-Oct-16
Approve Rubber Wall Guard (Below ATM)	1	24-Oct-16	24-Oct-16
Furnishing	11	26-Oct-16	05-Nov-16
Approve Curtains	1	26-Oct-16	26-Oct-16
Approve Fixed Furnitures	1	26-Oct-16	26-Oct-16



Remaining Work ◆ ◆ Milestone
Critical Remaining Work Summary

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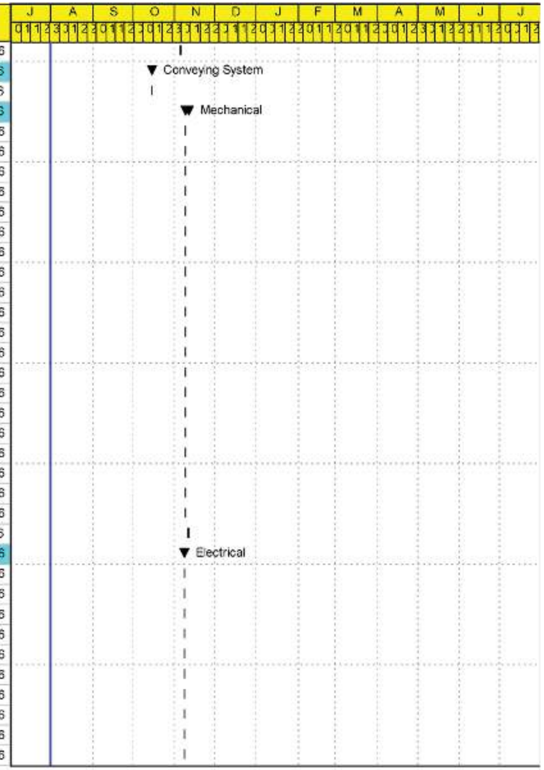
FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Approve Kitchen Cabinet	1	05-Nov-16	05-Nov-16
Conveying System	1	15-Oct-16	15-Oct-16
Approve Elevator	1	15-Oct-16	15-Oct-16
Mechanical	3	09-Nov-16	11-Nov-16
Approve Ducting Material & Insulation	1	09-Nov-16	09-Nov-16
Approve Roof Top Package Units	1	09-Nov-16	09-Nov-16
Approve Room Split Units	1	09-Nov-16	09-Nov-16
Approve VCD	1	09-Nov-16	09-Nov-16
Approve Diffusers,Registers,Grilles	1	09-Nov-16	09-Nov-16
Approve Electric Duct Heaters for Package Units	1	09-Nov-16	09-Nov-16
Approve Fans (TEF,KEF,EF)	1	09-Nov-16	09-Nov-16
Approve Condensate Drain Pipes	1	09-Nov-16	09-Nov-16
Approve FP Pipes & Accs	1	09-Nov-16	09-Nov-16
Approve FP Pumps & Accs	1	09-Nov-16	09-Nov-16
Approve Fire Cabinets	1	09-Nov-16	09-Nov-16
Approve Fire Extinguishers	1	09-Nov-16	09-Nov-16
Approve Sprinkler & Spray System	1	09-Nov-16	09-Nov-16
Approve Plumbing Pipes & Accs	1	09-Nov-16	09-Nov-16
Approve SS access cover for Meter Box	1	09-Nov-16	09-Nov-16
Approve Soil & Waste Water Pipes	1	09-Nov-16	09-Nov-16
Approve Sanitary Fixtures	1	09-Nov-16	09-Nov-16
Approve Water Booster Pumps	1	09-Nov-16	09-Nov-16
Approve Electric Water Heater	1	09-Nov-16	09-Nov-16
Approve GRP Water Tank	1	09-Nov-16	09-Nov-16
Approve Air Curtain	1	11-Nov-16	11-Nov-16
Electrical	1	08-Nov-16	08-Nov-16
Approve MSB, SMSB, ATS	1	08-Nov-16	08-Nov-16
Approve Distribution Boards	1	08-Nov-16	08-Nov-16
Approve Cables, Trays, Conduits	1	08-Nov-16	08-Nov-16
Approve AVA Alarm Panel	1	08-Nov-16	08-Nov-16
Approve 50 KVAR Capacitor	1	08-Nov-16	08-Nov-16
Approve Socket,Switches,Jn Box,DP	1	08-Nov-16	08-Nov-16
Approve Trunking	1	08-Nov-16	08-Nov-16
Approve Light Fixtures & Accs	1	08-Nov-16	08-Nov-16
Approve UPS	1	08-Nov-16	08-Nov-16
Approve Data Commun. System	1	08-Nov-16	08-Nov-16



Remaining Work ◆ ◆ Milestone
Critical Remaining Work Summary

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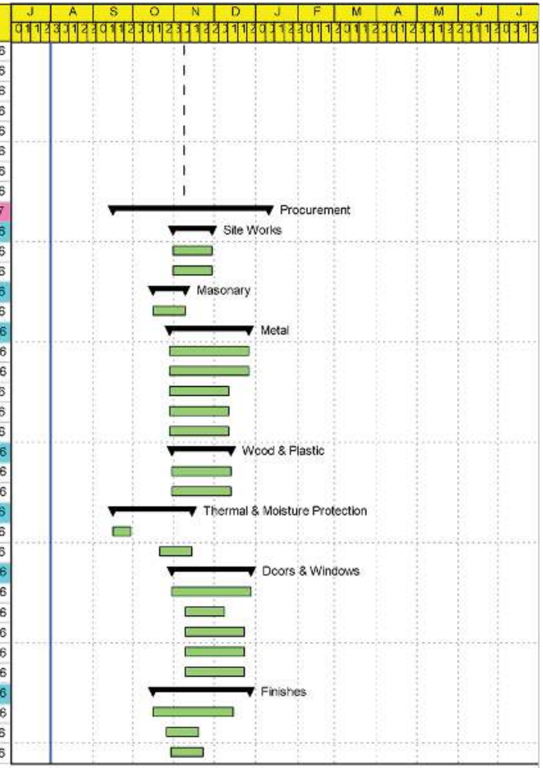
FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Approve Server Cabinet	1	08-Nov-16	08-Nov-16
Approve Standby Diesel Generator & Fuel Storage Tank	1	08-Nov-16	08-Nov-16
Approve Earthing System	1	08-Nov-16	08-Nov-16
Approve Fire Alarm System	1	08-Nov-16	08-Nov-16
Approve CCTV System	1	08-Nov-16	08-Nov-16
Approve Access Control System	1	08-Nov-16	08-Nov-16
Approve Intrusion Detection System	1	08-Nov-16	08-Nov-16
Approve Queing System	1	08-Nov-16	08-Nov-16
Procurement	117	16-Sep-16	10-Jan-17
Site Works	30	31-Oct-16	29-Nov-16
Procure Pavers, Kerbstone	30	31-Oct-16	29-Nov-16
Procure Plants	30	31-Oct-16	29-Nov-16
Masonary	25	16-Oct-16	09-Nov-16
Procure Block	25	16-Oct-16	09-Nov-16
Metal	60	28-Oct-16	26-Dec-16
Procure Steel Covers	60	28-Oct-16	26-Dec-16
Procure Handrail & Balustrade	60	28-Oct-16	26-Dec-16
Procure Wooden Cladding Material	45	28-Oct-16	11-Dec-16
Procure External Door Matt (Metal)	45	28-Oct-16	11-Dec-16
Procure Canopy Materials (Roof & Glass)	45	28-Oct-16	11-Dec-16
Wood & Plastic	45	30-Oct-16	13-Dec-16
Procure Counter Wood materials / Accs.	45	30-Oct-16	13-Dec-16
Procure Wooden Material (Wall/Ceiling/Skirting)	45	30-Oct-16	13-Dec-16
Thermal & Moisture Protection	60	16-Sep-16	14-Nov-16
Procure Water Proofing Material	14	16-Sep-16	29-Sep-16
Procure Thermal Insulation b/h Stone Cladding	25	21-Oct-16	14-Nov-16
Doors & Windows	60	30-Oct-16	28-Dec-16
Procure Vault Door	60	30-Oct-16	28-Dec-16
Procure Door (Steel / Wooden / Sliding)	30	09-Nov-16	08-Dec-16
Procure Hardware (Doors)	45	09-Nov-16	23-Dec-16
Procure Curtain Wall	45	09-Nov-16	23-Dec-16
Procure Aluminum Composite Panel	45	09-Nov-16	23-Dec-16
Finishes	73	16-Oct-16	27-Dec-16
Procure Granite/Marble Flooring	60	16-Oct-16	14-Dec-16
Procure Terrazo Tiles	25	26-Oct-16	19-Nov-16
Procure Gypsum Board Partition	25	29-Oct-16	22-Nov-16



Remaining Work ◆ ◆ Milestone

Critical Remaining Work Summary

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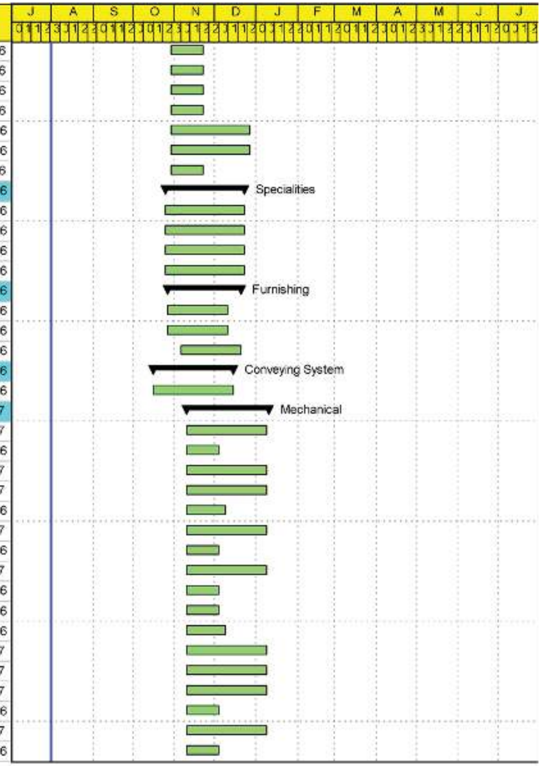
FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Procure Gypsum Ceiling & Accs	25	29-Oct-16	22-Nov-16
Procure Gypsum Tiles (60x60) & Accs	25	29-Oct-16	22-Nov-16
Procure Ceramic Tiles (Wall & Floor)	25	29-Oct-16	22-Nov-16
Procure Vinyl Tiles & Skirting	25	29-Oct-16	22-Nov-16
Procure Sandstone Cladding -Ext Walls	60	29-Oct-16	27-Dec-16
Procure Carpet	60	29-Oct-16	27-Dec-16
Procure Paints	25	29-Oct-16	22-Nov-16
Specialities	60	25-Oct-16	23-Dec-16
Procure Raised Floor System (Teller/Server)	60	25-Oct-16	23-Dec-16
Procure Toilet Accs	60	25-Oct-16	23-Dec-16
Procure Trash Box (ATM Area)	60	25-Oct-16	23-Dec-16
Procure Rubber Wall Guard (Below ATM)	60	25-Oct-16	23-Dec-16
Furnishing	55	27-Oct-16	20-Dec-16
Procure Curtains	45	27-Oct-16	10-Dec-16
Procure Fixed Furnitures	45	27-Oct-16	10-Dec-16
Procure Kitchen Cabinet	45	06-Nov-16	20-Dec-16
Conveying System	60	16-Oct-16	14-Dec-16
Procure Elevator	60	16-Oct-16	14-Dec-16
Mechanical	62	10-Nov-16	10-Jan-17
Procure GRP Water Tank	60	10-Nov-16	08-Jan-17
Procure Ducting Material & Insulation	25	10-Nov-16	04-Dec-16
Procure Roof Top Package Units	60	10-Nov-16	08-Jan-17
Procure Room Split Units	60	10-Nov-16	08-Jan-17
Procure VCD	30	10-Nov-16	09-Dec-16
Procure Diffusers,Registers,Grilles	60	10-Nov-16	08-Jan-17
Procure Electric Duct Heaters for Package Units	25	10-Nov-16	04-Dec-16
Procure Fans (TEF,KEF,EF)	60	10-Nov-16	08-Jan-17
Procure Condensate Drain Pipes	25	10-Nov-16	04-Dec-16
Procure FP Pipes & Accs	25	10-Nov-16	04-Dec-16
Procure FP Pumps & Accs	30	10-Nov-16	09-Dec-16
Procure Fire Cabinets	60	10-Nov-16	08-Jan-17
Procure Fire Extinguishers	60	10-Nov-16	08-Jan-17
Procure Sprinkler & Spray System	60	10-Nov-16	08-Jan-17
Procure Plumbing Pipes & Accs	25	10-Nov-16	04-Dec-16
Procure SS access cover for Meter Box	60	10-Nov-16	08-Jan-17
Procure Soil & Waste Water Pipes	25	10-Nov-16	04-Dec-16



Remaining Work ◆ Milestone
Critical Remaining Work Summary

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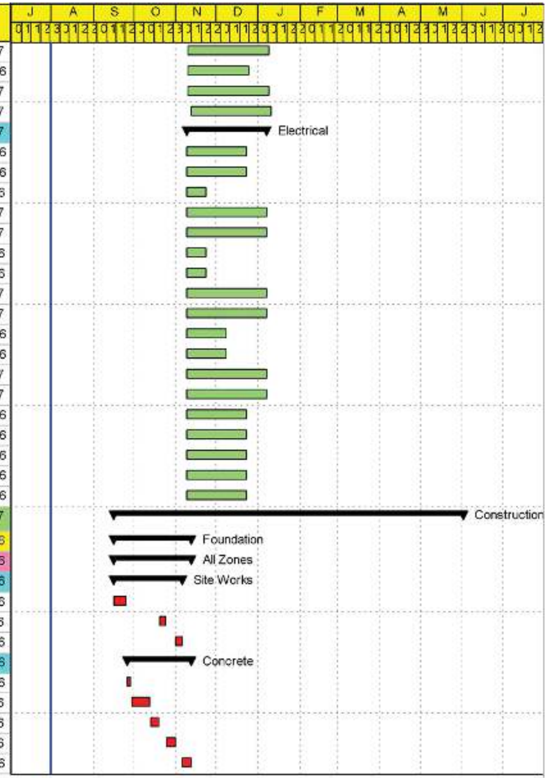
FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Procure Sanitary Fixtures	60	10-Nov-16	08-Jan-17
Procure Water Booster Pumps	45	10-Nov-16	24-Dec-16
Procure Electric Water Heater	60	10-Nov-16	08-Jan-17
Procure Air Curtain	60	12-Nov-16	10-Jan-17
Electrical	60	09-Nov-16	07-Jan-17
Procure MSB, SMSB, ATS	45	09-Nov-16	23-Dec-16
Procure Distribution Boards	45	09-Nov-16	23-Dec-16
Procure Cables, Trays, Conduits	15	09-Nov-16	23-Nov-16
Procure AVA Alarm Panel	60	09-Nov-16	07-Jan-17
Procure 50 KVAR Capacitor	60	09-Nov-16	07-Jan-17
Procure Socket, Switches, Jn Box, DP	15	09-Nov-16	23-Nov-16
Procure Trunking	15	09-Nov-16	23-Nov-16
Procure Light Fixtures & Accs	60	09-Nov-16	07-Jan-17
Procure UPS	60	09-Nov-16	07-Jan-17
Procure Data Commun. System	30	09-Nov-16	08-Dec-16
Procure Server Cabinet	30	09-Nov-16	08-Dec-16
Procure Standby Diesel Generator & Fuel Storage Tank	60	09-Nov-16	07-Jan-17
Procure Earthing System	60	09-Nov-16	07-Jan-17
Procure Fire Alarm System	45	09-Nov-16	23-Dec-16
Procure CCTV System	45	09-Nov-16	23-Dec-16
Procure Access Control System	45	09-Nov-16	23-Dec-16
Procure Intrusion Detection System	45	09-Nov-16	23-Dec-16
Procure Queing System	45	09-Nov-16	23-Dec-16
Construction	259	16-Sep-16	01-Jun-17
Foundation	58	16-Sep-16	12-Nov-16
All Zones	58	16-Sep-16	12-Nov-16
Site Works	51	16-Sep-16	05-Nov-16
Excavation -FD All Zones	10	16-Sep-16	25-Sep-16
Backfilling for Foundation -FD All Zones	5	20-Oct-16	24-Oct-16
Backfilling for Ground Beams -FD All Zones	5	01-Nov-16	05-Nov-16
Concrete	48	26-Sep-16	12-Nov-16
PCC for Foundation -FD All Zones	3	26-Sep-16	28-Sep-16
RCC for Foundation & Col. Neck -FD All Zones	14	29-Sep-16	12-Oct-16
Water Proofing works for Foundation -FD All Zones	7	13-Oct-16	19-Oct-16
RCC for Ground Beams -FD All Zones	7	25-Oct-16	31-Oct-16
RCC for Slab on Grade -FD All Zones	7	06-Nov-16	12-Nov-16



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Critical Remaining Work Summary

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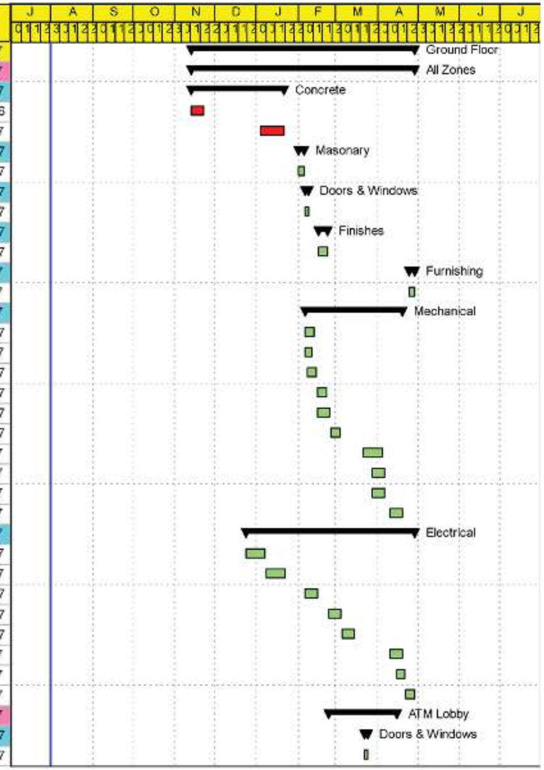
FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Ground Floor	167	13-Nov-16	28-Apr-17
All Zones	167	13-Nov-16	28-Apr-17
Concrete	70	13-Nov-16	21-Jan-17
RCC for Columns + Walls -GF All Zones	10	13-Nov-16	22-Nov-16
RCC for Slab -GF All Zones	18	04-Jan-17	21-Jan-17
Masonary	5	01-Feb-17	05-Feb-17
Blockwork -GF All Zones	5	01-Feb-17	05-Feb-17
Doors & Windows	3	06-Feb-17	08-Feb-17
Install Door Frames -GF All Zones	3	06-Feb-17	08-Feb-17
Finishes	7	16-Feb-17	22-Feb-17
Plaster -GF All Zones	7	16-Feb-17	22-Feb-17
Furnishing	5	24-Apr-17	28-Apr-17
Intall Curtains & Fixed Furnitures -GF All Zones	5	24-Apr-17	28-Apr-17
Mechanical	73	06-Feb-17	19-Apr-17
Fix Duct for HVAC -GF All Zones	7	06-Feb-17	12-Feb-17
Install WS & Sanitary Pipes+Fttngs -GF All Zones	6	06-Feb-17	11-Feb-17
Fix Insul'n to Duct HVAC -GF All Zones	7	08-Feb-17	14-Feb-17
Install VAV / VCD / Duct Heaters -GF All Zones	7	15-Feb-17	21-Feb-17
Fix FF Pipes & Fittings -GF All Zones	10	15-Feb-17	24-Feb-17
Install FC & F Extgnr -GF All Zones	7	25-Feb-17	03-Mar-17
Install Diffuser,Register,Grilles -GF All Zones	15	21-Mar-17	04-Apr-17
Install Electric Heater -GF All Zones	10	28-Mar-17	06-Apr-17
Install Plmbg & Sntry Fixtr+Fttng & Acc -GF All Zones	10	28-Mar-17	06-Apr-17
Install Sprinklers etc. -GF All Zones	10	10-Apr-17	19-Apr-17
Electrical	126	24-Dec-16	28-Apr-17
Fix Conduits (LV) -GF All Zones	15	24-Dec-16	07-Jan-17
Pulling Wires (LV) -GF All Zones	15	08-Jan-17	22-Jan-17
Fix Conduits,Backbox,trays etc. -GF All Zones	10	06-Feb-17	15-Feb-17
Pulling Wires -GF All Zones	10	23-Feb-17	04-Mar-17
Install DB,MCB & Connctn -GF All Zones	10	05-Mar-17	14-Mar-17
Install LV Devices -GF All Zones	10	10-Apr-17	19-Apr-17
Install Switches,Sockets -GF All Zones	7	15-Apr-17	21-Apr-17
Install Lights -GF All Zones	7	22-Apr-17	28-Apr-17
ATM Lobby	52	23-Feb-17	15-Apr-17
Doors & Windows	3	22-Mar-17	24-Mar-17
Install Door & Accs. -GF ATM Lobby	3	22-Mar-17	24-Mar-17



Remaining Work — Milestone
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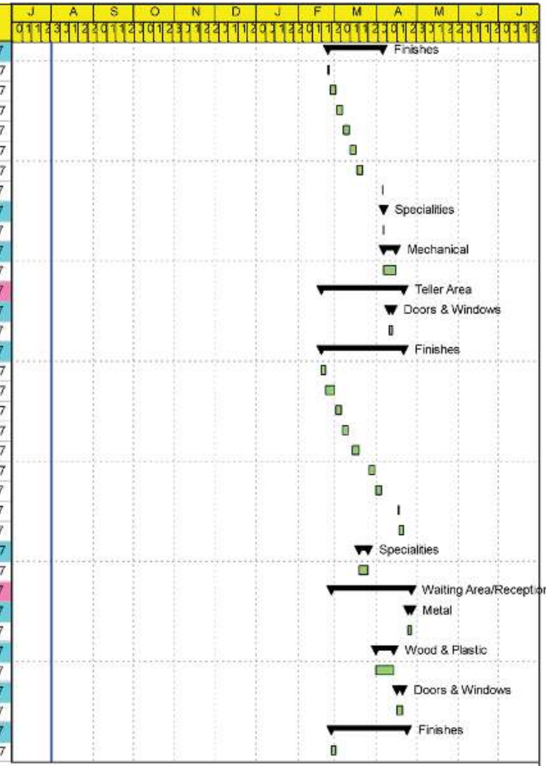
Figure 7.140 Contractor's Construction Schedule

FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Finishes	42	23-Feb-17	05-Apr-17
Screed on Floor -GF ATM Lobby	2	23-Feb-17	24-Feb-17
Install Suspension for Flase Ceiling -GF ATM Lobby	5	25-Feb-17	01-Mar-17
Install False Gypsum Ceilng -GF ATM Lobby	5	02-Mar-17	06-Mar-17
Install Terrazo + Vinyl Tiles + Skirting -GF ATM Lobby	5	07-Mar-17	11-Mar-17
Ceiling Paint (2 Coats) -GF ATM Lobby	5	12-Mar-17	16-Mar-17
Wall Paint (2 Coats) -GF ATM Lobby	5	17-Mar-17	21-Mar-17
Final Painting -GF ATM Lobby	1	05-Apr-17	05-Apr-17
Specialities	1	06-Apr-17	06-Apr-17
Install Trash Box -GF ATM Lobby	1	06-Apr-17	06-Apr-17
Mechanical	10	06-Apr-17	15-Apr-17
Install Air Curtain -GF ATM Lobby	10	06-Apr-17	15-Apr-17
Teller Area	63	18-Feb-17	21-Apr-17
Doors & Windows	3	10-Apr-17	12-Apr-17
Install Door & Accs. -GF Teller Area	3	10-Apr-17	12-Apr-17
Finishes	63	18-Feb-17	21-Apr-17
Screed on Floor -GF Teller Area	4	18-Feb-17	21-Feb-17
Install Wooden Wall Cladding + Painting -GF Teller Area	7	22-Feb-17	28-Feb-17
Install Suspension for Flase Ceiling -GF Teller Area	5	01-Mar-17	05-Mar-17
Install Gypsum Ceiling -GF Teller Area	5	06-Mar-17	10-Mar-17
Install Terrazo Flooring + Skirting -GF Teller Area	5	14-Mar-17	18-Mar-17
Ceiling Paint (2 Coats) -GF Teller Area	5	26-Mar-17	30-Mar-17
Wall Paint (2 Coats) -GF Teller Area	5	31-Mar-17	04-Apr-17
Final Painting -GF Teller Area	1	17-Apr-17	17-Apr-17
Install Carpet -GF Teller Area	4	18-Apr-17	21-Apr-17
Specialities	7	19-Mar-17	25-Mar-17
Install Raised Flooring System -GF Teller Area	7	19-Mar-17	25-Mar-17
Waiting Area/Reception	60	26-Feb-17	26-Apr-17
Metal	3	24-Apr-17	26-Apr-17
Install External Door Floor Metal Matt -GF Waiting Area/Reception	3	24-Apr-17	26-Apr-17
Wood & Plastic	14	31-Mar-17	13-Apr-17
Install Wooden Counter -GF Waiting Area/Reception	14	31-Mar-17	13-Apr-17
Doors & Windows	5	16-Apr-17	20-Apr-17
Install Door & Accs. -GF Waiting Area/Reception	5	16-Apr-17	20-Apr-17
Finishes	57	26-Feb-17	23-Apr-17
Screed on Floor -GF Waiting Area/Reception	4	26-Feb-17	01-Mar-17



Remaining Work ◆ ◆ Milestone
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FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Install Suspension for Flase Ceiling -GF Waiting Area/Reception	5	02-Mar-17	06-Mar-17
Install Gypsum Ceiling -GF Waiting Area/Reception	5	16-Mar-17	20-Mar-17
Install Marble Flooring -GF Waiting Area/Reception	7	24-Mar-17	30-Mar-17
Ceiling Paint (2 Coats) -GF Waiting Area/Reception	5	05-Apr-17	09-Apr-17
Wall Paint (2 Coats) -GF Waiting Area/Reception	5	10-Apr-17	14-Apr-17
Final Painting -GF Waiting Area/Reception	3	21-Apr-17	23-Apr-17
Safe Deposit Vault Area	58	09-Feb-17	07-Apr-17
Doors & Windows	7	28-Mar-17	03-Apr-17
Install Door & Accs. -GF Safe Deposit/Vault Area	7	28-Mar-17	03-Apr-17
Finishes	58	09-Feb-17	07-Apr-17
Screed on Floor -GF Safe Deposit/Vault Area	3	09-Feb-17	11-Feb-17
Install Suspension for Flase Ceiling -GF Safe Deposit/Vault Area	5	12-Feb-17	16-Feb-17
Install Gypsum Ceiling -GF Safe Deposit/Vault Area	5	22-Feb-17	26-Feb-17
Install Floor Marble/Terrazo/Vinyl + Skirting -GF Safe Deposit/Vault.	5	27-Feb-17	03-Mar-17
Ceiling Paint (2 Coats) -GF Safe Deposit/Vault Area	5	17-Mar-17	21-Mar-17
Wall Paint (2 Coats) -GF Safe Deposit/Vault Area	5	22-Mar-17	26-Mar-17
Final Painting -GF Safe Deposit/Vault Area	2	06-Apr-17	07-Apr-17
Filing Room	61	15-Feb-17	16-Apr-17
Doors & Windows	3	07-Apr-17	09-Apr-17
Install Door & Accs. -GF Filing Room	3	07-Apr-17	09-Apr-17
Finishes	61	15-Feb-17	16-Apr-17
Screed on Floor -GF Filing Room	3	15-Feb-17	17-Feb-17
Install Suspension for Flase Ceiling -GF Filing Room	5	20-Feb-17	24-Feb-17
Install 60x60 Ceiling -GF Filing Room	2	04-Mar-17	05-Mar-17
Install Terrazo Flooring + Skirting -GF Filing Room	5	09-Mar-17	13-Mar-17
Wall Paint (2 Coats) -GF Filing Room	4	14-Mar-17	17-Mar-17
Final Painting -GF Filing Room	1	16-Apr-17	16-Apr-17
Office Area	62	22-Feb-17	24-Apr-17
Doors & Windows	3	13-Apr-17	15-Apr-17
Install Door & Accs. -GF Office Area	3	13-Apr-17	15-Apr-17
Finishes	62	22-Feb-17	24-Apr-17
Screed on Floor -GF Office Area	4	22-Feb-17	25-Feb-17
Install Glass Wall Partition -GF Office Area	5	01-Mar-17	05-Mar-17
Install Suspension for Flase Ceiling -GF Office Area	5	06-Mar-17	10-Mar-17
Install Gypsum Ceiling -GF Office Area	5	11-Mar-17	15-Mar-17
Install Terrazo Flooring + Skirting -GF Office Area	5	19-Mar-17	23-Mar-17

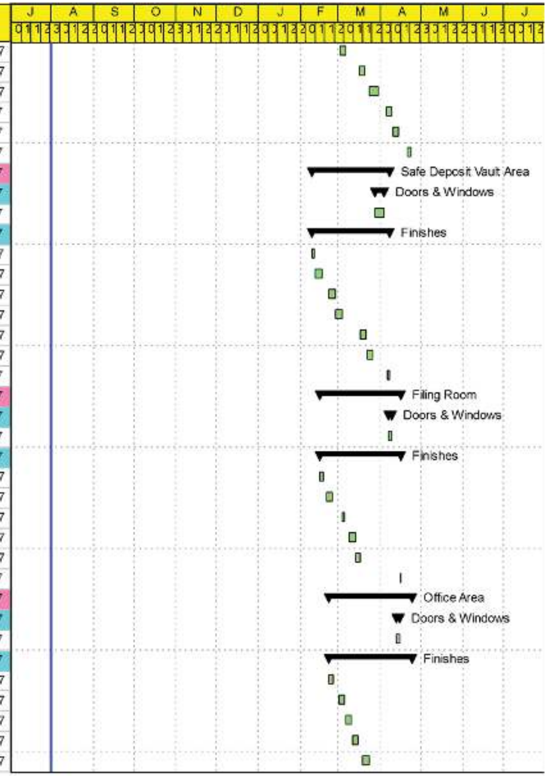

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FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Ceiling Paint (2 Coats) -GF Office Area	5	31-Mar-17	04-Apr-17
Final Painting -GF Office Area	2	16-Apr-17	17-Apr-17
Install Carpet -GF Office Area	3	22-Apr-17	24-Apr-17
Electrical Room/Drive thru ATM	65	12-Feb-17	17-Apr-17
Doors & Windows	3	04-Apr-17	06-Apr-17
Install Door & Accs. -GF Electrical Room/Drive thru ATM	3	04-Apr-17	06-Apr-17
Finishes	63	12-Feb-17	15-Apr-17
Screed on Floor -GF Electrical Room/Drive thru ATM	3	12-Feb-17	14-Feb-17
Install Suspension for Flase Ceiling -GF Electrical Room/Drive thru	5	15-Feb-17	19-Feb-17
Install 60x60 Ceiling -GF Electrical Room/Drive thru ATM	5	27-Feb-17	03-Mar-17
Install Terrazo Flooring + Skirting -GF Electrical Room/Drive thru AT	5	04-Mar-17	08-Mar-17
Wall Paint (2 Coats) -GF Electrical Room/Drive thru ATM	5	09-Mar-17	13-Mar-17
Final Painting -GF Electrical Room/Drive thru ATM	2	14-Apr-17	15-Apr-17
Specialities	2	16-Apr-17	17-Apr-17
Install Rubber Wall Guard (External) -GF Electrical Room/Drive thr	2	16-Apr-17	17-Apr-17
Mechanical	7	07-Apr-17	13-Apr-17
Install Mini Split Unit -GF Electrical Room/Drive thru ATM	7	07-Apr-17	13-Apr-17
Wet Area	64	06-Feb-17	10-Apr-17
Doors & Windows	3	25-Mar-17	27-Mar-17
Install Door & Accs. -GF Wet Area	3	25-Mar-17	27-Mar-17
Finishes	20	06-Feb-17	25-Feb-17
Screed on Floor -GF Wet Area	3	06-Feb-17	08-Feb-17
Install Ceramic Wall Tiles -GF Wet Area	5	09-Feb-17	13-Feb-17
Install Suspension for Flase Ceiling -GF Wet Area	4	14-Feb-17	17-Feb-17
Install 60x60 Ceiling -GF Wet Area	4	18-Feb-17	21-Feb-17
Install Ceramic Floor Tiles -GF Wet Area	4	22-Feb-17	25-Feb-17
Furnishing	7	28-Mar-17	03-Apr-17
Install Kitchen Cabinet -GF Wet Area	7	28-Mar-17	03-Apr-17
Mechanical	7	04-Apr-17	10-Apr-17
Install Fans (KEF,TEF) -GF Wet Area	7	04-Apr-17	10-Apr-17
Mezzanine Floor	170	14-Dec-16	01-Jun-17
All Zones	151	02-Jan-17	01-Jun-17
Concrete	31	27-Jan-17	26-Feb-17
RCC for Columns + Walls -MZ All Zones	10	27-Jan-17	05-Feb-17
RCC for Slab -MZ All Zones	21	06-Feb-17	26-Feb-17
Masonary	7	09-Mar-17	15-Mar-17

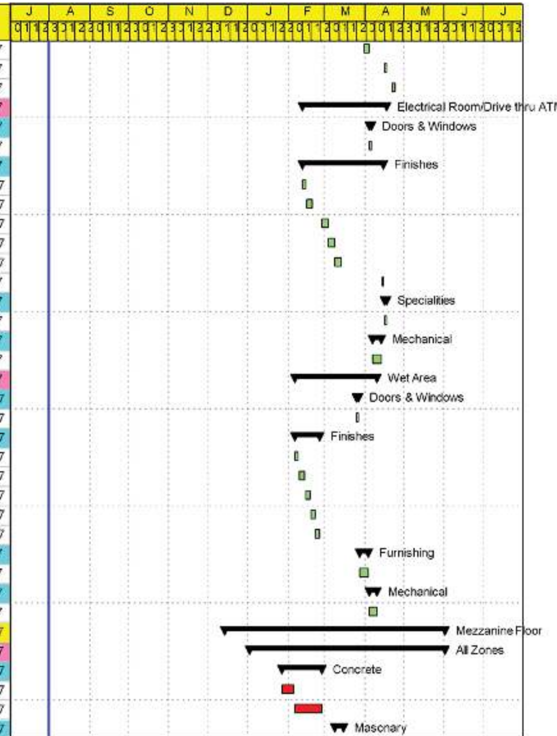

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FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Blockwork -MZ All Zones	7	09-Mar-17	15-Mar-17
Doors & Windows	5	16-Mar-17	20-Mar-17
Install Door Frames -MZ All Zones	5	16-Mar-17	20-Mar-17
Finishes	7	21-Mar-17	27-Mar-17
Plaster -MZ All Zones	7	21-Mar-17	27-Mar-17
Furnishing	3	26-May-17	28-May-17
Intall Curtains & Fixed Furnitures -MZ All Zones	3	26-May-17	28-May-17
Mechanical	72	16-Mar-17	26-May-17
Fix Duct for HVAC -MZ All Zones	10	16-Mar-17	25-Mar-17
Install WS & Sanitary Pipes+Fttngs -MZ All Zones	10	16-Mar-17	25-Mar-17
Fix Insul'n to Duct HVAC -MZ All Zones	7	21-Mar-17	27-Mar-17
Install VAV / VCD / Duct Heaters -MZ All Zones	5	28-Mar-17	01-Apr-17
Fix FF Pipes & Fittings -MZ All Zones	7	28-Mar-17	03-Apr-17
Install Diffuser,Register,Grilles -MZ All Zones	7	06-May-17	12-May-17
Install Electric Heater -MZ All Zones	5	06-May-17	10-May-17
Install Plmbg & Sntry Fixtr+Fttng & Acc -MZ All Zones	5	06-May-17	10-May-17
Install Sprinklers etc. -MZ All Zones	4	15-May-17	18-May-17
Install FC & F Extgnr -MZ All Zones	4	23-May-17	26-May-17
Electrical	151	02-Jan-17	01-Jun-17
Fix Conduits (LV) -MZ All Zones	15	02-Jan-17	16-Jan-17
Pulling Wires (LV) -MZ All Zones	15	17-Jan-17	31-Jan-17
Fix Conduits,Backbox,trays etc. -MZ All Zones	7	16-Mar-17	22-Mar-17
Pulling Wires -MZ All Zones	7	28-Mar-17	03-Apr-17
Install DB,MCB & Connctn -MZ All Zones	7	04-Apr-17	10-Apr-17
Install LV Devices -MZ All Zones	10	15-May-17	24-May-17
Install Switches,Sockets -MZ All Zones	7	19-May-17	25-May-17
Install Lights -MZ All Zones	7	26-May-17	01-Jun-17
Meeting Room	154	14-Dec-16	16-May-17
Doors & Windows	5	19-Apr-17	23-Apr-17
Install Door & Accs. -MZ Meeting Room	5	19-Apr-17	23-Apr-17
Finishes	154	14-Dec-16	16-May-17
Install Terrazo Flooring + Skirting -MZ Meeting Room	7	14-Dec-16	20-Dec-16
Install Glass Wall Partition -MZ Meeting Room	7	21-Dec-16	27-Dec-16
Install Suspension for Flase Ceiling -MZ Meeting Room	5	28-Dec-16	01-Jan-17
Screed on Floor -MZ Meeting Room	3	28-Mar-17	30-Mar-17
Install Gypsum Ceiling -MZ Meeting Room	5	04-Apr-17	08-Apr-17

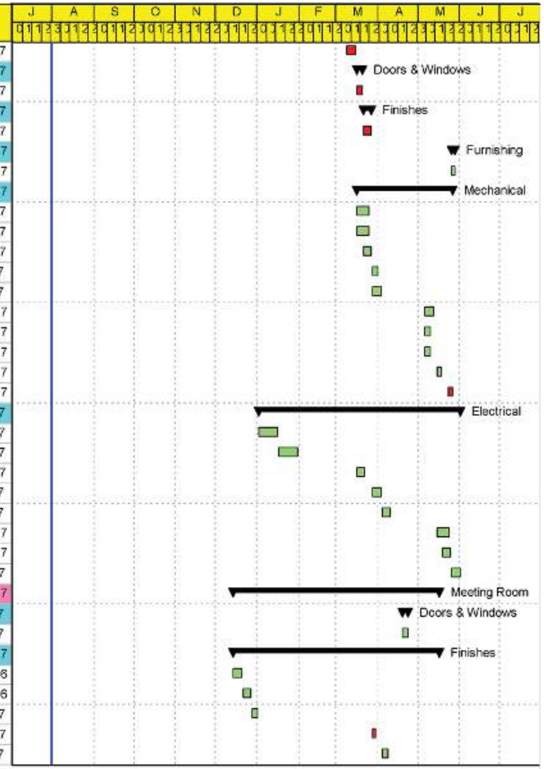

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FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Ceiling Paint (2 Coats) -MZ Meeting Room	5	09-Apr-17	13-Apr-17
Wall Paint (2 Coats) -MZ Meeting Room	5	14-Apr-17	18-Apr-17
Final Painting -MZ Meeting Room	1	13-May-17	13-May-17
Install Carpet -MZ Meeting Room	3	14-May-17	16-May-17
Teller Area	49	07-Apr-17	25-May-17
Doors & Windows	3	18-May-17	20-May-17
Install Door & Accs. -MZ Teller Area	3	18-May-17	20-May-17
Finishes	49	07-Apr-17	25-May-17
Install Screed -MZ Teller Area	3	07-Apr-17	09-Apr-17
Install Suspension for Flase Ceiling -MZ Teller Area	4	10-Apr-17	13-Apr-17
Install Gypsum Ceiling -MZ Teller Area	4	27-Apr-17	30-Apr-17
Install Terrazo Flooring + Skirting -MZ Teller Area	5	01-May-17	05-May-17
Wall Paint (2 Coats) -MZ Teller Area	5	13-May-17	17-May-17
Final Painting -MZ Teller Area	1	21-May-17	21-May-17
Install Carpet -MZ Teller Area	4	22-May-17	25-May-17
Specialities	7	06-May-17	12-May-17
Install Raised Flooring System -MZ Teller Area	7	06-May-17	12-May-17
Waiting Area/Reception	46	10-Apr-17	25-May-17
Wood & Plastic	14	11-May-17	24-May-17
Install Wooden Counter -MZ Waiting Area/Reception	14	11-May-17	24-May-17
Doors & Windows	4	19-May-17	22-May-17
Install Door & Accs. -MZ Waiting Area/Reception	4	19-May-17	22-May-17
Finishes	46	10-Apr-17	25-May-17
Screed on Floor -MZ Waiting Area/Reception	3	10-Apr-17	12-Apr-17
Install Suspension for Flase Ceiling -MZ Waiting Area/Reception	5	13-Apr-17	17-Apr-17
Install Gypsum Ceiling -MZ Waiting Area/Reception	5	01-May-17	05-May-17
Install Marble Flooring -MZ Waiting Area/Reception	5	06-May-17	10-May-17
Ceiling Paint (2 Coats) -MZ Waiting Area/Reception	4	11-May-17	14-May-17
Wall Paint (2 Coats) -MZ Waiting Area/Reception	4	15-May-17	18-May-17
Final Painting -MZ Waiting Area/Reception	1	25-May-17	25-May-17
Filing Room	45	02-Apr-17	16-May-17
Doors & Windows	3	27-Apr-17	29-Apr-17
Install Door & Accs. -MZ Filing Room	3	27-Apr-17	29-Apr-17
Finishes	45	02-Apr-17	16-May-17
Screed on Floor -MZ Filing Room	2	02-Apr-17	03-Apr-17
Install Suspension for Flase Ceiling -MZ Filing Room	4	04-Apr-17	07-Apr-17

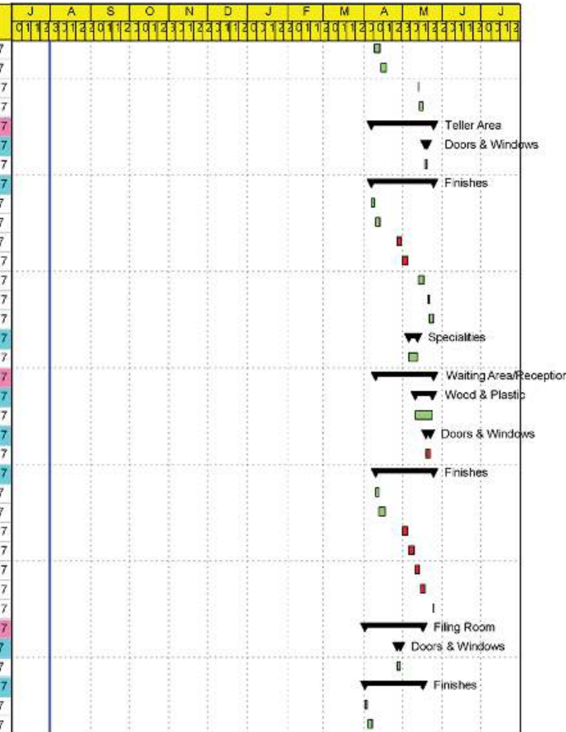

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FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Install 60x60 Ceiling -MZ Filing Room	4	15-Apr-17	18-Apr-17
Install Terrazo Flooring + Skirting -MZ Filing Room	4	19-Apr-17	22-Apr-17
Wall Paint (2 Coats) -MZ Filing Room	4	23-Apr-17	26-Apr-17
Final Painting -MZ Filing Room	1	16-May-17	16-May-17
Office Area	49	31-Mar-17	18-May-17
Doors & Windows	7	24-Apr-17	30-Apr-17
Install Door & Accs. -MZ Office Area	7	24-Apr-17	30-Apr-17
Finishes	49	31-Mar-17	18-May-17
Screed on Floor -MZ Office Area	2	31-Mar-17	01-Apr-17
Install Glass Wall Partition -MZ Office Area	5	02-Apr-17	06-Apr-17
Install Suspension for Flase Ceiling -MZ Office Area	4	07-Apr-17	10-Apr-17
Install Gypsum Ceiling -MZ Office Area	4	11-Apr-17	14-Apr-17
Install Terrazo Flooring + Skirting -MZ Office Area	5	15-Apr-17	19-Apr-17
Ceiling Paint (2 Coats) -MZ Office Area	4	20-Apr-17	23-Apr-17
Final Painting -MZ Office Area	2	14-May-17	15-May-17
Install Carpet -MZ Office Area	3	16-May-17	18-May-17
Wet Area	44	06-Apr-17	19-May-17
Doors & Windows	5	01-May-17	05-May-17
Install Door & Accs. -MZ Wet Area	5	01-May-17	05-May-17
Finishes	25	06-Apr-17	30-Apr-17
Screed on Floor -MZ Wet Area	2	06-Apr-17	07-Apr-17
Install Ceramic Wall Tiles -MZ Wet Area	4	08-Apr-17	11-Apr-17
Install Suspension for Flase Ceiling -MZ Wet Area	4	12-Apr-17	15-Apr-17
Install 60x60 Ceiling -MZ Wet Area	4	23-Apr-17	26-Apr-17
Install Ceramic Floor Tiles -MZ Wet Area	4	27-Apr-17	30-Apr-17
Furnishing	7	06-May-17	12-May-17
Install Kitchen Cabinet -MZ Wet Area	7	06-May-17	12-May-17
Mechanical	7	13-May-17	19-May-17
Install Fans (KEF,TEF) -MZ Wet Area	7	13-May-17	19-May-17
Server Room	44	04-Apr-17	17-May-17
Doors & Windows	5	02-May-17	06-May-17
Install Door & Accs. -MZ Server Room	5	02-May-17	06-May-17
Finishes	44	04-Apr-17	17-May-17
Screed on Floor -MZ Server Room	2	04-Apr-17	05-Apr-17
Install Suspension for Flase Ceiling -MZ Server Room	4	06-Apr-17	09-Apr-17
Install 60x60 Ceiling -MZ Server Room	4	19-Apr-17	22-Apr-17

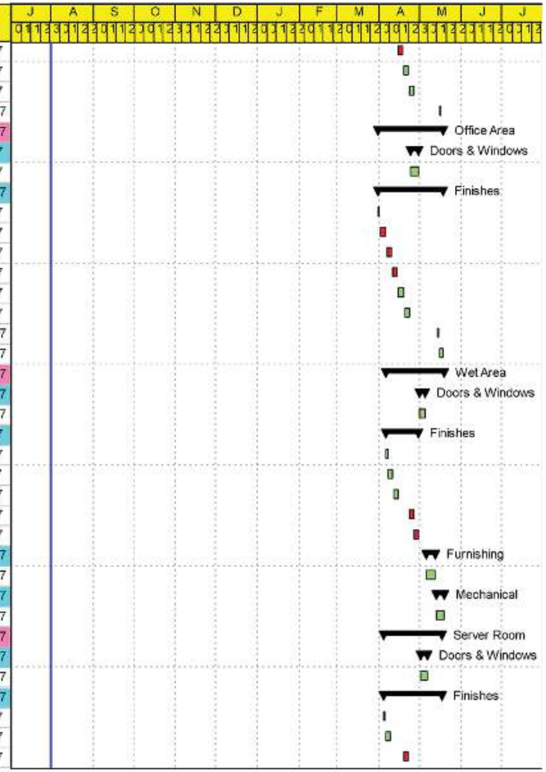

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FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Install Terrazo Flooring + Skirting -MZ Server Room	5	23-Apr-17	27-Apr-17
Wall Paint (2 Coats) -MZ Server Room	4	28-Apr-17	01-May-17
Final Painting -MZ Server Room	1	17-May-17	17-May-17
Electrical	10	07-May-17	16-May-17
Install Server Cabinet -MZ Server Room	10	07-May-17	16-May-17
Lower Roof	119	01-Feb-17	30-May-17
All Zones	119	01-Feb-17	30-May-17
Masonary	5	16-Mar-17	20-Mar-17
Blockwork -LR All Zones	5	16-Mar-17	20-Mar-17
Metal	5	21-May-17	25-May-17
Install Steel Covers to Shaft Openings -LR All Zones	5	21-May-17	25-May-17
Doors & Windows	61	21-Mar-17	20-May-17
Install Door Frames -LR All Zones	4	21-Mar-17	24-Mar-17
Install Door & Accs. -LR All Zones	2	19-May-17	20-May-17
Finishes	61	28-Mar-17	27-May-17
Plaster -LR All Zones	5	28-Mar-17	01-Apr-17
Screed on Floor -LR All Zones	3	02-Apr-17	04-Apr-17
Install Suspension for Flase Ceiling -LR All Zones	4	18-Apr-17	21-Apr-17
Install 60x60 Ceiling -LR All Zones	4	06-May-17	09-May-17
Install Terrazo Flooring + Skirting -LR All Zones	4	11-May-17	14-May-17
Wall Paint (2 Coats) -LR All Zones	4	15-May-17	18-May-17
Final Painting -LR All Zones	2	26-May-17	27-May-17
Mechanical	66	26-Mar-17	30-May-17
Install Roof Top Package Units -LR All Zones	15	26-Mar-17	09-Apr-17
Install Water Booster Pump -LR All Zones	15	26-Mar-17	09-Apr-17
Install FP Pumps -LR All Zones	15	04-Apr-17	18-Apr-17
Install GRP Tank -LR All Zones	15	10-Apr-17	24-Apr-17
Install Mini Split Unit -LR All Zones	10	21-May-17	30-May-17
Electrical	105	01-Feb-17	16-May-17
Install AVA Alarm Panel -LR All Zones	7	01-Feb-17	07-Feb-17
Install 50KVR Capacitor -LR All Zones	7	01-Feb-17	07-Feb-17
Fix Conduits,Backbox,trays etc. -LR All Zones	7	23-Mar-17	29-Mar-17
Pulling Wires -LR All Zones	7	30-Mar-17	05-Apr-17
Install DB,MCB & Connctn -LR All Zones	9	06-Apr-17	14-Apr-17
Install Switches,Sockets -LR All Zones	7	15-Apr-17	21-Apr-17
Install Lights -LR All Zones	7	22-Apr-17	28-Apr-17

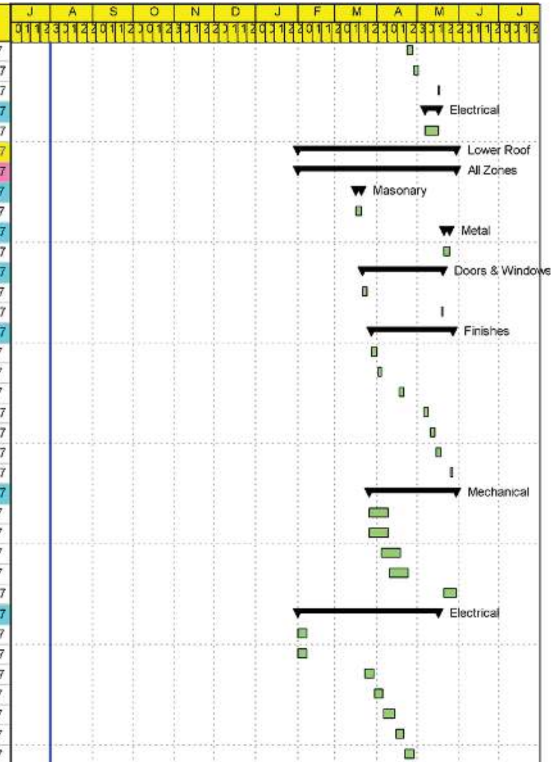

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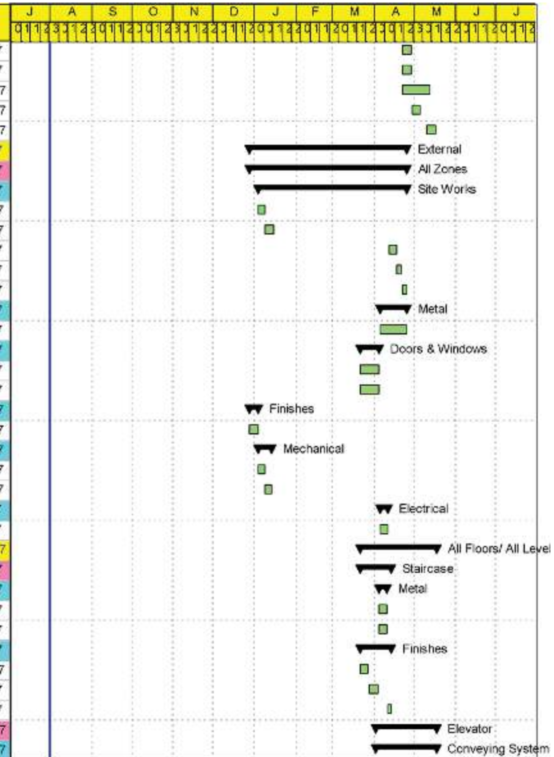
FIGURE 2.24 Continued

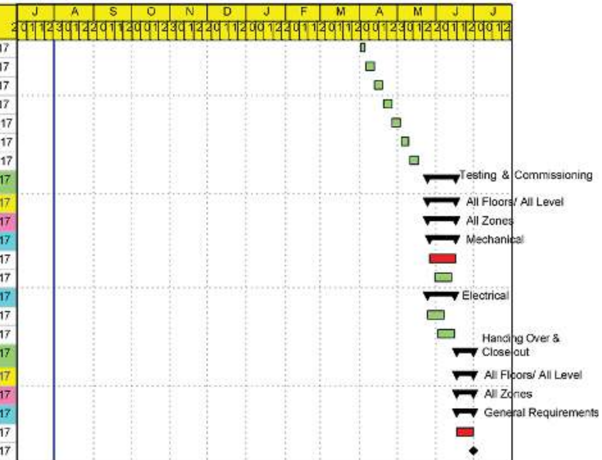
Activity Name	Original Duration	Start	Finish
Fix Conduits (LV) -LR All Zones	7	22-Apr-17	28-Apr-17
Install UPS -LR All Zones	7	22-Apr-17	28-Apr-17
Install Generator -LR All Zones	21	22-Apr-17	12-May-17
Pulling Wires (LV) -LR All Zones	7	29-Apr-17	05-May-17
Install LV Devices -LR All Zones	7	10-May-17	16-May-17
External	119	28-Dec-16	25-Apr-17
All Zones	119	28-Dec-16	25-Apr-17
Site Works	112	04-Jan-17	25-Apr-17
Lay Conc Kerbs -EX All Zones	5	04-Jan-17	08-Jan-17
Landscaping -EX All Zones	7	09-Jan-17	15-Jan-17
Lay Conc Pavers -EX All Zones	6	12-Apr-17	17-Apr-17
Install Traffic Signs -EX All Zones	4	18-Apr-17	21-Apr-17
Paint Road marking -EX All Zones	4	22-Apr-17	25-Apr-17
Metal	21	05-Apr-17	25-Apr-17
Install Canopy -EX All Zones	21	05-Apr-17	25-Apr-17
Doors & Windows	15	21-Mar-17	04-Apr-17
Install Curtain Wall -EX All Zones	15	21-Mar-17	04-Apr-17
Install Alu. Composite Panel -EX All Zones	15	21-Mar-17	04-Apr-17
Finishes	7	28-Dec-16	03-Jan-17
Install Thermal Insultaion & Stone Cladding -EX All Zones	7	28-Dec-16	03-Jan-17
Mechanical	10	04-Jan-17	13-Jan-17
Install Breaking inlet -EX All Zones	5	04-Jan-17	08-Jan-17
Install Water Meter with Box -EX All Zones	5	09-Jan-17	13-Jan-17
Electrical	7	05-Apr-17	11-Apr-17
Install Earthing System -EX All Zones	7	05-Apr-17	11-Apr-17
All Floors/ All Level	58	21-Mar-17	17-May-17
Staircase	24	21-Mar-17	13-Apr-17
Metal	7	04-Apr-17	10-Apr-17
Fix Hand Rail -AL Staircase	7	04-Apr-17	10-Apr-17
Install Balustrade -AL Staircase	7	04-Apr-17	10-Apr-17
Finishes	24	21-Mar-17	13-Apr-17
Screed on Floor -AL Staircase	7	21-Mar-17	27-Mar-17
Install Floor Marble + Skirting -AL Staircase	7	28-Mar-17	03-Apr-17
Paint Wall & Ceiling -AL Staircase	3	11-Apr-17	13-Apr-17
Elevator	46	02-Apr-17	17-May-17
Conveying System	46	02-Apr-17	17-May-17



Remaining Work ◆ ◆ Milestone
Critical Remaining Work Summary

FIGURE 2.24 Continued

Activity Name	Original Duration	Start	Finish
Shaft marking & Adjustments -AL Elevator	4	02-Apr-17	05-Apr-17
Instal Steel support columns -AL Elevator	7	06-Apr-17	12-Apr-17
Instal Metal Deck -AL Elevator	7	13-Apr-17	19-Apr-17
Guide rails marking & Instlfn -AL Elevator	7	20-Apr-17	26-Apr-17
Instal Elevator machine -AL Elevator	7	27-Apr-17	03-May-17
Instal Car & roping -AL Elevator	7	04-May-17	10-May-17
Instal asso. Electrical works -AL Elevator	7	11-May-17	17-May-17
Testing & Commissioning	23	25-May-17	16-Jun-17
All Floors/ All Level	23	25-May-17	16-Jun-17
All Zones	23	25-May-17	16-Jun-17
Mechanical	21	27-May-17	16-Jun-17
T&C of Mechanical Works -AL All Zones	21	27-May-17	16-Jun-17
T&C of HAVC Works -AL All Zones	14	31-May-17	13-Jun-17
Electrical	22	25-May-17	15-Jun-17
T&C of Low Voltage System -AL All Zones	14	25-May-17	07-Jun-17
T&C of High Voltage System -AL All Zones	14	02-Jun-17	15-Jun-17
Handing Over & Close-out	14	17-Jun-17	30-Jun-17
All Floors/ All Level	14	17-Jun-17	30-Jun-17
All Zones	14	17-Jun-17	30-Jun-17
General Requirements	14	17-Jun-17	30-Jun-17
Final Cleaning & Handing Over -AL All Zones	14	17-Jun-17	30-Jun-17
Project Completion -AL All Zones	0		30-Jun-17



Remaining Work ◆ Milestone
Critical Remaining Work Summary

Page 19 of 19

FIGURE 2.24 Continued

2.7.6 Develop Project S-Curve

S-Curve is a graphical display of cumulative cost, resources or other quantities plotted against time. During the construction phase, the contractor uses an S-Curve for forecasting cash flow, which is based on the work (activities) the contractor is expected to complete and how much amount (payment) will receive. Conceptually, cash flow is a simple comparison of when revenue will be received and when the financial obligations must be paid. It is also an indication of the progress of work to be completed in a project. This is obtained by loading each activity in the approved schedule with the budgeted cost in the BOQ. The process of inputting the schedule of values is known as cost loading. The graphical representation of the aforementioned is obtained as a curve and is known as an “S-Curve.” This also represents the planned progress of a project. Figure 2.25 illustrates planned project S-Curve prepared by the contractor that is based on the construction schedule.

2.7.6.1 Cost Loaded Curve

Figure 2.26 illustrates a cost loaded S-Curve prepared by the contractor.

2.7.7 Develop Contractor's Quality Control Plan

The construction project quality control process is a part of the contract documents that provide details about specific quality practices, resources, and activities relevant to the project. The purpose of quality control during construction is to ensure that the work is accomplished in accordance with the requirements specified in the contract. Inspection of construction work is carried out throughout the construction period either by the construction supervision team (consultant) or an appointed inspector agency. Quality is an important aspect of construction projects. The quality of the construction project must meet the requirements specified in the contract documents. Normally, the contractor provides on-site inspection and testing facilities at the construction site. On a construction site, inspection and testing are carried out at three stages during the construction period to ensure quality compliance.

1. Receipt of subcontractor for purchased materials or services. This is performed by a material inspection request submitted by the contractor to the consultant upon receipt of material.
2. During the construction process. This is carried out with the checklist request submitted by the contractor for testing ongoing work before proceeding to the next step.
3. Before final delivery for commissioning and handover.

Quality management in construction is a management function. In general, quality assurance and control programs are used to monitor design and construction conformance to established requirements as determined by the contract specifications. Instituting quality management programs reduces costs while producing the specified facility.

The CQCP is the contractor’s everyday tool to ensure meeting the performance standards specified in the contract documents. The adequacy and efficient management of the CQCP by contractor’s personnel has a great impact on both the performance of the contract and the owner’s quality assurance surveillance of the contractor’s performance.

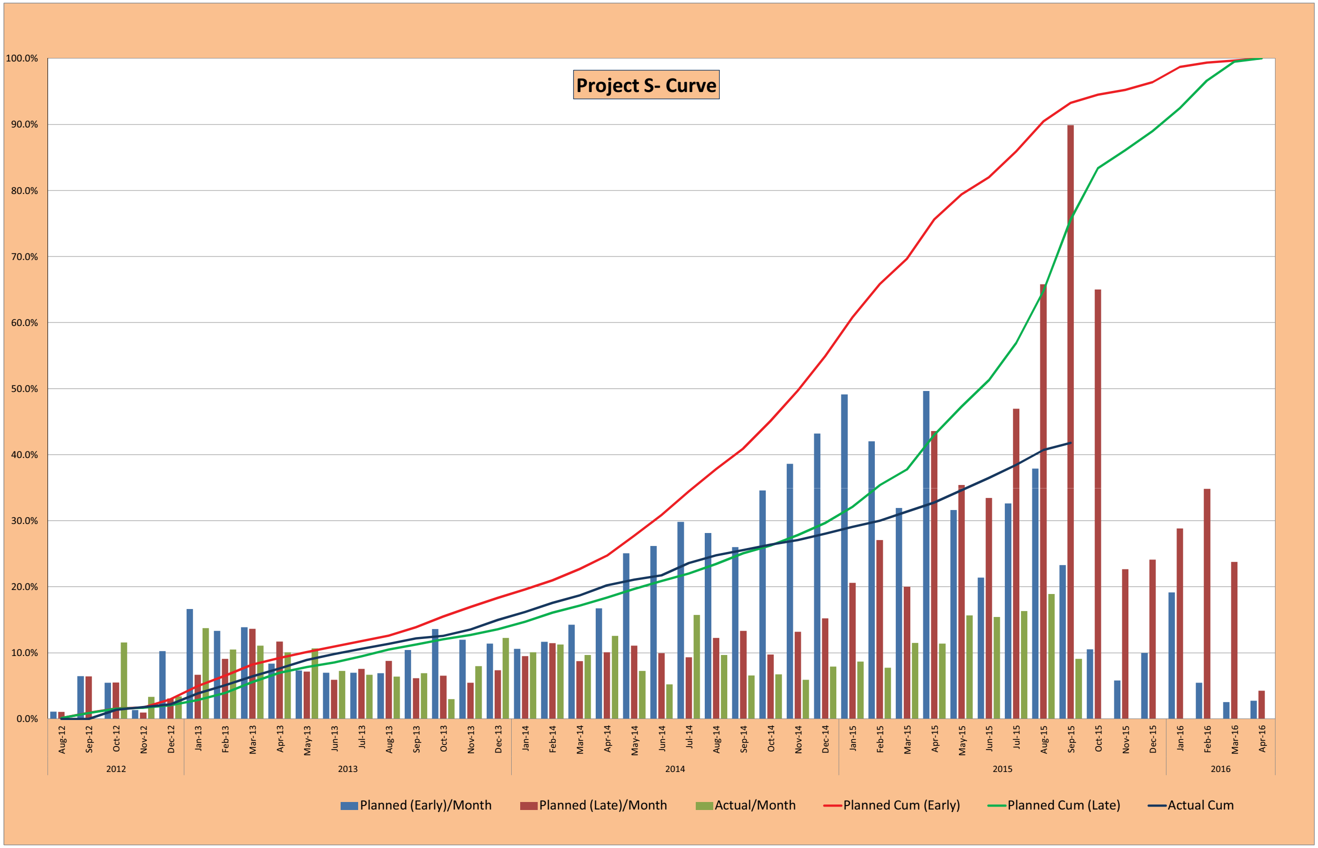
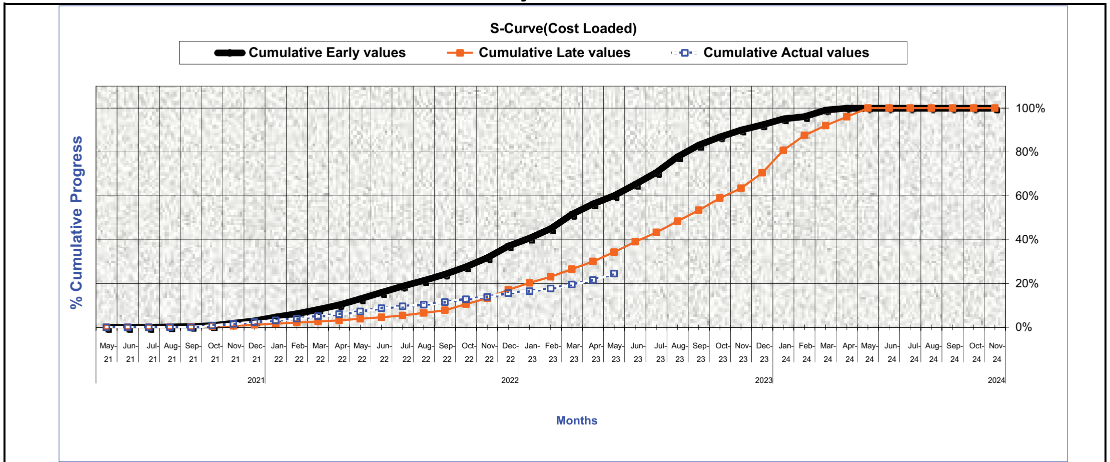


FIGURE 2.25 S-Curve (ES-LS).

Project Name



2021

Months	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
Early Values Monthly	0.0%	0.0%	0.0%	0.2%	0.2%	0.4%	1.1%	1.1%
Cumulative Early values	0.0%	0.0%	0.0%	0.2%	0.4%	0.8%	1.9%	3.0%
Late Values Monthly	0.00%	0.00%	0.01%	0.09%	0.14%	0.16%	0.26%	0.47%
Cumulative Late values	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.7%	1.1%
Actual Values Monthly	0.00%	0.00%	0.00%	0.00%	0.00%	0.785%	0.765%	0.820%
Cumulative Actual values	0.00%	0.00%	0.00%	0.00%	0.00%	0.785%	1.55%	2.37%

2022

Months	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
Early Values Monthly	1.7%	1.5%	1.9%	2.1%	2.7%	2.9%	2.8%	2.6%	2.8%	3.4%	4.1%	5.4%
Cumulative Early values	4.7%	6.2%	8.1%	10.3%	13.0%	15.9%	18.7%	21.4%	24.2%	27.6%	31.7%	37.1%
Late Values Monthly	0.52%	0.55%	0.49%	0.46%	0.75%	0.69%	0.81%	1.17%	1.23%	2.82%	2.64%	3.91%
Cumulative Late values	1.6%	2.2%	2.7%	3.1%	3.9%	4.6%	5.4%	6.6%	7.8%	10.6%	13.2%	17.2%
Actual Values Monthly	0.780%	0.800%	1.100%	0.930%	1.210%	1.530%	0.850%	0.730%	1.210%	1.270%	1.09%	1.70%
Cumulative Actual values	3.15%	3.95%	5.05%	5.98%	7.19%	8.72%	9.57%	10.30%	11.51%	12.78%	13.87%	15.57%

2023

Months	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23
Early Values Monthly	3.6%	4.3%	6.6%	4.8%	3.7%	5.2%	5.4%	7.1%	5.3%	3.7%	3.2%	2.4%
Cumulative Early values	40.7%	45.0%	51.6%	56.3%	60.1%	65.3%	70.7%	77.8%	83.1%	86.8%	90.0%	92.4%
Late Values Monthly	3.12%	2.79%	3.49%	3.49%	4.27%	4.72%	4.31%	5.06%	5.06%	5.50%	4.53%	7.03%
Cumulative Late values	20.3%	23.1%	26.6%	30.0%	34.3%	39.0%	43.3%	48.4%	53.5%	59.0%	63.5%	70.5%
Actual Values Monthly	0.92%	1.21%	1.80%	2.06%	2.94%							
Cumulative Actual values	16.49%	17.70%	19.50%	21.56%	24.50%							

2024

Months	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24
Early Values Monthly	2.7%	1.1%	3.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Cumulative Early values	95.1%	96.1%	99.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Late Values Monthly	10.21%	6.87%	4.44%	4.04%	3.91%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cumulative Late values	80.7%	87.6%	92.0%	96.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Actual Values Monthly											
Cumulative Actual values											

Notes : 1- Planned Values are based on Contractor's Cost Loaded Schedule submitted on 05-May-21.

2- The actual % progress up to 30-Apr-23 are based on value of work done.

FIGURE 2.26 Cost loaded S-Curve.

The CQCP is the documentation of the contractor's process for delivering the level of construction quality required by the contract. It is a framework for the contractor's process for achieving quality construction. The CQCP does not endeavor to repeat or summarize contract requirements. It describes the process that contractors will use to ensure compliance with the contract requirements. The quality plan is virtually manually tailor-made for the project and is based on contract requirements.

In the quality plan, the generic documented procedures are integrated with any necessary additional procedures peculiar to the project in order to attain specified quality objectives. Application of various quality tools, methods, and principles at different stages of construction projects is necessary to make the project qualitative, economical, and meet the owner's needs/specification requirements.

Based on contract requirements the contractor prepares his/her quality control plan and submits the same to the consultant for their approval. (Figure 1.66 discussed earlier illustrates the logic flow for a contractor's quality control plan.) This plan is being followed by the contractor to maintain the project quality.

The contractor's quality control plan is prepared based on project-specific requirements as specified in the contract documents. The plan outlines the procedures to be followed during the construction period to attain the specified quality objectives of the project fully complying with the contractual and regulatory requirements.

Appendix A illustrates an outline of the contractor's quality control plan for a major building construction project. However, the contractor has to take into consideration requirements listed under the contract documents depending on the nature and complexity of the project.

2.7.8 Develop Resource Management Plan

In most construction projects, the contractor is responsible to engage subcontractors, specialist installers, suppliers, arrange for materials, equipment, construction tools, and all types of human resources to complete the project as per contract documents and to the satisfaction of owner/owner's appointed supervision team. Workmanship is one of the most important factors to achieve the quality in construction, therefore, it is required that the construction workforce is fully trained and has full knowledge of all the related activities to be performed during the construction process.

Once the contract is awarded, the contractor prepares a detailed plan for all the resources he/she need to complete the project. The contractor also prepares a procurement log based on the project completion schedule.

Contract documents normally specify a list of the minimum number of core staff to be available on-site during the construction period. The absence of any of these staff may result in a penalty to be imposed on the contractor by the owner.

Contractor's human resources mainly consist of two categories:

1. Contractor's own staff and workers.
2. Subcontractor's staff and workers.

The main contractor has to manage all these personnel by:

1. Assigning the daily activities.
2. Observing their performance and work output.

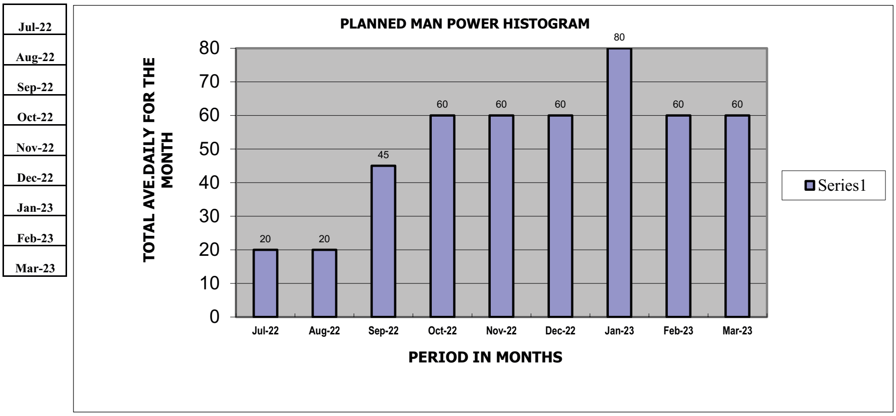


FIGURE 2.27 Contractor's manpower plan.

3. Daily attendance.
4. Safety during the construction process.

Figure 2.27 illustrates the contractor's planned manpower chart for the construction project.

In most construction projects, the contractor is responsible for procurement of materials, equipment, and systems to be installed on the project. The contractors have their own procurement strategies. While submitting the bid, the contractor obtains quotations from various suppliers/subcontractors. The contractor has to consider the following, as a minimum, while finalizing the procurement:

- Contractual commitment.
- Specification compliance.
- Statutory obligations.
- Time.
- Cost.
- Performance.

Please refer to Figure 1.70 discussed earlier under Section 1.3.2.7.2.3, which illustrates the material management process for a construction project.

Likewise, the contract documents specify that a minimum number of equipment is to be available at the site during the construction process to ensure smooth operation of all the construction activities. Figure 2.28 illustrates a planned equipment schedule listing equipment the contractor has to make available at a major building construction project.

2.7.9 Develop Communication Plan

For the smooth flow of construction process activities during the construction phase, proper communication and submittal procedures need to be established between all

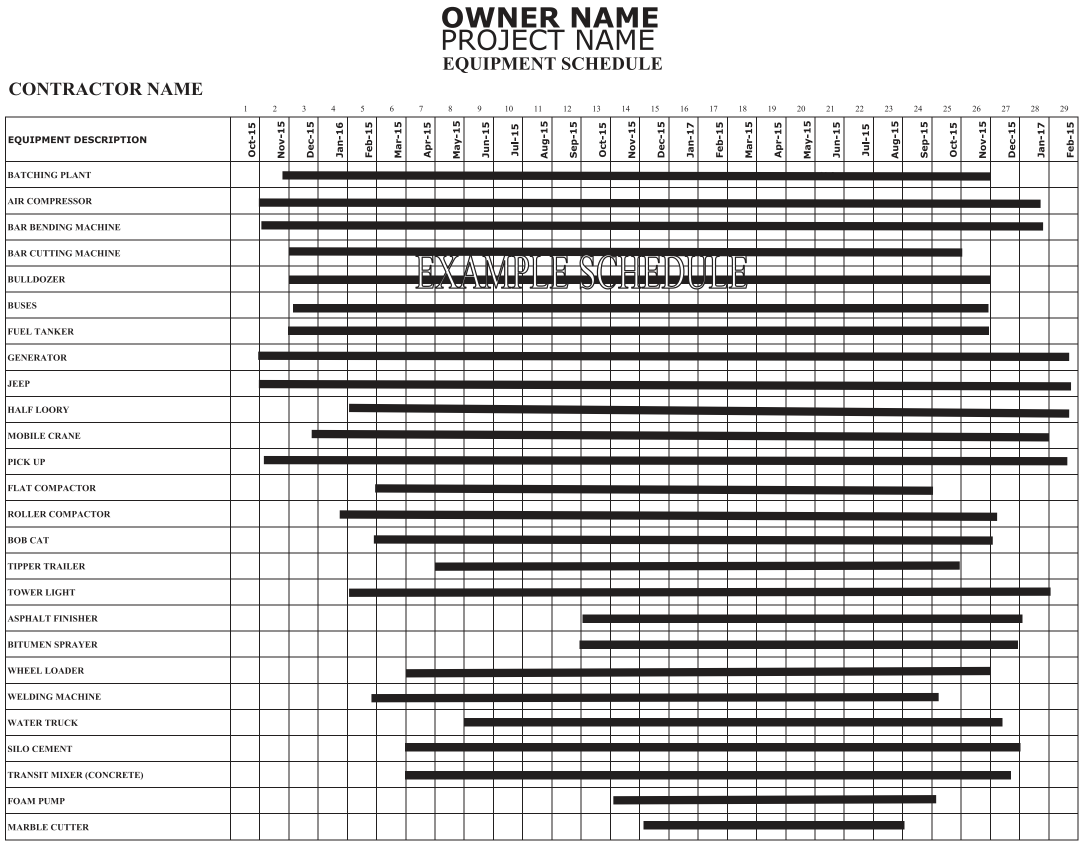


FIGURE 2.28 Equipment schedule.

the concerned parties at the beginning of the construction activities. The communication during construction the phase is mainly between three parties. These are:

1. Owner
2. Construction Supervisor (Consultant)
3. Contractor

In certain cases, it may be that the agency construction manager is involved in the project on behalf of the project owner.

Each of these participants has to develop their own communication plan.

Table 2.34 illustrates the contents of the communication plan.

Project communication management process is already discussed under Section 1.3.2.8. The communication between contractor and supervisor takes place through a transmittal form. Table 1.30 lists various types of transmittal forms used during construction projects. Number of copies, distribution, and communication methods are specified in the contract documents. Table 2.32 discussed earlier in Section 2.7.3.6, illustrates an example matrix for site administration of a building construction project. Proper adherence to these duties helps smooth the implementation of a project. Correspondence between consultant and contractor is normally

TABLE 2.34
Contents of Communication Management Plan

Section	Topic
1	Introduction
	1.1 Project Description
2	Stakeholders
	2.1 Project Team Directory
	2.2 Project Organization Chart
	2.3 Roles and Responsibilities
	2.4 Stakeholders Requirement
3	Communication Methods
4	Communication Management Constraints
5	Communication Matrix
6	Distribution of Communication Documents
	5.1 General Correspondence
	5.2 Submittals
	5.3 Status Reports
	5.4 Meetings
	5.5 Management Plans
	5.6 Change Orders
	5.7 Payments
6	Regulatory Requirements
7	Communication Plan Update

through letters or job site instructions. Figure 2.29 is a job site instruction form used by the consultant to communicate with the contractor.

2.7.10 Develop Risk Management Plan

The probability of occurrence of risk during the construction phase is very high compared to the design phases. During the construction phase, uncertainty comes from various sources as this phase has involvement of various participants. Risk in

Project Name
Consultant Name

JOB SITE INSTRUCTION (JSI)

CONTRACTOR: ______________________ JSI No. : ____________

CONTRACT No.: ______________________ DATE : ____________

The work shall be carried out in accordance with the Contract Documents without change in Contract Sum or Contract Time. Proceeding with the work in accordance with these instructions indicates your acknowledgement that there will be no change in the Contract Sum or Contract Time.

Subject:

SAMPLE FORM

ATTACHMENTS: (List attached documents that support description.)

Signed: ______________________ Received by Contractor : ____________

Resident Engineer

Date:

Distribution: ☐ Owner ☐ A/E ☐ Contractor

FIGURE 2.29 Job site instruction form.

construction projects has already been discussed under Section 1.3.2.9.5. Since the duration of the construction phase is longer than earlier phases, the contractor has to also consider the occurrence of financial, economic, commercial, political, and natural risks. The contractor has to develop a risk management plan as discussed under Section 1.3.2.9. Figure 1.89, discussed earlier illustrates the risk management cycle (process) and Table 1.35 lists the probability of occurrence of various categories of risks during a construction project.

Table 2.35 lists the major risks during the construction phase and mitigation actions. The contractor has to monitor the occurrence of these risks and take necessary measures to mitigate to effects on the project.

2.7.11 Develop HSE Plan

In construction projects, the requirements to prepare a Safety Management Plan (SMP) by the contractor are specified under contract documents. The contractor has to

TABLE 2.35
Major Risks during Construction Phase and Mitigation Actions

Sr. No.	Description of Risk	Mitigation Action
1	Incompetent subcontractor.	Contractor has to monitor the workmanship and work progress.
2	Failure of team members not performing as expected.	Select competent candidate. Provide training.
3	Low bid project cost.	Contractor to try competitive material, improve method statement, and higher production rate from its manpower
4	Delay in transfer of site.	Contractor to adjust the construction schedule.
5	Delay in mobilization.	Adjust construction schedule accordingly.
6	Scope/design changes.	Resolve change order issues in order not to delay the project.
7	Different site conditions to the information provided.	Contractor to investigate site conditions prior to starting the relevant activity.
8	Inadequate site investigation data.	Contractor to investigate site conditions prior to starting the relevant activity.
9	Conflict in contract documents.	Amicably resolve the issue.
10	Incomplete design.	Raise request for information (RFI).
11	Incomplete scope of work.	Raise request for information (RFI).
12	Design changes.	Follow contract documents for change order.
13	Design mistakes.	Raise request for information (RFI).
14	Errors and omissions in contract documents.	Raise request for information (RFI).
15	Incomplete specifications.	Raise request for information (RFI).
16	Inappropriate construction method.	Raise request for information (RFI) and correct the method statement.
17	Conflict with different trades.	Coordinate with all trades while preparing coordination and composite drawings.

(*Continued*)

TABLE 2.35 Continued
Major Risks during Construction Phase and Mitigation Actions

Sr. No.	Description of Risk	Mitigation Action
18	Change in laws and regulations.	Contractor to inform owner/consultant and raise RFI.
19	Statutory/regulatory delay.	Regular follow-up by the contractor, owner with the regulatory agency.
20	Project schedule.	Compress duration of activities.
21	Inappropriate schedule/plan.	Contractor to prepare schedule taking into consideration site conditions all the required parameters.
22	Delay in change order negotiations.	Request owner/supervisor/project manager to expedite the negotiations and resolve the issue.
23	Resource availability (material).	Contractor to make extensive search.
24	Resource (labor) low productivity.	Contractor to engage competent and skilled labors.
25	Equipment/plant productivity.	Contractor hire/purchase equipment to meet project productivity requirements.
26	Insufficient skilled workforce.	Contractor arranges workforce from alternate sources.
27	Failure/delay of machinery and equipment.	Contractor to plan procurement well in advance.
28	Failure/delay of material delivery.	Contractor to plan procurement well in advance.
29	Delay in approval of submittals.	Notify owner/project manager.
30	Delays in payment.	Contractor to have contingency plans.
31	Quality of material.	Locate suppliers having proven record of supplying quality product.
32	Variation in construction material price.	Contractor to negotiate with supplier/manufacturer for best price. Contractor to request for change order if applicable as per contract.
33	Damage to equipment.	Regularly maintain the equipment. Take immediate action to repair damaged equipment.
34	Damage to stored material.	Contractor to follow proper storage system.
35	Structure collapse.	Contractor to ensure that formwork and scaffolding is properly installed.
36	Access to worksite.	Access road to be planned in coordination with adjacent area and local authority.
37	Leakage of hazardous material.	Contractor to take necessary protect to avoid leakage. Store in safe area.
38	Theft at site.	Contractor to monitor access to site. Record entry/exit to the site. Provide fencing around project site.
39	Fire at site.	Contractor to install temporary firefighting system. Inflammable material to be stored in safe and secured place with necessary safety measures.
40	Injuries.	Contractor to keep first aid provision at site. Take immediate action to provide medical aid.
41	New technology.	Owner/contractor to mutually agree for changes in the contract for better performance of project.

submit the plan for review and approval by supervisor/consultant during mobilization stage of construction phase. The following are outlines normally specified in the contract documents that are to be considered by the contractor to establish a safety management system in order to raise the level of safety and health and prevent accidents:

1. Project scope detailing description of project and safety requirements.
2. Safety policy statement documenting the contractor's/subcontractor's commitment and emphasis on safety.
3. Regulatory requirements about safety.
4. Roles and responsibilities of all individuals involved.
5. Site communication plan detailing how safety information will be shared.
6. Emergency evacuation plan.
7. Accident reporting system.
8. Hazard identification, risk assessment, and control.
9. Accident investigation to document root causes and determine corrective and preventive actions.
10. Measures for emergency situations.
11. Plant, equipment maintenance, and licensing.
12. Routine inspections.
13. Continuous monitoring and regular assessment.
14. Health surveillance.
15. System feedback and continuous improvements.
16. Safety assurance measures.
17. Evaluation of subcontractor's safety capabilities.
18. Site neighborhood characteristics and constraints.
19. Safety audit.
20. Documentation.
21. Records.
22. System education and training.
23. System update.

Table 2.36 illustrates the contents of an HSE plan.

2.7.12 Execute Project Works

The contractor is given a few weeks to start the construction work after signing the contract. A letter from the client/owner is issued to the contractor to begin the project work subject to the conditions of the contract. This letter is known as a "notice to proceed" letter.

2.7.12.1 Notice to Proceed

The notice to proceed authorizes the contractor to proceed with work to construct the project/facility as per the agreement. Prior to issuance of a notice to proceed, the owner has to ensure that:

- Necessary permits have been obtained from the relevant authorities/agencies to hand over the construction site to the contractor.

TABLE 2.36
Contents of HSE Plan

Section	Topic		
1	Introduction		
	1.1	Project Description	
2	Project General Requirements		
3	HSE Policy		
4	Regulatory Requirements		
	4.1	Occupational Health, Health Surveillance	
	4.2	Safety	
	4.3	Environmental	
5	Project HSE Issues		
6	HSE Organization		
	6.1	HSE Organization Chart	
	6.2	Roles and Responsibilities	
	6.3	Communication Plan	
7	Safety Management Plan		
	7.1	Design, Detailed Engineering	
	7.2	Construction	
	7.3	Process Related Activities	
	7.4	Non-Process Related Activities	
	7.5	Project Start-Up	
8	Emergency Evacuation Plan		
	8.1	Accident Reporting	
	8.2	Action Plan	
	8.3	Measures for Emergency Situations	
	8.4	Disaster Control	
9	Training		
	9.1	Awareness	
	9.2	Meetings	
	9.3	Drills	
10	Monitoring		
	10.1	Routing Inspection	
	10.2	Protective Equipment	
	10.3	Plant, Equipment, Machinery	
	10.4	Fire prevention	
	10.5	Gas and Chemical Leak Detection	
	10.6	Safety Measures	
		10.6.1	Preparatory Activities
		10.6.2	Execution/Installation/Construction Activities
		10.6.3	Start-Up Activities
	10.7	Hygiene	

(*Continued*)

TABLE 2.36 Continued
Contents of HSE Plan

Section	Topic
	10.8 House Keeping
	10.9 Analysis and Evaluation
	10.10 Subcontractor's Compliance
11	Hazards Management
	11.1 Safety Hazards
12	Procedure for Project HSE Review (PHSER)
13	First Aid and Medical Services
14	Environmental Protection and Control Measures
15	Waste Management
16	Risk Identification, Management
17	Material Handling
18	Preventive Action
19	Documentation
20	Record
21	Internal Audit
22	Management Review
23	System Update/Continual Improvement

- Supervision staff/project manager/construction manager is selected to supervise the work.
- Relevant departments have been informed about signing of the contract for availability of funds.
- Supervision undertaking the guarantee is signed by the supervision consultant.
- Owner's representative is selected.
- Notice to proceed date is mutually discussed and agreed as per the conditions of contract.
- All the copies of construction documents are distributed to concerned stakeholders.
- Authorization letter to the owner's representative and the engineer's representative has already been issued.

Figure 2.30 is a sample notice to proceed.

2.7.12.2 Kickoff Meeting

The "kickoff meeting" is the first meeting with the owner/client and project team members. It is also called a pre-construction meeting. The kickoff meeting provides an opportunity for all project team members to interact and get to know each other.

Figure 2.31 is an example kickoff meeting agenda.

LETTERHEAD

Ref: ---------------------
Date: ------------------------

NOTICE TO PROCEED

To,

Contractor Name: SAMPLE LETTER

Address:

Subject: Contract Number------------

Attention: -------------------

Sir/Madam

You are hereby authorized to proceed with Project No. ------------- in accordance with construction contract dated ------------. This contract calls for all the contracted works to be completed within --------- calendar days. The date of enterprise shall be --------------.

Sincerely,

Enclosures:

CC:

FIGURE 2.30 Notice to proceed.

2.7.12.3 Mobilization

The activities to be performed during the mobilization period are defined in the contract documents. During this period the contractor is required to perform many of the activities before the beginning of actual construction work at the site. Necessary permits are obtained from the relevant authorities to start the construction works. Upon receipt of the construction site from the owner, the contractor starts mobilization work that consists of preparation of site offices/field offices for the owner,

PROJECT NAME

Contract Number:			
Type of Meeting:		**Date of Meeting:**	
Place of Meeting:		**Time of Meeting:**	
Owner:			
Project/Construction Manager			
A/E (Consultant)			

AGENDA SAMPLE AGENDA

1.0 Points to be Discussed

1.1 Intoduction

1.2 Project goals and objectives

1.3 Scope of work

1.4 Permit, Bonds, Insurance

1.5 Site handover procedure

1.6 Mobilization

1.7 Contractor's organization chart

1.8 Construction Schedule

1.9 Communication and Correspondance

1.10 Transmittals and Submittal procedure

1.11 Meetings (Progrees, Coordination)

1.12 Quality Management

1.13 Risk Management

1.14 Site safety

1.14 Payment

1.15 Nominated sub contractors

2.0 Any other business

FIGURE 2.31 Kickoff meeting agenda.

supervision team (consultant), and the contractor himself. This includes all the necessary on-site facilities and services necessary to carry out specific work and tasks. Mobilization activities usually occur at the beginning of a project but can occur anytime during a project when specific on-site facilities are required. During this time the project site is handed over to the contractor. The contractor performs a site survey and testing of soil, etc. to facilitate the start of construction work.

In anticipation of the award of the contract, the contractor begins the following activities in advance, but these are part of the contract documents and the contractor's action is required immediately after signing of the contract in order to start construction.

1. Mobilization of Construction Equipment and Tools
2. Manpower to Execute the Project

2.7.12.3.1 Bonds, Permits and Insurance

As per contract documents the contractor has to:

1. Submit advance payment guarantee.
2. Permit from local authority (municipality).
3. Insurance policies covering the following areas:
   a. Contractor's all risks and third-party insurance policy.
   b. Contractor's plant and equipment insurance policy.
   c. Workmen's compensation insurance policy.
   d. Site storage insurance policy.

Normally the submitted originals are retained by the owner and the copies are kept with the resident engineer or project/construction manager.

2.7.12.3.2 Temporary Facilities

The requirements to set up temporary facilities are specified in the contract. The contractor has to submit layout plans, dimensions and other pertinent details for temporary facilities to be constructed. These include:

1. Site offices for owner, supervisor (consultant, construction manager, project manager).
2. Storage facilities.
3. Toilets and washrooms.
4. Sanitary and drainage system.
5. Drinking water facility.
6. Site electrification.
7. Temporary firefighting system.
8. Site fence.
9. Site access road.
10. Signage.
11. Fuel storage area.
12. Guard room.
13. Testing laboratory.

Upon approval of plans, the contractor proceeds with construction of temporary facilities and necessary utilities.

The contractor has to designate an authority-approved dumping area for waste material.

2.7.12.3.3 Contractor's Core Staff

The contractor's core staff requirements and their qualifications are listed under tendering procedures. (Typical list of contractor's core staff already discussed under Section 2.7.3.3.) The absence of these staff from the project site without prior permission attracts a penalty to the contractor. Normally the penalty amount is specified in the contract documents. Upon signing of the contract, the contractor has to submit the names of the staff for the positions described in the contract documents for approval from the owner/consultant to work on the project. The contractor has to select an appropriate candidate to propose for the specified position. (Please refer to Section 1.2.3 and Figure 1.18 candidate selection procedure Figure 1.19 staffing.) Figure 2.32 is the staff approval request form used by the contractor to propose the staff to work for these positions and submitted along with the qualifications and experience certificates of the proposed staff.

Contractor has to submit an organization chart based on the typical minimum core staff list and approved staff.

2.7.12.3.4 Approval of Subcontractor

As per the tendering procedures the contractor has to declare the names of subcontractors and specialists to perform the designated work. The subcontractors for various sub-projects have to be submitted for approval in a timely and orderly manner, as planned in the approved work program, so that work progresses in a smooth and efficient manner. The subcontractor submission log helps the project manager to remind the main contractor to submit, the subcontractors on time.

The request includes all the related information to prove the subcontractor's capability of providing the services to meet the project quality and have enough available resources to meet the specified schedule, past performance, and if any quality system is implemented. Figure 2.33 is a request for subcontractor approval to be submitted by the contractor for approval of any subcontractor proposed to work on the construction project. Sometimes the owner/consultant nominates subcontractor(s) to execute a portion of a contract and is known as a nominated subcontractor.

2.7.12.3.5 Management Plans

Upon signing the contract, the contractor has to submit mainly the following plans to the supervisor (consultant) for their review and approval:

1. Contractor's Construction Schedule
2. Contractor's Quality Control Plan
3. Site Communication Plan
4. HSE Plan

Among these plans, the construction schedule is the most important. This is the first and foremost program the contractor has to submit for approval. The contractor cannot proceed with construction unless the preliminary construction schedule is approved. In certain cases, the progress payment is related to approval of contractor's construction schedule. The contractor is not paid unless the contractor's construction schedule is approved.

Project Name
Consultant Name

REQUEST FOR SITE STAFF APPROVAL

CONTRACT NO. : NO. :
CONTRACTOR : DATE:

SAMPLE FORM

To : Owner

1. Name :
2. Profession :
3. Position No. in Document-I :
4. No. of years of Experience :
5. Membership of Professional Body : Valid ☐ Not Valid ☐
6. Requested Date of Commencement :
7. Remarks :

Signature Contractor's Project Manager

OWNER COMMENTS APPROVED ☐ NOT APPROVED ☐

Owner Rep. Signature Date

Distribution OWNER A/E CONTRACTOR

FIGURE 2.32 Staff approval request.

For the smooth implementation of a project, proper communication system is established clearly identifying the submission process for correspondence and transmittals. Correspondence between consultant and contractor is normally done through job site instructions whereas correspondence between owner, consultant, and contractor is normally done through letters. Figure 2.29, discussed earlier, is a sample job site instruction form used by the consultant to communicate with the contractor, and Table 2.32, discussed earlier, is an example matrix for site administration.

Project Name

Contract No.:
Contractor :

CONTRACTOR REQUEST
FOR SUBCONTRACTOR APPROVAL

Serial No.: ....

Kindly approve the following as a SUBCONTRACTOR in the above mentioned Project

Subcontracted Works Ref. ____________
Subcontractor ____________
Address (Head Office) ____________
____
Reference Letter ____________

Attachments:

Commercial Register	☐	Foundation Contract	☐
Experience	☐	Resources	☐
Current Work	☐	Financial Status	☐
Others (List, if any)	☐		

....
....
....

Performance Bond (Yes/No) No. ____________

Signed by
Contractor's Representative .... Date: ....

OWNER'S NAME

Received by: ____________ Signature : ____________ Date: ....

SITE SUPERVISION CONSULTANT

Received by: ____________ Signature : ____________ Date: ....

Consultant's recommendation : ____________
....
....
....
....
....

Signed by
Resident Engineer .... Date: ....

Distribution : OWNER(Original) Supervision Consultant (Copy) Contractor (Copy)

Note : Contractor shall submit Original to the OWNER with copy to Site Supervision Consultant.

FIGURE 2.33 Request for subcontractor approval.

2.7.12.4 Manage Execution of Work

The contractor is responsible for executing the contracted work in accordance with contract drawings and specifications as specified in the contract documents. The contractor has to arrange the necessary resources to complete the project within the schedule and contracted amount. The contractor has to maintain the executed work until handing over the project to the owner/end user and maintain it for an additional period if contracted to do so. During construction period, the contractor has to protect the executed/installed work to ensure that the work is not damaged. The contractor has to use new and approved materials to construct the project/facility.

Construction activities mainly consist of the following:

- Site work such as cleaning and excavation of project site.
- Construction of foundations, including footings and grade beams.
- Construction of columns and beams.
- Forming, reinforcing, and placing the floor slab.
- Laying up masonry walls and partitions.
- Installation of roofing system.
- Finishes.
- Furnishings.
- Conveying system.
- Installation of fire suppression system.
- Installation of water supply, plumbing, and public health system.
- Installation of heating, ventilating, and air conditioning system.
- Integrated automation system.
- Installation of electrical lighting and power system.
- Emergency power supply system.
- Fire alarm system.
- Information and communication technology system.
- Electronic security and access control system.
- Landscape work.
- External work.

2.7.12.4.1 Perform Quality Assurance

Quality assurance during construction phase to provide evidence and confidence by the contractor that the works, materials, and systems installed shall meet the owner's objectives as specified in the contract documents and to ensure and guarantee that performance of the project/facility is fully functional to the satisfaction of the owner/end user.

The contractor performs the quality assurance process by:

1. Selecting the materials, systems fully complying with contract specifications, and installing the approved materials and systems only.
2. Preparing the shop drawings detailing all the requirements included in the working drawings and installing/executing the work as per approved shop drawings.
3. Installing the work, materials, and systems as per specified method statement and as per recommendations from the manufacturer of the products.

The approved materials, systems, and shop drawings are used by the supervision team to inspect the executed work and control the quality of work.

The detailed procedure for submitting shop drawings, materials, and samples is specified under section "SUBMITTAL" of contract specifications. The contractor has to submit the same to owner/consultant for their review and approval. The consultant reviews the submittal and returns the transmittal to the contractor with an appropriate action. (Please refer to Section 1.3.2.8.1.3 (Chapter 1) Establish Submittal Procedure.)

2.7.12.4.1.1 Materials The contractor has to install the material specified under particular specifications (document III.2) and contract drawings (III.3) (Section 2.5.3.1). The contractor has to submit the material specified in the contract documents prior to execution/installation of work.

The contractor has to submit the following, as minimum, to the owner/consultant to get their review and approval of materials, products, equipment, and systems. Contractor cannot use these items unless they are approved for use in the project.

Product Data

The contractor has to submit the following details:

- Manufacturers' technical specifications related to the proposed product.
- Installation methods recommended by the manufacturer.
- Relevant sheets of manufacturer's catalog(s).
- Confirmation of compliance with recognized international quality standards.
- Mill reports (if applicable).
- Performance characteristics and curves (if applicable).
- Manufacturer's standard schematic drawings and diagrams to supplement standard information related to project requirements and configuration of the same to indicate product application for the specified work (if applicable).
- Compatibility certificate (if applicable).
- Single source liability (this is normally required for systems approval where different manufacturer's items are used).

Compliance Statement

The contractor has to submit a specification comparison statement along with the material transmittal. The compliance statement form is normally included as part of contract documents. The information provided in the compliance statement helps consultant to review and verify product compliance with the contracted specifications.

In case of any deviation to a specified item, the contractor has to submit a schedule of such deviation(s) listing all the points not conforming to the specification.

In certain projects, the owner is involved in approval of materials.

Samples

The contractor has to submit (if required) the sample(s) from the approved material to be used for the work. The samples are mainly required to:

- Verify color, texture, and pattern.
- Verify that the product is physically identical to the proposed and approved material.
- To be used for comparison with products and materials used in the work.

At times it may be specified to install the sample(s) in a manner to facilitate review of qualities indicated in the specifications.

Figure 2.34 illustrates the procedure for the selection of material/product whereas Figure 2.35 illustrates material/product/system approval procedure.

2.7.12.4.1.2 Shop Drawings The contract drawings and specifications prepared by the design professionals are indicative and generally meant for determining the tender pricing and for planning the construction project. In many cases they are not sufficient for installation or execution of work at various stages. More details are required during the construction phase to ensure specified quality. These details are provided by the contractor in the shop drawings. Shop drawings are used by the contractor as reference documents to execute/install the work. Detailed shop drawing helps the contractor to achieve zero defects in installation at the first stage itself, thus avoiding any rejection/rework.

The number of shop drawings to be produced is mutually agreed upon between the contractor and consultant depending on the complexity of the work to be installed and to ensure that adequate details are available to execute the work.

The contractor is required to prepare shop drawings taking into consideration the following as a minimum but not limited to:

1. Reference to contract drawings. This helps A/E (consultant) to compare and review the shop drawing to that of contract drawing.
2. Detail plans and information based on the contract drawings.
3. Notes of changes or alterations from the contract documents.
4. Detail information about fabrication or installation of work.
5. All dimensions needed to be verified at the job site.
6. Identification of product.
7. Installation information about the materials to be used.
8. Type of finishes, colors, and textures.
9. Installation details relating to the axis or grid of the project.
10. Roughing in and setting diagram.
11. Coordination certification from all other related trades (subcontractors).

The shop drawings are to be drawn accurately to scale and shall have project-specific information in it. The shop drawings shall not be reproductions of contract drawings.

Immediately after approval of individual trade shop drawings, the contractor has to submit the builder's workshop drawings, composite/coordinated shop drawings

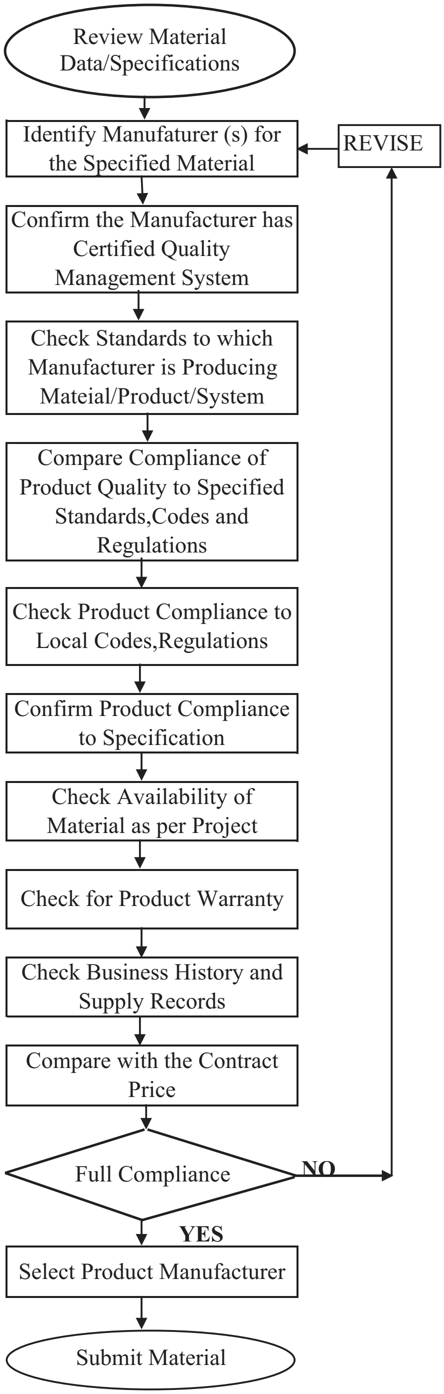


FIGURE 2.34 Material/product selection procedure.

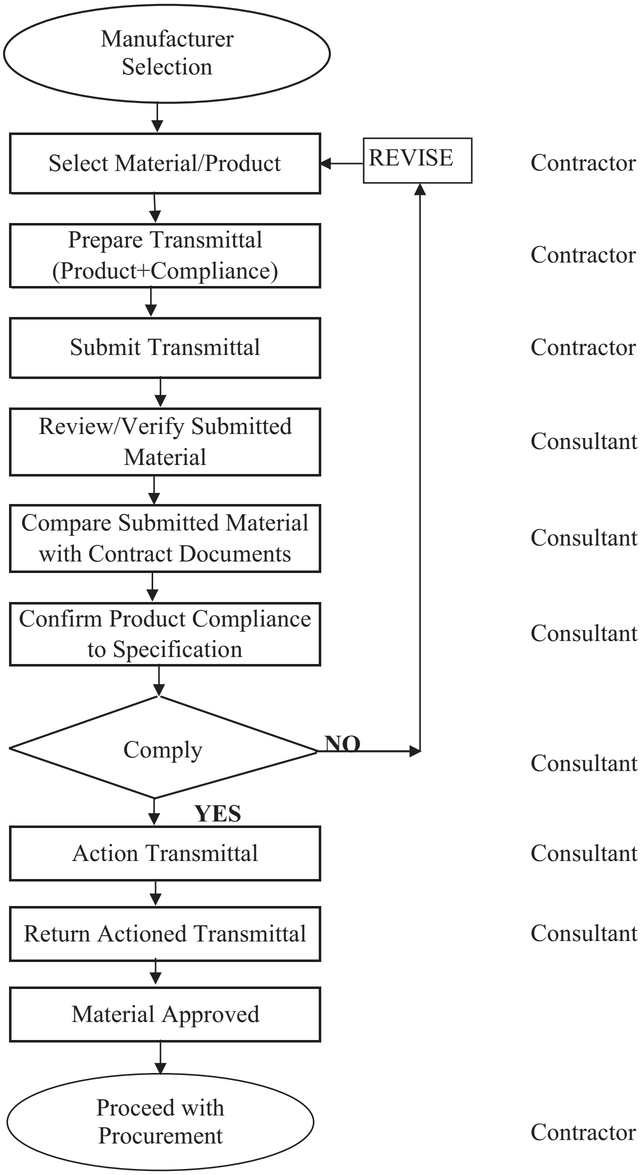


FIGURE 2.35 Material/product/system approval procedure.

taking into consideration the following as a minimum. Figure 2.36 illustrates shop drawing preparation and approval procedure. (Please also refer to Figure 4.30 PDCA cycle, discussed in Volume 1, for preparation of shop drawings.)

Based on the contract drawings, the contractor prepares shop drawings and submits the same to consultant for approval. All the work is executed as per approved shop drawings. The contractor has to consider the following points as a minimum, while developing shop drawings of different trades, to meet the design intents.

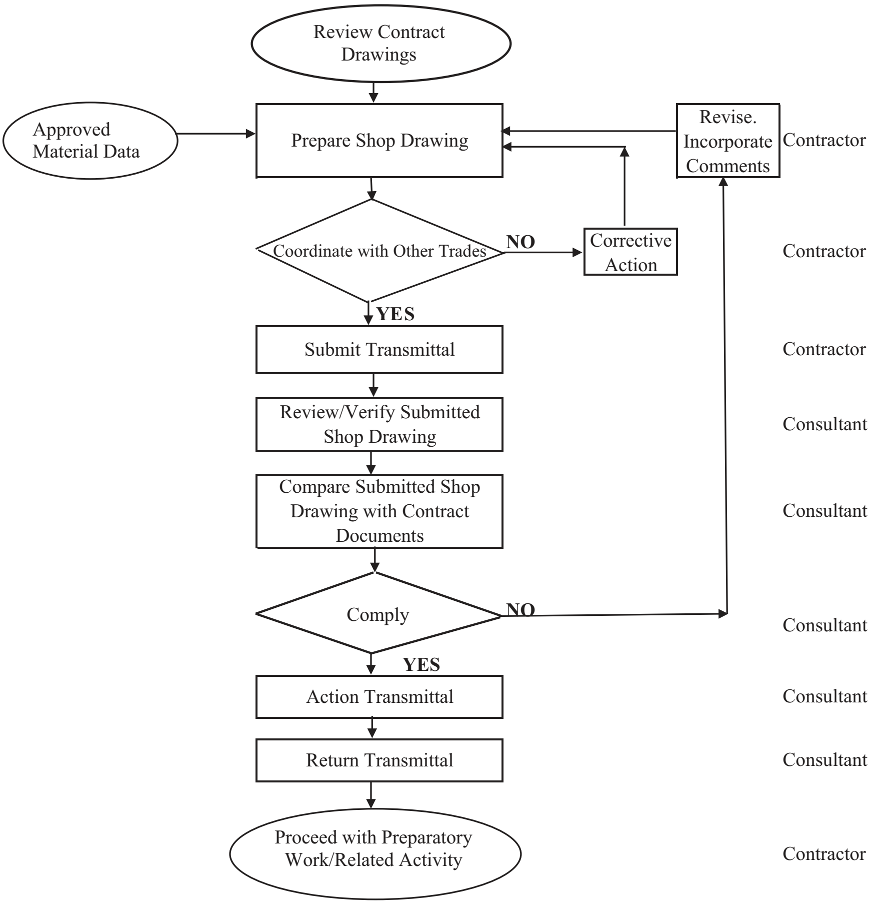


FIGURE 2.36 Shop drawing preparation and approval procedure.

Architectural Work

The architectural workshop drawings mainly cover masonry, doors and windows, cladding, partitioning, reflected ceiling, stone flooring, toilet details, stair details, and roofing. A brief requirement to prepare shop drawings for these sections is as follows:

1. Masonry

   The shop drawings for masonry work shall include the minimum:

   - Area layout.
   - Guidelines.
   - Height of masonry.
   - Type and thickness of blocks used for masonry.
   - Reinforcement details.
   - Fixation details.
   - Openings in the block work for other services.
   - Sills.

- Lintels.
- Plastering details, if applicable.

2. Doors and Windows

   The shop drawings for doors and windows shall include:
   - Size of doors and windows.
   - Type of material.
   - Thickness of frames.
   - Details of door leaves.
   - Details of glazing.
   - Fixing details.
   - Schedule of doors and windows.
3. Cladding

   The shop drawings for cladding shall include:
   - Type of cladding material.
   - Size of panels/tiles and thickness.
   - Elevations.
   - Fixation method, anchorage, and supports.
   - Openings for other services.
4. Partitioning

   The shop drawings for partitions shall include:
   - Type of partitioning material.
   - Size of panels.
   - Frame size and installation details.
   - Partition support system.
   - Fixation details of panels.
5. Reflected Ceiling

   The shop drawings for reflected ceiling shall include:
   - Type of ceiling material.
   - Size of ceiling panels, thickness of material.
   - Ceiling level.
   - Suspension system and framing.
   - Layout showing jointing layout, faceting, and boundaries between materials.
   - Location of light fittings, detectors, sprinklers, grills, etc.
   - Location of access panel.
6. Stone Flooring

   The shop drawings for flooring shall include:
   - Type of flooring material.
   - Size of flooring tiles.
   - Layout.
   - Screeding details.
   - Jointing details.
   - Flooring pattern.
   - Cut out for other services.
   - Control joints and jointing method.
   - Anti-Slip inserts.
   - Separators.
   - Thresholds.

7. Toilet Details
   The shop drawings for toilet details shall include:
   - Layout.
   - Plan.
   - Sections.
   - Installation details of sanitary wares and fixtures.
   - Installation details of toilet accessories.
   - Jointing method.
   - Material finishes and surface textures.
   - Installation details of toilet mirror.
8. Stair Details
   The shop drawings for stairs details shall include:
   - Steps details, riser, treads, width, height.
   - Finishing details.
   - Handrail details.
   - Sections.
   - Plan.
9. Roofing—Waterproofing
   The shop drawings for roofing details shall include:
   - Insulation details.
   - Installation details of insulation.
   - Installation of water proofing material.
   - Control joints/expansion joints details.
   - Tiling details.
   - Flashings.

Structural Work

The structural workshop drawings are to be prepared according to ACI 315 and shall mainly cover reinforced concrete, formwork, precast concrete, and structural steel fabrication. A brief requirement to prepare these shop drawings is as given:

1. Reinforced Concrete
   The reinforced concrete workshop drawings to be prepared according to ACI 315 and shall have the following details:
   - The size of reinforcement material.
   - Bar schedule.
   - Stirrup spacing.
   - Bar bent diagram.
   - Arrangement and support of concrete reinforcement.
   - Dimensional details.
   - Special reinforcement required for openings through concrete structure.
   - Type of cement and its strength.
2. Formwork
   Formwork has great importance from a safety point of view. The shop drawing of formwork shall include:
   - Details of individual panels.
   - Position, size, and spacing of adjustable props.

- Position, size, and spacing of joints, soldiers, ties, and the like.
- Details of formwork for columns, beams, parapets, slabs, and kickers.
- Details of construction joints and expansion joints.
- Details of retaining walls, core walls, and deep beams showing the position and size of ties, joints, soldiers, and sheeting, together with detailed information on erection and casting sequences and construction joints.
- General assembly details including propping, prop bearings, and through propping.
- All penetrations through concrete.
- Full design calculations.

3. Precast Concrete

   The shop drawings for precast concrete work have great importance as the casting is carried out at a precast concrete factory. All the required details need to be shown on these drawings to ensure precast elements are produced without any defects. The shop drawing should provide details of fabrication and installation of precast structural concrete units. It shall indicate member location, plans, elevations, dimensions, shapes, cross sections, openings, and type of reinforcement, including special reinforcement, if any. The following information also has to be indicated in the shop drawings:
   - Welded connections by the American Welding Society's standards symbol.
   - Details of loose and cast-in hardware, insets, connections, joints, and all types of accessories.
   - Location and details of anchorage device to be embedded in other construction.
   - Comprehensive engineering analysis including fire resistance analysis.

4. Structural Steel Fabrication

   The shop drawings for fabrication of structural steel shall include:
   - Details of cuts, connections, splices, camber, holes, and other pertinent data.
   - Welding standards symbols.
   - Size and length of bolts, indicating details of material and strength of bolts.
   - Details of steel bars, plates, angles, beams, channels.
   - Method of erection.
   - Details of anchorage details, templates, and installation details of bolts.

Elevator Work

- Overall elevation (vertical) for elevator area.
- Floor levels.
- Hoist way plan, sections, and anchoring details for installation of rails.
- Machine room plan and installation details for drive and controller.
- Equipment layout in machine room/hoistway.
- Cuttings/openings, sleeves required in the concrete slab/walls.
- Details and level of cab overhead.
- Details and levels about the pit.
- Location and level of hall button and hall position indicator.
- Openings for landing door, entrance view and finishes level.

- Finishes of cab, door, indicators.
- Power supply devices and equipment grounding.
- Interface with elevator management system, if any.

Mechanical Work (Fire Suppression, Water Supply, and Plumbing)

The shop drawings for mechanical work shall include but are not limited to:

- Sprinkler layout.
- Hose reel details.
- Hose reel cabinet size, location, and installation details.
- Fire pump location and installation details.
- Location of flow switches.
- Riser diagram for water supply system.
- Size of piping.
- Piping route.
- Piping levels and slope.
- Pipes and sleeves for utility services.
- Size of isolating valves and their location.
- Equipment plan layout.
- Pump room details.
- Storage tank details.
- Details of toilet accessories and connection details.
- Riser diagram for rainwater system.
- Drainage system piping.
- Location of vents and traps.
- Location of cleanouts.
- Riser diagram for stormwater system.
- Stormwater system.
- Electrical power connection details.
- Interface with fire alarm and building management system.

HVAC Work

The shop drawing for HVAC work shall include the following but not limited to:

- Location of equipment and its configuration.
- Piping size.
- Piping route and levels.
- Ducting size.
- Ducting route and levels.
- Insulation details.
- Suspension/hanger details.
- Equipment layout and plan/plant room details.
- Riser diagram for chilled water system.
- Installation details of equipment.
- Size of diffusers and grills.
- Installation details of grills.

- Exhaust and ventilation fans layout and details.
- Riser diagram for exhaust air system.
- Return air opening details.
- Equipment schedule.
- Electrical connection and power supply details.
- Control details.
- Sequence of operation.
- Schematic diagram for HVAC system.
- Schematic diagram for the building management system by configuring all the equipment and components.

Electrical Work

The shop drawings for electrical work shall indicate but not limited to:

- Size and type of conduits, raceways, and exact routing of the same.
- Size of cable trays, cable trunking, their installation methods, and exact route indicating the level.
- Size of wires and cables.
- Small power layout.
- Large power layout.
- Wiring accessories with circuit references.
- Lighting layout with circuit references.
- Installation details of light fixtures.
- Emergency lighting system.
- External lighting layout.
- Feeder pillar location and installation details.
- Bus duct installation details.
- Field installation wiring details for light, power, controls, and signals.
- Installation details of lighting control panel.
- Installation details of distribution boards, switchboards, and panels.
- Location of distribution boards.
- Panels, switchboards layout in low-tension (LT) room.
- Installation details of bus duct.
- Schematic diagram showing the configuration of all the equipment.
- Load schedules as per actual connected loads.
- High voltage panel layout.
- Substation layout.
- Interface with solar power/alternate energy system.
- Voltage drop calculations.
- Short circuit calculations.
- Grounding (earthing) system.
- Lightning protection system.
- Diesel generator installation details.
- Automatic transfer switch (ATS) installation details.
- Interface with other systems.

HVAC Electrical Work

The shop drawings for HVAC electrical work shall include:

- Wiring diagram of individual components and accessories.
- MCC and starter panels.
- Installation details of MCC panels, starter panels.
- Schematic diagram including power and control wiring.
- Type and size of conduit and number and size of wires in the conduit.
- Type and size of cable.
- Details of protection and interlocks.
- Details of instrumentation.
- Description of sequence of operation of equipment.

Low Voltage Systems

The shop drawings for low voltage systems like BMS, fire alarm systems, communication systems, public address systems, audio-visual systems, CCTV/security systems, and access control systems shall consist of:

- Size of conduits and raceways, their routing and levels.
- Location of components, wiring accessories.
- Installation details of components, wiring accessories.
- Wiring and cabling details.
- Installation details of racks.
- Installation details of equipment.
- Location and installation details of panels.
- Schematic/riser diagram configuring all the components and equipment used in the system.
- Interface with other system(s).

Landscape Work

The shop drawings for landscape shall include:

- Boundary limit.
- Excavation area.
- Excavation level.
- Type of soil in different areas.
- Location of plants, trees, shrubs, etc.
- Foundation details for plants, trees, shrubs, etc.
- Location of sidewalk.
- Location of driveways.
- Foundation for paving.
- Grass areas.
- Location of services, ducts for utilities.
- Location of light poles/bollards.
- Foundation for light poles/bollards.
- Details of special features.
- Details of irrigation system.

External Work (Infrastructure)

The shop drawing for external work (infrastructure) shall include:

- Width of the road.
- Grading details.
- Thicknesses of asphalt layers.
- Pavement details.
- Location of manholes and levels.
- Services/utilities pipe routes.
- Location of light poles.
- Cable routes.
- Trench details.
- Road marking.
- Traffic signs and signals.

Builders Workshop Drawings

Builders workshop drawings indicate the openings required in the civil or architectural work for services and other trades. These drawings indicate the size of openings, sleeves, level references with the help of detailed elevation and plans. Figure 2.37 illustrates builder's workshop drawing preparation and approval procedure.

Composite/Coordination Shop Drawings

The composite drawings indicate the relationship of components shown on the related shop drawings and indicate the required installation sequence. Composite drawings shall show the interrelationship of all services with each other and with the surrounding civil and architectural work. Composite drawings shall also show the detailed coordinated cross sections, elevations, reflected plans, etc. resolving all conflicts in levels, alignment, access, space, etc. These drawings are to be prepared taking into consideration the actual physical dimensions required for installation within the available space. Figure 2.38 illustrates the composite drawing preparation and approval procedure.

2.7.12.4.1.3 Method Statement

The contractor has to execute the work as per the method statement specified in the contract. The contractor has to submit a method statement to consultant for their approval as per the contract documents to ensure compliance with the contract requirements. The method statement shall describe the steps involved for execution/installation of work by ensuring safety at each stage. It shall have the following information:

1. Scope of work: Brief description of work/activity.
2. Documentation: Relevant technical documents to undertake this work/activity.
3. Personnel involved.
4. Safety arrangement.
5. Equipment and plant required.
6. Personal protective equipment.
7. Permits/authorities' approval to work.

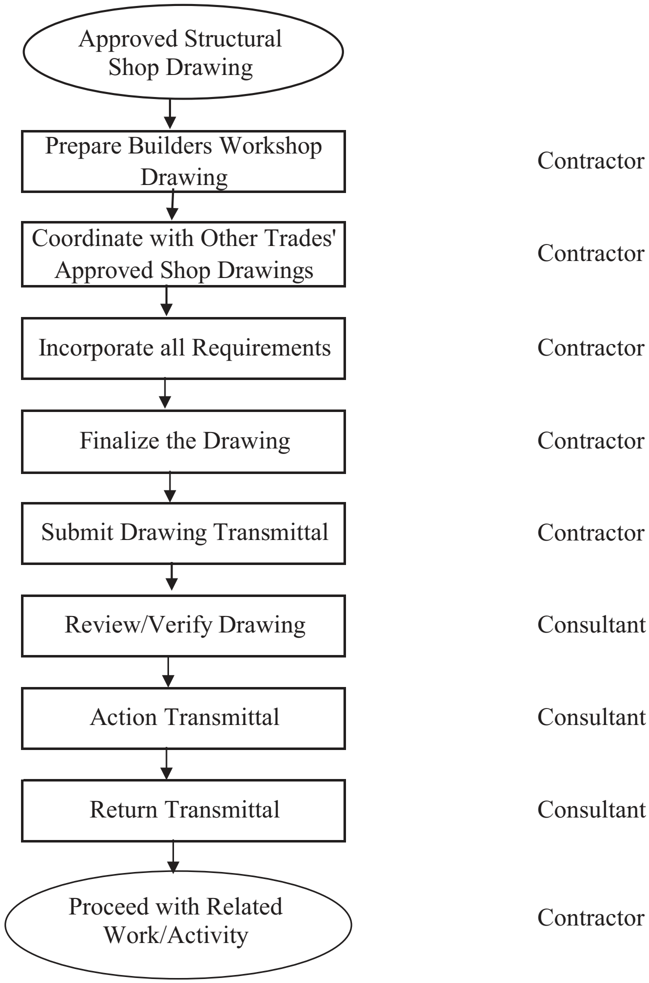


FIGURE 2.37 Builders workshop drawing preparation and approval procedure.

8. Possible hazards.
9. Description of the work/activity: Detailed method of sequence of each operation/key steps to complete the work/activity.

Figure A.2 to A.9 discussed under Appendix A, are illustrative examples of the work sequence of major activities, for different trades, performed during construction process.

2.7.12.4.2 Manage Changes

It is common that during the construction process, there will be some changes to the original contract. Even under most ideal circumstances, contract documents cannot

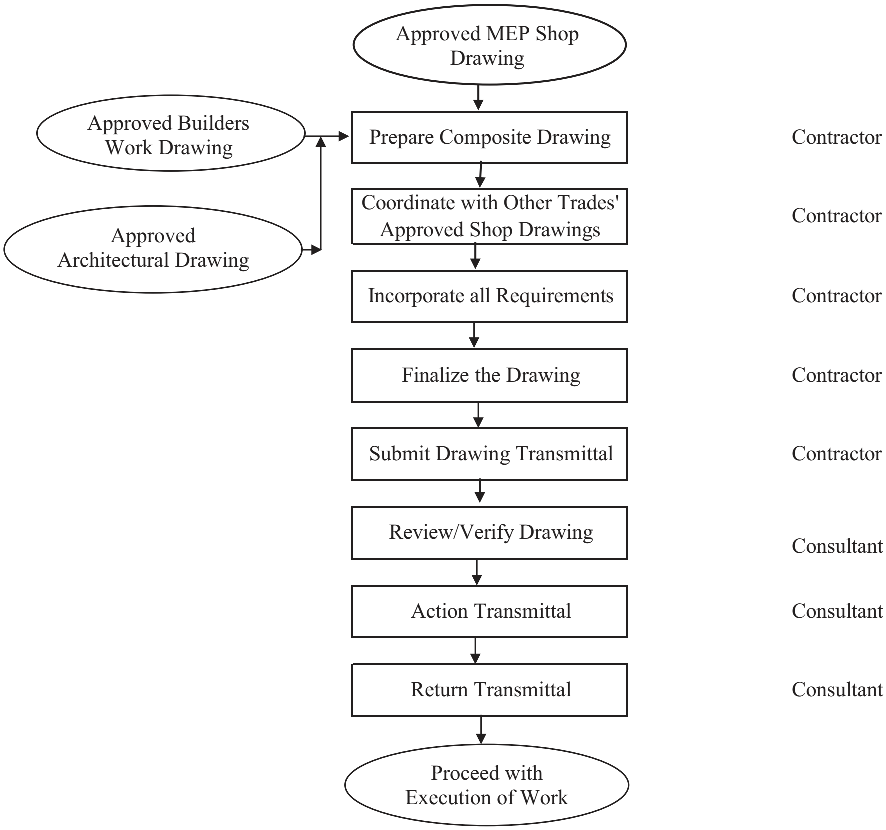


FIGURE 2.38 Composite drawing preparation and approval procedure.

provide complete information about every possible condition or circumstance that the construction team may encounter. The causes for changes have already been discussed under Section 1.3.2.3.6 (please refer to Table 1.16).

These changes help build the facility to achieve project objectives. These changes are identified as the construction proceeds. Prompt identification of such requirements helps both the owner and the contractor to avoid unnecessary disruption of work and its impact on cost and time. Refer to Figure 1.39 RFI form that the contractor submits to the consultant to clarify differences/errors observed in the contract documents, changes in construction methodology, changes in the specified material, etc.

These queries are normally resolved by the concerned supervision engineer. However, it is likely that the matter has to be referred to the designer as RFI has many other considerations to be taken care of, and which may be beyond the capacity of supervision team members to resolve. Such queries may result in variations to the contract documents. Figure 1.46 illustrates the flow diagram for processing of RFI. It is in the interest of both owner and contractor to resolve RFI expeditiously to avoid their effect on the construction schedule. A SWI is issued to the contractor that gives instruction to the contractor to proceed with the change(s). (Please refer to Figure 1.43, which is a sample SWI form.) All the necessary documents are sent along with the SWI to the contractor. SWI is also used to instruct contractors for owner-initiated changes. Subsequently, the contractor submits a variation order proposal form to the owner/consultant for approval of change(s) in the contract. (Please refer to Figure 1.41.)

Similarly, if the contractor requires any modification to the specified method, then the contractor submits a request for modification to the owner/consultant. Figure 1.44, discussed earlier, illustrates the request for modification. Usually, these modifications are carried out by the contractor without any extra cost or time obligation toward the contract.

It is the normal practice that, for the benefit of the project, the engineer's representative assesses the cost and time related to SWI or request for changeover and obtains preliminary approval from the owner and the contractor is asked to proceed with such changes. The cost and time implementation are negotiated and formalized simultaneously/later to issue the formal variation order. In all the circumstances where a change in contract is necessary the owner's approval has to be obtained. Figure 1.46 illustrates the form used by the engineer's representative to obtain change order approval from owner.

Once cost and time implications are negotiated and finalized and both the owner and contractor approve the same, a variation order is issued to the contractor and changes are adjusted with contract sum and schedule. Figure 1.47a illustrates a variation order form issued to formalize the change order and Figure 1.47b illustrates an attachment to the change order.

Any change initiated by the owner is resolved as per the process discussed under Section 1.2.3.6 and illustrated by Figure 1.45.

2.7.12.4.2.1 Resolve Conflict

It is essential that changes in the project are managed as quickly as possible in accordance with the conditions of the contract. However, disputes and conflicts in construction projects are inevitable due to the fact that with all the precautionary steps, discrepancies or errors do occur in the contract documents. The following methods are normally followed to resolve the conflict:

- Negotiation
- The economic method to resolve the conflict is negotiation. Negotiation involves compromise. Both parties should discuss the issue by arranging meetings of all the project team members involved and whose input to the issue will help resolve the conflict. The issue to be analyzed with the help of related documents, substantiation for claim, and justification for claim. If agreement is not reached, the involved senior representatives from both parties.
- Mediation
- Mediation is a process in which a neutral third-party group is involved to assist the parties to a dispute in reaching an amicable agreement that resolves the conflict.
- Arbitration

- Arbitration is the voluntary submission of a dispute to one or more impartial persons for final and binding determination. There are certain agencies that certify arbitrators.
- Litigation
- Litigation means to apply to the court to resolve the dispute.

2.7.12.4.3 Manage Construction Quality

The construction project quality control process is a part of the contract documents that provide details about specific quality practices, resources, and activities relevant to the project. The purpose of quality control during construction is to ensure that the work is accomplished in accordance with the requirements specified in the contract. Inspection of construction work is carried out throughout the construction period either by the construction supervision team (consultant) or an appointed inspector agency. Quality is an important aspect of construction projects. The quality of the construction project must meet the requirements specified in the contract documents. Normally, the contractor provides on-site inspection and testing facilities at construction site. On a construction site, inspection and testing is carried out at three stages during the construction period to ensure quality compliance.

1. During construction process. This is carried out with the checklist request submitted by the contractor for testing of ongoing work before proceeding to the next step.
2. Receipt of subcontractor or purchased material or services. This is performed by a material inspection request submitted by the contractor to the consultant upon receipt of materials.
3. Before final delivery for commissioning and handover.

Quality management in construction is a management function. In general, quality assurance and control programs are used to monitor design and construction conformance to established requirements as determined by the contract specifications. Instituting quality management programs reduces costs while producing the specified facility. The contractor's quality control plan, discussed under Appendix A, is followed throughout the construction project. Table 2.37 illustrates the contractor's responsibilities to manage construction quality.

2.7.12.4.4 Manage Construction Resources

The success of a construction project depends largely on availability, performance and utilization of resources. In construction projects, the resources are linked with duration of project and each activity is allocated a specific resource to be available at a specific time. The construction resource mainly consists of:

1. Construction Workforce
   a. Contractor's own staff and workers.
   b. Subcontractor's staff and workers.
2. Construction Equipment, Machinery
3. Construction Material, Equipment, and Systems to be Installed on the Project

TABLE 2.37
Contractor's Responsibility to Manage Construction Quality

Sr. No.	ACTIVITY	AREAS OF QUALITY CONTROL							
		MAIN CONTRACTOR		SUBCONTRACTORS					
		HEAD OFFICE/ QUALITY MANAGER	PROJECT SITE/ PROJECT MANAGER	STRUCTURAL	INTERIOR	MRCHANICAL (HVAC+PHFF)	ELECTRICAL	LANDSCAPE	EXTERNAL
1	Prepare Quality Control Plan	□	■	□	□	□	□	□	□
2	Construction Schedule	□	■	□	□	□	□	□	□
3	Mobilization	□	■	□	□	□	□	□	□
4	Staff Approval	□	■	□	□	□	□	□	□
5	Prepare Material Submittal		■	■	■	■	■	■	■
6	Submit Material Transmittal		■	□	□	□	□	□	□
7	Prepare Shop Drawings		■	■	■	■	■	■	■
8	Submit Shop Drawing Transmittal		■	□	□	□	□	□	□
9	Material Sample	□	■	■	■	■	■	■	■
10	Receiving Material Inspection		■	■	■	■	■	■	■
11	Material Testing		■	■	■	■	■	■	■
12	Mock-Up		■	■	■	■	■	■	■
13	Site Work Inspection		■	■	■	■	■	■	■
14	Quality of Work		■	■	■	■	■	■	■
15	Prepare Checklist		■	■	■	■	■	■	■
16	Submit Checklist		■	□	□	□	□	□	□

(*Continued*)

TABLE 2.37 Continued
Contractor's Responsibility to Manage Construction Quality

Sr. No.	ACTIVITY	AREAS OF QUALITY CONTROL							
		MAIN CONTRACTOR		SUBCONTRACTORS					
		HEAD OFFICE/ QUALITY MANAGER	PROJECT SITE/ PROJECT MANAGER	STRUCTURAL	INTERIOR	MRCHANICAL (HVAC+PHFF)	ELECTRICAL	LANDSCAPE	EXTERNAL
17	Corrective/Preventive Action		■	■	■	■	■	■	■
18	Daily Report		■	□	□	□	□	□	□
19	Monthly Progress Report		■	□	□	□	□	□	□
20	Progress Payment	□	■	□	□	□	□	□	□
21	Site Safety		■	■	■	■	■	■	■
22	Safety Report		■	□	□	□	□	□	□
23	Waste Disposal		■	■	■	■	■	■	■
24	Reply to Job Site Instruction		■	□	□	□	□	□	□
25	Reply to Non-Conformance Report		■	□	□	□	□	□	□
26	Documentation		■	□	□	□	□	□	□
27	Testing and Commissioning		■	■	■	■	■	■	■
28	Project Closeout Documents	□	■	□	□	□	□	□	□
29	Punch List		■	■	■	■	■	■	■
30	Request for Issuance of Substantial Completion Letter	□	■	□	□	□	□	□	□

■ **Primary Responsibility** □ **Advise/Assist**

In most construction projects, contractor is responsible to engage all types of human resources to complete the project, subcontractors, specialist installers, suppliers, arrange equipment, construction tools, and materials as per contract documents and to the satisfaction of owner/owner's appointed supervision team. Workmanship is one of the most important factors to achieve the quality in construction, therefore it is required that the construction workforce is fully trained and has full knowledge of all the related activities to be performed during the construction process.

2.7.12.4.4.1 Construction Workforce Once the contract is awarded, the contractor prepares a detailed plan for all the resources he/she needs to complete the project. Contract documents normally specify a list of the minimum number of core staff to be available at the site during the construction period. The absence of any of these staff may result in a penalty to be imposed on the contractor by the owner.

A typical list of contractor's minimum core staff needed during the construction period for execution of work of a major building construction project is discussed under Section 2.7.3.3.

Contractor's human resources mainly consist of two categories:

1. Contractor's own staff and workers.
2. Subcontractor's staff and workers.

The human resources required to complete the projects are based on a resource-loading program. It is necessary that all the construction resources are coordinated and brought together at the right time in order to complete them on time and within budget.

The main contractor has to manage all these personnel by:

1. Assigning the daily activities.
2. Observing their performance and work output (productivity).
3. Daily attendance.
4. Safety during construction process.

Figure 2.39 illustrates the contractor's actual manpower chart of a construction project.

2.7.12.4.4.2 Subcontractor In most construction projects, the main contractor engages subcontractors and specialist contractors to execute a certain portion of the contracted project work. The main contractor has to monitor the performance of the subcontractor throughout the project to ensure project success. In order to achieve project objectives, it is essential that the main contractor and subcontractor maintain a partnering relationship. In order for the smooth execution of the project, both parties should have cooperative, collaborative, and joint problem-solving attitudes. Their aim should be to achieve a successful project and maintain long-term business relationships.

The main contractor-subcontractor relationship starts the moment the subcontractor is selected and a contract/agreement is signed to execute the project.

It is important that necessary precautions and care are taken to prequalify and select the subcontractor. Table 2.31, discussed earlier, lists questionnaires to prequalify the subcontractor.

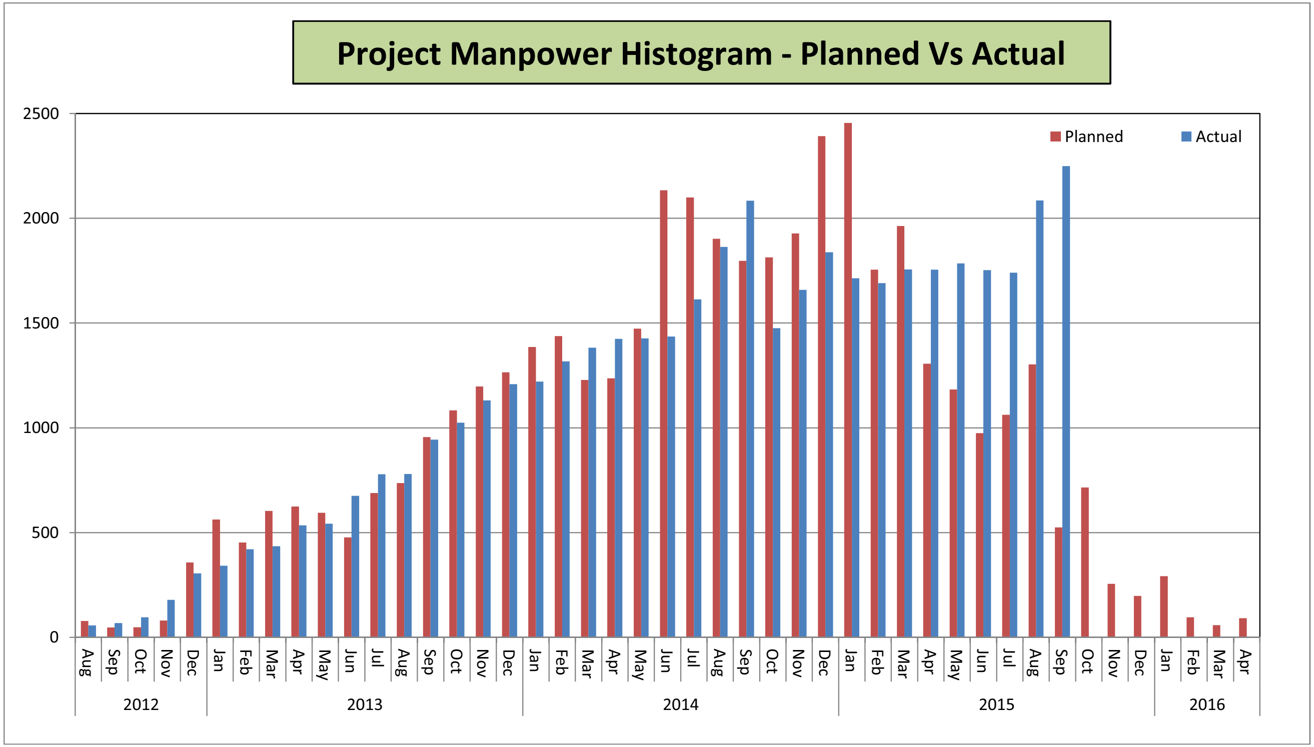


FIGURE 2.39 Contractor's manpower chart.

In certain cases, the subcontractor is involved with the main contractor from tendering stage. The main contractor takes into consideration the prices quoted by the subcontractor while submitting the proposal. The contractor price between main contractor and subcontractor can be:

- Back-To-Back on the main contractor prices keeping agreed-upon margin for the main contractor. OR
- Negotiated prices with the subcontractor in which case the main contractor's contract awarded prices are not known to the subcontractor.

In order for successful execution of the project, it is necessary to have a subcontractor management plan in place to ensure that each of the subcontractors executes the project as specified without affecting the project quality and schedule.

The following is the typical contents of a subcontractor management plan:

1. Introduction
2. Organization
    a. Organization Chart
    b. Roles
    c. Responsibilities
3. Scope of Work
4. Quality Management Plan
5. Project Coordination Method
6. Submittals
    a. Material
    b. Shop Drawings
7. Resource Management
    a. Training
8. Change Management
9. Communication
    a. Meetings
10. Risk Management
11. HSE Management
12. Documentation
13. Invoicing, Payments
14. Closeout Contract

2.7.12.4.4.3 Construction Equipment Likewise, the contract documents specify that a minimum number of equipment is to be available at site during the construction process to ensure smooth operation of all the construction activities. Figure 2.40 illustrates the equipment list and utilization schedule for a major building construction project.

2.7.12.4.4.4 Construction Material The contractor also prepares a procurement log based on the project completion schedule.

EQUIPMENT LIST AND UTILIZATION SCHEDULE FOR MAJOR BUILDINGS PROJECT

Sr. No.	Item Description	Unit	NUMBERS PER MONTH																
			2019					2020											
			AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Tower Crane	Nos.	_	_	4	9	9	9	9	9	9	9	9	9	9	9	9	9	9
2	Construction Hoist	Nos.	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
3	Mobile Crane	Nos.	_	_	1	1	2	2	2	4	4	4	4	4	4	4	4	4	4
4	Bulldozer	Nos.	_	3	4	4	2	2	2	_	_	_	_	_	_	_	_	_	_
5	Dump Truck	Nos.	_	4	4	4	4	4	4	_	_	_	_	_	_	_	_	_	_
6	Excavator	Nos.	_	2	2	2	2	2	2	2	2	_	_	_	_	2	_	_	_
7	JCB	Nos.	_	1	4	4	4	2	2	_	_	_	_	_	_	_	_	_	_
8	Concrete Pump	Nos.	_	_	2	6	6	6	6	4	4	4	4	4	4	4	4	4	4
9	Transit Mixer	Nos.	_	_	10	30	30	30	30	30	15	15	15	15	15	15	15	15	15
10	Fork Lift	Nos.	_	_	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
11	Trailer	Nos.	_	_	2	4	4	4	4	4	2	2	2	2	2	2	2	2	2
12	Total Station	Nos.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
13	Theodoliite	Nos.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
14	Level Instrument	Nos.	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
15	Precision Level	Nos.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
16	Bar Bending Machine	Nos.	_	_	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6
17	Bar Cutting Machine	Nos.	_	_	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6
18	Bar Screw - Tread	Nos.	_	_	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
19	Diesel Generator	Nos.	_	_	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
20	Compactor	Nos.	_	_	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
21	Crawler Compactor	Nos.	_	_	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
22	High Pressure Pump	Nos.	_	_	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
23	Manual Hoist	Nos.	_	_	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
24	ConcreteVibrator	Nos.	_	_	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
25	Mortar Mixer	Nos.	_	_	_	_	_	_	_	_	_	_	_	_	6	6	6	6	6
26	Welding Machine	Nos.	_	_	_	4	4	4	4	4	4	50	50	50	50	50	50	50	50
27	Circular Saw	Nos.	_	_	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
28	Pipe Painting Machine	Nos.	_	_	_	_	_	_	_	_	_	_	2	2	2	2	2	2	2
29	Main Ditribution Panel	Nos.	_	_	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
30	Duct Fabrication Machine	Nos.	_	_	_	_	_	_	_	_	_	_	_	_	_	2	2	2	2
31	Electric Hammer	Nos.	_	_	4	4	4	4	4	4	4	4	4	4	4	4	12	12	12
32	Power Float	Nos.	_	_	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
33	Angle Grinder	Nos.	_	_	_	_	4	4	4	4	4	4	4	4	4	4	4	4	4
34	Electric Hand Drill	Nos.	_	_	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
35	Lighting Equipment	Nos.	_	_	5	5	10	10	10	10	10	10	10	10	10	10	10	10	10
36	Air Jack	Nos.	_	_	_	_	_	_	2	2	2	2	2	2	2	2	6	6	6
37	Angle Saw	Nos.	_	_	_	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Sr. No.	Item Description	NUMBERS PER MONTH																								
		2021												2022												
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAY
1	Tower Crane	9	9	9	9	8	8	8	8	8	8	8	4	4	_	_	_	_	_	_	_	_	_	_	_	_
2	Construction Hoist	4	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	_
3	Mobile Crane	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	_
4	Bulldozer	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
5	Dump Truck	4	4	4	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
6	Excavator	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
7	JCB	2	2	2	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
8	Concrete Pump	4	4	4	4	4	4	4	4	4	4	4	4	4	_	_	_	_	_	_	_	_	_	_	_	_
9	Transit Mixer	15	15	15	15	15	15	15	15	15	15	15	15	15	_	_	_	_	_	_	_	_	_	_	_	_
10	Fork Lift	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	_
11	Trailer	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	_
12	Total Station	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
13	Theodoliite	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
14	Level Instrument	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
15	Precision Level	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
16	Bar Bending Machine	6	6	6	6	6	6	6	6	6	6	6	6	6	_	_	_	_	_	_	_	_	_	_	_	_
17	Bar Cutting Machine	6	6	6	6	6	6	6	6	6	6	6	6	6	_	_	_	_	_	_	_	_	_	_	_	_
18	Bar Screw - Tread	2	2	2	2	2	2	2	2	2	2	2	2	2	_	_	_	_	_	_	_	_	_	_	_	_
19	Diesel Generator	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
20	Compactor	4	4	4	4	2	2	2	2	2	2	2	2	2	_	_	_	_	_	_	_	_	_	_	_	_
21	Crawler Compactor	2	2	2	2	2	2	2	2	2	2	2	2	2	_	_	_	_	_	_	_	_	_	_	_	_
22	High Pressure Pump	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	_
23	Manual Hoist	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	_
24	ConcreteVibrator	25	25	25	25	25	25	25	25	25	25	25	25	25	_	_	_	_	_	_	_	_	_	_	_	_
25	Mortar Mixer	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	_
26	Welding Machine	50	20	20	20	20	50	50	50	50	50	50	50	20	20	20	20	20	20	20	20	20	20	20	20	_
27	Circular Saw	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	_
28	Pipe Painting Machine	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	_	_	_	_	_	_
29	Main Ditribution Panel	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
30	Duct Fabrication Machine	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	_	_	_	_	_	_
31	Electric Hammer	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	_
32	Power Float	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	_	_	_	_	_	_
33	Angle Grinder	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	_
34	Electric Hand Drill	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	_
35	Lighting Equipment	10	10	10	10	10	10	10	10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	_
36	Air Jack	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	_
37	Angle Saw	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	_

FIGURE 2.40 Contractor's equipment chart.

In most construction projects, the contractor is responsible for procurement of materials, equipment, and systems to be installed on the project. The contractors have their own procurement strategies. While submitting the bid, the contractor obtains quotes from various suppliers/subcontractors. Figure 2.41 illustrates the material procurement procedure to be followed by the contractor.

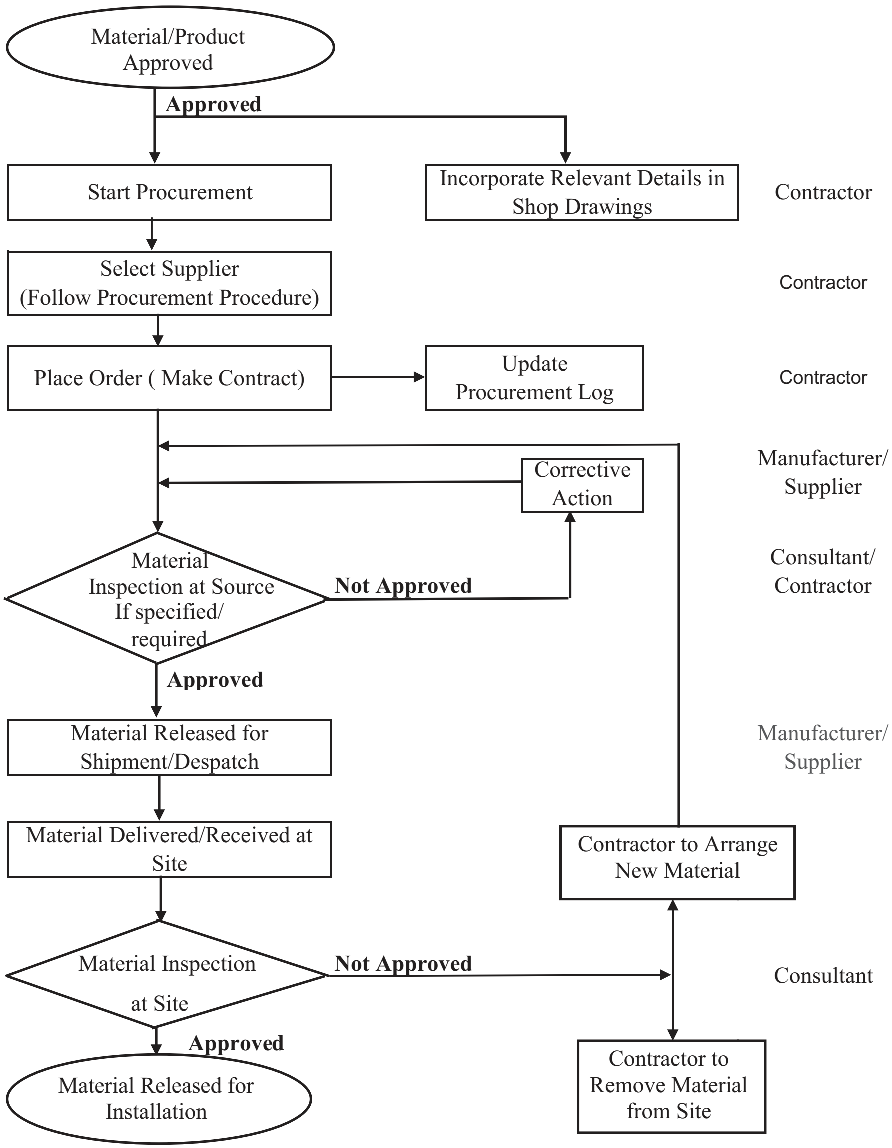


FIGURE 2.41 Material procurement procedure.

The contractor has to ensure that construction material is available at the project site on time to avoid any delay. Delivery of long lead items has to be initiated at an early stage of the project and monitored closely. Late order placement for materials, results in delayed delivery of materials, which, in turn, affects the timely completion of the project and is a common scenario in construction projects. Hence these logs have to be updated regularly and prompt actions have to be taken, to avoid delays. The contractor is required to provide twice a month or at any time requested by the owner/consultant, full and complete details of all products/systems procurement data relating to all the approved products/systems that have been ordered and/or procured by the contractor for use in the construction project. The contractor maintains contractor's procurement log E-2 (please refer to Figure 1.71) to keep track of material status. The log E-2 is normally submitted by the contractor along with the monthly progress report.

2.7.12.4.4.5 Supply Chain Management Supply chain management in construction projects is managing and optimizing the flow of construction materials, systems, equipment, and resources to ensure timely availability of all the construction resources without affecting the progress of work at the site. Figure 2.42 illustrates the supply chain management process in construction projects.

In construction projects, the supply chain management starts from the inception of the project. The designer has to consider the following while specifying the products (materials, systems, equipment) for use/installation in the project:

- Quality management system followed by the manufacturer/supplier.
- Quality of product.
- Reliability of product.
- Reliability of manufacturer/supplier.

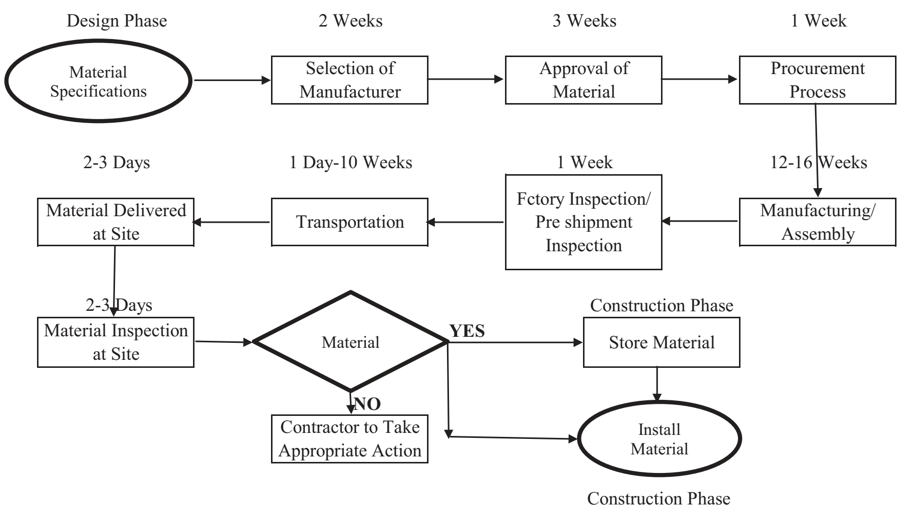


FIGURE 2.42 Supply chain management process.

- Durability of product.
- Availability of product for entire project requirement.
- Price economy/cost efficiency.
- Sustainability.
- Conformance to applicable codes and standards.
- Manufacturing time.
- Location of the manufacturer/supplier from the project site.
- Interchangeability.
- Avoid monopolistic products.

Product specifications are documented in the construction documents (particular specifications). In certain projects, the documents list the names of recommended manufacturers/suppliers. However, in order of continuous and uninterrupted supply of specified products, the contractor has to consider the following:

- Quality management system followed by the manufacturer/supplier.
- Historical rejection/acceptance record.
- Reliability of the manufacturer/supplier.
- Product certification.
- Financial stability.
- Proximity to the project site.
- Manufacturing/lead time.
- Availability of product as per the activity installation/execution schedule.
- Manufacturing capacity.
- Availability of quantity to meet the project requirements.
- Timeliness of delivery.
- Location of manufacturer/supplier.
- Product cost.
- Transportation cost.
- Product certification.
- Risks in delivery of product.
- Responsiveness.
- Cooperative and collaborative nature to resolve problems.

In major construction projects, the following items are required in bulk quantities:

- Concrete
- Concrete Block
- Conduit
- Utility Pipes
- Light Fixtures
- Electrical Devices
- Plumbing Fixtures

The contractor can follow a just-in-time method to procure these items and avoid a large inventory at project site. The contractor has to select a reliable manufacturer/

supplier for these products and ensure that the manufacturer/supplier is capable of maintaining a continuous flow of these items at short notice. The contractor can sign an agreement with the manufacturer/supplier for entire project quantity with an agreed-upon delivery schedule as per the requirement at site.

In order to ensure supply chain payments are made promptly, the cash flow system should be projected accordingly as the supply chain may be affected due to interruption in payments toward the supply of products.

2.7.12.4.5 Manage Communication

For smooth implementation of the project, a proper communication system is established, clearly identifying the submission process for correspondence, submittals, minutes of meetings, and reports.

2.7.12.4.5.1 Correspondence Normally, all the correspondence between contractor and consultant is through a submittal transmittal form (please refer to Figure 1.74). Correspondence between consultant and contractor is normally done through job site instructions whereas correspondence between owner, consultant, and contractor is normally done through letters. Figure 2.29, discussed earlier, is a sample job site instruction form used by the consultant to communicate with the contractor.

2.7.12.4.5.2 Submittals Contract documents specify the number of copies to be submitted to various stakeholders. Please refer to Figure 1.78, already discussed under Section 1.3.2.8.1, for the submittal process. Table 1.30, discussed earlier under Section 1.3.2.8.1, lists different types of forms used in construction projects.

2.7.12.4.5.3 Meetings

There are various types of meetings conducted during execution of project. These meetings are conducted at an agreed-upon frequency. The meetings during construction phase are held for specific reasons. For example:

1. Kick-off meeting is held to acquaint project team members and discuss project objectives, procedures, and other contract information.
2. Progress meetings to review work progress.
3. Coordination meetings to coordinate among different disciplines and resolve the issues.
4. Quality meetings to discuss on-site quality issues and improvements to the construction process.
5. Safety meetings to discuss site safety and environmental issues.

Table 2.38 lists points to be discussed during safety meetings.

Apart from the previously discussed meeting, the contractor, consultant, owner can call for a meeting to discuss any project-relevant issue or information.

Prior to conducting any meeting, an agenda is circulated to stakeholders and team members to attend the meeting. Figure 1.82, discussed earlier, illustrates a sample agenda format for a meeting. The proceedings of the meeting are recorded, and minutes of the meeting are circulated among all attendees and others per the approved form for minutes of the meeting. Figure 2.43 illustrates minutes of meeting format.

TABLE 2.38
Points to be Discussed during Safety Meetings

Serial Number	Points to be Reviewed	YES/NO
1	Whether meetings are held as planned and attended by all the concerned persons.	
2	Whether all the items from the previous meetings addressed and appropriate actions taken.	
3	Whether all the accidents/incidents/near misses recorded and reviewed to identify common issues and learning points.	
4	Whether training needs identified.	
5	Whether records of training programs maintained.	
6	Whether actions/feedback from weekly meetings reviewed and appropriate action taken.	
7	Whether suggestions/comments from safety tours are implemented.	
8	Whether safety awareness programs are regularly held.	
9	Whether safety warning signs are displayed and operative.	
10	Whether sirens and alarm bells are functioning properly.	
11	Whether temporary firefighting system in action and all the equipment are update.	
12	Whether regular check and audits are performed?	
13	Has the latest regulation been introduced by authority and informed to all concerned?	
14	Was there any visit by competent authority and their observations are taken care?	
15	Whether escape route and assembly points are displayed.	
16	Do all the workforces have personal protective equipment?	
17	Whether first aid box has all the required medicines.	

2.7.12.4.5.4 Reports During the construction phase, the following reports are submitted by the contractor:

- Progress Reports such as:
  - Daily report.
  - Weekly report.
  - Monthly progress report.
- Safety report.
- Risk report.

2.7.12.4.6 Manage Risks

During construction project, the assigned project team members have to identify the risk, and also to estimate the likely occurrence of risk, and develop a response plan to mitigate, avoid the risk. Table 2.39 lists potential risks that occur during construction phase and its effects on scope, schedule, and cost.

2.7.12.4.7 Manage Contracts Contract management during construction phase is an organizational method, process and procedure to manage all contract agreements involved between the owner, contractor, subcontractor, manufacturers, and

PROJECT NAME
Consultant Name

MINUTE OF MEETING

Contract No. : ____________________ **Date** : __________

Contractor : ____________________

Meeting Type		MOM No.	
		Date	
Meeting Location		Time	

ITEM	DESCRIPTION OF DISCUSSION	STATUS	PRIORITY	ACTION			
				By	Due	Started on	Closed on

Prepared by:

Distribution Owner Contractor A/E

FIGURE 2.43 Minutes of meeting format.

suppliers. During construction phase, contracts are managed mainly by the following parties who are directly involved for execution of project:

- Consultant/Construction (Project) Manager
- Contractor
- Apart from these two parties, subcontractors and vendors also have their contract management system.

TABLE 2.39
Potential Risks Affecting Scope, Schedule, Cost, and Mitigation Plan

Sr. No.	Potential Risk	Probable Effects	Control Measures/Mitigation Action
1.0 Scope			
1.1	Scope/Design Changes	• Project Schedule • Project Cost • Claim	• Compress schedule. • Resolve change order issues in order not to delay the project.
1.2	Different Site Conditions information provided	• Change in Scope of Work • Delay in project	• Contractor to investigate site conditions prior to starting the relevant activity
1.3	Inadequate Site Investigation Data	• Additional Work • Scope Change	• Contractor to investigate site conditions prior to starting the relevant activity
1.4	Conflict in Contract documents	• Project Delay	• Amicably resolve the issue
1.5	Incomplete Design	• Project Scope • Project Schedule • Project Cost	• Raise request for information (RFI). • Resolve issue in accordance with contract documents.
1.6	Incomplete Scope of Work	• Project Scope • Project Schedule • Project Cost	• Raise request for information (RFI). • Resolve issue in accordance with contract documents.
1.7	Design Changes	• Project Scope • Project Schedule • Project Cost	• Follow contract documents for change order.
1.8	Design Mistakes	• Project Scope • Project Schedule • Project Cost	• Raise request for information (RFI). • Resolve issue in accordance with contract documents.
1.9	Errors and Omissions in Contract Documents	• Project Scope • Project Schedule • Project Cost	• Raise request for information (RFI). • Resolve issue in accordance with contract documents.
1.10	Incomplete Specifications	• Project Scope • Project Schedule • Project Cost	• Raise request for information (RFI). • Resolve issue in accordance with contract documents.
1.11	Conflict with Different Trades	• Project Delay	• Coordinate with all trades while preparing coordination and composite drawings.
1.12	Inappropriate Construction Method	• Project Delay • Claim	• Raise request for information (RFI) and correct the method statement.
1.13	Quality of Material	• Project Delay	• Locate suppliers having proven record of supplying quality product.
2.0 Schedule			
2.1	Incompetent Subcontractor	• Project Delay • Project Quality	• Contractor has to monitor the workmanship and work progress.
2.2	Delay in Transfer of Site	• Project Delay	• Contractor to adjust the construction schedule.
2.3	Delay in Mobilization	• Project Delay	• Adjust construction schedule accordingly.
2.4	Project Schedule	• Project Completion	• Compress duration of activities.

(*Continued*)

TABLE 2.39 Continued
Potential Risks Affecting Scope, Schedule, Cost, and Mitigation Plan

Sr. No.	Potential Risk	Probable Effects	Control Measures/Mitigation Action
2.5	Inappropriate Schedule/ Plan	• Project Delay	• Contractor to prepare schedule taking into consideration site conditions all the required parameters.
2.6	Delay in Change Order Negotiations	• Project Schedule	• Request owner/supervisor/project manager to expedite the negotiations and resolve the issue.
2.7	Resource Availability (Material)	• Project Delay	• Contractor to make extensive search.
2.8	Resource (Labor) Low Productivity	• Project Quality • Project Delay	• Contractor to engage competent and skilled labors.
2.9	Equipment/Plant Productivity	• Project Delay	• Contractor hire/purchase equipment to meet project productivity requirements.
2.10	Insufficient Skilled Workforce	• Project Duration	• Contractor arranges workforce from alternate sources.
1.11	Failure/Delay of Machinery and Equipment	• Project Delay	• Contractor to plan procurement well in advance.
1.12	Failure/Delay of Material Delivery	• Project Delay	• Contractor to plan procurement well in advance.
2.13	Delay in Approval of Submittals	• Project Delay	• Notify owner/project manager.
2.14	Delays in Payment	• Project Delay • Claim	• Contractor to have contingency plans. • Owner to pay as per contract.
2.15	Statutory/Regulatory Delay	• Project Delay	• Regular follow-up by the contractor, owner with the regulatory agency.
3. Cost			
3.1	Low Bid Project Cost	• Project Quality	• Contractor to try competitive material, improve method statement and higher production rate from its manpower.
3.2	Variation in Construction Material Price	• Project Quality • Project Cost	• Contractor to negotiate with supplier/ manufacturer for best price. Contractor to request for change order if applicable as per contract.
3.3	Damage to Equipment	• Schedule	• Regularly maintain the equipment. Take immediate action to repair damage equipment.
3.4	Damage to Stored Material	• Project Delay • Material Quality	• Contractor to follow proper storage system.
3.5	Structure Collapse	• Injuries • Project Delays	• Contractor to ensure that formwork and scaffolding is properly installed.
3.6	Leakage of Hazardous Material	• Safety Hazards	• Contractor to take necessary protect to avoid leakage. Store in safe area.

(Continued)

TABLE 2.39 Continued
Potential Risks Affecting Scope, Schedule, Cost, and Mitigation Plan

Sr. No.	Potential Risk	Probable Effects	Control Measures/Mitigation Action
4.0 General			
4.1	Failure of Team Members not Performing as Expected	• Project Quality • Project Delay	• Select competent candidate. Provide training.
4.2	Change in Laws and Regulations	• Scope/Specification Changes • Variation Order	• Contractor to inform owner/consultant and raise request for information (RFI).
4.3	Access to Worksite	• Extra/Additional Time to Access Site	• Access road to be planned in coordination with adjacent area and local authority.
4.4	Theft at Site	• Project Delay	• Contractor to monitor access to site. Record entry/exit to the site. Provide fencing around project site.
4.5	Fire at Site	• Project Delay	• Contractor to install temporary firefighting system. Inflammable material to be stored in safe and secured place with necessary safety measures.
4.6	Injuries	• Project Delay	• Contractor to keep first aid provision at site. Take immediate action to provide medical aid.
4.7	New Technology	• Scope Change • Schedule • Cost	• Owner/contractor to mutually agree for changes in the contract for better performance of project.

The contract management process starts once the contract is signed. The consultant is responsible for managing the contract on behalf of the owner. The consultant monitors scope, schedule, cost, and quality of the construction to ensure contract conditions are met. The contractor is responsible for ensuring that all project work is executed within the agreed-upon time and cost in accordance with the contract conditions and specifications.

For successful contract management, the contractor as well as the consultant/CM/PM has to consider the following points while executing the project:

1. Use of the RFI to get clarification on some aspects of the project. There are two parts in RFI. These are:
   a. “Question” by the contractor.
   b. “Answer” by the owner (consultant).
2. Execution of project work using specified and approved materials, equipment, and systems.
3. Developing project execution plan considering realistic duration for each activity.

4. Execution of contracted work in a timely manner in accordance with agreed-upon schedule.
5. Dealing variations to the specified product, method, work in accordance with related specification, contract clauses and by providing substantiation and justifications that have resulted proposing alternative or substitute material.
6. Managing errors, omissions, and additions strictly in accordance with contract terms and avoiding any delays to the project.
7. Conducting meetings to monitor progress and clarify prevailing project issues.
8. Cooperating with all team members to fulfill their contractual obligations.
9. Resolving disputes in an amicable way by adopting a cooperative approach.
10. Providing resources to ensure timely availability of competent workforce as per resource schedule.
11. Taking action on all the transmittals within agreed-upon period.
12. Timely reply to all correspondences, queries.
13. Communicating issues and problems well in advance.
14. Not to ignore problems/issues with the hope that they might go away.
15. Arranging payment of progress payment as per contractual entitlement within stipulated time.
16. Maintaining list of claims on monthly basis.
17. Settling claims in accordance with contract terms.
18. Maintaining proper logs and records.

2.7.12.4.8 Manage Site Safety and Protect Environment The construction industry has been considered dangerous for a long time. The nature of work at site always presents some dangers and hazards. There is a relatively high number of injuries and accidents at construction sites. Safety represents an important aspect of construction projects. Every project manager tries to ensure that the project is completed without major accidents on the site.

The construction site should be a safe place for those who are working at the site. Necessary measures are always required to ensure the safety of all those working at construction site. Effective risk control strategies are necessary to reduce and prevent accidents.

Contract documents normally stipulate that the contractor, upon signing of contract, has to submit safety and accident prevention programs. It emphasizes that all the personnel have to put effort into preventing injuries and accidents. In the program, the contractor has to incorporate requirements of safety and health requirements of local authorities, manuals of accident prevention in construction, and all other local codes and regulations. The contractor has to also prepare an Emergency Evacuation Plan (EEP). The EEP is required to protect personnel and to reduce the number of fatalities in case of major accidents at site. The evacuation routes have to be displayed at various locations in a manner. Transfer points and gathering points to be designated and signboards to be displayed all the time. Evacuation sirens are to be sounded on a regular basis in order to ensure smooth functioning of the evacuation plan.

A safety violation notice is issued to the contractor/employee if the contractor or any of his/her employees are not complying with safety requirements. Figure 2.44 illustrates a safety violation notice to be actioned by the contractor.

Project Name
Consultant Name

Contract No.:	**SVN No.**
Contractor:	**Date :**
	Time:

SAFETY VIOLATION REPORT

SAFETY RELATED ITEMS			
Sr.No.	**Description**	**Sr.No.**	**Description**
1	Access Facilities	13	Hygieninc
2	Barricade/Railing	14	Lifting Gears
3	Construction Equipment	15	Poor lighting
4	Crane	16	Protective Equipment
5	Earhtwork/Excavation	17	Safety Gears
6	Electrical	18	Scaffolding
7	Fire Fighting/Protection	19	Site Fencing
8	First Aid	19	Storage Facilities
9	Formwork	20	Unsafe access
10	Hand and Power Tools	21	Vehicles
11	Hazars/Imflamable Material	22	Welding/Hot Work
12	Hoist	23	Others
12	House Keeping	24	

VIOLATION DESCRIPTION	**Action code:**	
Item No.	**Location**	**Description**

ORIGINATOR:	**RESIDENT ENGINEER:**

CONTRACTOR'S ACTION				
Item No.	**Location**	**Action**	**Date**	**Time**

SAFETY OFFICER:	**CONTRACTOR'S PROJECT MANAGER:**

Action Code: A For immediate action /( )hours B Within ( ) days

FIGURE 2.44 Safety violation notice.

Penalties are also imposed on the contractor for non-compliance with the site safety program. Figure 2.45 illustrates a sample safety disciplinary notice form for breach of safety rules. Different colors of cards may be issued along with the notice. Table 2.40 illustrates concepts of issuance of different colors of cards.

Penalties are also imposed on the contractor for non-compliance with the site safety program. The safety program shall embody the prevention of accidents, injury, occupational illness, and property damage. The contract specifies that a

PROJECT NAME	
CONSULTANT NAME	
Safety Disciplinary Notice	
Notice No.:	Date:
Name of Employee: Contractor Name: Area/Floor: Date & Time of Observance:	SAMPLE FORM
Type of Notice	
	First/Verbal Warning (White Card)
	Second/Written Warning (Yellow Card**)**
	Suspension from Site (Red Card)
Reason for Issuance of Notice:	
Action Required by Recipient:	
Date by Which Action is Required:	
Issued by: Signature:	Date:
Reveived by:	Date:

CC: Owner ☐ Resident Engineer ☐ Project Manager ☐

FIGURE 2.45 Safety disciplinary notice.

safety officer is engaged by the contractor to follow safety measures. The safety officer is normally responsible for:

1. Conducting safety meetings.
2. Monitor on-the-job safety.
3. Inspect the work and identify hazardous area.

TABLE 2.40
Concept of Safety Disciplinary Action

Serial Number	Card Color	Type of Disciplinary Action	Warning Validity	Reasons for Disciplinary Action
1	White	Verbal Followed by Safety Discipline Notice	One Month to Three Months	1. Failure to use personal protective equipment. 2. Failure to use define access. 3. Working on plant, crane, vehicle without license. 4. Working with unsafe scaffolding. 5. Working on unsafe platform. 6. Using unsafe sling or ropes for lifting. 7. Working on unsafe ladders.
2	Yellow	Issuance of Safety Discipline Notice and Suspension from Work for the Rest of the Day	Six Months	1. Repetition of activities listed under "White Card" within one month of issuance of first notice. 2. Failure to observe HSE related instructions. 3. Failure to work as per instructed method of work, as per given task. 4. Failure to follow storage principles about hazardous materials.
3	Red	Issuance of Safety Disciplinary Notice and Suspension from Site for One Month	One Year	1. Breach of safety rules where there is risk to life. 2. Removal of safety devices, interlocks, guard rails, barriers without any authority. 3. Deliberately exposing public to danger by not complying with agreed safe methods of work. 4. Disposal of hazardous material in unsafe area.

4. Initiate safety awareness program.
5. To ensure availability of first aid and emergency medical services as per local code and regulations.
6. To ensure that the personnel are using protective equipment such as hard hat, safety shoes, protective clothing, life belt, protective eye coverings.
7. To ensure that temporary firefighting system is working.
8. To ensure that work areas and access are free from trash, and hazardous material.
9. Housekeeping.

Construction sites have many hazards that can cause serious injuries and accidents. The contractor has to identify these areas and to ensure that all site personnel and subcontractor employees working at the site are aware of unsafe acts, potential and actual hazards, and the immediate corrective action to be taken and adhere to safety plan and procedures.

Following is the list of some of the common areas that can cause injuries/accidents:

1. Unsafe access.
2. Ladders.
3. No barricades around excavated areas, trenches, openings, holes, and platforms.
4. Non-Barricades/railings on the stairs.
5. Scaffolding.
6. Lifting gear.
7. Crane.
8. Hoist.
9. Welding.
10. Hand and power tools.
11. Poor lighting.
12. Fire.

The following are general safety guidelines contractor may follow to avoid accidents/injuries:

1. Safe access.
2. Ensure ladders are in good condition and properly secured.
3. Provide barricades around openings, holes, and platform.
4. Choose the right system of scaffolding for the job to be performed.
5. Checking lifting gears for capacity, condition of wire rope, slings, hooks, eyebolts, shackles, proprietary lighting equipment, spreader beam.
6. Ensure the crane is:
   - On firm, level ground and outriggers are fully extended.
   - Check safe working load against the load to be lifted.
   - Ensure that load swing is minimum.
   - Select right type of chain.
   - Keep the load clear of personnel.
7. Hoist is certified by a third party, and the certificate is valid.
8. Wear all protective equipment and garments necessary to be safe on the job.
9. Wear and use eye protection coverings.
10. Use safety shoes.
11. Use hard hat.
12. Use safety belts.
13. Use respiratory mask whenever required.
14. Use right size of hand tools.
15. Before any plant or mechanized equipment is placed in use, check it is certified for safe operating condition.
16. Before using electric tools:
    - Check it is properly earthed.
    - Cable, plugs, or connectors are sound and properly wired.

17. Use proper guards while using power tools such as circular saws, portable grinders, bench grinders.
18. Use safe loading/unloading techniques.
19. All material stored at site to be stacked properly to ensure that it is stable and secure against sliding or collapse.
20. Work areas and means of access should be maintained in a safe and orderly condition.
21. Mark access and escape route.
22. Keep passageways and accessways free from materials, supplies, and obstructions all the time.
23. Mark all the hazardous areas.
24. Prohibit storage of flammable and combustible material.
25. No smoking sign to be displayed.
26. Install sirens and alarm bells at site.
27. Ensure temporary firefighting system is working all the time.
28. All formwork, shoring, and bracing should be designed, fabricated, erected, supported, braced, and maintained so that it will safely support all vertical and lateral loads that might be applied until such loads can be supported by the structure.
29. While placing concrete:
    - Make use of protective clothing and equipment.
    - Use appropriate gloves.
    - Use rubber boots.
    - Wear protective goggles.
    - Tale necessary precautions while using concrete skips or concrete.
30. Display safety signs such as DANGER, CAUTION, and WARNING on all live electrical panels.
31. Post safety, warning signs, and notices of weekly project safety records.
32. Conduct "Safety Awareness" programs.

The contractor is responsible for ongoing maintenance of accident/incident records on the construction site and their notification to the consultant. Figure 2.46 is an accident reporting form and Figure 2.47 is a summary procedure to be followed once an accident takes place at the site. (Please refer to Figure 4.34, Volume 1, for site safety improvement.)

2.7.12.4.9 Manage Project Finance In construction projects, maximum amount is expended during construction phase. During this phase:

1. Owner has to make payments to:
    a. Main contractor.
    b. Supervisor (consultant).
    c. Construction/project manager, if applicable.
    d. Specialist consultant.
    e. Specialist contractor.
    f. Any other party such as direct appointments.
    g. Owner-supplied items, if any.

Project Name

ACCIDENT REPORT

CONTRACT : ____________________ CONTRACT NO. : ____________

CONTRACTOR : ____________________ REPORT # : ____________

SUBCONTRACTOR : ____________________ REPORT DATE : ____________

SAMPLE FORM

ACCIDENT DATE			
ACCIDENT TIME			
ACCIDENT LOCATION			
INJURED PERSON		I.D.#	
ADDRESS		AGE	
ACCIDENT DETAILS : - CAUSE - PERSONAL INJURY - PROPERTY DAMAGE			
ACCIDENT REPORTED BY		I.D.#	
ACCIDENT REPORTED TO		I.D.#	
WITNESSED BY		I.D.#	
INVESTIGATED BY		I.D.#	
ACTION TAKEN : - MEDICAL AID - FOLLOW UP - LEGAL ACTION			

NOTE : IDENTIFY ENTRY PASS NUMBERS FOR ALL INDIVIDUALS INVOLVED

____

CONTRACTOR REP.SIGNATURE.

FIGURE 2.46 Accident report.

2. Main contractor has to make payments to:
   a. Subcontractors.
   b. Suppliers (material procurement).
   c. Designer, if any design work is involved.

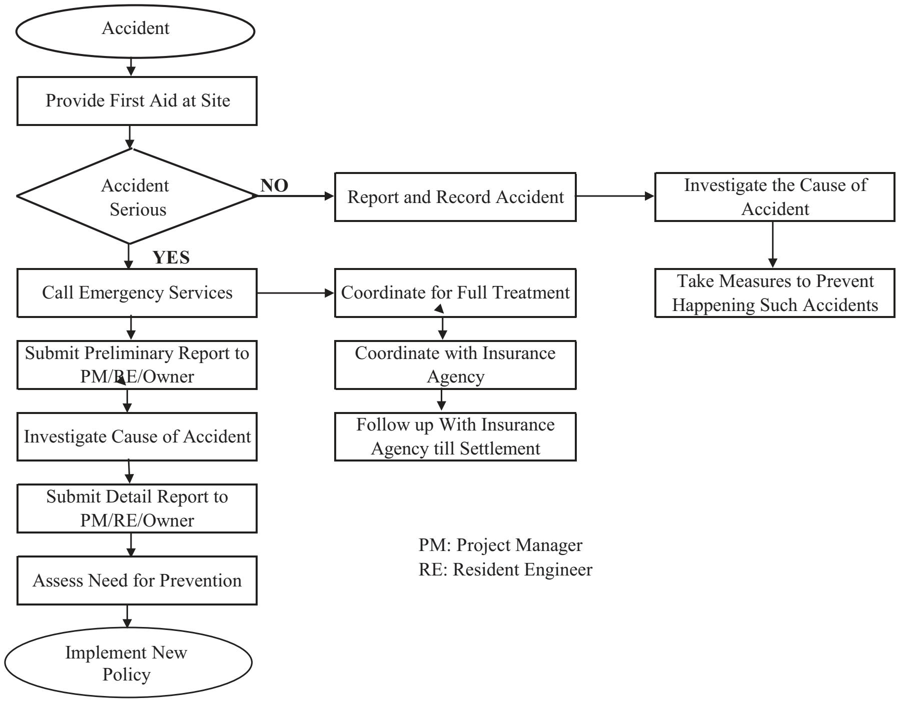


FIGURE 2.47 Summary procedure for action after accident.

d. Workforce.
e. Rent (equipment rent, rental vehicles).

3. Subcontractor has to make payment to:
   a. Suppliers.
   b. Specialists.

The owner's payment is mainly related to progress payment claimed and approved by the consultant, advance payments (if any as per contract) to the contractor, monthly fees to the consultant's, construction/project manager.

Contractor and subcontractor's payments are linked to the approved executed works.

The management of finance for the project is done through project cash flow forecast.

Cash Flow

Cash flow = Cash in Cash out

The forecasting of cash flow is important for the smooth functioning of contract to ensure that an appropriate level of funding is in place and suitable draw-down facilities are available. Cash flow prediction is normally made with the help of S-Curve. The S-Curve stands for "Standard" curve, but the name has also taken into account the shape of the letter "S."

The contractor prepares "S" based on expected work progress on a monthly basis.

Forecasting of cash flow is important to:

- Ensure that sufficient funds are available to meet the demand during construction to fulfill the commitment/obligations.
- Sufficient funds are available when it is required (timing).
- Ensure maximum utilization of funds.

In order to prepare the S-Curve, accurate information on the following elements is required:

- Total expenses.
- Total income.
- Timing of payment.

The resource loaded construction schedule can be used to calculate cash flow forecast. The S-Curve for owner is different than that of the contractor.

The owner has to take into consideration the following points while preparing a cash flow:

- Errors and omissions.
- Effects of change order or variation.
- Effect of inflation.
- Effect of international exchange rate.
- Change in the sequence of work schedule to expedite or to mitigate delay.
- Payment toward material at site or off-site.
- Provisional sum in the contract.

Similarly, while preparing the cash flow, the contractor has to consider the following points:

- Delay in execution of work.
- Productivity less than estimated.
- Delay in receipt of payment.
- Advance payment, if any, for material.
- Different site conditions.
- Stoppage of work due to bad weather.
- Re-sequencing of work.
- Delay in material delivery at site resulting in payment not claimed.
- Higher material price than estimated.
- Fluctuation in international exchange rate.

Figure 2.48 is illustrative S-Curve for the contractor.

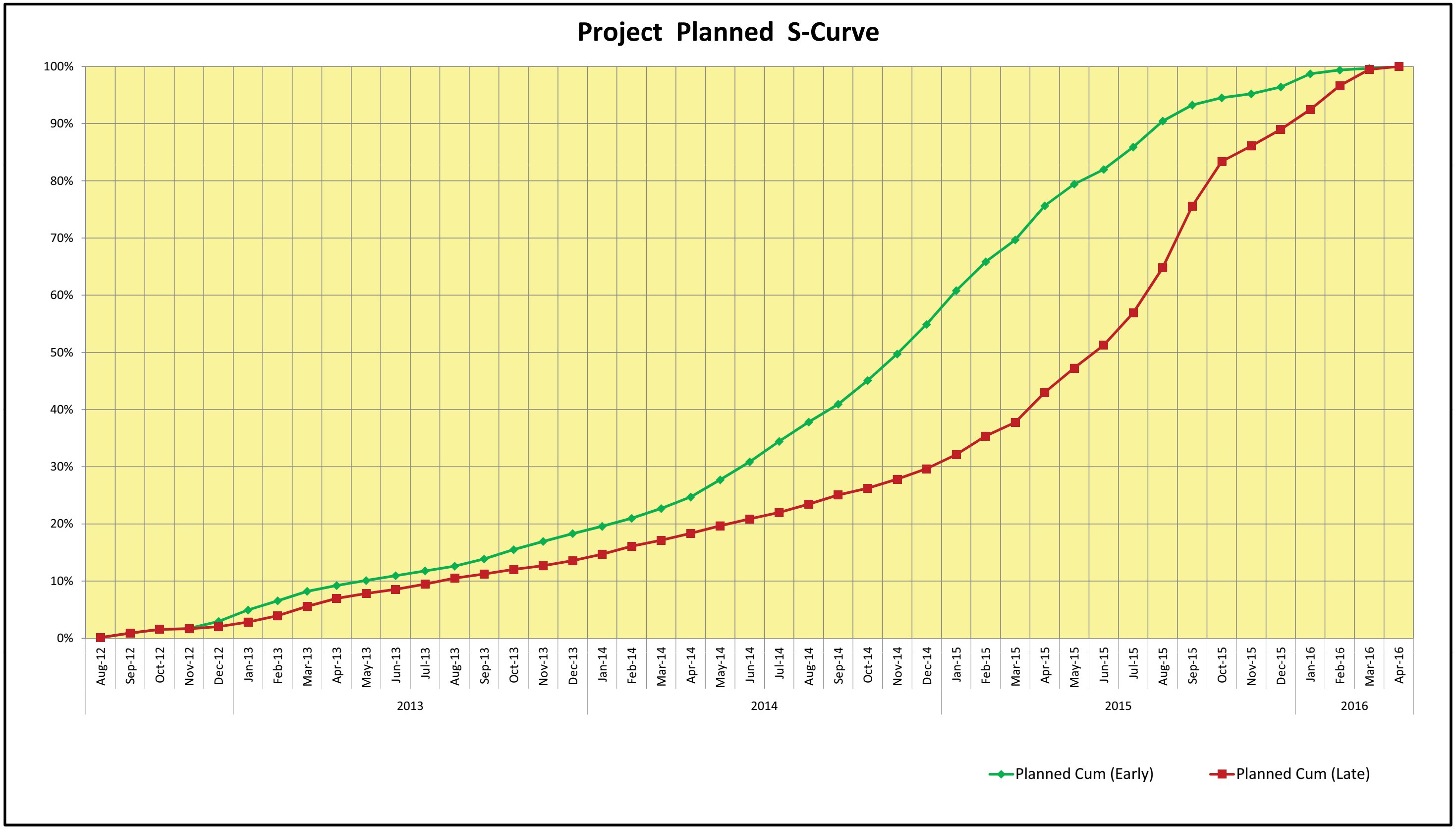


FIGURE 2.48 S-Curve for contractor.

Payments

The contractor's payment is related to the approved executed works. The contractor submits the payment on a monthly basis. Figure 2.49 illustrates progress payment submission format generally used by the contractor, Figure 2.50 illustrates process for progress payment approval, and Figure 2.51 illustrates payment certificate format normally prepared by RE/CM to recommend payment to the contractor.

2.7.12.4.10 Manage Claims Most claims in construction projects are due to:

- Errors and omissions in the contract documents.
- Incomplete design.
- Design changes.
- Delay in payment by the owner.
- Delay in transfer of site.
- Delay in approval of submittals.

Table 1.54 under Section 1.2.3.13 lists major causes of claims.

Identify Claims

The contractor during the construction phase has to identify the errors or omissions in the contract, if any, and follow the contractual procedure to resolve the issues. Table 1.55 under Section 1.2.3.13 lists the claims in construction projects and their effects on construction projects.

Prevent Claims

Table 1.56 under Section 1.2.3.13 has listed actions to be taken to prevent/mitigate claims

Resolve Claims

Any claim submitted by the contractor has to be resolved by the project team members amicably as per the conditions of contract.

Figure 2.52 illustrates the claim resolution process.

2.7.13 Monitor and Control Project Works

Monitoring and controlling project work depend on the type of project delivery system. In major projects, the owner engages construction/project management firm that is responsible for supervising, monitoring, and controlling construction activities performed by the contractor. However, in most cases, supervision of the project during construction phase is carried out by the consultant who is involved in designing the project. The Resident Engineer (R.E.) along with supervision team members is responsible to supervise, monitor, control, and implement the procedure specified in the contract documents and ensuring completion of the project within specified time, budget and per defined scope of work. In order to ensure a smooth flow of supervision activities, RE has to follow the organization's supervision manual and contractual requirements. Table 2.41 illustrates an example checklist listing the items

Project Name																	
Contractor Name: **Project Number**																	
Serial Number	BOQ Reference	Description	Original Reference				Work Completed (Quantity/Percentage)							Cummulative Work			Approved Amount
							Previous			Current				Previous+Current			
			Unit	BOQ Quantity	Unit Price	Total Amount	Quantity	Percentage (%)	Total Amount	Quantity	Percentage (%)	Check List/ Approval Refrence	Total Amount	Quantity	Percentage (%)	Total Amount	

FIGURE 2.49 Progress payment submission form.

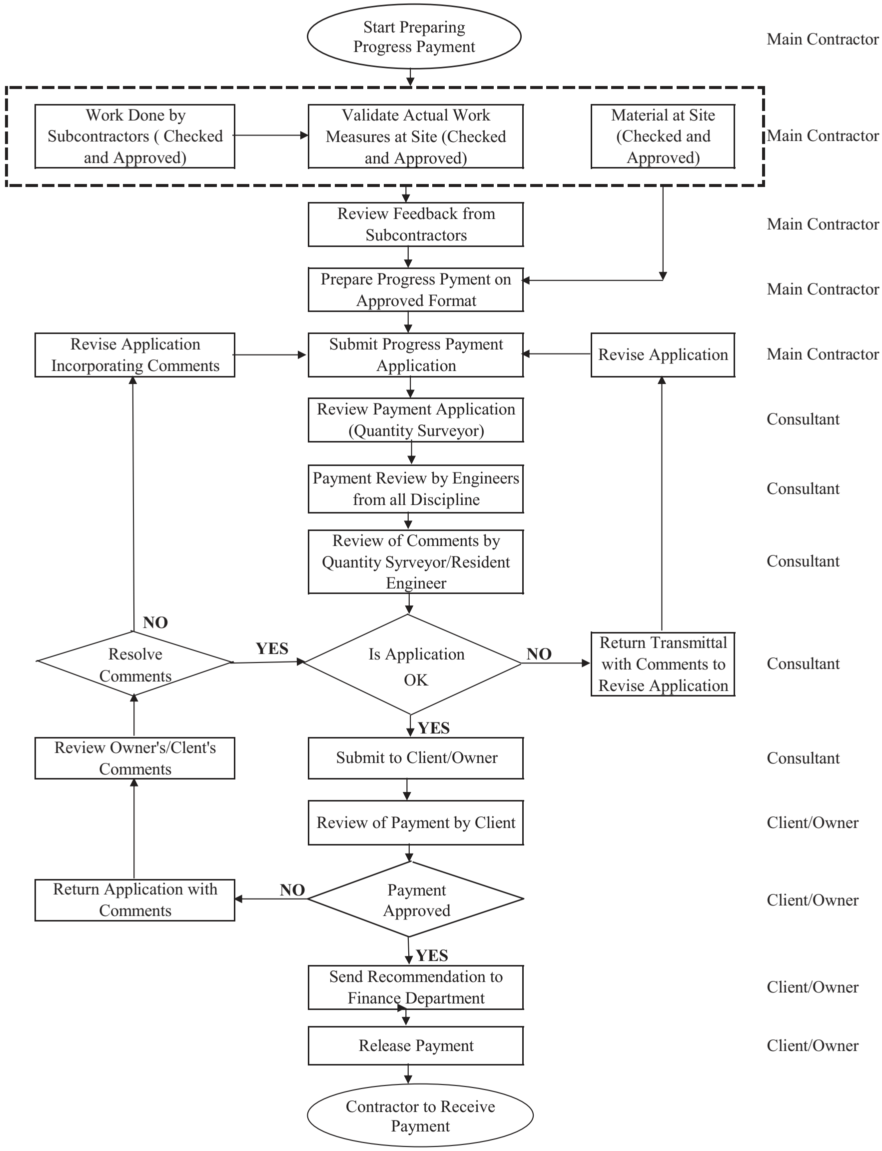


FIGURE 2.50 Process for progress payment approval.

to be verified by the RE to ensure availability of all the necessary documents and information to facilitate smooth flow of supervision work.

Monitoring and controlling the project is an ongoing process. It starts from the inception of the project and continues till handover of the project. Monitoring and control of construction project is operative during the execution of the project, and its aim is to recognize any obstacles encountered during execution and to apply

PROJECT NAME

PAYMENT CERTIFICATE

CONTRACT NO. :
CONTRACTOR :
PAYMENT CERTIFICATE NO. :
DATE :

SAMPLE FORM

Original Contract Value	:	Commencement Date	:
Orovisional Items	:	Contract Period (days)	:
Variation Orders Additon	:	Extension of Time(days)	:
Variation Order (Omission)	:	Date of Completion	:
Current Contract Value	:		

Work Executed up to:			**Amount**
Work Executed of Original Contract			
Work Executed of Variation Orders			
Work Executed of Provisional Sum			
Total Material on Site	X 80%		
Total Amount Due			
Additions / Deductions :			
Amount of Retention	X10%	Deduct	
Advance Payment (1st Installment)	% of Contract Value		
Advance Payment (2nd Installment)	% of Contract Value		
Total			
Repayment	% of Total Amount Due		
	Balance (Add)	Add	
Release of Retention		Add	
Less Omissions			
Deduct Previous Payments (including advance payment up to PC # 1)		Deduct	
	NET AMOUNT DUE TO CONTRACTOR		

Amount in Word:

(Note: The amount to be paid to the Contractor's Account No. xxxxxxxxxxx)

RECOMMENDED BY RESIDENT ENGINEER DATE

CONTRACTOR'S REPRESENTATIVE DATE

FIGURE 2.51 Payment certificate form.

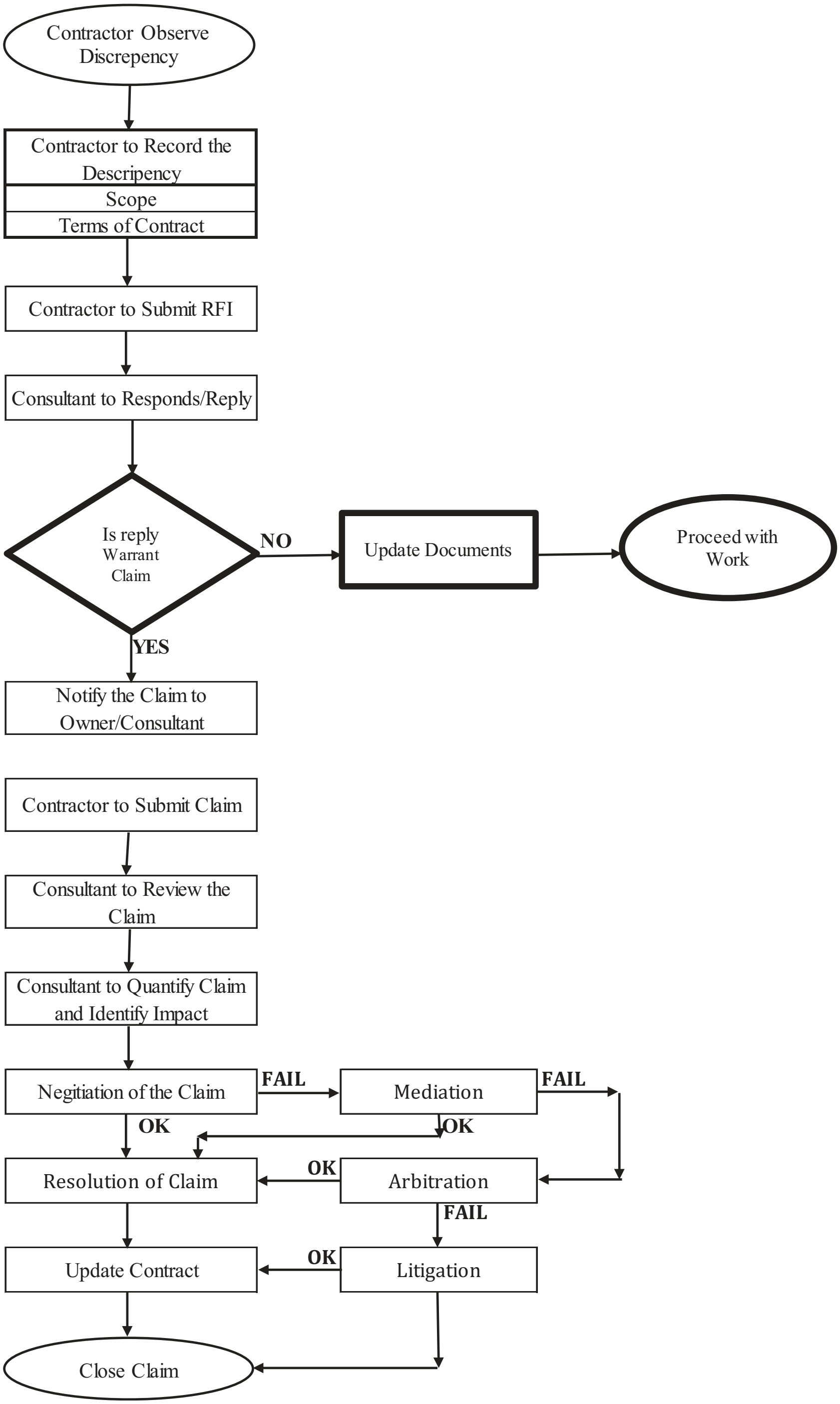


FIGURE 2.52 Claim resolution process.

TABLE 2.41
Consultant's Checklist for Smooth Functioning of Project

Serial Number	Items to be Checked/Verified	
I	**Project Details**	
	I.1	Scope of work.
	I.2	Project objectives.
	I.3	Project deliverables.
II	**Project Organization**	
	II.1	Organization chart and roles and responsibilities of defined supervision staff.
	II.2	Supervision staff deployment matching with project requirements.
	II.3	Contractor's staff deployment plan approved as per contract requirements.
	II.4	Responsibility matrix prepared and approved by the client and distributed among all project parties.
	II.5	Project directory.
III	**Mobilization**	
	III.1	Site permit from authorities available.
	III.2	Project plot boundaries are marked as per the permit.
	III.3	Project commencement order issued.
	III.4	Copy of permit issued to the contractor.
	III.5	Temporary site offices drawings approved.
	III.6	Temporary firefighting plan approved by respective authority.
	III.7	Copies of contractor's performance bond, guarantees, insurance policies and licenses available at site.
	III.8	Copies of consultant's performance bond, guarantees, insurance policies and licenses available at site.
	III.9	Preconstruction meeting conducted and submittal and approval procedures discussed and agreed.
IV	**Project Administration**	
	IV.1 Contract Documents	
	IV.1.1	Signed copy of contract between owner and contractor available at site.
	IV.1.2	Copies of contract documents available at site.
	IV.1.3	Contracted BOQ is available.
	IV.1.4	All volumes of particular specifications available.
	IV.1.5	Contracted drawings are available.
	IV.1.6	Authority approved drawings, duly stamped, available.
	IV.1.7	Addendum, if any, to the contract available.
	IV−1.8	Replies to tender queries available.
	IV−1.9	Copy of signed contract documents and drawings handed over to contractor and has acknowledged the same.
	IV−1.10	Log for codes and standards available.
	IV.2 Document Management	
	IV.2.1	Document control system is in place.
	IV.2.2	Filing index is available.
	IV.2.3	Material submittal log is available.
	IV.2.4	Shop drawing submittal log is available.
	IV.2.5	Logs for correspondence between various parties available.

(*Continued*)

TABLE 2.41 Continued
Consultant's Checklist for Smooth Functioning of Project

Serial Number		Items to be Checked/Verified
	IV.2.6	Log for checklist (request for inspection) available.
	IV.2.7	Log for JSI (job site instruction) available.
	IV.2.8	Log for SWI (site work instruction) available.
	IV.2.9	Log for RFI (request for information) available.
	IV.2.10	Log for VO (variation order) available.
	IV.2.11	Log for NCR (non-conformance report) available.
	IV.2.12	Material sample log and place identified
	IV.2.13	Log for equipment test certificate available.
	IV.2.14	Log for visitor's at site.
	IV.2.15	Contractor's staff approval log in place.
	IV.2.16	Subcontractor's approval log in place.
	IV.2.17	Consultants staff approval in place.
	IV.2.18	Overtime request log available.
V	**Communication**	
	V.1	Communication matrix established and agreed by all the parties.
	V.2	Distribution system for transmittals/submittals agreed.
VI	**Project Monitoring and Control**	
	VI.1	Daily report log in place.
	VI.2	Weekly report log in place.
	VI.3	Monthly report log in place.
	VI.4	Progress meetings log in place.
	VI.5	Minutes of meetings log in place.
	VI.6	Progress payment log in place.
	VI.7	Construction schedule log in place.
VII	**Construction**	
	VII.1	Quality control plan log in place.
	VII.2	Safety management plan log in place.
	VII.3	Risk management plan log in place.
	VII.4	Method statement submittal log in place.
	VII.5	Accident and fire report.
	VII.6	Off-Site inspection visits.
	VII.7	Location of gathering point established.
VIII	**General**	
	VIII.1	Correspondence between site and head office.
	VIII.2	Staff related matters.
	VIII.3	Copy of supervision manual available.
	VIII.4	Emergency contact telephones and contact details displayed at site.

measures to mitigate these difficulties and to ensure that the goals and objectives of the project are being met.

Monitoring is collecting, recording, and reporting information concerning any and all aspects of project performance that the project manager or others in the organization need to know. Monitoring of construction projects is normally done by collecting and recording the status of various activities and compiling them in the form of progress reports. These are prepared by the consultant and contractor and distributed to the concerned members of the project team.

Monitoring involves not only tracking time but also budget, quality, resources and risk. Monitoring construction projects is normally done by compiling status of various activities in the form of progress reports. These are prepared by contractors, the supervision team (consultant), construction/project management team. The objectives of project monitoring and control are:

1. To report the necessary information in detail and in an appropriate form that can be interpreted by management and other concerned personnel to provide the information about how resources are being used to achieve project objectives.
2. To provide an organized and efficient means of measuring, collecting, verifying, and quantifying data reflecting the progress and status of execution of project activities, with respect to schedule, cost, resources, procurement, and quality.
3. To provide an organized, efficient, and accurate means of converting the data from the execution process into information.
4. To identify and isolate the most important and critical information about the project activities to enable decision-making personnel to take corrective action for the benefit of the project.
5. To forecast and predict future progress of activities to be performed.

Figure 2.53 illustrates a logic flow diagram for monitoring and control process, and Table 2.42 illustrates monitoring and control references for construction projects.

Construction project control is exercised through knowing where to put the main efforts at a given time and maintaining good communication. There are mainly three areas where project control is required:

1. Quality (Scope)
2. Schedule
3. Budget

All of these areas are to be kept in balance to achieve project objectives. In order to accomplish the project objectives in construction projects, monitoring, and control is done through various tools and methods. There are mainly three elements that need monitoring and control. These are:

1. Quality (Scope)
2. Schedule (Work Progress)
3. Budget (Cost Control)

2.7.13.1 Control Scope

The project requirements set out in the contract documents determine the project scope, which is described in terms of project deliverables in the form of specifications and drawings. During construction phase, the contractor has to execute/install the work as defined in the project specifications and contract drawings. The

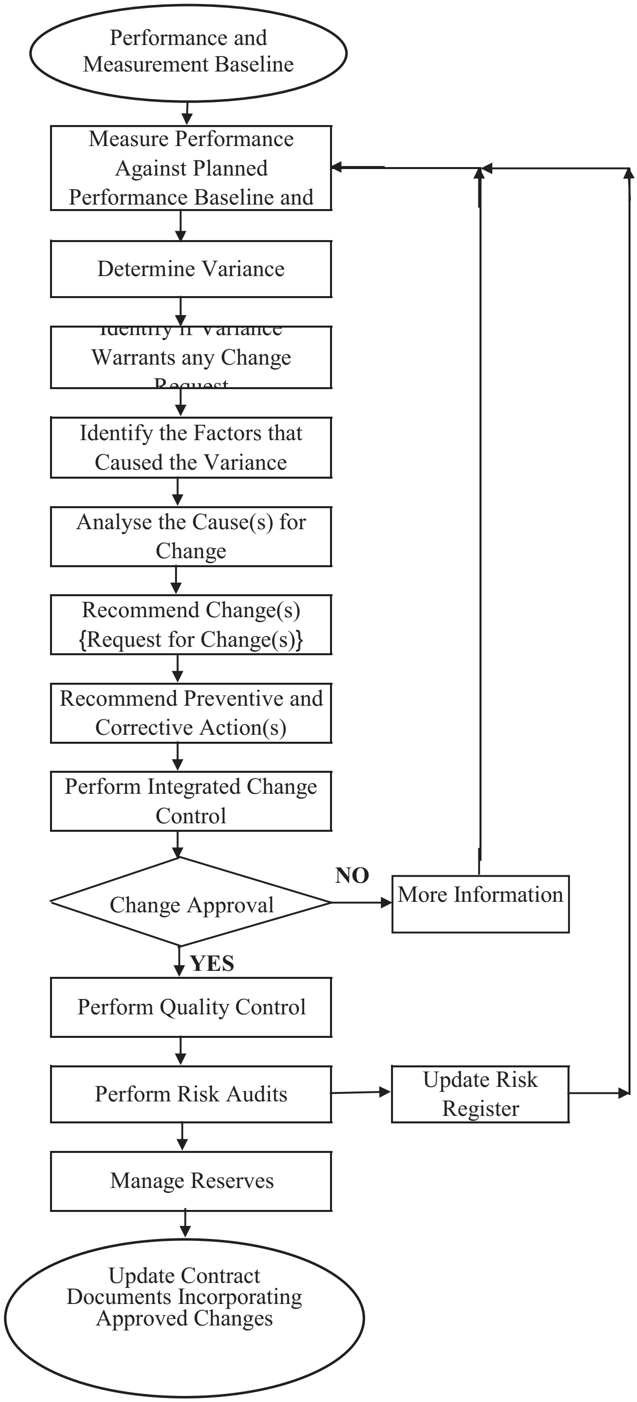


FIGURE 2.53 Logic flow diagram for monitoring and control process.

TABLE 2.42
Monitoring and Control References for Construction Projects

Serial Number	Elements	Contract Reference	Contractor Reference
1	Performance Baseline	Schedule	1. Contractor's Construction Schedule
		Specifications, Drawings	1. Approved Materials 2. Approved Shop Drawings 3. Approved Composite Drawings
		Cost	1. Approved S-Curve
2	Data Collection Methods	Reports	1. Daily Report 2. Weekly Report 3. Monthly Report 4. Safety Report 5. Risk Report 6. Accident Report 7. Checklist 8. Risk Report
3	Frequency of Data Collection	1. Daily 2. Weekly 3. Monthly	1. Daily Report 2. Weekly Report 3. Monthly Report
4	Status Information Collection	1. Logs 2. Reports 3. Meetings 4. Checklists	1. Logs 2. Reports 3. Meetings 4. Checklists
5	Comparison Between Planned and Actual (Variance)	1. S-Curves 2. Milestones	1. Progress Reports 2. Progress Payment 3. Milestones
6	Analysis	1. Price Analysis	1. Construction Schedule Attachment 2. Progress Payment
7	Corrective Action	1. Comments by Consultant	1. Incorporate Comments
8	Change Order	1. Variation Order	1. Request for Information 2. Request for Modification 3. Request for Variation
9	Document Updates	1 On Regular Basis	1. Reports

contractor has to make certain that the project changes do not result in compromising the intended project deliverables in terms of required quality and performance as defined in the scope baseline.

2.7.13.2 Monitor Progress

The approved contractor's construction schedule is the performance baseline for construction projects and achieved by collecting information through different methods. Work progress is monitored through various types of logs, S-Curves, reports, and meetings.

2.7.13.2.1 Logs

There are various types of logs used in construction projects for monitoring and controlling construction activities. The main logs used in a construction project are as follows:

1. Subcontractors Submittal and Approval Log
2. Submittal Status Log
3. Shop Drawings and Materials Logs—E1
4. Procurement Log—E2
5. Equipment Log
6. Manpower Logs

These logs provide necessary information about the status of subcontractors, materials, shop drawings, procurement, and availability of contractor's resources and help determine its effects on project schedule and project completion.

2.7.13.2.2 S-Curves

Figure 2.54 illustrates S-Curve for planned work versus actual work.

2.7.13.2.3 Reports

2.7.13.2.3.1 Progress Reports Apart from different types of logs and submittals, progress curves, time control charts, and the contractor's progress is monitored through various types of reports and meetings. These are:

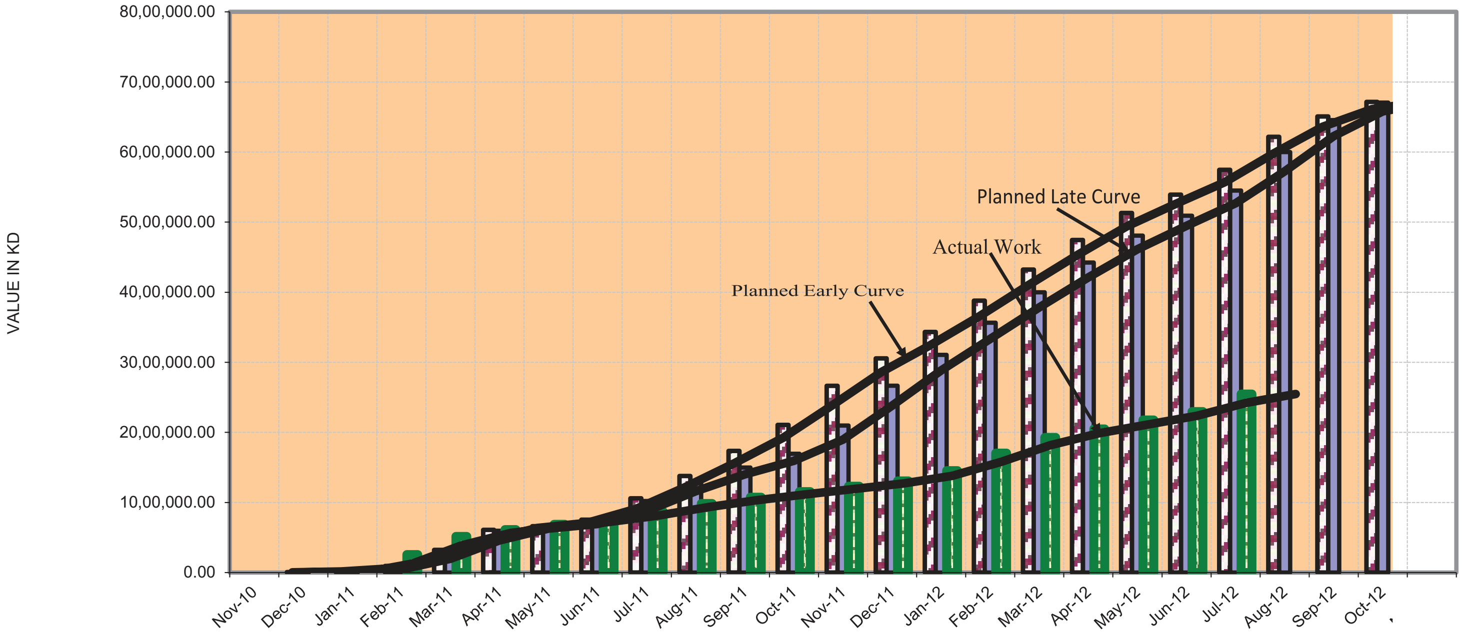
1. Daily Report
2. Weekly Report
3. Monthly Report

Contractor's daily progress is monitored through a daily progress report submitted by the contractor on the morning of the work day following the day to which the report relates. It gives the status of all the resources available at site for that particular day. It shows the details of contractor's staff and manpower, contractor's plant and equipment, and material received at site. Details of the subcontractor's work and resources are also included in the report. Figure 2.55 illustrates the daily progress report of a building construction project.

Along with the daily report, the contractor submits a work-in-progress report. Figure 2.56 illustrates the same.

Figure 2.57 illustrates the checklist status report that is also to be submitted along with the daily report. This will help contractors as well as supervision consultants to monitor the quality of work on a daily basis by knowing how many checklists are approved and how much of the work is not conforming to the specified requirements.

The monthly report giving details of all the site activities, along with the photographs is submitted by the contractor to the consultant/owner for their information to know the progress of work during the month. Table 2.43 illustrates the contents of contractor's monthly progress report and Table 2.44 illustrates contents of consultant's monthly progress report.



	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11
Early Cumm	0	6392	26731	93560	323104	609009	661356	753920	105906	137761	173574	210663
Late Cumm	0	6392	18596	70897	321942	596242	655611	732216	102140	130356	149699	169552
Actual Cumm		0.00	0.00	256317	515390	613064	688080	751868	872868	985358	107497	115468

	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-1	
Early Cumm	266429	305602	343299	387972	432310	474545	513094	539219	574679	621758	650838	67159	
Late Cumm	209816	266429	310499	356581	400046	442309	480724	509199	544928	600066	645599	67071	
Actual Cumm	123186	130772	145423	170423	192823	204923	217723	229723	254723				

FIGURE 2.54 Planned versus actual S-Curve.

Project Name

Consultant Name

CONTRACTOR'S DAILY PROGRESS REPORT

Contract No.:- **Contract Day No.**

Contractor :- **Date**

SAMPLE FORM

This daily report to be completed on both sides and submitted to the Resident Engineer following the report date.

Contractor's Staff and Manpower Required			Contractor's Staff and Manpower Additional		
Job Description	No.	Actual	Job Description	Skilled	Un-skilled
Contractor's Representative	1		Secretary		
Project Manager	1		Store keeper		
Deputy Project Manager	1		Carpenter		
Planning Manager	1		Steel Bender		
Deputy Planning Manager	1		Concrete workers		
Quality Control Manager	1		Mason		
Quality Control Engineer	1		Plasterer		
Quantity Surveyor	1		Tiler		
Assistant Quantity Surveyor	1		Marble		
Site Engineer (Architect)	2		Ceramic		
Site Civil Engineer	2		Stone		
Site Engr. (Water & Sewerage)	2		Precast		
HVAC Engineer	2		Safety officer		
Mechanical/Fire Fighting Engr.	1		Painter		
Electrical Engineer	2		Plumber		
Communications Engineer	1		HVAC		
Site Engineer (Marine)	1		Fire system		
Site Engr. (Roads & Services)	1		Seaman (Diver)		
Material Engineer	1		Mechanical supervisor		
Assistant Material Engineer	1		Driver		
Landscape Gardner	1		Operator		
Safety Engineer	1		Welder		
Co-ordinator	1		Electrician		
Surveying Engineer	1		Mech. & Elec. Workshop labour		
Surveyor	1		Labour		
Supervisor	4		Others		
Computer Programmer	1				
Computer Draftsman	2				
Draftsman	1				
Laboratory Engineer	1				
Laboratory Technician	1				
	40				

Distribution

Original : Resident Engineer Contractor…………………………………….

CC : Owner

FIGURE 2.55 Daily progress report.

2.7.13.2.3.2 Safety Report

The contractor submits a safety report every month listing important activities with photographs.

2.7.13.2.3.3 Risk Report

Identify occurrence of new risks and report the same if this will have any effect on project progress and performance.

Project Name
Consultant Name

WORK IN PROGRESS REPORT

Contract No.: **Contract Day No. :**
Contractor: **Date :**

On Site Activities									
During the Day					Expected Next Day				
No.	Description	Area	Unit	Qty.	No.	Description	Area	Unit	Qty.
Reasons for Delay, if any.									

Off Site Work/Activities							
During the Day				Expected Next Day			
No.	Subcontractor Name	Work Description	Qty.	No.	Subcontractor Name	Work Description	Qty.
Reasons for Delay,if any.							

FIGURE 2.56 Work in progress.

2.7.13.2.3.4 Meetings

Progress Meetings

Progress meetings are conducted at an agreed-upon interval to review the progress of work and discuss the problems, if any, for smooth progress of construction activities. The contractor submits pre-meeting submittal to project manager/consultant, normally two days in advance of the scheduled meeting date. The submittal consists of:

1. List of completed activities.
2. List of current activities.
3. Two weeks lookahead.
4. Critical activities.
5. Materials submittal log.
6. Shop drawings submittal log.
7. Procurement log.

Project Name
Consultant Name

DAILY CHECKLIST STATUS

Contract No.: **Contract Day No. :**
Contractor: **Date :**

Sr.No.	Checklist No.	Description	Activity	Area/Location	Action	Remedial Action*	Remark

SAMPLE FORM

* For Not Approved Checklist

FIGURE 2.57 Checklist status.

Apart from the issues related to the progress of work and programs, site safety and quality-related matters are also discussed in these meetings. These meetings are normally attended by the owner's representative, designer/consultant staff, contractor's representative, and subcontractor's responsible personnel.

Coordination Meetings

Coordination meetings are held from time to time to resolve coordination matters among various trades.

Quality Meetings

Quality meetings are conducted to discuss quality issues at site and how to improve the construction process to avoid/reduce rejection and rework.

Safety Meetings

Safety meetings are also held to discuss related health, site safety, and environmental matters.

The frequency of conducting meetings is agreed upon between all the parties at the beginning of construction phase. Normally the construction manager/resident engineer prepares the agenda for the meeting and circulates it to all the participants. The contractor informs resident engineer in advance about the points the contractor would like to discuss, which are included in the agenda. The minutes of meetings are recorded and circulated among all the attendees and others per the approved responsibility/site communication matrix.

TABLE 2.43
Monthly Progress Report—Contractor

EXAMPLE CONTENTS

Contents of Monthly Report

Serial Number	Contents		Description
1	**Executive Summary—Tabular**		
	1.1	Summary Status Report	Brief description of the project status up-to-date such as manpower, cash, activities.
	1.2	NOC's Report	No objection certificate report.
	1.3	Project Manager Narratives	Narrative description of project status up-to-date.
2	**Progress Layouts**		
	2.1	Updated Milestone Table	Comparison of planned versus actual for contractual milestones per construction unit\design, track delays for major trades through the color theme.
	2.2	Updated Major of Events Table	Comparison of planned versus actual for major trades per construction unit\design, track delays for major trades through the color theme.
	2.3	Updated Layouts	Same as (2.1) but presentation per milestone phase (drawing).
3	**Updated Execution Program**		
	3.1	Updated Milestone Schedule—Roll Up "Update versus Latest Target"	To indicate the status of the control and key milestones comparing the current status with the baseline.
	3.2	Updated Detailed Schedule	All activities in detail.
	3.3	One Month Lookahead Program	Same as (3.2) but includes only the detailed activities for the coming month BUT IN EXCEL FORMAT.
4	**Submittal Status Report (E1 Log)**		Updated status of submittals.
	4.1	Submittal Status Report	Briefly describe the project submittal status up-to-date.
	4.2	Detailed E1 Log	Detailed description of the project submittal status up-to-date.
5	**Procurement Status Report (E2 Log)**		Updated procurement status.
6	**Status of Information Requested**		
	6.1	RFI Status report	Request for Information (RFI)
	6.2	NCR Report	Non-Conformance Request (NCR)
	6.3	PCO and NOV Log	Potential change order and notice of variation summary.

(*Continued*)

TABLE 2.43 Continued
Monthly Progress Report—Contractor

Contents of Monthly Report

Serial Number	Contents		Description
7	**Updated Cost Loaded Program**		
	7.1	T-7 Updated Status Report	Money progress = physical * budgeted cost for each running or completed activity.
	7.2	Updated Cost Loaded Schedule	Same like T-7 but money values not percentages.
	7.3	Updated Work in Place (%) Report	Histogram and cumulative curve.
	7.4	Updated Cash Flow Report	Histogram and cumulative curve.
8	**Updated Manpower Histogram**		Histogram and cumulative curve.
9	**Updated Schedule of Construction Equipment and Vehicles**		Tabular report.
10	**Updated Critical Indicators**		
	10.1	Shop Drawings Status Report	Histogram and cumulative curve.
	10.2	Material Status Report	Histogram and cumulative curve.
	10.3	Construction/Leading Indicators	Each trade alone.
	10.4	Line of Balance Diagram	It indicates all progress of the major trades as line cumulative chart.
11	**Updated Progress Photographs**		-
12	**Updated Safety Inspection Checklist**		Tabular report.
13	**Contractor Information**		Organization chart, tabular report.

TABLE 2.44
Monthly Progress Report—Consultant

1.0	**Contract Particulars**	
	1.1	Project Description
	1.2	Project Data
2.0	**Construction Schedule**	
3.0	**Progress of Works**	
	3.1	Temporary Facilities and Mobilization
	3.2	Summary of Construction Progress

(*Continued*)

TABLE 2.44 Continued
Monthly Progress Report—Consultant

		3.2.1	Status
		3.2.2	On-Shore Progress
		3.2.3	Off-Shore Progress
4.0	**Time Control**		
	4.1	CPM Schedule—Level One (Target vs. Current) Summary by Building/Marine	
	4.2	CPM Schedule—Level Two (Target vs. Current)—Summary by Building/Division	
	4.3	30 days Lookahead Schedule	
	4.4	Time Control Conclusion	
5.0	**Cost Control**		
	5.1	Financial Progress	
	5.2	Cash Flow Curve and Histogram	
	5.3	Work in Place S-Curve and Histogram	
	5.4	Cost Control Conclusion	
6.0	**Status of Contractor's Submittals**		
	6.1	Material Status	
	6.2	Shop Drawing Status	
7.0	**Subcontractors**		
8.0	**Consultant's Staff**		
9.0	**Quality Control**		
10.0	**Meetings**		
11.0	**Site Work Instructions**		
12.0	**Variation Orders**		
13.0	**Construction Photographs**		
14.0	**Contractors Resources**		
15.0	**Others Matters**		
	15.1	Safety	
	15.2	Weather Conditions	
	15.3	Important Developments/Proposals/Submissions	

2.7.13.2.4 Digitized Monitoring of Work Progress

The work progress is normally monitored through daily and monthly progress reports. Monthly progress report consists of progress photographs to document physical progress of work. These photographs are used to compare compliance with the planned activities and actual performance. Figure 2.58 illustrates a traditional monitoring system.

With the advent of technology, it is possible to monitor and evaluate construction activities using cameras and related software technologies. In this process, digital images are captured through the use of cameras. These photographs are processed using photo modeler software and developing a 3-D model view of the digital picture captured from the site. The captured as-built data is compared to the planned activities by interfacing through the integrated information modeling system. The use of the system:

- Improve the accuracy of information.
- Avoid delays in getting the information.
- Improve communication among all parties.

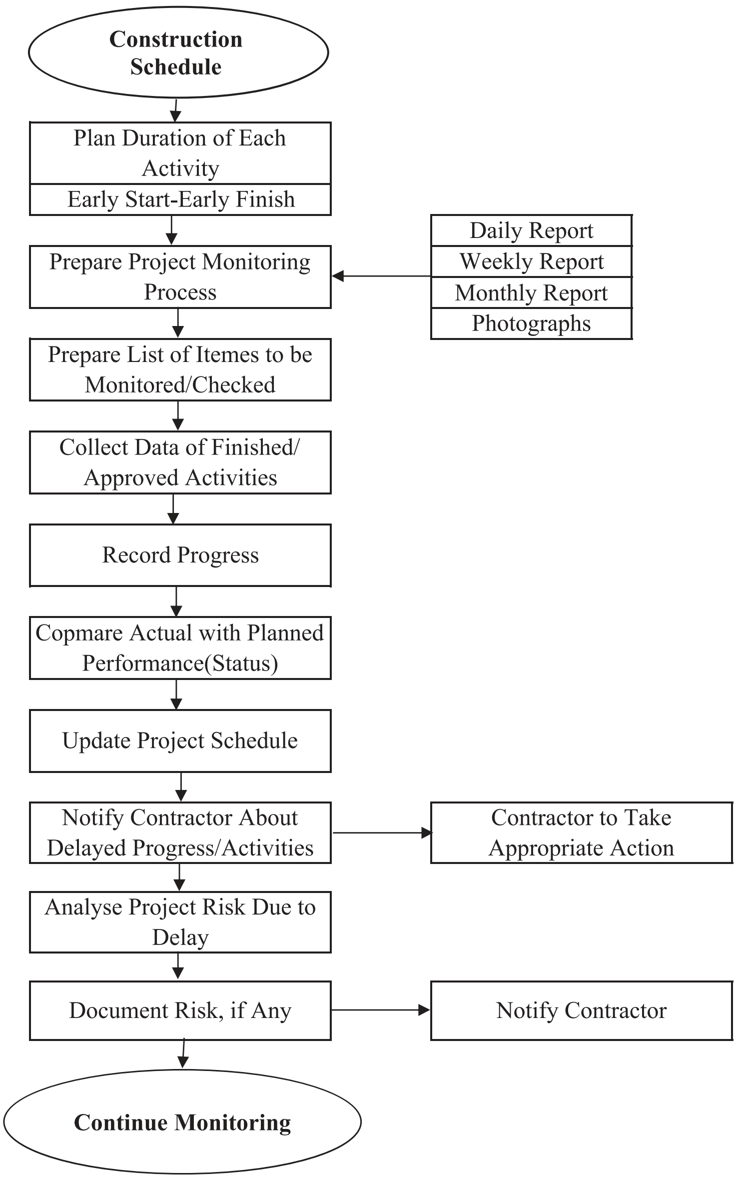


FIGURE 2.58 Traditional monitoring system.

- Improve effective control of the project.
- Improve document recording.
- Help reduce claims.

Figure 2.59 illustrates a schematic for a digitized monitoring system.

2.7.13.2.5 Monitoring of Submittals

It is required that the contractor's submittals are processed, and a response is sent within the specified period mentioned in the contract. The consultant is required to maintain the log for material submittals, shop drawing submittals and also all the correspondence between the contractor and client. Figure 2.60 illustrates an example log for monitoring material/shop drawing submittals.

2.7.13.3 Control Schedule

Completion of construction projects within a defined schedule is most important. Time control status is prepared in different formats to monitor the project completion time. Figure 2.61 illustrates project progress status of a building construction

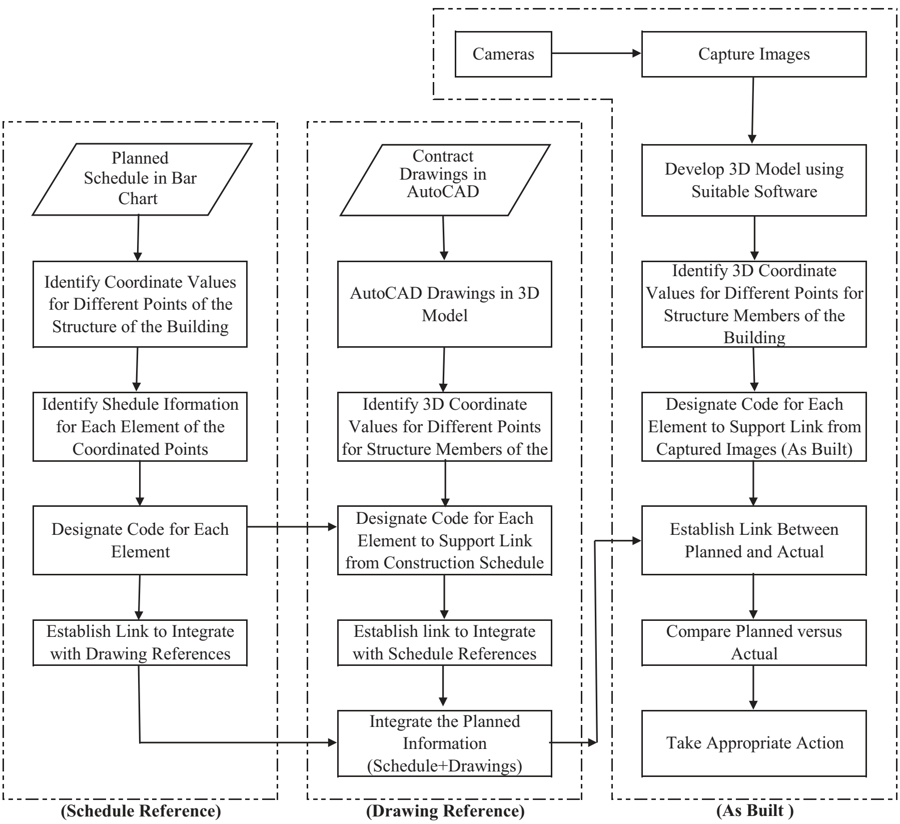


FIGURE 2.59 Digitized monitoring system.

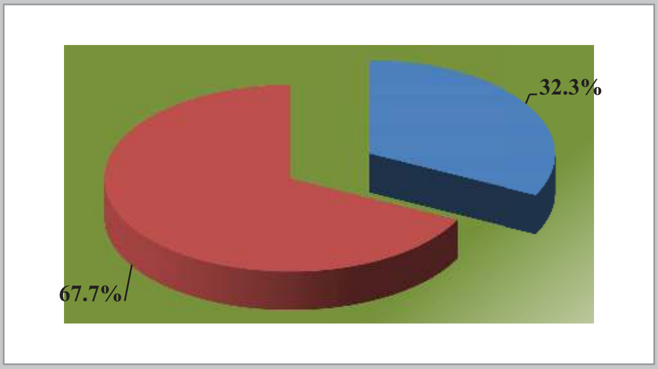
Project Name
Consultant Name

Contractor Name: Contract No.:
Week Start Date:

Transmittal No.	Rev. No.	Transmittal Date	Date Received	Description	Document Reference	Responsible Engineer	Action Code	Reply Date	Action Pending	Remark/ Reason for Pending

FIGURE 2.60 Submittal monitoring log.

Project Progress Status



Time Elapsed- Days	413	32.30%
Time Remaining-Days	867	67.70%

Current Project Status			
	June 15, 2015		
Completion Period (Days)	1280		
Duration Elapsed (Days)	413		
% Elapsed Duration	32.30%		
Remainin Duration (Days)	867		
% Remaining Duration	67.70%		
Total Contract Amount (KD)	14,20,61,073.44		
Earned Value in KD upto date	Early	Late	Actual
	3,14,94,939.98	2,56,13,611.54	1,94,22,904
Project Completion % till date	22.17%	18.03%	13.67%

FIGURE 2.61 Project progress status.

project. This chart presents an overall picture of the elapsed period of the project and remaining period of the scheduled project duration, and actual progress versus planned progress.

2.7.13.4 Control Cost

Monitoring and control of project payment is essential with the budgeted amount. This is done through monitoring cash flow with the help of S-Curves and progress curves which give exact status of payment and also identify if it is exceeding the budget. Uninterrupted cash flow is one of the most important elements in the overall success of the project. Figure 2.62 illustrates planned and actual cost s-curve.

2.7.13.4.1 Project Payment/Progress Curve (S-Curve)

Cash flow is a simple comparison of when revenue will be received and when the financial obligations must be paid. It is also an indication of the progress of work to be completed in a project. This is obtained by loading each activity into the approved schedule with the budgeted cost in the BOQ. The process of inputting a schedule of values is known as cost loading. The graphical representation is obtained as a curve and is known as the S-Curve.

2.7.13.4.2 Earned Value Management

Earned value management is a methodology used to measure and evaluate project performance against cost, schedule, and scope baseline. It compares the amount of planned work with what is actually accomplished to determine whether the project is progressing as planned. Earned Value Analysis is used to:

- Measure progress of the project budget, schedule, and scope to know how much percentage of:
  - Budget spent.
  - Time elapsed.
  - Work done.
- Forecast its completion date and cost.
- Provide budget and schedule variances.

The following are the basic terminologies used in earned value management:

1. BCWS → Budgeted Cost of Work Scheduled or Planned Value (PV)
   It is planned cost of total amount of work scheduled to be performed by the milestone date.
2. BCWP → Budgeted Cost of Work Performed or Earned Value (EV)
   It is the actual cost incurred to accomplish the work that has been done to date.
3. ACWP → Actual Cost of Work Performed or Actual Cost (AC)
   It is the planned cost to complete the work that has been done.

2.7.13.5 Control Quality

In order to achieve quality in construction projects, all of the work has to be executed as per approved shop drawings using approved materials and fully coordinating with different trades. Proper sequencing and method statement for installation of work must be followed by the contractor to avoid rejection/rework. Figure 2.63 illustrates the sequence of execution of work.

Following this sequence will help the contractor to avoid the rejection of work. Rejection of the checklist will result in rework that will need time to redo the work and cost implications to the contractor. Frequent rejection of work may delay the project ultimately affecting the overall completion schedule.

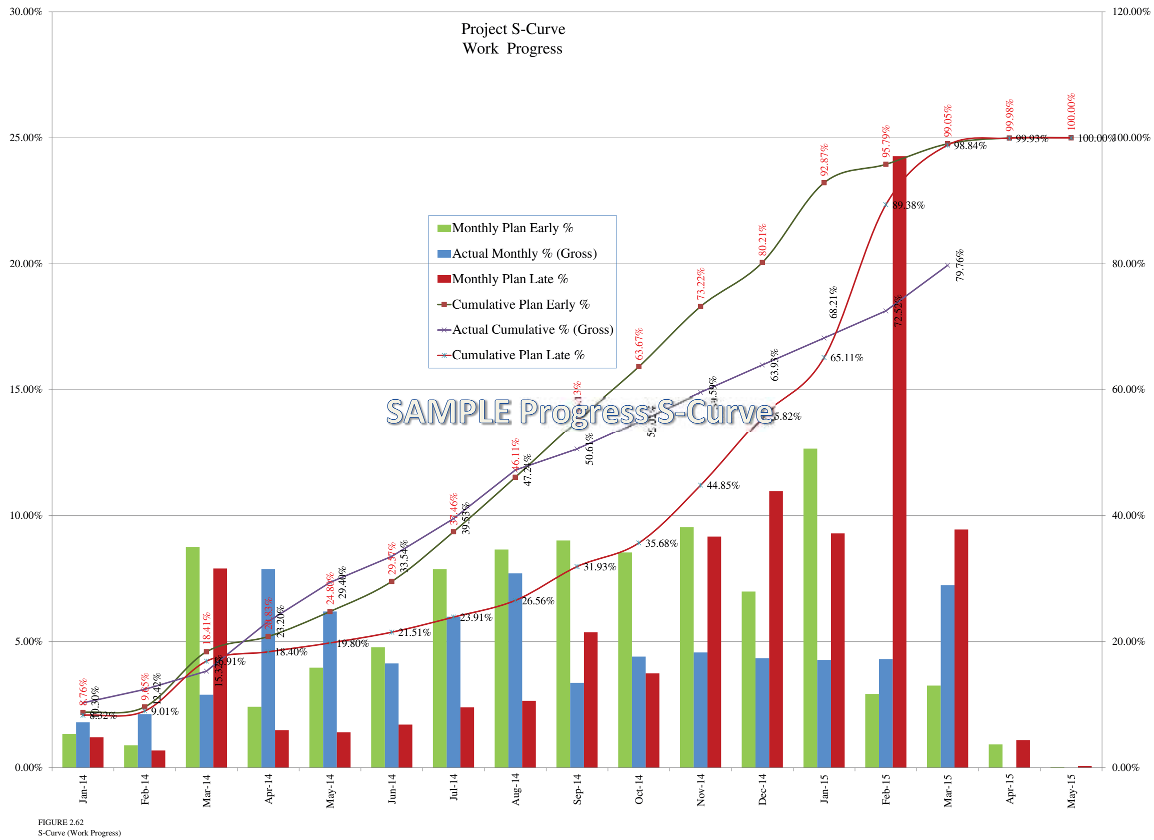


FIGURE 2.62 Planned versus actual cost S-Curve.

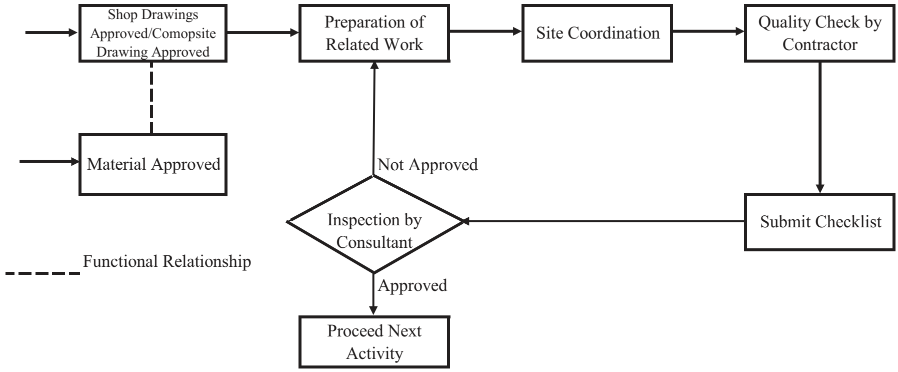


FIGURE 2.63 Sequence of execution of work.

2.7.13.5.1 Inspect Executed Works

The inspection of construction work is performed throughout the execution of the project. Inspection is an ongoing activity to physically check the installed works. Checklists are submitted by the contractor to the consultant, who inspects the executed works/installations. If the work is not carried out as specified, then it is rejected, and the contractor has to rework or rectify the same to ensure compliance with the specifications. During construction, all the physical and mechanical activities are accomplished on the site. The contractor carries out a final inspection of the work to ensure full compliance with the contract documents.

During the construction process the contractor has to submit the checklists to the consultant to inspect the works. Submission of a checklist or request for inspection is an ongoing activity during the construction process to ensure proper quality control of construction. Concrete work is one of the most important components of building construction. The concrete work has to be inspected and checked at all stages to avoid rejection or rework. Necessary care has to be taken right from the control of design mix of the concrete till the casting is complete and cured. The contractor has to submit a checklist at different stages of concrete work and has to make certain tests, specified in the contract, during casting of concrete. In order to ensure that structure concrete work is executed without any defects or rejection and achieves concrete strength as specified, proper sequencing of work is important. Figure 2.64 illustrates the flowchart for concrete casting and Figure 2.65 illustrates the process for structural concrete work.

The following are the checklists that the contractors submit at different stages of the concrete process.

Figure 2.66 illustrates a checklist for quality control of formwork.

Figure 2.67 illustrates notice for daily concrete casting.

Figure 2.68 illustrates a checklist for concrete casting.

Figure 2.69 illustrates checklist for quality control of concreting.

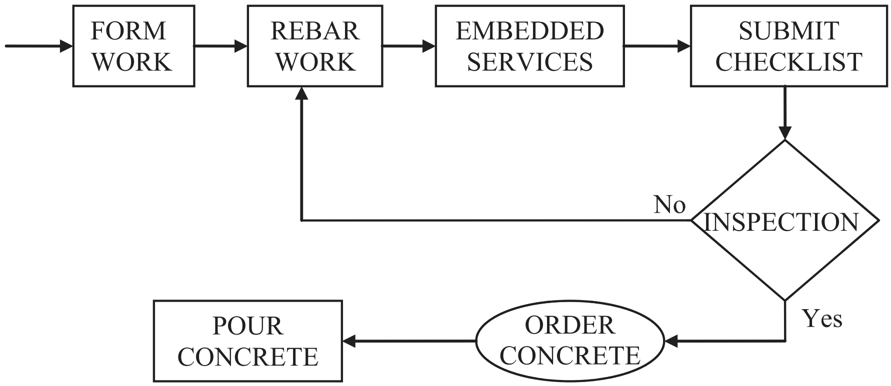


FIGURE 2.64 Flow chart for concrete casting.

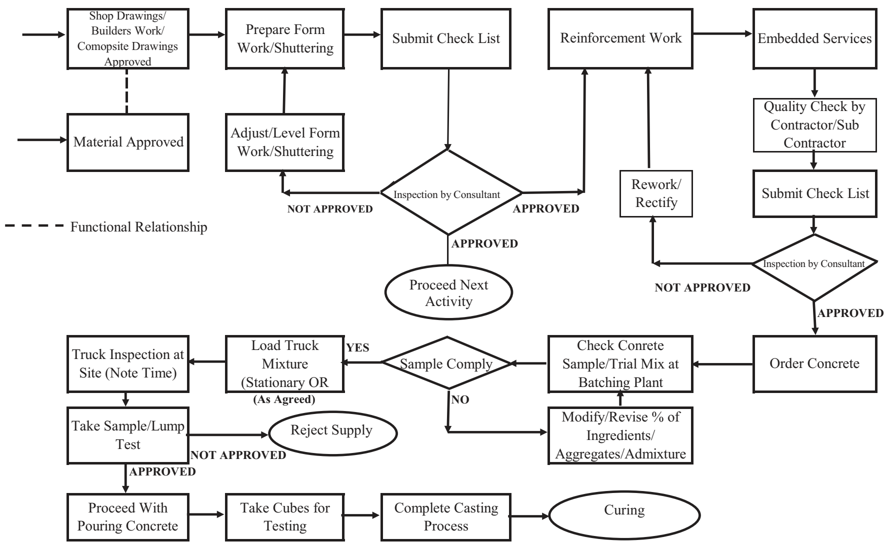


FIGURE 2.65 Process for structural concrete work.

Figure 2.70 illustrates a report on concrete casting.

Figure 2.71 illustrates a notice for testing at the lab.

Figure 2.72 illustrates concrete quality control form.

In certain projects, the owner asks the contractor to involve an independent testing agency for quality control of concrete. The agency is responsible for quality control of materials, performing tests, and submitting test reports to the owner.

Project Name

Consultant Name

QUALITY CONTROL OF FORMWORK / FALSEWORK / DIMENSIONS / LEVELS

CONTRACTOR: **DATE :** __/__/__

CONTRACT NO:

Site Engineer : ______________________

Inspected Element : ______________________

(N.B.: This form is to be prepared by the Site Engineer and submitted to the R.E.)

(A=Acceptable, N=Needs Adjustment, U=Unsatisfactory)

1) Form Dimensions & Levels :

		A	N	U
1.1	Setting Out			
1.2	Top of Concrete Level Ready for Casting			
1.3	Dimensions			
1.4	Heights & Levels			
1.5	Chamfers			

SAMPLE FORM

2) Falsework :

		A	N	U
2.1	Supports			
2.2	Rigidity			
2.3	Bracing			
2.4	Screw Jacks			
2.5	Timber Straightness			
2.6	Splices of Vertical Members			

3) Formwork :

		A	N	U
3.1	Rigidity			
3.2	Water Tightness			
3.3	Steel Bolts / Rods / Ties			
3.4	Openings & Inserts			
3.5	Cleanliness			
3.6	Oiling			
3.7	Working Platforms and Walkways			

R.E's Comments :

____

____

____

____

Signature of Resident Engineer ______________________ **Date :** ______________

FIGURE 2.66 Checklist for quality control of formwork.

Project Name
Consultant Name

NOTICE OF DAILY CONCRETE CASTING

CONTRACTOR: **DATE :**
CONTRACT NO:

The following is the tentative schedule of our concrete casting for elements already inspected and accepted for casting this day :

NO.	LOCATION	ELEMENT	GRADE Mpa	QTY m^3	TENTATIVE CASTING TIME	
					START	FINISH
TOTAL						

SAMPLE FORM

Your action for supervision of the above would be very much appreciated.

SITE ENGINEER	CONTRACTOR MANAGER
______________________	______________________

CONSULTANT RECEIVED: ______________________ Date: TIME: ____

R. E's COMMENTS:-

Resident Engineer Date

FIGURE 2.67 Notice for daily concrete casting.

Figure 2.73 illustrates a cause-and-effect diagram to analyze causes for rejection of concrete work not meeting the specified requirements.

In order to get approval of executed/installed work/system, the contractor has to submit checklists for all the installations and work executed as per the contract documents and as per the approved shop drawings and materials. Figure 2.74 illustrates a checklist for general work to be inspected by the consultant.

Project Name
Consultant Name

CHECKLIST FOR CONCRETE CASTING

CONTRACTOR: ____________________

CONTRACT NO: ____________________ **Date :** / /

Building / Structure : ____________________
Element : ____________________

No.	Description	Status	
		Availability	Detail
	PLANT & TOOLS		
1	Concrete Pumps		
2	Standby Concrete Pumps		
3	Cranes		
4	Truck Mixers		
5	Vibrators		
6	Trowlers		
7	Lighting		
8	Access Means		
9	Communications		
	QUALITY CONTROL		
1	Cubes		
2	Slump Apparatus		
3	Thermometer		
	STAFF & LABOUR		
1	Engineer		
2	Foreman		
3	Carpenter		
4	Steel Fixer		
5	Electrician		
6	Mechanic		
7	Vibrating Labour		
8	Trowling Labour		
9	Ordinary Labour		

SAMPLE FORM

SITE ENGINEER **CONTRACTOR MANAGER**

CONSULTANT RECEIVED: ____________________ DATE: / / TIME: ________

COMMENTS:

Signature of Resident Engineer: ____________________ **Date:** ____________

FIGURE 2.68 Checklist for concrete casting.

Project Name

Consultant Name

QUALITY CONTROL OF CONCRETING

CONTRACTOR: DATE : / /

CONTRACT NO:

Site Engineer : ______________________

Inspected Element : ______________________

(N.B.: This form is to be prepared by the Site Engineer and submitted to the Consultant)

Starting Time

Maximum Recorded Temperature

Finishing Time

Total Concrete Quantity

Average Slump

Cubes ID's

Number of Vibrators Available through S U

Process Compaction (S=Satisfactory, U=Unsatisfactory)

Preparation of Previous Construction Joints Yes No

Stopped at Preplanned Locations Yes No

Preparation of New Construction Joints Yes No

Curing Starting Time

Measurements of Falsework / Formwork Deformation S U

After Casting (S=Satisfactory, U=Unsatisfactory).

R.E's Comments :

Resident Engineer : ______________________ Date : ______________

FIGURE 2.69 Quality control of concreting.

Owner Name

Consultant Name

REPORT ON CONCRETE CASTING AT SITE (CC)

CONTRACTOR: CC No.:____________

CONTRACT NO: Date:______________

Time:______________

Location:	Zone:	Approved Check List Ref:	
		No.	Date :
Type of Concrete	(Required Strength)		
Starting Time			
Finishing Time			
Approximate Quantity	m3	No. of Trucks	
Test Cubes / Cylinders	Total No.	Sr. Nos.	
	Cylinder Nos.	Slump	Average
SLUMP IN CENTIMETERS			
Engineer on Duty	Name :		Time:

Resident Engineer's Remarks :

Machinery: ____________________

Manpower: ____________________

Workmanship: ____________________

Rate of Casting: ____________________

Others:

Distribution: Engineer Resident Engineer Contractor

FIGURE 2.70 Report on concrete casting.

Project Name

Consultant Name

NOTICE FOR TESTING AT SITE LAB.

CONTRACTOR: **Date :** / /

CONTRACT NO:

The following is the tentative schedule for testing activities in the Site Laboratory.

I. SOIL TESTING

NO.	LOCATION	SAMPLE	TYPE OF TESTING

II. CONCRETE CUBES TESTING

NO.	LOCATION	AGE OF CONCRETE	NO. OF CUBES

SAMPLE FORM

We request your to witness the testing at……….A.M./P.M.

SITE ENGINEER	CONTRACTOR MANAGER
____________________	____________________

CONSULTANT RECEIVED: ______________________ Date: / / Time:____

R.E's Comments :
Signature of Resident Engineer Date:

FIGURE 2.71 Notice for testing at lab.

Project Name

Consultant Name

CONCRETE QUALITY CONTROL FORM

CONTRACTOR: Serial No.: _______________

CONTRACT NO:

Building ________________	Drawing Refer. ________________	Concrete Temp. ___________
Particular Area ________________	Type of Concrete ___________	Slump (mm) _____________
Date of Cube ________________	Special Material ___________	Drawing Refer. ___________
Conc. Supplier ________________	Truck # ________________	

Date of Test ____/____/_________ Age of Cubes ___________ Days

Cube No.	Width cm	Length cm	Height cm	Area cm2	Weight gram	Volume cm3	Density g/cm3	Failing Load kN	Compressive Strength N/mm2	Type of Failure
1										
2										
3										

SAMPLE FORM

Required 7 Day Strength _______________ Average Comp. Strength _______________

Laboratory Technician Consultant Contractor

Date of Test __________________ Age of Cubes ___________ Days

Cube No.	Width cm	Length cm	Height cm	Area cm2	Weight gram	Volume cm3	Density g/cm3	Failing Load kN	Compressive Strength N/mm2	Type of Failure
1										
2										

Required 14 Day Strength _______________ Average Comp. Strength _______________

Laboratory Technician Consultant Contractor

Date of Test __________________ Age of Cubes __________________

Cube No.	Width cm	Length cm	Height cm	Area cm2	Weight gram	Volume cm3	Density g/cm3	Failing Load kN	Compressive Strength N/mm2	Type of Failure
1										
2										

Required 28 Day Strength _______________ Average Comp. Strength _______________

Laboratory Technician Consultant Contractor

Distribution: ☐ Owner ☐ A/E ☐ Contractor

FIGURE 2.72 Concrete quality control form.

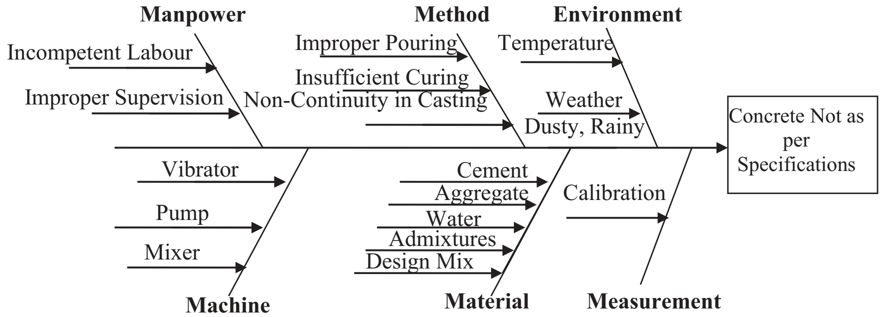


FIGURE 2.73 Cause and effect diagram to analyze concrete.

If the consultant finds that an item has been executed at site not as per contract documents, specifications, or general code of practice, then a remedial note is issued by the consultant. Figure 2.75 illustrates a remedial note.

The contractor is required to reply on the same form after taking necessary action. Upon finalization of the issue the withdrawal notice is issued by the consultant/supervision staff.

Consultant's supervision staff always makes a routine inspection during the construction process. A non-conformance report is prepared and sent to the contractor to make corrective/preventive action toward this activity. Figure 2.76 illustrates a non-conformance report used for a building construction project.

2.7.13.6 Control Risk

The contractor has to prepare risk plan and the response to control, mitigate the risk. Table 2.45 illustrates risk plan for material handling at site, and Table 2.46 illustrates risk plan for material delivery using a mobile crane.

Table 2.36, discussed earlier, has listed probable risks during construction phase. Table 2.39, discussed earlier, illustrates risk affecting scope, schedule, and cost, and its effect and mitigation plan.

2.7.14 Validate Executed Work

The inspection of construction work is performed throughout the execution of project. Inspection is an ongoing activity to physically check the installed works. Checklists are submitted by the contractor to the consultant to inspect the executed works/installations.

Table 2.47 lists the items to be checked by the consultant and probable reasons for rejection of executed works.

If the work is not carried out as specified, then it is rejected, and the contractor has to rework or rectify the same to ensure compliance with the specifications.

Project Name

Project Name

CHECKLIST

CONTRACTOR : ____________ CHECK LIST No. : [ ]

CONTRACT No. : ____________ PREVIOUS C.L. No. : [ ]

TO : **Resident Engineer**

CCS ACTIVITY NO : ________ SPECIFICATION DIVISION : ________ SECTION : ________

AREA : [ ] Building Works [ ] Electrical Works [ ] Mechanical Works

[ ] HVAC Works [ ] Finishes Works [ ]

Please inspect the following :-

Location :

Work :

SAMPLE FORM

Sketch(es) attached { } No.

The work to be inspected has been coordinated with all related subcontractors.

Estimated Quantity of Work : ________ Date & Time Inspection Required : ________

Contractor Signature : ________ Date & Time ________

Received By : ________ Date & Time ________

C.C.: Owner Rep: ________ Date & Time ________

(All request must be submitted at least 24 hours prior to the required inspection)

Reply: The above is Approved/Not approved for the following :-

Inspected by ________ Date & Time ________ Resident Engineer ________ Date & Time ________

Received by Contractor ________ Date & Time ________

C.C.: Owner Rep: ________ Date & Time ________

FIGURE 2.74 Checklist for general work.

Project Name
Consultant Name

REMEDIAL NOTE (RN)

Contractor: ____________________________ R.N. No.: __________

Contract No.: ____________________________ DATE: ____________

Your attention is drawn to the following works which have not been carried out in accordance with the Contract and are therefore not acceptable. Failure to carry out remedial works within a reasonable period of time may result either in additional work at your expense, or the Employer may elect to invoke Clause ---of the General Conditions of Contract.

LOCATION:

DEFECTS:

SAMPLE FORM

Signed: ________________ Resident Engineer   Received by: ________________ Contractor/Date

Distribution: ☐ Owner ☐ A/E ☐ Contractor ☐

FIGURE 2.75 Remedial note.

During construction, all the physical and mechanical activities are accomplished on the site. The contractor carries out a final inspection of the work to ensure full compliance with the contract documents.

2.8 TESTING, COMMISSIONING, AND HANDOVER PHASE

Testing, commissioning, and handover are the last phase of the construction project life cycle. This phase involves testing of electromechanical systems, commissioning of the project, obtaining authorities' approval, training of user's personnel, handing over of technical manuals, documents, and as-built drawings to the owner/owner's

Project Name
Consultant Name

NON-CONFORMANCE REPORT
NO. [ ]

CONTRACTOR: **DATE :** / /

CONTRACT NO:

Location of Non-Conformance :

Drawing / Specification :

SAMPLE FORM

Description of Non-Conformance :

Resident Engineer : ____________________

Corrective / Preventive Action : (Proposed by Contractor)

Quality Control Engineer : ________________

Contractor Manager: ____________________ **Date:** ____________________

Comments:

Resident Engineer: ____________________ **Date:** ____________

FIGURE 2.76 Non-Conformance report.

TABLE 2.45
Risk Plan for Material Handling

RISK ASSESSMENT										
OWNER NAME										
PROJECT NAME										
ACTIVITY = MATERIAL HANDLING										
SL. NO.	**Hazard**	**Potential Accident or Identified Risk**	**Initial Risk Rating**		**Risk Factor**	**CONTROL MEASURES IN PLACE/ MITIGATION ACTIONS**	**FINAL RISK RATING**		**Residual Risk Factor**	**Risk Acceptable**
			Probability x Severity				**Probability x Severity**			
1	Fall of Materials	Serious Injury or Permanent Disability	3	3	9	a. Secure materials stored in tiers by stacking, racking, blocking, or interlocking to prevent them from falling. b. Stack the materials properly in marked location. c. When lifting objects, lift with your legs, keep your back straight, do not twist, and use handling aids. d. Loads with sharp or rough edges, wear gloves or other hand and forearm protection. e. Dock boards must have handholds, or other effective means for safe handling.	2	1	2	**Low**
2	Fall of Personnel	Injury to Personnel	3	3	9	a. Store materials safely to avoid struck by/crushed by hazards. b. Do not stand in corners where emergency movement is restricted. c. When lifting objects, lift with your legs, keep your back straight, do not twist, and use handling aids. d. Wear PPE. e. Use taglines to control the load movement. f. Avoid lifting above the shoulder level.	3	1	3	**Low**

Source:

RPN-Risk Priority Number	
8–16	**High Risk**
4–6	**Medium Risk**
1–3	**Low Risk**

TABLE 2.46
Risk Plan for Material Delivery Using Mobile Crane

RISK ASSESSMENT										
OWNER NAME										
PROJECT NAME										
ACTIVITY = MATERIAL DELIVERY USING MOBILE CRANE										
SL. NO.	**Hazard**	**Potential Accident or Identified Risk**	**Initial Risk Rating**		**Risk Factor**	**CONTROL MEASURES IN PLACE/MITIGATION ACTIONS**	**FINAL RISK RATING**		**Residual Risk Factor**	**Risk Acceptable**
			Probability	**x Severity**			**Probability**	**x Severity**		
1	a. Fall of object from the height during lifting. b. Failure of slings or lifting gears.	May cause permanent disability or death to the person. Damage to the property.	4	4	16	a. Plan the load and lift accordingly. b. Check all the lifting equipment and materials before commencing the work. c. Adopt proper signaling method and ensure proper communication and coordination. d. Ensure proper guiding of the load to avoid jerks and swaying of the load. e. Ensure that the crane, lifting gears, etc. have been tested and examined by the approved third-party agencies. f. Ensure that the rigger or signal man are certified competent enough for lifting operations. g. Wear appropriate PPE. h. No one should stand under the suspended load. i. Area to be cordoned off by tiger or warning tape. j. Alert the other employees by displaying the warning signs/posters during hoisting the truss. k. Ensure that the SWL is not exceeded. l. Never leave the load suspended without an operator at the controls. m. Ensure the slings used are suitable for the purpose intended. n. Ensure that the movement of the load is clear of all obstructions and overhead hazards.	2	1	2	**Low**

RPN-Risk Priority Number	
8–16	**High Risk**
4–6	**Medium Risk**
1–3	**Low Risk**

TABLE 2.47
Probable Reasons for Rejection of Work

Sr. No.	Description of Work	Probable Reasons for Rejection
Shoring		
1	Shoring	No adequate support for shoring. Vertical plumb level not proper. No proper bracing. Not enough depth. Anchor test not approved.
2	Dewatering	Water level not under control.
Earth Works		
1	Excavation	Not as per specified level. Surface is not even. Excavated material not removed from the site.
2	Backfilling	Compaction is not proper. Backfilling thickness is not as specified. Soil is rubbish and loose. Soil test (strength) failed.
Concrete Sub Structure		
1	Blinding Concrete	Thickness not as specified. Concrete strength not as specified.
2	Termite Control	Uneven spray.
3	Reinforcement of Steel	Reinforcement arrangement not as specified. Support not proper. Water stops are not provided. Construction joints are not provided.
4	Concrete Casting	Concrete strength not as specified.
5	Shuttering for Beams and Columns	Shuttering dimensions not as specified. Shuttering is not strong enough. Shutters are not vertical. Shuttering height not proper.
Concrete Super Structure		
1	Reinforcement of Steel for Beams and Columns	Reinforcement arrangement not as specified. Support not proper.
2	Shuttering for Columns and Beams	Shuttering dimensions not as specified. Shuttering is not strong enough. Shutters are not vertical. Shuttering height not proper.
3	Concrete Casting of Beams and Columns	Concrete strength not as specified.
4	Formwork for Slab	Props spacing not correct. Props are not sturdy. Formwork surface is not clean.
5	Reinforcement for Slab	Reinforcement arrangement not as specified. Reinforcement is not properly placed and secured. Spacers are not provided. Minimum concrete cover not provided. Construction joints not provided.
6	Concrete Casting of Slab	Concrete strength not as specified. Casting level in not proper.
7	Precast Panels	Panels are not fixed properly. Load test on panel not performed before erection.

(*Continued*)

TABLE 2.47 Continued
Probable Reasons for Rejection of Work

Sr. No.	Description of Work	Probable Reasons for Rejection
Masonry		
1	Block work	Block alignment is not proper. Joints are not aligned. Guidelines are missing. Anchor beads are not provided. Reinforcement mesh is not provided. Mortar is not as specified.
2	Concrete Unit Masonry	Block alignment is not proper. Joints are not aligned. Reinforcement mesh is not provided. Mortar is not as specified.
Partitioning		
1	Installation of Frames	Stud spacing not correct. Fixation method is not as specified. Insulation is not provided.
2	Installation of Panels	Alignment not proper. Joints are not proper. Panels are not painted.
Metal Work		
1	Structural Steel Work	Anchorage and fixing not proper. Method of erection not as specified. Fire protection is not applied. Finishing is different than specified.
2	Installation of Cat Ladders	Fixation is not proper. Alignment is not done. Finishing is not as specified.
3	Installation of Balustrade	Fixation is not proper. Alignment is not done. Finishing is not as specified.
4	Installation of Space Frame	Fixation is not proper. Alignment is not done. Finishing is not as specified.
5	Installation of Handrails and Railings	Fixation is not proper. Alignment is not done. Finishing is not as specified.
Thermal and Moisture Protection		
1	Applying Waterproofing Membrane	Number of layers not as specified. There is no overlap between the rolls. Application not done properly. Number of coats as per specs not applied. There is no skirting. Leakage test failed.
2	Installation of Insulation	Fixation is not properly. Insulation thickness is not as specified.
Doors and Windows		
1	Aluminum Windows and Doors	Dimensions are not as specified. Accessories and hardware are different than specified. Windows are not air/water tight and not sealed properly. Doors are not opening properly.
2	Glazing	Color and type are different than specified. Fixing method is not proper. Cracks are observed in some of the units.
3	Steel Doors and Windows	Alignment not proper. Hardware and accessories not as specified. Finishing is not proper.
4	Wooden Frames	Dimensions are different. Finishing is not as specified.
5	Wooden Doors	Alignment not proper. Finishing is not as specified. Fixation hardware is not as specified.

(*Continued*)

TABLE 2.47 Continued
Probable Reasons for Rejection of Work

Sr. No.	Description of Work	Probable Reasons for Rejection
6	Curtain Wall	Pattern is not as specified. Glazing is different than specified. Drainage system is not provided. Expansion joints not provided. Wind pressure and water test failed.
7	Hatch Doors	Door is not aligned. Finishing is not matching as per architectural requirements. Fixing is not proper.
8	Louvers	Alignment and levels not proper. Accessories not as specified.
Internal Finishes		
1	Plastering	Cracks in the plaster. Voids are observed. Specified accessories not used. Hollow sound observed. Curing is not enough.
2	Painting	Number of layers not as specified. Color and texture is not proper.
3	Cladding–Ceramic	Alignment, angles, and joints are not proper. Grouting is not done properly. Color and texture pattern is not matching
4	Cladding—Marble	Fixation is not proper. Alignment, angles, and joints are not proper. Lines are not matching.
5	Ceramic Tiling	Alignment, angles, and joints are not proper. Grouting is not done properly. Color and texture pattern is not matching
6	Stone Flooring	Fixation is not proper. Alignment, angles and joints are not proper.
7	Acoustic Ceiling	Suspension system is not as specified. Alignment, levels, and joints are not proper. Services openings are not provided. Ceiling height not matching with approved level.
8	Demountable Partitions	Fixation is not proper. Alignment is not done properly.
Furnishing		
1	Carpeting	Joints are not smooth. Carpet fixed without adhesive. Edges are not trim properly. Color and texture not matching.
2	Blinds	Stacking/rolling not proper. Fixing is not secured.
3	Furniture	Location is not as per approved layout. Dimensions are not correct. Finishing is nor proper. Fixation is not secured properly. Accessories are not matching with the furniture.
External Finishes		
1	Painting	Number of layers not as specified. Color and texture is not proper.
2	Brickwork	Brick alignment is not proper. Joints are not aligned. Grouting is not proper.
3	Stone	Fixation is not proper. Alignment, angles, and joints are not proper. Color and texture not matching.
4	Cladding—Aluminum	Alignment is not proper. Cladding is not leveled and aligned. Fixation is not secured. Joints are without sealant.
5	Cladding—Granite	Fixation is not proper. Alignment, angles, and joints are not proper. Color and texture not matching.

(*Continued*)

TABLE 2.47 Continued
Probable Reasons for Rejection of Work

Sr. No.	Description of Work	Probable Reasons for Rejection
6	Curtain Wall	Accessories are not properly fixed. Leveling and alignment not done. Drainage system is not provided. Wind pressure and water tests failed.
7	Glazing	Glass type is different than specified and approved. Fixation is not secured. Leveling and alignment not done properly. Joints have gap. Frame finishing is not as per approved sample.
Equipment		
1	Installation of Maintenance Equipment	Brackets are not fixed at specified location.
2	Installation of Kitchen Equipment	Equipment is not fixed as per approved layout.
3	Installation of Parking Control	Barrier is not fixed at specified location. Control panel is not terminated.
Roof		
1	Parapet Wall	Parapet level is not correct. Finishing is not as specified.
2	Thermal Insulation	Type of insulation and thickness is different than specified.
3	Waterproofing	Number of layers are less than specified. Application is not smooth. There is no overlap between the sheets. Skirting is not provided. Water test failed.
4	Roof Tiles	Thickness of tiles is less than specified. Tiles are not aligned and leveled. Joints are not proper.
5	Installation of Drains	Drains are not located as per approved shop drawings. Fixation is not proper.
6	Installation of Gutters	Type of gutters is different than specified. Gutters are not aligned and leveled.
Elevator System		
1	Installation of Rails	Fixation is not proper.
2	Installation of Door Frames	Frame is not aligned properly.
3	Installation of Cabin	Cabin is not leveled.
4	Cabin Finishes	Cabin finishes are incomplete.
5	Installation of Wire Rope	Rope joints are weak.
6	Installation of Drive Machine	Drive is leveled properly. Equipment earthing is not done.
7	Installation of Controller	Location of controller is not proper. Controller is not terminated. Equipment earthing is not provided. Identification label is not provided.

(*Continued*)

TABLE 2.47 Continued
Probable Reasons for Rejection of Work

Sr. No.	Description of Work	Probable Reasons for Rejection
Mechanical Work		
A. Fire Fighting System		
1	Installation of Piping System	Pipes are dirty need cleaning ang painting.
2	Installation of Sprinklers	Sprinkler spacing not as per authorities approved shop drawing.
3	Installation of Foam System	Foam agent concentration level not proper.
4	Installation of Pumps	Eccentric reducer needs to be fixed at the suction side of the pump. Pumps are not leveled. Cable termination not complete. Equipment earthing not done.
5	Installation of Hose Reels/ Cabinet	Cabinet door not closing properly. Color of cabinet to be as per authorities' requirement.
6	Installation of Fire Hydrant	Fire hydrant to be fixed properly at specified location.
7	External Fire Hose Cabinet	External fire hose cabinet need hose rack.
B. Water Supply		
1	Installing of Piping System	Pipe supports required to keep the pipe in straight position.
2	Installation of Pumps	Pumps are not leveled. Cable termination not complete. Equipment earthing not done.
3	Filter Units	Filter installed without bypass line and TAB point for pressure gauge.
4	Toilet Accessories	Towell rod not fixed.
5	Installation of Insulation	Insulation has cuts. Insulation is not covered with canvas.
6	Water Heaters	Water heater drain not installed.
7	Hand Dryers	Installation height is more than specified. Termination is not proper.
8	Water Tank	Float switch for pump not installed.
C. Drainage System		
1	Installation of Pipes Below-Grade	Drainage pipe to be tightened properly. Slope not proper.
2	Installation of Pipes Above-Grade	Slope not proper. More supports are required.
3	Installation of Manholes	Manhole level is not correct.
4	Installation of Clean Out, Floor Drains	Floor drains and clean out are not flush with the floor finish.

(*Continued*)

TABLE 2.47 Continued
Probable Reasons for Rejection of Work

Sr. No.	Description of Work	Probable Reasons for Rejection
5	Installation of Sump Pumps	Height of float switch need adjustment.
6	Installation of Gratings	Grating frame not flush with floor finish level.
D. Irrigation System		
1	Installation of Piping System	Pipe crossing under road need sleeves.
2	Installation of Pumps	Pumps installed without suction strainer.
3	Installation of Controls	Controllers are not weatherproof. Installation height is not proper. Fixing method is not proper.
HVAC Works		
1	Installation of Piping	Hanger supports are not properly fixed. Invert level is not correct. Piping is rusty, not clean, and not painted.
2	Installation of Ducting	Duct level not correct. Duct metal not clean. Suspension system not properly fixed. No proper sealant around duct joints.
3	Installation of Insulation	Insulation has cuts. Straps not fixed at specified interval.
4	Installation of Dampers, Grills, and Diffusers	Material is squeezed. Color is faded. Material not matching with architectural requirements.
5	Installation of Cladding	Cladding surface is not even. Cladding is not overlapped and sealed properly.
6	Installation of Fans	Fans fixing is not secured.
7	Installation of Fan Coil Units (FCU)	FCU level not correct. FCU fixed without spring isolators. No slope for drain pipe.
8	Installation of Air Handling Units (AHU)	No flexible connector between chilled water piping and AHU. AHU body is damaged. Body paint is peeled off.
9	Installation of Pumps	Pumps are not leveled. Cable termination not complete. Equipment earthing not done.
10	Installation of Chillers	Rubber isolators not installed. Anchorage not fixed properly.
11	Installation of Cooling Towers	Vibration springs not installed. Damage in cooling tower surface. Spray nozzle damaged.
12	Installation of Thermostat and Controls	Location not as specified. Thermostat body damaged.
13	Installation of Starters	Location to be near the equipment. Installation hight not as specified.

(*Continued*)

TABLE 2.47 Continued
Probable Reasons for Rejection of Work

Sr. No.	Description of Work	Probable Reasons for Rejection
14	Building Management System (BMS)	All the components not installed. Termination not complete. Wiring not dressed and bunched properly.
Electrical Work		
1	Conduiting—Raceways	Method of installation not proper. Conduit run is not parallel. Minimum clearance from other services less than specified. Supports are not secured, straps or clamp not provided. Spacing between embedded conduit and concrete aggregate is not as specified. Fastening of conduit with reinforced steel is not secured. Location of sleeves not as per app roved shop drawings. Location of boxes is not as specified and is not coordinated.
2	Cable Tray—Trunking	Cable trays are not aligned properly. Cable tray run is not parallel and no proper bends. Supports are not as per approved shop drawings. Minimum spacing between any cable tray and other services not maintained. Supports are not secured.
3	Floor Boxes	Location is not coordinated. Level of floor boxes is not proper
4	Wiring	Number of wires in the conduit is not as per approved shop drawing. Circuit wiring for switches not properly done. Termination method is not proper.
5	Cabling	Distance between two cables on cable tray is less than twice the diameter of larges cable diameter. Cable tie is not provided. Circuit identification is missing.
6	Installation of Bus Duct	Supports are not fixed properly. Connction between the ducts is not proper. Level of installation is not as specified. Spacing between parallel is less than specified. Supports are not secured.
7	Installation of Wiring Devices/Accessories	Installation height is not as specified. Coordination with architectural requirements not done to match with the finishes.
8	Installation of Light Fittings	Installation methods are not correct. Proper size of hangers and support not provided. Location and levels are not matching with architectural requirements.
9	Grounding	Welding method for joining tapes is not thermoweld type. Connection methods between tape and clamp to be as specified. Provide clamp at specified distance.
10	Distribution Switch Boards	Installation hight of boards not as specified. Termination of wires/cables not done properly. Shrouding for cable not provided. Wires and cables do not have continuity. Wires in distribution board are not properly dressed and bunched.
11	Installation of Diesel Generator Set	DG set not aligned properly. Exhaust system and piping not properly installed. Cables not terminated. Panels not installed. Day tank not installed. Pump system not properly fixed.

(*Continued*)

TABLE 2.47 Continued
Probable Reasons for Rejection of Work

Sr. No.	Description of Work	Probable Reasons for Rejection
Fire Alarm System		
1	Installation of Detectors, Bells, Pull Stations, Interface Modules	Location is not as specified. Hight of installation not matching with shop drawing and architectural requirements.
2	Installation of Repeater Panel	Installation height not as specified, method of installation not proper. Termination of cables is not done.
3	Installation of Mimic Panel	Installation height not as specified. Method of installation not proper. Termination of cables is not done.
4	Installation of Fire Alarm Panel	Installation height not as specified. Method of installation not proper. Termination of cables is not done.
Telephone/Communication System		
1	Installation of Racks	Method of installation not as per approved shop drawing. Termination of cables not done properly. Racks are not leveled. Cables are not labeled.
2	Installation of Switches	Switches are not properly installed. Switched are not installed in sequence. Cabling is not complete. Identification label not provided for cables
Public Address System		
1	Installation of Speakers	Fixing of speakers is not secured. Hight of installation is not as specified. Speakers installed in false ceiling do not have proper support.
2	Installation of Racks	Method of installation not as per approved shop drawing. Termination of cables not done properly. Racks are not leveled. Cables are not labeled.
3	Installation of Equipment	Equipment is not properly installed. Cabling is not proper.
Audio Visual System		
1	Installation of Speakers	Fixing of speakers is not secured. Hight of installation is not as specified. Speakers installed in false ceiling do not have proper support.
2	Installation of Monitors/ Screens	Method of fixing nor proper. Installation hight is not as per approved shop drawings.
3	Installation of Racks	Method of installation not as per approved shop drawing. Termination of cables not done properly. Racks are not leveled. Cables are not labeled.
4	Installation of Equipment	Equipment is not properly installed. Cabling is not proper.
CCTV/Security System		
1	Installation of Cameras	Fixing of cameras not proper. Installation height is not as specified. Termination of cameras not proper.
2	Installation of Panels	Panels not properly fixed. Cabling not complete.

(*Continued*)

TABLE 2.47 Continued
Probable Reasons for Rejection of Work

Sr. No.	Description of Work	Probable Reasons for Rejection
3	Installation Monitors/ Screens	Method of fixing nor proper. Installation hight is not as per approved shop drawings.
Access Control		
1	Installation of RFID Proximity Readers, Fingerprint Readers	Readers not installed properly.
2	Installation of Magnetic locks, Release Buttons, Door Contacts	Magnetic locks not fixed properly. Release buttons not installed at specified hight and location.
3	Installation of Panel	Panels not properly fixed. Cabling not complete.
4	Installation of Server	Cable termination not proper. Cables to be properly dressed. Identification labels not provided.
Systems Integration		
1	Installation of Switches	Switches not stacked as per sequence. Identification labels not provided
2	Installation of Servers	Cable termination not proper. Cables to be properly dressed. Identification labels not provided.
External Works		
1	Site Works	Compaction failure. Grading level not proper. Slope is not provided.
2	Asphalt Work	Asphalt levels not proper. Asphalt material not as specified.
3	Pavement Works	Pavement limits not as per approved layout. Curb stones not laid properly.
4	Piping Works	Pipe not laid at specified depth. No protection on pipes. Pipe joints not done well. Leakage observed.
5	Electrical Works	Cable not buried properly. Location of light poles not correct. Light poles are not vertically installed.
6	Manholes	Location of manholes not correct. Manhole level not correct.
7	Road Marking	Marking color not as specified.

representative. During this period the project is transferred/handed over to the owner/end user for their use and a substantial completion certificate is issued to the contractor. Table 2.48 illustrates the major activities relating to testing, commissioning, and handover phase based on the project management process group's methodology.

2.8.1 Identify Testing and Start-Up Requirements

Testing and start-up requirements are specified in the contract documents. It is essential to inspect and test all the installed/executed work prior to handing over the project

TABLE 2.48
Major Activities Relating to Testing, Commissioning, and Handover Phase Processes

Testing, Commissioning and Handover Phase

Management Processes	Project Management Process Group				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Integration Management	Executed Project/Facility Testing and Commissioning Program Contract Documents	Testing, Commissioning, and Handover Plan	Testing and Commissioning Authorities Approval Punch List/Snag List As-Built Drawings Manuals Spare Parts	Punch List/Snag List Testing and Commissioning Requirements	Handover of Project/Facility
Stakeholder Management	Identify Stakeholders	Stakeholders Requirements	Move-in Plan		Project Acceptance/ Takeover
Scope Management		Contract Documents		Authorities Approval Stakeholders Approval	Lesson Learned
Schedule Management		Testing Schedule Commissioning Schedule			
Cost Management					
Quality Management				Project Quality	
Resource Management		Demobilization Plan			Assign New Project/ Termination
Communication Management		Test Results			
Risk Management		Plan Start-Up Risk		Control Risk	

(*Continued*)

TABLE 2.48 Continued
Major Activities Relating to Testing, Commissioning, and Handover Phase Processes

Management Processes	Project Management Process Group				
	Initiating Process	**Planning Process**	**Execution Process**	**Monitoring and Controlling Process**	**Closing Process**
Contract Management		Prepare Contract Closeout Documents	Finalize Closeout Documents	Check Documents for Compliance to Contract Requirements	Close Contracts
HSE Management					
Financial Management		Financial Administration and Records	Payment to All Contractors and Subcontractors		Payment to All Contractors and Subcontractors Payment toward all Purchases
Claim Management		Claim Resolution		Check for Claims	Settlement of Claims

Note: These activities may not be strictly sequential, however, the breakdown allows implementation of project management function more effectively and easily manageable at different stages of the project phase.

to the owner/end user. Generally, all work is checked and inspected on a regular basis while the construction is in progress, however, there are certain inspections and tests to be carried out by the contractor in the presence of owner/consultant. These are especially for electromechanical systems, conveying systems, electrical works, low voltage systems, information, and technology-related products, emergency power supply systems, and electrically operated equipment that are energized after connection of a permanent power supply. Testing of all these systems starts after completion of installation works. By this time, the facility is connected to a permanent electrical power supply and all the equipment is energized.

2.8.2 Develop Testing, Commissioning, and Handover Plan

The testing is mainly carried out on electromechanical work/systems and electrically operated equipment/systems that are energized after connection of a permanent power supply to the facility. These include the following:

1. Conveying System.

2. Water supply, plumbing, and public health system.
3. Fire suppression system.
4. HVAC system.
5. Integrated automation system (building automation system).
6. Electrical lighting and power system.
7. Grounding (earthing) and lightning protection system.
8. Fire alarm system.
9. Telephone system.
10. Information and communication system.
11. Electronic security and access control system.
12. Public Address System.
13. Emergency power supply system.
14. Electrically operated equipment.

The testing of these works/systems is essential to ensure that each individual work/system is fully functional and operates as specified. The tests are normally coordinated and scheduled with specialist contractors, local inspection authorities, third-party inspection authorities, and manufacturers' representatives. Sometimes the owner's representative may accompany the consultant to witness these tests.

Test procedures are submitted by the contractor, along with the request for final inspection. Standard forms, charts, and checklists are used to record the testing results.

2.8.3 Manage Stakeholders

Following stakeholders are involved during testing, commissioning, and handover phase:

1. Owner
   - Owner's Representative/Project Manager
2. Construction Supervisor
   - Construction Manager (Agency)
   - Consultant (Designer)
   - Specialist contractor
3. Contractor
   - Main Contractor
   - Subcontractor
   - Testing and Commissioning Specialist
6. Regulatory Authorities
7. End User
8. Third-Party Inspecting Agency

2.8.3.1 Select Team Members

During the testing and commissioning phase it is essential to select team members having experience in testing and commissioning of major projects. The team members can be from the same supervision team that was involved during execution of the project, if they have experience to carry out testing and commissioning. In most cases, the manufacturer's representative is involved in testing the supplied systems/equipment. The owner may engage specialist firms to perform start-up activities and commission the project.

2.8.3.2 Select TAB Subcontractor

The contract documents generally specify to engage specialist firms to perform Testing, Adjusting, and Balancing (TAB) of HVAC work. The firm is responsible to confirm that the HVAC installations meet the specified cooling and heating system requirements.

2.8.3.3 Develop Responsibility Matrix

Table 2.49 lists responsibilities of consultant during closeout phase, and Table 2.50 illustrates contribution of various participants during testing, commissioning, and handover phases.

2.8.4 Develop Scope of Work

The contract documents specify the testing and commission work to be performed by contractor, subcontractor, and specialist supplier of equipment/systems. The following is the main scope of work to be carried out during this phase:

1. Testing of all systems.

TABLE 2.49
Typical Responsibilities of Consultant during Project Closeout Phase

Serial Number	Responsibilities
1	Ensure that occupancy permit from respective authorities is obtained.
2	Ensure that all the systems are functioning and operative.
3	Ensure that job site instruction (JSI), non-conformance report (NCR) are closed.
4	Ensure that site is cleaned, and all the temporary facilities and utilities are removed.
5	Ensure that master keys handed over to the owner/end user.
6	Ensure that guarantees, warrantees, bonds are handed over to the client.
7	Ensure that operation and maintenance manuals handed over to the client.
8	Ensure that test reports, test certificates, inspection reports handed over to the client.
9	Ensure as-built drawings handed over to the client/end user.
10	Ensure that spare parts are handed over to the client.
11	Ensure that snag list prepared and handed over to the client.
12	Ensure that training for client/end user personnel completed.
13	Ensure that all the dues of suppliers, subcontractors, contractor paid.
14	Ensure that retention money is released.
15	Ensure that substantial completion certificate issued and maintenance period commissioned.
16	Ensure that supervision completion certificate from the owner is obtained.
17	Lesson learned documented.

2. Commissioning of all systems.
3. Obtaining authorities' approvals.
4. Submission of as-built drawings.
5. Submission of technical manuals and documents.
6. Submission of warranties and guarantees.
7. Training of owner/user's personnel.
8. Handover of spare parts.
9. Handover of facility to owner/end user.
10. Occupancy/operation of new facility.
11. Preparation of punch list.
12. Issuance of substantial certificate.
13. Lessons learned.

Table 2.51 lists the items to be tested and commissioned prior to handover of the project.

TABLE 2.50
Responsibilities of Various Participants (Design-Bid-Build Type of Contracts) during Testing, Commissioning, and Handover Phase

Phase	Responsibilities		
	Owner	Designer	Contractor
Testing, Commissioning, and Handover	• Acceptance of Project • Takeover • Substantial Completion Certificate • Training • Payments	• Witness Tests • Check Closeout Requirements • Recommend Takeover • Recommend Issuance of Substantial Completion Certificate	• Testing • Commissioning • Authorities Approvals • Documents • Training • Handover

TABLE 2.51
Major Items for Testing and Commissioning of Equipment

Serial Number	Discipline	Items
1.0	Elevator	1. Power Supply 2. Speed 3. Capacity to Carry Design Load 4. Number of Stops 5. Emergency Landing 6. Emergency Call System 7. Elevator Management System 8. Interface with Fire Alarm System

(*Continued*)

TABLE 2.51 Continued
Major Items for Testing and Commissioning of Equipment

Serial Number	Discipline	Items
2.0 Mechanical		
2.1	Mechanical (Fire Suppression)	1. Sprinklers 2. Piping 3. Fire Pumps 4. Power Supply and Controls 5. Emergency Power Supply for Fire Pumps 6. Hydrants 7. Hose Reels 8. Water Storage Facility 9. Gaseous Protection System for Communication Rooms 10. Fire Protection System for Diesel Generator Room 11. Interface with Fire Alarm System 12. Interface with BMS
2.2	Mechanical (Public Health)	1. Piping 2. Pipe Flushing and Cleaning 3. Pumps 4. Boilers 5. Hot Water System 6. Water Supply and Purity 7. Fixtures 8. Power supply for Equipment 9. Controls 10. Drainage System/Irrigation System
2.3	HVAC	1. Pipe Cleaning and Flushing 2. Chemical Treatment 3. Pumps 4. Duct Work 5. Air Handling Unit 6. Heat Recovery Unit 7. Split Units 8. Chillers 9. Cooling Towers 10. Heating System (Controls, Piping, Pumps) 11. Fans (Ventilation, Exhaust) 12. Humidifiers 13. Starters 14. Variable Frequency Drive 15. Motor Control Centers (MCC Panels) 16. Chiller Control Panels 17. Building Management System (BMS) 18. Interface with Fire Alarm System 19. Thermostat 20. Air Balancing

(*Continued*)

TABLE 2.51 Continued
Major Items for Testing and Commissioning of Equipment

Serial Number	Discipline	Items
4.0 Electrical		
4.1	Electrical (Power)	1. Lighting Illumination Levels 2. Working of Photocells and Controls 3. Wiring Devices (Power Sockets) 4. Lighting Control Panels 5. Electrical Distribution Boards 6. Electrical Bus Duct System 7. Main Switch Boards/Sub Main Switch Boards 8. Minimum Low-Tension Panels 9. Isolators 10. Emergency Switch Boards 11. Motor Control Centers (MCC Panels) 12. Audiovisual Alarm Panel 13. Diesel Generator 14. Automatic Transfer Switch (ATS) 15. UPS (Uninterrupted Power Supply) 16. Earthing (Grounding) System 17. Lightning Protection System 18. Surge Protection System 19. Power Supply to Equipment (HVAC, Mechanical, Elevators, Others) 20. IP Rating of Outdoor Switches, Isolators, Switch Boards 21. Interface with BMS 22. Emergency Power System 23. Exhaust Emission of Generator
4.2	Electrical (Low Voltage)	1. Fire Alarm System 2. Communication System 3. CCTV System 4. Access Control System 5. Public Address System 6. Audiovisual System 7. Master Satellite Antenna System
4.3	External Works	1. Lighting Poles 2. Boundary Wall Lighting 3. Lighting Bollards 4. Irrigation System 5. Electrical Distribution Boards
4.4	General	1. Power supply for Gate Barriers 2. Automatic Gates 3. Rolling Shutters 4. Window Cleaning System 5. Gas Detection System 6. Water/Fluid Leak Detection System

2.8.5 Establish Testing, Commissioning Quality Procedure

Commissioning is the orderly sequence of testing, adjusting and balancing the system and bringing the systems and subsystems into operation and starts when the construction and installation of work is complete. Commissioning is normally carried out by contractor or specialist in the presence of consultant and owner/owner's representative, and user's operation and maintenance personnel to ascertain proper functioning of the systems to the specified standards.

The commissioning of the construction project is a complex and intricate series of start-up operations and may extend over many months. Testing, adjusting, and operation of the systems and equipment are essential in order to make the project operational and useful for the owner/end user. It requires extensive planning and preparatory work that commences long before the construction is complete. All the contracting parties are involved in the start-up and commissioning of the project as it is required for the project to be handed over to the owner/user. Figure 2.77 illustrates testing and commissioning process.

2.8.6 Execute Testing and Commissioning Works

Figure 2.78 illustrates a flowchart for development of inspection and test plan and Figure 2.79 is a request form for final inspection of electromechanical work.

2.8.7 Develop Documents

Figure 2.80 illustrates a list of project closeout documents to be submitted for project closeout.

2.8.7.1 As-Built Drawings

Most contracts require the contractor to maintain a set of record drawings. These drawings are marked to indicate the actual installation where the installation varies appreciably from installation shown in the original contract. Revisions and changes to the original contract drawings are almost certain for any construction project. All such revisions and changes are required to be shown on the record drawings. As-built drawings are prepared by incorporating all the modifications, revisions, and changes made during the construction. These drawings are used by the user/operator after taking over the project for their reference. It is the contractual requirement that the contractor hand over as-built drawings along with record drawings, record specifications, and record product data to the owner/user before handing over of the project and issuance of substantial completion certificate. In certain projects contractor has to submit field records on excavation and underground utility services detailing their location and levels.

2.8.7.2 Technical Manuals and Documents

Technical manuals, design and performance specifications, test certificates, warranties, and guarantees of the installed equipment are required to be handed over to the owner as part of contractual conditions.

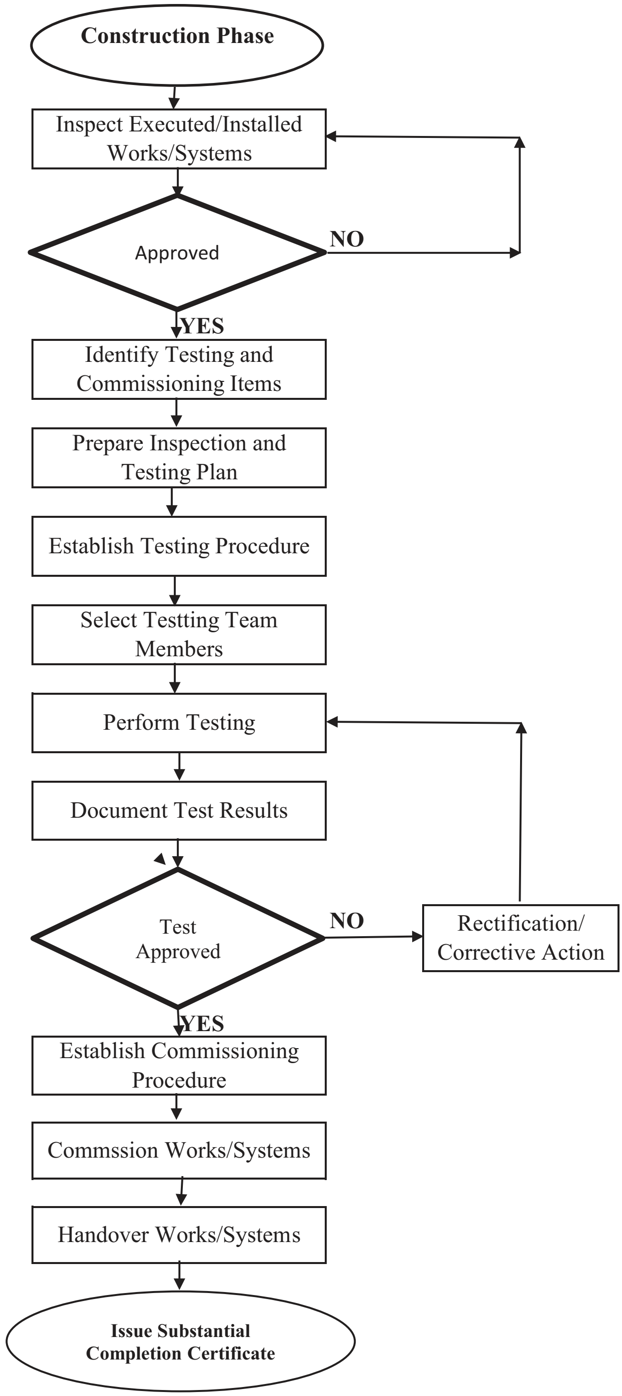


FIGURE 2.77 Testing and commissioning process.

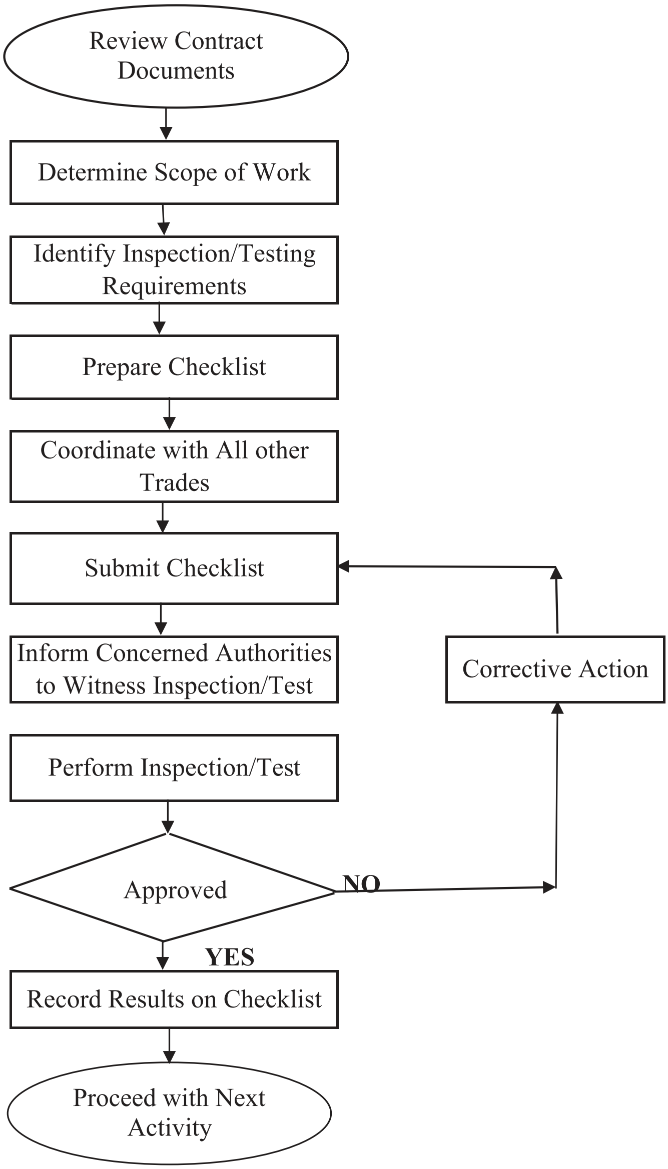


FIGURE 2.78 Inspection and test plan.

Systems and equipment manuals submitted by the contractor to the owner/end user generally consist of:

- Source Information
- Operating Procedures
- Manufacturer's Maintenance Documentation

Project Name

Project Name

ON SITE TESTING OF ELECTRO-MECHANICAL WORKS

CONTRACTOR : ____________ CHECK LIST No. : [ ]

SUBCONTRACTOR: ____________ DATE [ ]

FOLLOWING WORKS ARE READY FOR INSPECTION ON: ____________ TIME: ____________

[ ] ELECTRICAL [ ] MECHANICAL

LOCATION: ____________ DRAWING REF: ____________

SPECIFICATION NO : ____________ DIVISION : ____________ SECTION : ____________

Description of Work/System:

TEST PROCEDURE:	YES	[ ]	NO	[ ]
METHOD STAEMENT:	YES	[ ]	NO	[ ]

CONTRACTOR SIGNATURE: ____________ DATE: ____________

A/E REMARKS:

CONSULTANT ENGINEER: ____________ RESIDENT ENGINEER: ____________

DATE: ____________ DATE: ____________

Distribution [ ] OWNER [ ] R.E. [ ] CONTRACTOR

FIGURE 2.79 Request form to check electromechanical work.

- Maintenance Procedure
- Maintenance and Service Schedules
- Spare Parts List and Source Information
- Maintenance Service Contract
- Warranties and Guarantees

Procedure for submission of all these documents is specified in the contract document.

Description	Testing and Commissioning	As-Built Drawings	Operation and Maintenance	Guarantees	Warranties	Government Authorities	Record Documents	Test Certificates	Samples	Spare Parts	Punch Lists	Final Cleaning	Training	Taking Over Certificate	Remarks
ARCHITECTURAL WORKS															
CIVIL WORKS															
MECHANICAL WORKS															
HVAC WORKS															
ELECTRICAL WORKS (LIGHT & POWER)															
ELECTRICAL WORKS (LOW VOLTAGE)															
FINISHES															
EXTERNAL WORKS															

SAMPLE FORM

FIGURE 2.80 Project closeout documents.

2.8.7.3 Warranties and Guarantees

Contractor has to submit warranties and guarantees in accordance with the contract documents. Normally the guarantee for waterproofing work varies from 15 to 20 years. Similarly, the warranty for a diesel generator is set at five years.

2.8.8 Monitor Work Progress

Schedule for testing, commissioning, and handover phase to be prepared, and all the activities to be performed as per agreed-upon plan.

2.8.9 Train Owner's/End User's Personnel

Normally, training of user's personnel is part of contract terms. The owner/user's commissioning, operating, and maintenance personnel are trained and briefed before commissioning starts in order to familiarize the owner/user's personnel about the installation work, and also to ensure that the project is put into operation rapidly, safely, and effectively without any interruption. Timings and details of training vary widely from project to project. Training must be completed well in advance of the requirement to make the operating teams fully competent to be deployed at the right time during commissioning. This needs to be planned from project inception so that the roles and activities of the commissioning and operating staff are integrated into a coherent team to maximize their effectiveness.

2.8.10 Handover the Project

Once the contractor considers that the construction and installation of work have been completed as per the scope of contract, final tests have been performed, and all the necessary obligations have been fulfilled, the contractor submits a written request to the owner/consultant for handing over of the project and for issuance of substantial completion certificate. This is done after testing and commissioning is carried out and it is established that the project can be put in operation, or the owner can occupy the same. In most construction projects there is a provision for partial handover of the project.

The contractor starts handing over all completed works/systems that are fully functional, and the owner has agreed to take over the same. A handing over certificate is prepared and signed by all the concerned parties. Figure 2.81 illustrates a sample handing over certificate.

2.8.10.1 Obtain Authorities' Approval

Necessary regulatory approvals from the respective concerned authorities are obtained so that the owner can occupy the facility and start using/operating the same. In certain countries, all such approvals are needed before electrical power supply is connected to the facility. It is also required that the building/facility is certified by the related fire department authority/agency that it is safe for occupancy.

2.8.10.2 Handover Spare Parts

Most contract documents include the list of spare parts, tools, and extra materials to be delivered to the owner/end user during the closeout stage of the project. The contractor has to properly label these spare parts and tools clearly indicating the manufacturer's name and model number if applicable. Figure 2.82 illustrates spare parts handing over form used by the contractor.

2.8.10.3 Accept/Takeover the Project

Normally, a final walk-through inspection is carried out by the committee that consists of owner's representative, design and supervision personnel, and contractor to decide the acceptance of work and that the project is complete enough to be put in use and operational. If there are any minor items that remain to be finished, then such list is attached with the certificate of substantial completion for conditional acceptance of the project. Issuance of substantial completion certificate certifies acceptance of work. If the remaining work is of a minor nature, then the contractor has to submit a written commitment that he/she shall complete said work within the agreed-upon period. A memorandum of understanding is signed between the owner and the contractor that the remaining work will be completed within an agreed-upon

Project Name

Project Name

HANDING OVER CERTIFICATE

CONTRACTOR : ______________________ CERTIFICATE No. :

SUBCONTRACTOR: ______________________ DATE

SPECIFICATION NO : ____________ DIVISION : ____________ SECTION : ____________

DRAWING No. BOQ REF: ____________

AREA : ☐ Building Works ☐ Electrical Works ☐ Mechanical Works

☐ HVAC Works ☐ Finishes Works ☐

SAMPLE FORM

Description of Work/System:

The work/system mentioned above is completed by the contractor as specified and has been inspected and tested as per contract documents.The work/system is fully functional to the satisfation of owner/end user.The contractor hand over the said work/system to the owner/end user as on ---------------.The guarentee/warranty of work/system shall start as of ------------- and shall be valid for a period of ------------------years(duration) from the date of issuance of substantial completion certificate.The contractor shall be liable contractually till the end of warranty/guarentee period.

SIGNED BY:

OWNER/END USER: ______________________ CONTRACTOR: ______________________

CONSULTANT: ______________________ SUBCONTRACTOR: ______________________

FIGURE 2.81 Handover certificate.

period. Table 1.51 under Section 1.3.2.10.7 illustrates a list of activities that need to be considered for project closeout.

2.8.11 Close Contract

Table 1.51, discussed earlier under Section 1.3.2.10.7, lists all the activities to be completed to close the contract.

Project Name

Project Name

HANDING OVER OF SPARE PARTS

CONTRACTOR: ______________________ CERTIFICATE No. : [ ]

SUBCONTRACTOR: ______________________ DATE [ ]

SPECIFICATION NO : ______________ DIVISION __________ SECTION : __________

DRAWING No. ______________ BOQ Ref. __________

AREA : [ ] Building Works [ ] Electrical Works [ ] Mechanical Works

[ ] HVAC Works [ ] Finishes Works [ ]

Following Spare Parts have been handed over to the owner/end user

Description of Spare Parts

Sr.No.	Description	BOQ Reference	Spec. Ref.	Manufacturer	Specified Qty	Delivered Qty

SAMPLE FORM

(Attach additional sheet,if required)

SIGNED BY:

OWNER/END USER: ______________ CONTRACTOR: ______________

CONSULTANT: ______________ SUBCONTRACTOR: ______________

FIGURE 2.82 Spare parts handover form.

2.8.11.1 Prepare Punch List

Owner/consultant inspects the work and informs contractor of unfulfilled contract requirements. A punch list (snag list) is prepared by the consultant listing all the items still requiring completion or correction. The list is handed over to the contractor for rework/correction of the work mentioned in the punch list. Contractor resubmits inspection requests after completing or correcting previously notified works.

TABLE 2.52
Punch List

OWNER NAME:		
PROJECT NAME:		
PUNCH LIST:		
Punch List Number:		Date:
Building Name		Floor
Area/Zone		Room Number
Serial Number	**Item**	**Remark**
1	Flooring	
2	Skirting	
3	Walls	
4	Ceiling	
5	Door	
6	Windows	
7	Door Hardware	
8	Window Hardware	
9	Electrical Light Fixture	
10	Wiring Devices (Sockets)	
11	HVAC Grill	
12	HVAC Diffuser	
13	Thermostat	
14	Sprinklers	
15	Fire Alarm Detectors	
16	Speakers	
17	Communication System Devices	
18	TV Outlets	
19	Any Other Item	

A final snag list is prepared if there are still some items that need corrective action/completion by the contractor if such remaining work is to be completed within the agreed period to the satisfaction of the owner/consultant. Table 2.52 is a sample form for preparation of a punch list.

2.8.11.2 Prepare Lesson Learned

The construction/project manager, consultant, and contractor have to prepare lessons learned and document the same for future references to improve the processes and organizational performance. This includes:

- Reasons for delay.
- Resigns for rejection/rework.
- Preventive/corrective actions.
- Cost overruns.

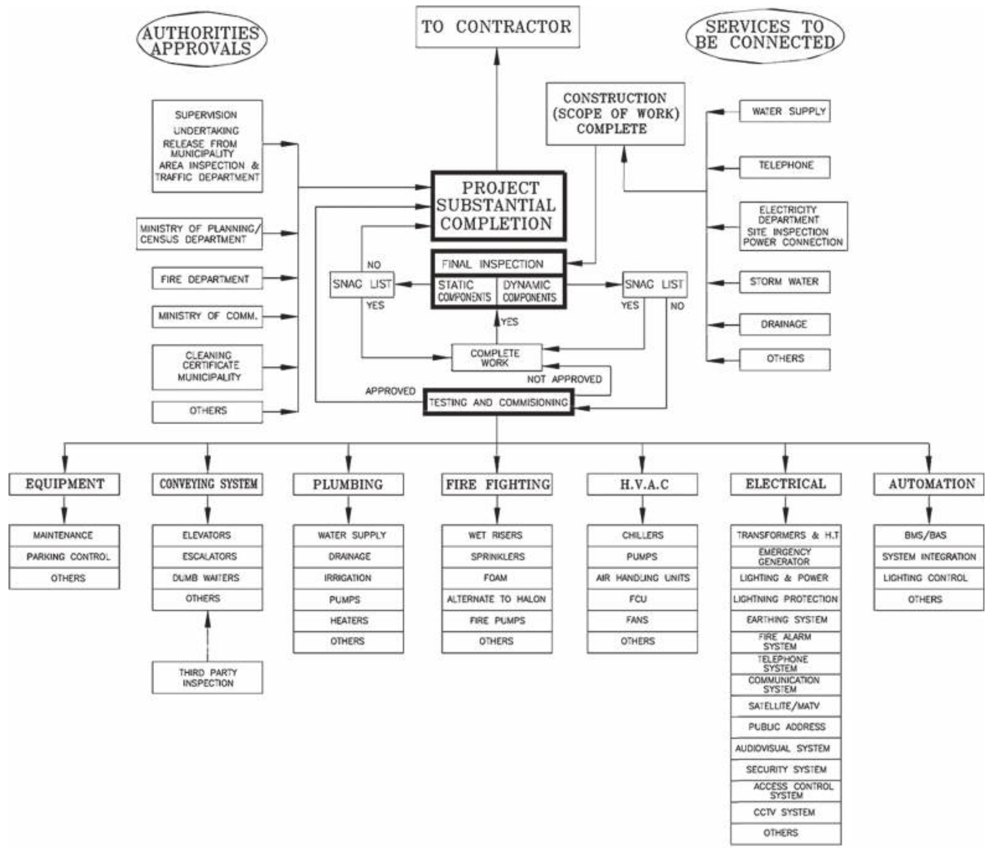


FIGURE 2.83 Project substantial completion procedure.

- Causes for claims.
- Reasons for conflict.

2.8.11.3 Issue Substantial Completion Certificate

A substantial completion certificate is issued to the contractor once it is established that the contractor has completed work in accordance with the contract documents and to the satisfaction of the owner. The contractor has to submit all the required certificates and other documents to the owner before issuance of the certificate. Figure 2.83 illustrates procedure for issuance of substantial certificates normally used for building construction projects in Kuwait. Authorities' approval requirements mentioned in this figure may vary from country to country, however, other requirements need to be completed by the contractor for issuance of substantial completion certificate.

The certificate of substantial completion is issued to the contractor and the facility is taken over by the owner/end user. By this stage owner/end user already takes possession of the facility, and operation and maintenance of the facility commences. The project is declared complete and is considered the end of the construction project life cycle.

The defect liability period starts after issuance of substantial certificate.

During this period, the contractor has to complete the punch list items and also to rectify the defects identified in the project/facility.

2.8.11.4 Terminate/Demobilize Team Members

The project team members are demobilized from the project and their services are either terminated or shifted to other projects if positions are available to accommodate. In certain cases, the project members join members of the functional team at the project office.

2.8.12 Settle Payments

The owner has to settle all the dues toward the consultant, contractor, and other parties involved. Similarly, the contractor has to settle due payments to their subcontractors and suppliers.

2.8.13 Settle Claims

The entire project-related claims are to be amicably settled as per contract conditions to close the project.

3 Lean Construction

Zofia K. Rybkowski and Lincoln H. Forbes

3.1 LEAN CONSTRUCTION

Lean project delivery or lean construction—a project delivery philosophy that aims to reduce waste and add value using continuous improvement in a culture of respect—was developed to address many of the productivity problems currently plaguing the Architecture, Engineering, and Construction (AEC) sector. The purpose of this chapter is to provide an overview of the challenges the sector is currently facing, a brief history of the emergence of lean construction as a countermeasure response to these challenges, and principles, tools, and processes typically implemented during lean project delivery.

3.2 CURRENT CHALLENGES IN THE AEC INDUSTRY

3.2.1 Low Overall Productivity

The Bureau of Labor Statistics does not maintain an official productivity index for the construction industry, the only major industry that is not tracked consistently. Productivity in construction is usually expressed in qualitative terms, and cannot easily be analyzed empirically. A number of independent studies estimated that construction productivity increased at a rate of 33%—or 0.78% per year—between 1966 and 2003.

This productivity growth is less than one-half that of the US nonagricultural productivity gains during the same period, which averaged 1.75% annually. An estimate by the National Institute of Science and Technology (NIST) points to a decline in US construction productivity over a 40-year period to 2007 that was −0.6% per year, versus a positive non-farm productivity growth of 1.8% per year. The increased productivity in non-farm-related industries may be attributable to mechanization, automation, and prefabrication.

Similarly, most of the improvement in construction productivity has been the result of research and development work in the manufacturing industry related to construction machinery. Earthmoving equipment has become larger and faster; power saws have replaced handsaws. However, despite increased productivity of individual activities, there has been evidence to suggest that *overall* construction productivity has declined over the past fifty years. Again, this is in clear contrast to observable increases in productivity for non-farm-related industries (Teicholz from Eastman et al. 2001). As shown in Figure 3.1, the decline continues despite the introduction of significant technological advances, suggesting that improving the situation may have more to do with healing an increasingly fragmented, non-collaborative industry than with only enhancing the productivity of its individual components.

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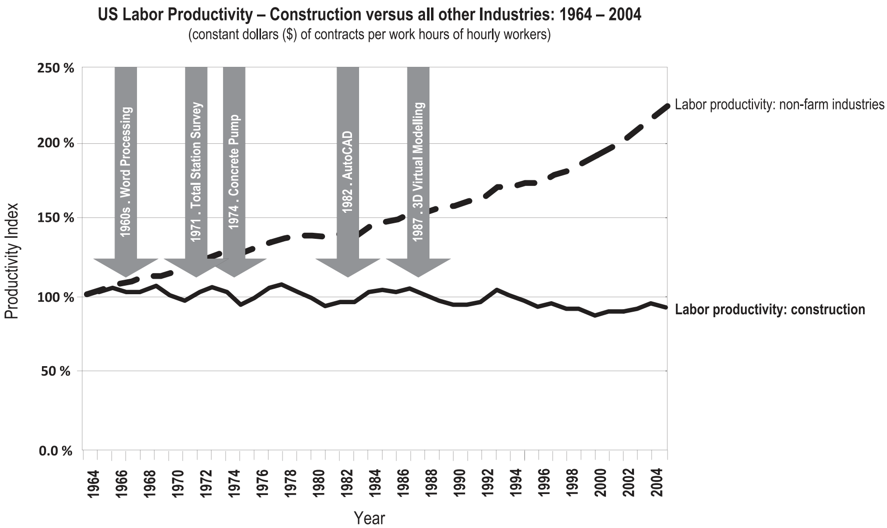


FIGURE 3.1 Entry year of several technological advances.

The entry years of several technological advances, such as word processing, total station, concrete pump, AutoCAD, and 3-D modeling (ArchiCAD), are juxtaposed, suggesting a solution for an unproductive industry may reside beyond technology.

3.2 2 Indications of Industry Failure

In order to better understand problems plaguing the industry, construction management research has focused on identifying sources of failure. For example, Josephson and Hammarlund (1999) observed seven building projects during a six-month period, analyzed nearly 3000 defects, and then identified the root causes of the defects. Perhaps surprisingly, the researchers discovered that the greatest numbers of defects were not induced by stress or risk, but instead by a lack of motivation and knowledge among four participant categories surveyed: Designers, site managers, workers, and subcontractors. Researchers found a strong alignment of ranking among the top two causes within each of the four categories. This finding is detailed in Table 3.1.

Other researchers have focused less on defects and more on the adversarial nature of the construction industry. For example, Black et al. (2000) surveyed over 78 consultants, contractors and clients. They found that respondents perceived traditional design-bid-build systems as failing in a number of ways, including: widespread exploitation, overly rigid specifications, decisions made with limited knowledge, and a focus placed on short-term (rather than long-term) success. Such failings appear to be pervasive and common to the design-bid-build delivery method, regardless of geography or nationality (Proverbs et al. 2002).

Research has pointed to a significantly high level of wasted resources in the construction industry—both human and material. An article entitled "Construction and the Internet" published on January 15, 2000 in *The Economist*, noted that up

TABLE 3.1
Causes of Defects

	Cause of Defect (% of defect cost per category)			
	Workmanship	***Site Management***	***Subcontractors***	***Design***
Motivation	69	50	47	35
Knowledge	12	31	27	44
Information	2	8	13	18
Stress	1	6	3	2
Risk	16	5	10	1

to 30% of construction costs are due to inefficiencies, mistakes, delays, and poor communications.

The Construction Industry Institute (CII) estimates that in the US:

- 10% of project cost is spent on rework.
- 25–50% of construction costs are lost to waste and inefficiencies in labor and materials control.
- Losses are incurred in errors in information in translating designs to actual construction.
- Inadequate interoperability accounts for losses of $17–36 billion per year due to communication difficulties between software used by different actors in the design and construction supply chain (Ballard and Kim 2007; Gallaher et al. 2004).

The observations of a Construction Industry Cost Effectiveness (CICE) study in 1983 are still relevant today. The study teams noted that “more than half the time wasted in construction is attributable to poor management practices.” They concluded that “if only the owners who pay the bills are willing to take the extra pains and pay the often-small extra cost of more sensible methods they will reap the benefit of more construction for their dollars.”

The construction industry is not unified on the measurement of productivity or overall performance. Many researchers define construction project success in terms of: 1) Cost—within budget; 2) Schedule—on time completion within schedule; 3) Safety—high safety levels—few or no accidents; and 4) Quality—conformance with specifications within a few defects. Some view quality as one point of a triangle with cost and schedule; quality is often the first to be sacrificed in favor of cost savings and schedule reductions. Many contractors believe that it is impossible to meet desirable benchmarks in all four factors simultaneously and that there is a zero-sum relationship between them. In other words, an accelerated schedule is expected to result in increased costs and lower levels of safety and quality.

One conundrum is that the concept of construction performance does not emphasize productivity and quality initiatives. The work of many researchers has revealed an industry tendency to measure performance in terms of the following: Completion on time, completion within budget, and meeting quality requirements (i.e., conformance to plans, specifications, and construction codes).

From an industry-wide perspective, little attention has been directed to owner satisfaction as a performance measure. The emerging adoption of lean construction is beginning to change attitudes very gradually since lean practices emphasize providing customer value, but that process is likely to take many years. Although the Malcolm Baldrige National Quality Award was established in 1987, in the period of nearly forty years that have elapsed since its inception, the construction industry has been greatly under-represented.

There is a general lack of productivity/quality awareness in the industry among all parties, including owners. Owners have come to accept industry pricing; prices have simply become higher on a per-unit basis. By contrast, manufacturing activities have become cheaper over time on a per-unit basis.

Traditional architect/engineer contracts are said to be unclear with respect to professional standards of performance, often leading to unmet expectations. Construction owners feel that typical A/E contracts protect designers at the owner's expense. For example, prevailing contract language often relieves designers of any role inthe case of a lawsuit or arbitration between an owner and contractor. An outgrowth of this is the practice of "substantial completion," where a job is usable but has 5% of the remaining work in the form of a "punch list." An owner often has a very difficult time persuading a contractor to finish that work. Other stakeholders, too, feel frustrated. For example, architects often feel under-compensated for the amount of work they are asked to do. Also, specialty contractors sometimes argue they are forced to carry an unfair share of risk and blame if something goes wrong.

3.3 THE LEAN CONSTRUCTION RESPONSE

3.3.1 Lean Construction Defined

Lean construction emerged as a response to such frustrations with construction productivity, as well as to concerns about commonly observed errors, delays, cost overruns, and safety (Forbes and Ahmed 2010). Founded on a belief that problems in the construction industry are a byproduct of deep-seated systemic inefficiencies in the way increasingly specialized stakeholders interact, lean construction aims to address these interactions in a holistic way.

Lean Construction (LC) is an innovative project delivery approach that addresses many of the shortcomings of traditional project management. It has several interpretations, including lean project delivery, integrated project delivery, and collaborative project delivery. It is based on the "lean" manufacturing principles that are a foundation of the Toyota Production System (TPS) (Howell 1999). Lean *production* pursues the ideal to: "(1) do what the customer wants, (2) in no time, and (3) with nothing in stores" (Tommelein 2015). Lean construction practitioners seek to apply lean production theories to both design and construction practices. Its three tenets are: Minimize waste and add value in all forms, continuously improve products and systems, and maintain respect for people. The lean construction philosophy views a project as a "promise delivered by people working in a network of commitments" (Macomber and Howell 2005).

Lean construction is described as a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value (Koskela 2002). In his Transformation Flow Value (TFV) theory of lean construction, Koskela argued that all three aspects of construction must be managed simultaneously for successful project delivery (Tommelein 2015). Abdelhamid (2013), defines lean construction as:

> a holistic facility design and delivery philosophy with an overarching aim of maximizing value to all stakeholders through systematic, synergistic and continuous improvement in the contractual arrangements, the product design, the construction process design and methods selection, the supply chain, and the workflow reliability of site operations.

Current definitions of lean construction are varied, in part, because lean construction thinking continually emerges from a grassroots, communal, and collaborative base. There is a general reluctance by lean construction pioneers to define a concept that might limit or exclude the contributions of the community that lean product delivery (LPD) is intended to embrace and motivate. Nevertheless, some definitions have been advanced and are summarized in Table 3.2.

More recently, lean construction has come to be defined by a triangle that addresses the way a system must be restructured in order to function as lean (Figure 3.2).

The three sides of this triangle include the organization and commercial terms that are both underlain by a unique operating system. For example, while traditional construction is *profit*-driven, LPD is *value*-driven. In traditional construction, the operating system is *push*-driven, whereas in LPD, it is *pull*-driven; the organization suboptimizes each *part*, operating by *command and control*, whereas LPD optimizes the *whole,* facilitating *collaboration;* and in traditional construction, the commercial terms are *transactional*, whereas in LPD they are *relational* (Mossman 2014).

Another way to envision lean construction is through the lens of a graphic definition proposed by Rybkowski et al. (2013). The authors challenged lean industry practitioners and academics to graphically illustrate their understanding of lean thinking on the backs of cocktail napkins. A resulting composite diagram situates the PDCA (plan-do-check-act) continuous improvement cycle as the engine for incremental transformations (Figure 3.3).

The black and white inverted triangles illustrate that, as waste is reduced, capital spent on waste can instead be diverted toward added value for the project. The OAEC acronym within each PDCA cycle signifies that all transformations from current to improved future states are accomplished collaboratively with OAEC team members (owner, architect, engineer, and constructors). All actions are performed within a culture of respect. Horizontal lines between PDCA cycles represent the need to standardize improvements. If done according to lean principles, overall time, cost, quality, safety, and morale will improve simultaneously. The ability for all five metrics to improve concurrently qualifies lean construction as a paradigm shift, distinguishing it from the time-cost-trade-off phenomenon often observed in more

TABLE 3.2
Definition of Lean Construction

1	Lean Construction is a "way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value."	(Koskela et al. 2002)
2	"Lean Construction is a production management based project delivery system emphasizing the reliable and speedy delivery of value. It challenges the generally accepted belief that there are always trade-offs between time, cost and quality."	(LCI 2013)
3	"Lean Construction is a set of ideas, practiced by individuals in the construction industry, based in the holistic pursuit of continuous improvements aimed at minimizing costs and maximizing value to clients in all dimensions of the built and natural environment: planning, design, construction, activation, operations, maintenance, salvaging, and recycling."	(AGC 2013)
4	Lean Construction is "A holistic facility design and delivery philosophy with an overarching aim of maximizing value to all stakeholders through systematic, synergistic, and continuous improvements in the contractual arrangements, the product design, the construction process design and methods selection, the supply chain, and the workflow reliability of site operations."	(Abdelhamid 2013)
5	"Whereas current project management approaches reduce total performance by attempting to optimize each activity, lean construction succeeds by optimizing at the project level. As opposed to the less effective current project management approaches, which reduce total performance by attempting to optimize each activity."	(Forbes and Ahmed 2010, p. 19)
6	Lean construction is "the improving of the construction process to profitably deliver what the customer needs while having the right systems, resources, and measure to deliver things right the first time. It is focused on value from the customer's perspective, more than on cost, and seeks to remove all non-value-adding activities (wastes)."	(PDCA 2012, p. 226)
7	"The ideas of lean thinking comprise a complex cocktail of ideas including continuous improvement, flattened organisation structures, teamwork, the elimination of waste, efficient use of resources and co-operative supply chain management. Within the UK construction industry, the language of lean thinking has since become synonymous with best practice."	(Green 2002)
8	"Lean stems from the recognition that the world is subject to all kinds of variation and that one can distinguish good variation from bad variation. Good variation is variation that customers intentionally want (e.g. people want buildings to not all look the same); all other variation is bad. To improve performance, lean starts by relentlessly driving out bad variation and then buffering where needed to protect the system from the impact of remaining variation."	(Tommelein 2015)

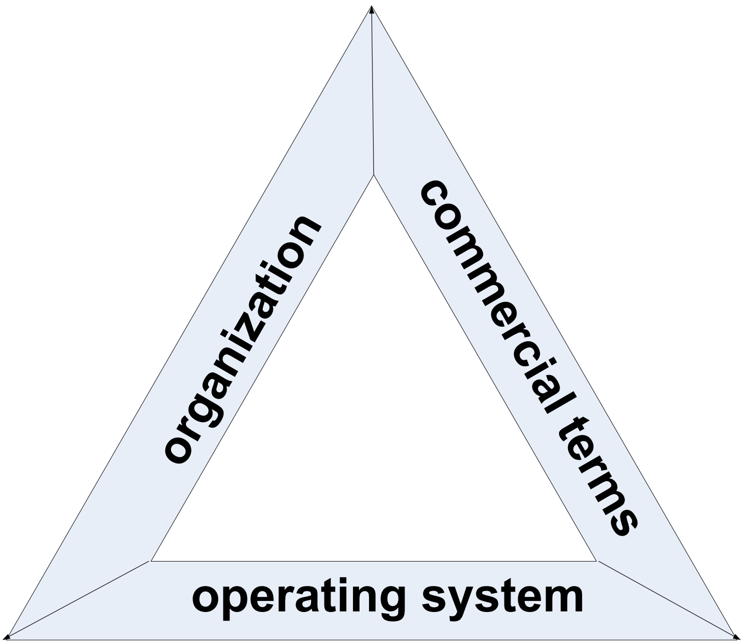


FIGURE 3.2 Characteristics to draw lean and traditional project delivery systems.

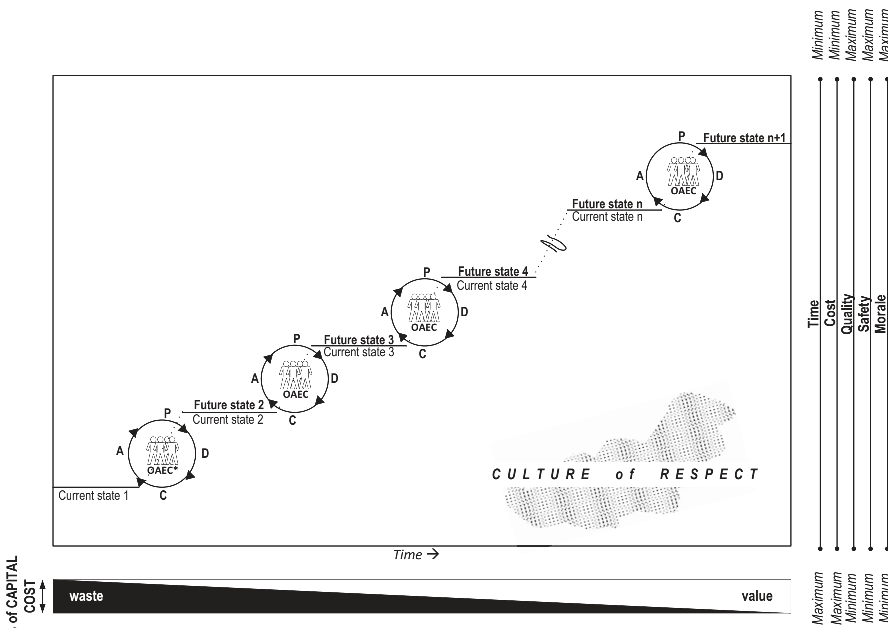


FIGURE 3.3 Kaizen stairway.

traditional (i.e., design-bid-build) project delivery methods (Feng et al. 1997; Hegazy 1999; LCI 2013; Siemens 1971), described in Section 2.2. The diagram visually captures the final objective of lean construction, which is to *reduce waste and add value using continuous improvement within a culture of respect.*

3.3.2 Lean Goals and the Elimination of Waste

In the manufacturing world, the goal of lean is to produce a product that satisfies the customer's requirements—while minimizing waste and maximizing value. At the risk of appearing overly simplistic, it may be useful to draw an analogy between lean construction and a lean animal. The word "lean" might be associated with the lithe body of the cheetah which has evolved to build adequate muscle and minimize fat, enabling it to optimize speed while hunting. But an Artic seal insulated by a thick layer of blubber also conforms to the lean ideal. The ultimate lean goal is to create a product that is "fit for use" or to customer satisfaction while minimizing waste and maximizing value.

In construction, waste is everywhere—and waiting to be eliminated. For example, adversarial relationships, claims and disputes, demotivated workers, defects, etc., as discussed in Section 2.2, can all be considered sources of waste because these actions do not add value to the final product. One of the benefits of waste reduction is that resources that would have been spent on waste can be reallocated to enhancement of value, as suggested by Figure 3.4.

Lean construction maximizes value, reduces waste, and applies specific techniques in an innovative project delivery approach including supply chain management and just-in-time techniques as well as the open sharing of information and close collaboration between all the parties involved in the production process. Lean manufacturing is an outgrowth of the Toyota Production System (TPS) that was developed by Taiichi Ohno in the 1950s (Womack et al. 1990). Ohno had observed mass production at Ford Motor Corporation's manufacturing facilities in the US and recognized that there was

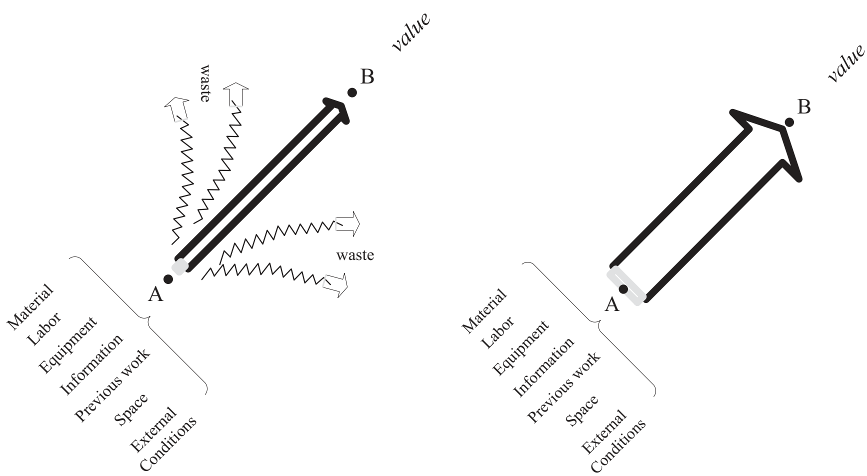


FIGURE 3.4 Recapturing waste as value.

much waste (muda) everywhere. Ohno and Shigeo Shingo (Ohno 1988), an industrial engineer at Toyota identified *seven wastes* in mass production systems:

1. Overproducing.
2. Idle time waste—waiting time/queue time.
3. Transporting/conveyance waste.
4. Processing waste—waste in the work itself.
5. Inventory waste—having unnecessary stock on hand.
6. Wasted operator motion—using unnecessary motion.
7. Producing defective goods—waste of rejected production.

Ohno sought to develop a delivery process that met customers' needs with very little inventory because inventory is costly to store and maintain. It is also risky to hold because it may physically degrade with time and its functions may become obsolete.

To eliminate wasteful inventory, the Toyota Production System was based on the "Just-In-Time" (JIT) philosophy. Its three tenets were minimizing waste in all forms, continuous improvement of processes and systems, and maintaining respect for all workers. Its benefits include reduced inventories (and space), higher human productivity, shorter cycle times, shorter lead times, fewer errors, and higher morale. In the mid-1970s, Toyota reduced the time needed to produce a car from fifteen days to one day, using JIT. It is important to note that Ohno's improvement of Toyota's production process was not necessarily a new technology, but rather the result of involving all participants in a new philosophy of avoiding waste.

3.3.3 Brief History of Lean Construction

Lean construction became grafted onto a rich value tradition and knowledge base of antecedent thought. Although some authors argue that TPS planted the flag of lean thinking, TPS itself emerged from pioneers of process productivity, such as Frederick Taylor, Frank and Lillian Gilbreth, Henry Ford, and W. Edwards Deming. In Japan, the auto manufacturer Toyota rose from the devastation of World War II by drawing heavily on the teachings of statistics gurus, Walter A. Shewhart and W. Edwards Deming, the latter who visited the recovering nation. Toyota heeded Deming's teachings, and perceptive writings of the Japanese businessman, Taiichi Ohno, reflect his indebtedness to Deming, Ford, and other productivity pioneers (Ohno 1988). MIT International Motor Vehicle Program co-authors Womack et al. (1990) described successful theories and methods used by Toyota in their revolutionary book, *The Machine that Changed the World* (Womack et al. 1990). The term "lean" was coined by John Krafcik in a 1988 article derived from his MIT master's thesis. Toyota's successes in terms of improved revenue, speed of production, and refined product quality, prompted manufacturers in other industries to investigate ways to duplicate their success. Jeffrey Liker assembled key elements of Toyota's practices into his book, *The Toyota Way*—now read and discussed during company brown bag lunches and sometimes described as "the bible of Lean." Other similarly themed productivity-enhancement theories also emerged, including Eliyahu Goldratt's fictitious work, *The Goal*, which introduced his theory of constraints to the manufacturing community, and has since joined Womack, Jones, Roos, and Liker's books as necessary reading in the lean canon.

In the now renowned CIFE Technical Report Number 72 entitled: *Application of the New Production Philosophy to Construction* (Koskela 1992) Lauri Koskela stood on the principles of a manufacturing movement that he termed "the new production philosophy" and applied its principles to the construction industry. Koskela spent a year at Stanford University as a visiting scholar and authored a study entitled "Applications of The New Production Philosophy to Construction." He drew parallels between both fields by characterizing construction as a form of production. Koskela looked to the manufacturing industry for a new direction for construction. Specifically, he modeled this new production philosophy after Toyota's highly successful TPS. Researchers had already recommended solutions to the construction industry's underperformance including industrialization (prefabrication and modularization), automation and robotics, and information technology to reduce fragmentation. Koskela proposed a new approach that was not based on technology, but rather on the principles of a production philosophy. He noted its evolution through three stages:

1. Tools, such as kanban and quality circles;
2. A manufacturing method; and
3. A management philosophy (lean production, just-in-time/total quality control (JIT/TQC), etc.).

Koskela inferred from a number of productivity-based studies on US and European manufacturing plants that the most successful methods were based on the JIT philosophy. Manufacturing studies by other researchers, such as Schonberger (1986), Harmon and Peterson (1990) reinforced this observation.

In a typical production process, material is converted (transformed) in a number of discrete stages. It is also inspected, moved from one operation to another, or made to wait. Inspection and waiting are considered flow activities. Conversion activities are considered to add value while flow activities do not add value.

Koskela visualized lean construction as a flow process combined with conversion activities and noted that only the conversion activities add value. This was the Transformation Flow Value (TVF) theory of construction. Production improvements can be derived by eliminating or reducing flow activities while making conversion activities more efficient. He pointed to earlier studies that showed that only 3% to 20% of the steps in a typical process add value and that their share of the total cycle time is only 0.5% to 5% (Koskela 1992).

Although mentioned third in the TFV lineup, the creation of *value*—to design a product or building to customer satisfaction—is arguably the most critical of the three since it only makes sense to design a building within budget and on time if it serves the function for which it was intended (Ballard 2009).

Koskela attributed the predominance of non-value-adding activities to three root causes: design, ignorance, and the inherent nature of production. Design was due to the subdivision of tasks; each added subtask increased the incidence of inspecting, waiting, and moving. A natural tendency for processes to evolve over time without close analysis leads to ignorance of their inherent wastefulness. The inherent nature of production is that events such as defects and accidents add to non-value-added steps and time between different conversion activities.

Incorporating Koskela's concepts, Glenn Ballard and Greg Howell cemented their own observations of the need to enhance reliability of project planning and founded the Lean Construction Institute in August 1997 (Lean Construction Institute 2009), formalizing a collaboration that has shaped the discourse on lean construction.

Howell and Ballard's experimental fieldwork applied lean theory to construction processes; they collected metrics to substantiate results obtained during the playing of live simulations, and eventually drew validation from computer simulations of UC Berkeley civil engineering academician, Iris D. Tommelein et al. (1999). Collecting data from live and computerized simulations confirmed the mathematical logic of lean principles and gave assurance to practitioners that the successes enjoyed during case studies could be trusted as generalizable and repeatable. A substantial acceleration point came when attorney Will Lichtig joined the pioneers and enshrined lean principles into a legal document entitled the Integrated Form of Agreement (IFOA; Lichtig 2004). Unlike the "partnering" movement of the 1990s, which brought stakeholders together for a typical weekend retreat and encouraged participants to sign a legally *un*enforceable declaration of collaboration, the IFOA instead incentivized synergistic behavior with financial rewards and backed collaboration with legal consequences. In their book, *Lean Project Delivery and Integrated Practices in Modern Construction:* Forbes and Ahmed (2020) captured the range and breadth of developments in lean construction that had taken place since its inception.

Ballard's research led to the development of the *Last Planner System of Production Control*™, a method in which participants in the design and/or construction processes are empowered to engage in detailed planning and coordination needed to secure near-seamless interaction. The methodology includes procedures for removing constraints before work is initiated, as well as measurement systems to gauge performance, and feedback to introduce corrective actions at frequent intervals during a project when they can have the maximum effect on outcomes.

3.3.4 THE LEAN PROJECT DELIVERY SYSTEM (LPDS): A CLOSER LOOK

The Lean Project Delivery System (LPDS)™ provides a means of addressing industry shortcomings and improving the entire design and construction process (Ballard 2000b; Ballard and Howell 2003). It was developed by Glenn Ballard in 2000 and subsequently refined. Whereas traditional industry practice separates the roles of designers and constructors, the LPDS sees the activities of these professionals as a continuum for project management to achieve three fundamental goals (Koskela 2000):

- Deliver the product;
- Maximize value; and
- Minimize waste.

3.3.4.1 The Structure of THE LPDS

The LPDS model improves project delivery via the following characteristics:

- Downstream stakeholders are involved in front-end planning and design through cross-functional teams;
- Project control has the job of execution as opposed to reliance on after-the-fact variance detection;
- Pull techniques are used to govern the flow of materials and information through networks of collaborating specialists;
- Capacity and inventory buffers are minimized and only used to absorb variability that cannot be removed; and
- Feedback loops are incorporated at every level, dedicated to rapid system adjustment; that is, learning (Ballard and Howell 2003).

The LPDS comprises a number of phases that are represented as inverted triangles. Figure 3.5 illustrates the same.

The system juxtaposes the phases in such a manner as to apply production system design principles to enhance the delivery of the entire project from predesign to completion and use.

The phases include:

1. Project Definition
2. Lean Design
3. Lean Supply
4. Lean Assembly
5. Use/Completion

Each LPDS project phase is described in greater detail next.

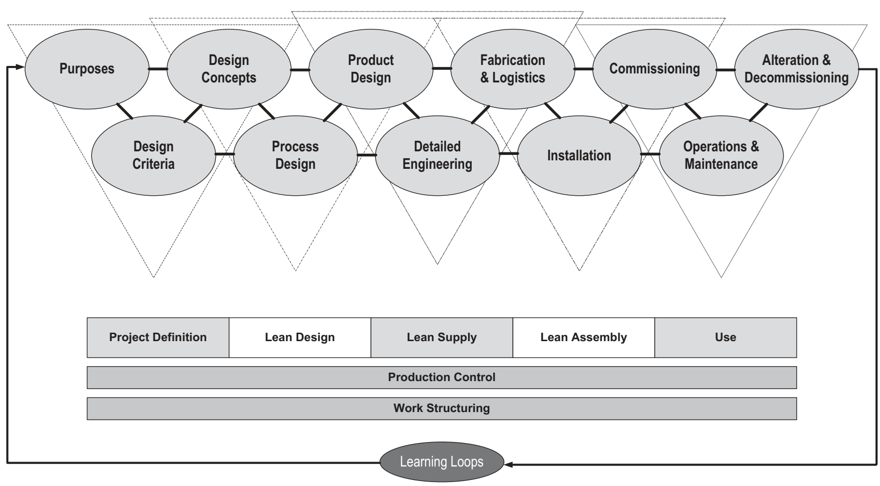


FIGURE 3.5 Lean project delivery system.

The project definition phase typically involves developing project alternatives at a conceptual level, analyzing project risks and the economic payoff, and developing a financial plan. Effective project scope definition enables all involved parties to understand the owner's needs and to work toward meeting those needs.

The project definition phase comprises:

- Needs and values determination;
- Design criteria; and
- Conceptual design.

In the needs and values determination, design professionals assist the owner/client in clarifying a value proposition; that is, the purpose of the project and the needs to be served. A design criteria document describes specific needs to be met, such as size, space proximities/adjacencies, and energy efficiency requirements. Conceptual design uses the design criteria and value proposition to define an outline design that serves as a starting point for the design phase.

The *lean design phase* comprises conceptual design, process design, and product design. It builds on the output from the project definition phase, but with a deviation from traditional design practice. The design team often starts by designing the design process; they use adhesive notes ("stickies") on a wall to ensure that design assignments have the necessary prerequisite work completed and that no constraints will delay the process. Design is done with both the construction product and the process in mind. Constructability reviews and value engineering are not seen as tools to apply in a problem-solving mode but instead are continually integrated with decision-making in the design process.

The third phase, the *lean supply phase*, comprises product design, detailed engineering, fabrication, and logistics (Ballard and Howell 2003); it requires up-front product and process design to define what is needed and when it should be delivered. This is especially important with engineered-to-order components as utilized in Engineering Procurement and Construction (EPC) projects. Lean supply also includes reducing the lead time for project information requirements. Lean supply addresses these problems through three main approaches:

1. Improving workflow reliability;
2. Using web-based project management software to increase transparency across value streams; and
3. Linking production workflow with material supply.

The fourth phase, the *lean assembly phase*, is practiced in the actual construction of a project, putting materials, systems, and components in place to create a completed facility.

In the Last Planner System of Production Control (LPS), work structuring culminates in the form of schedules that represent specific project goals. Schedules are created for each phase of the project, beginning at the design phase and ending at project completion. The production control provided by the LPS deploys the activities necessary to accomplish those schedules. The horizontal bars in the diagram labeled "production control" and "work structuring" refer to the management of production throughout the project.

The commissioning process provides quality assurance by ensuring that all systems have been installed by the contractor as promised in keeping with the designer's plans and specifications. It improves the probability that the facility will meet the owner's project requirements and perform as expected, to provide user satisfaction.

The fifth and last phase, the *use phase*, refers to a completed facility. Following successful commissioning, the facility should undergo a protracted operations and maintenance phase as it is used. The circle labeled "Alteration and Decommissioning" refers to a future activity when the facility may be repaired, renovated, or taken out of service.

"Learning loops" refer to the application of root cause analysis to the LPS on a weekly basis to review Percent Planned Complete (PPC) values and commitment reliability.

Learning is also accomplished through the process of Post Occupancy Evaluation (POE) in which a facility is surveyed after occupancy/acceptance to review the consequences of decisions made during the execution of the project. POE enables project participants to "learn from the past."

3.3.4.2 Facilitating Flow Through Work Structuring and Production Control

Achieving *flow* is one of the hallmarks of lean, and various tools have been developed by the lean construction community to help facilitate it. Work structuring and production control are used throughout a project to manage production. The term *work structuring* was developed by the Lean Construction Institute (Ballard 2000b) to describe construction-related process design. It is a process of subdividing work so that pieces are different from one production unit to the next to promote flow and throughput and to have work organized and executed to benefit the project as a whole. The Last Planner System of Production Control and target value design are methods that have been developed by LCI to promote flow. But before these tools can be described, it is important to help the reader recognize situations of *flow* and *non-flow*. It is possible to represent activity flows graphically so that managers can identify opportunities to enhance it.

3.3.4.2.1 Representing and Visualizing Flow

Every lean project is initiated by clearly defining *value* through rigorous consultation with the owner. Once value has been defined, a lean project management process is identifiable by the way it *flows* toward the owner's defined value. For JIT processing, the right elements need to be brought together at the right place, at the right time (i.e., in the right sequence), and in the right quantities. Once this happens, a construction project process—like that of a product assembly line—can start to flow. By contrast, failure to bring together the right elements, at the right place, at the right time, and in the right quantities, introduces *constraints;* that block the flow process. Unless constraints are removed, the construction process encounters a bottleneck, and the success metrics of lean—namely time, cost, quality, safety, and morale (Liker 2004; figure 3–3, p. 33)—start to suffer.

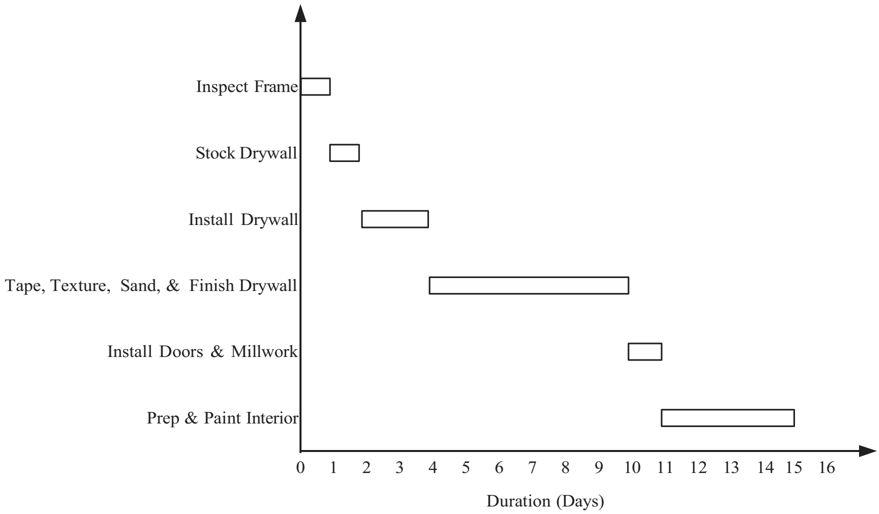


FIGURE 3.6 Example of bar chart.

Production control typically relies on a bar chart, where a horizontal bar extends from the very inception of the project to its conclusion. One of the simplest ways to visualize project flow is via a *line of balance* (LOB) schedule (also called a location-based or velocity schedule). A line of balance schedule is similar to a typical bar (Gantt) chart except that the vertical axis has been transformed into an abscissa (y-axis) onto which each activity's expected location is recorded. As with a bar chart, activity durations are represented along the ordinate (x-axis).

By way of example, Figure 3.6 shows a bar chart that was used to schedule the installation of drywall. When converted into a LOB schedule (Figure 3.7), activity rates and potential conflicts (Figure 3.8) become clear. Note that the rate is represented by the slope of the line, as the slope increases (the line becomes more vertical), the rate increases.

Similarly, as the slope decreases (the line becomes more horizontal), the rate decreases. If there is a need to complete a project sooner, rates of individual activities may be increased by adding labor and equipment. Gaps between activities may be minimized when there is a reduction of risk. Also, if a project's completion time is not urgent, the project manager can more easily identify opportunities to reduce labor or equipment dedicated to specific activities, confident that doing so will not adversely affect overall project completion time. On a line of balance schedule, flow starts when activity rates align. When flows become parallel, they approach the lean ideal (Figures 3.9 and 3.10).

Line of balance schedules may be used for heavy civil (horizontal) construction, as well as building (vertical) projects. For the latter, the y-axis is labeled according to floor levels or areas of repetitive work. Here, too, LOB scheduling makes it easier for managers to visualize constraints to flow. Once constraints have been identified

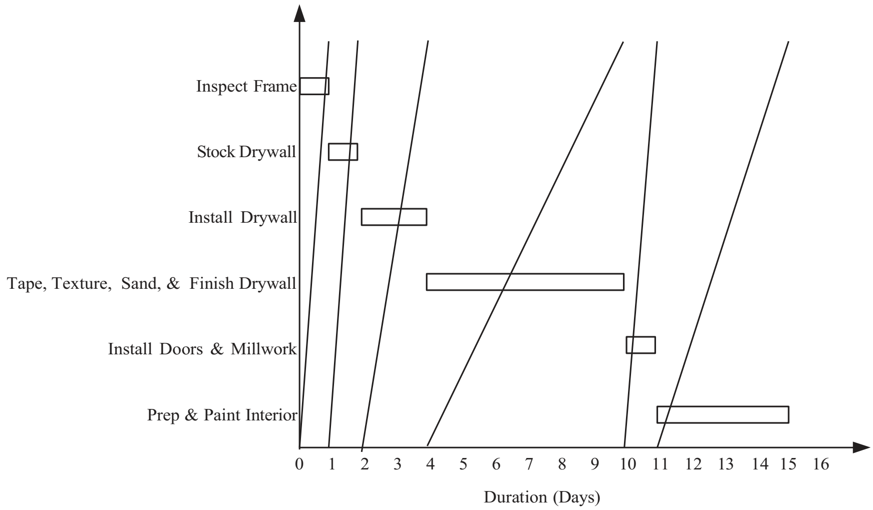


FIGURE 3.7 Example of bar chart representing installation.

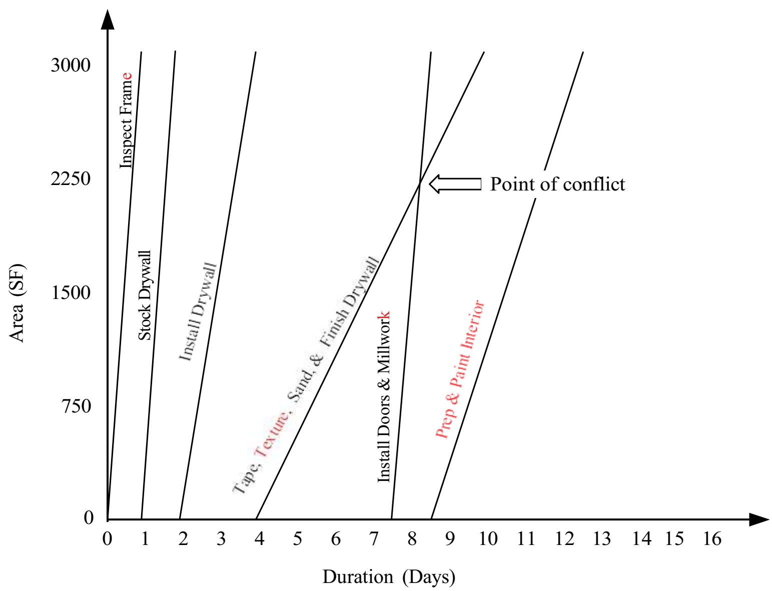


FIGURE 3.8 Line of balance.

and removed, productivity may be enhanced, and flow facilitated (Figure 3.9 and Figure 3.10).

Interestingly, achieving flow does not necessarily demand access to cutting-edge technology. For example, although the Empire State Building was constructed in the late 1920s in New York City without contemporary forms of technology, near

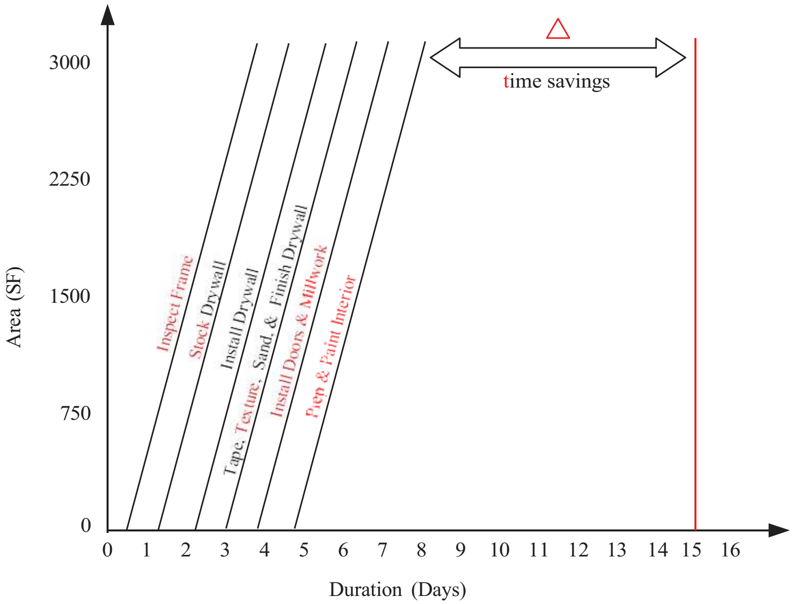


FIGURE 3.9 Parallel flow.

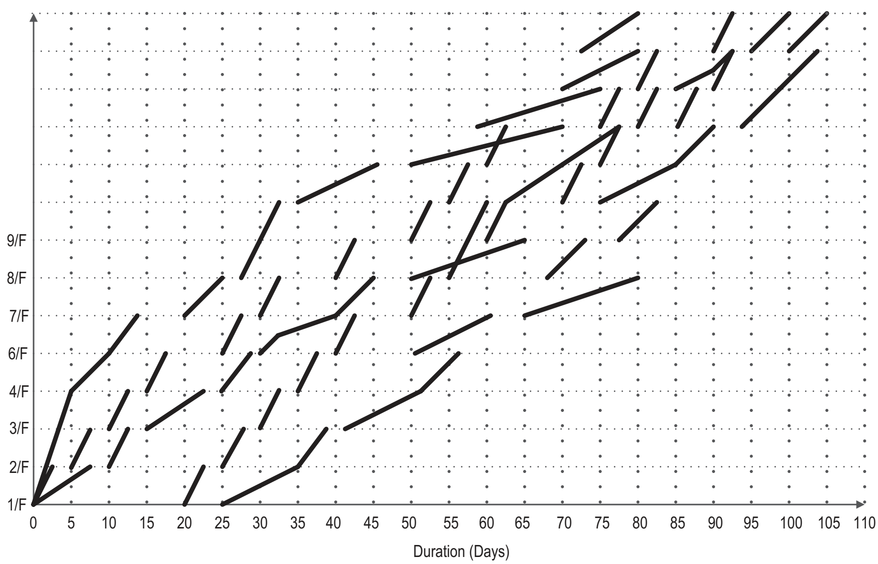


FIGURE 3.10 Example of line of balance.

FIGURE 3.11 Building section.

parallel flows were achieved, and the skyscraper was completed in just 16 months (Figure 3.11).

In order to understand how flow can be reached by implementing lean principles, it helps to begin with some of the insights of W. Edwards Deming that have contributed to contemporary lean thought.

Lean thinking is predicated on observations that blockages to flows often have less to do with worker incompetency, as is often believed, than to inherent inefficiencies of a system in which workers are asked to perform. This is because, unlike traditional project management that depends on the lone project manager to orchestrate construction processes, lean construction focuses on respect for the judgment and experience of those who actually perform the work. This belief lies at the heart of the work of one of the pioneers of pre-lean thinking, mid-twentieth-century statistician W. Edwards Deming. Deming exported his principles to post-World War II Japan, aiding the country's rapid economic recovery and subsequent quality revolution. Later in life, Deming facilitated workshops for business disciples, and recruited volunteers during these workshops to play his famous "red bead experiment." During the simulation, participants were asked to fill 50 depressions by dipping a dimpled paddle into a bin of red and white beads. Their task—to minimize the drawing of red ("problem") beads. Deming played task-master, he reprimanded workers for drawing too many red beads but also showered them with praise and promises of bonuses whenever a draw revealed a small number of red beads. Unaware that the ratio of red and white beads in the bin made success more a statistical fluke than a measure of actual accomplishment, participants struggled in vain to find ways to lower their red bead count. Deming used the simulation game as a metaphor to represent existing business practices in corporate America.

Like Deming, proponents of lean construction argue that traditional construction delivery methods are rigged. Through the collection of data, they demonstrate that efforts to improve productivity by stakeholders—owners, architects, engineers, contractors, specialty contractors, suppliers, and attendant industries—are continually frustrated because traditional construction delivery methods are riddled with wasteful practices and constraints that systematically clog process flow. As a result, attempts to improve time, cost, quality, safety, and morale routinely fail.

3.3.4.2.2 The Last Planner System of Production Control

Lean construction practitioners recognize that perfect flow toward value can be attained only if wasteful practices are eliminated, and variability and constraints systematically removed. To streamline processes, lean practitioners first map existing practices in order to identify and eliminate *waste*—anything that does not add value for which the owner is willing to pay. Ohno (1988) included the following seven outcomes and practices as waste: defects, overproduction, waiting, transporting, movement, inappropriate processing, and inventory. Additional outcomes and practices have since also been identified as waste by members of the lean construction community. But the message is clear: Wasteful activities unnecessarily drive up costs, extend processing time, imperil safety, degrade quality, and damage morale.

Lean project delivery methods, such as the *Last Planner System of Production Control*™ (LPS), were developed so that critical project stakeholders can systematically identify waste and constraints far in advance and remove each before activity work is scheduled to begin (Ballard 2000a). By way of example, in order to assemble prefabricated, flat-packed kitchen cabinets in a house, the following prerequisites are required: Wall and floor onto which the cabinetry will be hung, and installed; sufficient laydown area; shelves, cabinet doors, hinges, etc.; skilled labor; appropriate tools and equipment; weather that permits transportation of materials and labor, freedom from labor strikes, permitting issues, sufficient time, etc.; and an assembly instruction sheet. In other words, the following resources must be made available for assembly to take place: *Prerequisite work, space, materials, labor, tools and equipment, external conditions,* and *information*. Absence or delay of any of these elements represents a *constraint* that must first be removed for the process to flow.

Lean construction pioneers realized early on that one of the chief wastes in the industry is an inaccurate scheduling process. The reason traditional scheduling is so poorly informed is that knowledge is dispersed among those who actually complete the work. Scheduling centralized in the project manager is typically flawed because it has been developed by someone who does not actually complete the work. By contrast, LPS overcomes this limitation by engaging "boots-on-the-ground" personnel to collectively develop and inform the project schedule. Not to be confused with software solutions, LPS is often most effective as a "low-tech" application, engaging participants by asking them to arrange activities with colored notes ("stickies") on a wall. LPS uses *pull scheduling* (i.e., critical completion milestones are first established, and activities are scheduled backward in time from these milestones). In addition to including stakeholders in the advance for identification and removal of constraints, flow is aided by engaging them in an accountability exercise known as PPC, or *percent planned complete*, where the percentage of promises kept versus promises made is regularly recorded. The simple act of recording and publicly posting daily PPC has been shown to reduce the variability of scheduled work, and consequently enhance project flow (Ballard 2000a).

3.3.4.2.2.1 Reverse Phase Scheduling LPS is a method for applying lean techniques to construction. It emphasizes control by proactively assisting activities to conform to plan, as opposed to the construction tradition of monitoring progress against schedule and budget projections. A production planning and control system, it is the brainchild of the Lean Construction Institute co-founder, Glenn Ballard (Ballard 2000a). The term "last planner" refers to the front-line supervisor. Ballard initiated pull-in construction by asking construction partners to engage in a process known as *reverse phase scheduling*. Once a client's time constraint has been established, the deadline is fixed to a wall with a self-adhesive notecard. Team members then plan activities collaboratively and collectively—also on the wall using self-adhesive notecards—and backward from the posted deadline. The deadline establishes the basis for a type of *takt time*, which is the rate at which individual activities need to be accomplished in order to meet the client's required deadline. It must be mentioned here that, unlike a manufacturing assembly line where the final design is known before manufacturing the product, the last planner is applied while the design of a building is under development. This means precisely that the construction times of various phases of the building cannot be more than estimates and the term "takt time" must be applied loosely to the last planner as a general rate at which a project must be "pulled" in order to meet the required time constraints. Nevertheless, the analogy is helpful for understanding how lean construction principles intersect with those of lean manufacturing.

There are four components of the Last Planner System—Master Scheduling, Phase Scheduling, Lookahead Planning, and Commitment/Weekly Work Plan—as graphically depicted in Figure 3.12 (Hamzeh 2009). The last two phases, lookahead planning and weekly work plan, are of special interest to us here.

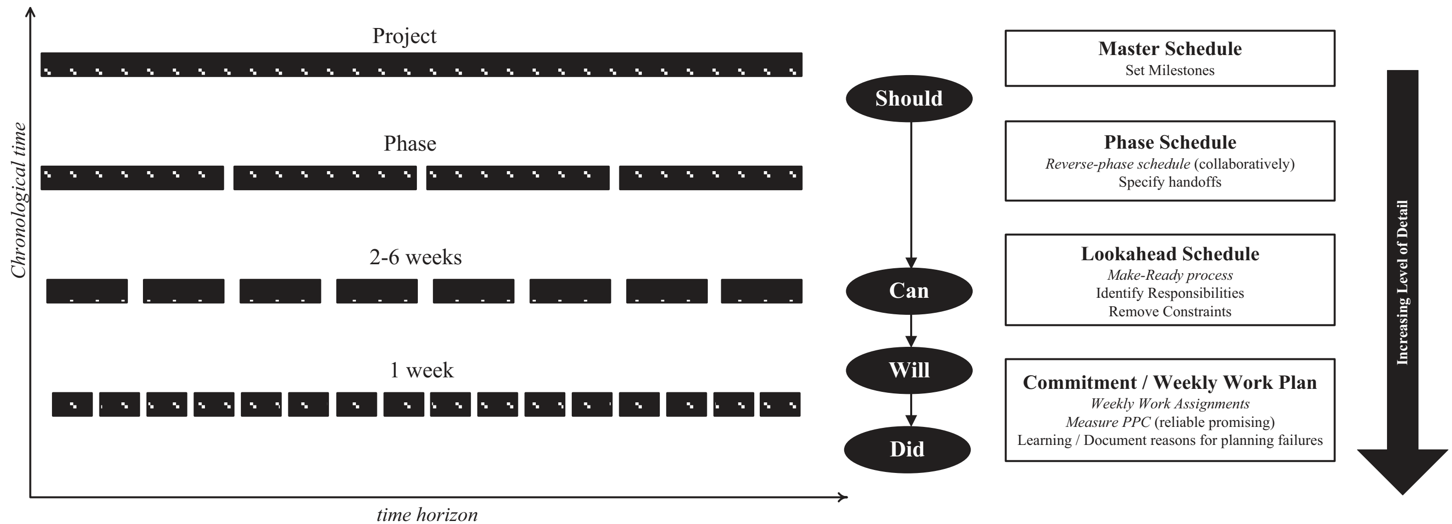


FIGURE 3.12 The last planner system.

Reverse phase scheduling (RPS) or "pull planning" is used as a starting point for the Last Planner System. It is a detailed work plan that specifies the handoffs between trades for each project phase (Ballard and Howell 2003). In practice, subcontractors participate extensively in RPS on a wall-mounted board to plan their schedules in concert with the schedule for each project phase. Traditional construction emphasizes pushing tasks to meet this optimistic schedule, with little thought to what CAN and WILL be done. In LPS, the master schedule is refined as a reverse phase schedule by using a team to work backward from the expected completion date. This team comprises the "last planners" from different trades/subcontractors. The master schedule and reverse phase schedule indicate what work SHOULD be done in order to meet the schedule.

During *lookahead planning*, constraints are systematically removed to ensure that which SHOULD be done CAN be done. The *weekly work planning* process then assures that which CAN be done actually WILL be done (Figure 3.12).

The Percent Plan Complete (PPC) "public" declaration accounting system incentivizes those who commit to performing various tasks to follow through with their commitments. Root cause analysis of problems encountered on that which the team actually DID, helps generate countermeasures that will enshrine learning and advance the team toward a more advanced step of the lean plan-do-check-act cycle—ensuring never-ending levels of continuous improvement.

It might be argued that a critical purpose of the last planner, is to serve as a series of conceptual kanbans, where metaphorical carts have been replaced by a scheduling directive called the *weekly work plan*. Although last-planner-as-kanban is an imperfect metaphor, the two processes share some common traits. On the weekly work plan, the "last planner"—the individual responsible for organizing final work assignments for the overall project—divides work into defined (often day-long) batch sizes. The last planner then "fills the kanban carts"—assigning work to each day of the work week. Like the bus driver who must wait at a stop to conform to an overall transit plan if he/she arrives ahead of schedule, no member of a team may perform work either before or after his/her turn has been designated. Team members are, in effect, informed by the last planner facilitator about when to get on the bus—not a moment before and not a moment after the appropriate time. This is the essence of the just-in-time system, so integral to lean thinking (Rybkowski 2010).

Most construction projects are unique to their site and function. Because of the one-off nature of most construction projects, no one individual—not even an experienced project manager—can know all that is required to fill the metaphorical kanban carts. The last planner acknowledges this by engaging the "Big Room" concept of meetings common to lean thinking. The term Big Room refers to the need to bring together all those who are critical to the design of a building so that their knowledge can inform that which needs to be done during a regular specified time period. The day or half-day of a weekly workplan in the Last Planner can be imagined as an empty kanban cart waiting to be filled with resources that will be transformed at designated stations. In Figure 3.13, the collective experience of team members in the Big Room is symbolized by a cloud of shared knowledge.

Naturally, one risk of a just-in-time delivery system is that it may place an unfair burden on those who must fill a cart. Anyone who has heard the words "I need it tomorrow"

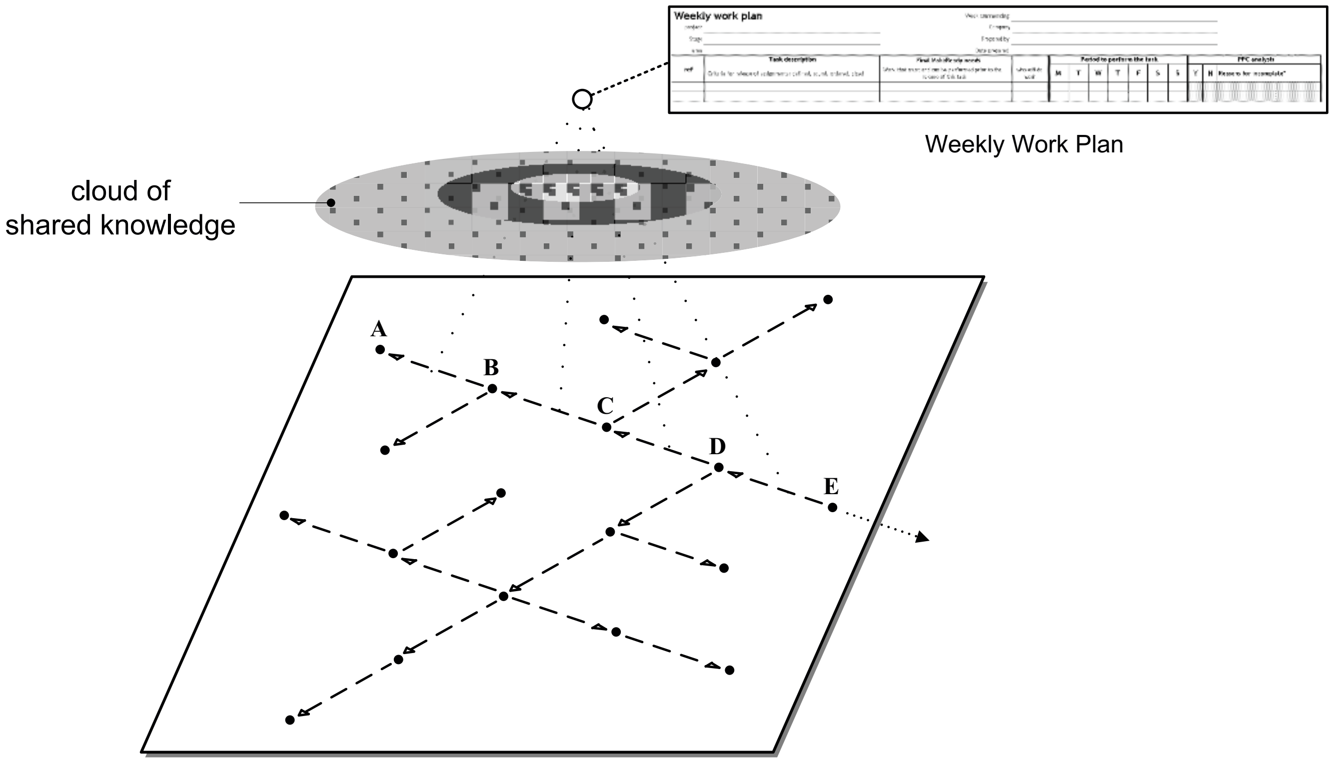


FIGURE 3.13 The last planner "kanban."

or, worse yet—"give it to me now"—knows how unreasonable such directives can be. Responding to this, lean practitioners frequently use the phrase "last responsible moment" instead of just-in-time. The lookahead plan of the Last Planner System focuses on constraints analysis and removal, making JIT achievable, as shown in Figure 3.14.

3.3.4.2.2.2 Removing Constraints

By the time a task is committed during a weekly work plan meeting, the expectation is that it will be completed as scheduled to maintain a predictable flow of work through the network of specialists. Therefore, anything that might hinder completion of the task needs to be cleared before it is assigned. During lookahead planning (2–6 weeks before weekly work plan assignments are made), tasks are *made ready.* In a landmark paper on shielding, Ballard and Howell proposed five *quality criteria* against which a task must be checked before it is allowed into the weekly work plan (Ballard and Howell 1998). These are:

1. *Definition:* Is the task specific? Will it be clear when it has been finished?
2. *Soundness:* Are all materials available, including completed prerequisite work, for the task to be performed?
3. *Sequence:* Is the task being performed in the correct order?
4. *Size:* Is the task sized to the capacity of the crew?
5. *Learning:* When assignments are not completed, are they tracked, and reasons identified?

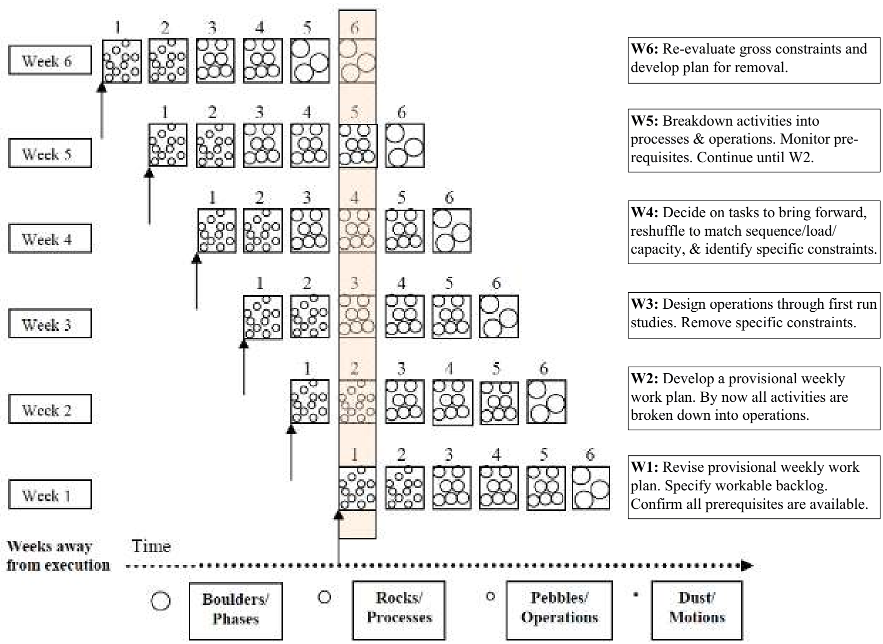


FIGURE 3.14 Six-week lookahead planning.

TABLE 3.3
Weekly Work Plan

Ref	Task Description	Final Make Ready Needs Work That Must be Performed Prior to the Release of this Task	Who Will do Work	Period to Perform the Task							PPC Analysis		
				M	T	W	T	F	S	S	Y	N	Reasons for Incomplete

The facilitator of the meeting checks for these conditions in order to ensure that the *customer* of any task (the trade that immediately follows) is furnished with all that is necessary to complete the task successfully. Because all downstream work suffers when a task cannot be completed, it is crucial that the facilitator rigorously honor this checklist. Once a task has been made ready, it can safely be assigned to enter the flow.

The quality criterion "soundness" is satisfied through constraint analysis and removal. In the public transit metaphor, the quality criterion "soundness" is analogous to a parent who wakes up, dresses, feeds a school child, and sends her/him to the bus stop in time to board the bus at its scheduled arrival time. As in the metaphorical kanban cart, a weekly work plan signals a request for a task to be completed for the customer that follows (Table 3.3).

It includes critical information such as the description of the task, a final check that all prerequisite tasks have been completed and all quality criteria have been met, and an indication as to when the task will be performed that week.

3.3.4.2.2.3 Percent Planned Complete Variability is undesirable when attempting to achieve flow. To test this principle, Tommelein (1997, 1998, 2000) developed two computer models to simulate variability within manufacturing processes. The researcher compared the total time required to complete a process when individual component tasks were assigned deterministic (set) times versus when they were assigned stochastic (distributed) completion times. The results demonstrated the detrimental impact of variability on flow. Figure 3.15 illustrates the same.

The impact of variability is important because work cannot be infinitely buffered. The weekly work plan kanban "batch" of one day, for example, still requires a defined time limit that should not be exceeded if flow is to be maintained. The assumption is that some work will be accomplished more quickly, and other work will take longer than planned. Using a public bus route as a metaphor, a scenario may be envisioned where traffic is so light that the driver arrives at stops ahead of schedule. Alternatively, a bus driver may be trapped behind an unforeseen traffic accident—making the vehicle arrive at stops later than any reasonable amount of buffering could have accommodated. But, in addition to some events that may be beyond a driver's control, buses can also be delayed by unmotivated or careless bus drivers. Accountability is important because it increases reliability and reduces

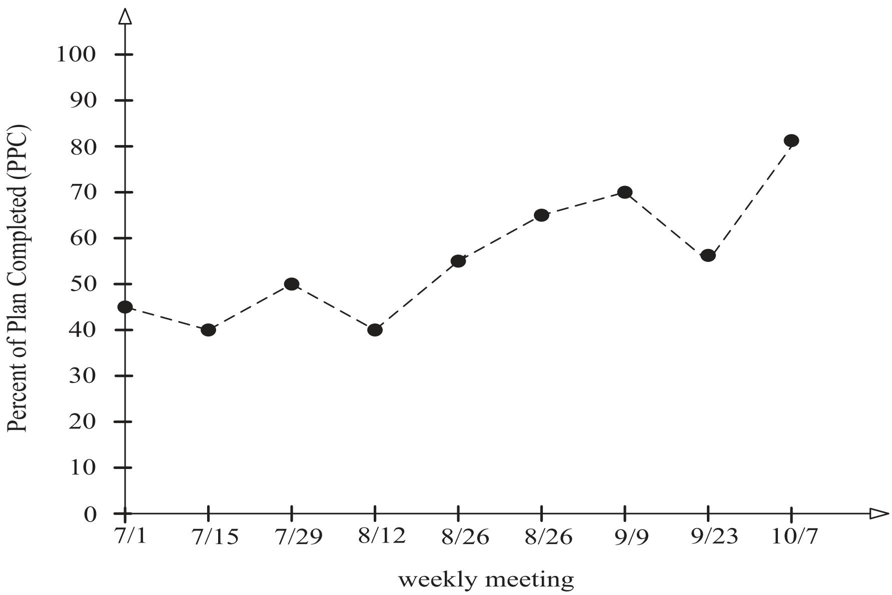


FIGURE 3.15 Percent plan complete (PCC) chart.

variability. For public transportation networks in the US to operate according to a reliable schedule, drivers operating ahead of schedule often pause longer at specified stops to realign their actual schedule with the publicly posted schedule.

The critical nature of worker accountability is recognized by the LPS. For example, a measure of workflow reliability called *Percent Plan Complete (PPC)* is embedded in the weekly work plan process; PPC is used to increase the reliability of planning by reducing variability. The idea is that specific tasks are designated to be completed before the next "Big Room" Last Planner meeting is listed. During the Last Planner meetings, each list is checked for its level of completion. Research has demonstrated that when more disciplined screening of potential commitments is used in combination with urgent expectations and peer pressure to make reliable promises, PPC increases. This increase suggests that the reliability of planning increases (Ballard 1999; Ballard and Howell 1998).

Because the variability of completion times for dependent activities negatively affects project schedules, it is advantageous to reduce variability. A publicly posted PPC chart increases the reliability of deliverables by motivating workers to maximize their PPC ratings.

It is important to note that PPC should not be mistaken as an indicator of productivity. In fact, stakeholders sometimes under-promise simply to boost their PPC score. The role of PPC is instead to enhance the reliability of the work promised, making future planning more reliable.

When a task is not completed as planned, the weekly work plan includes a section to indicate the cause for the divergence under "reason for non-completion" in order to incorporate learning into the process should a similar situation arise again.

3.3.4.3 Target Value Design

Target Value Design (TVD) involves designing to a specific estimate instead of estimating based on a detailed design. It seeks to address the problem that affects many projects, namely, designing and constructing a building that costs more than expected. Traditionally, various design disciplines work from a common schematic design to develop designs in their areas of expertise. Working in their respective offices they are subject to "project creep." With little cross-functional collaboration project designs often become overpriced, unconstructible, and behind schedule. (Forbes and Ahmed 2010) Corrective action may include a misuse of value engineering to radically cut the scope of a project or to suppress certain features that are desirable, but unaffordable. Furthermore, the lack of collaboration often results in early design decisions that are later found to be suboptimal, but difficult to change. Ultimately, much time and effort are wasted, and the design cycle is longer than it should be. These wastes run counter to the lean philosophy.

Since TVD applies target costing to building construction, it helps to first define target costing. According to Cooper and Slagmulder (1997), "Target Costing is a disciplined process for determining and realizing the total cost at which a proposed product with specified functionality *must* be produced to generate the desired profitability at its anticipated selling price in the future." It is perhaps simplest to illustrate target costing as it applies to product design and then highlight how target costing differs from traditional product costing. In traditional product costing, a manufacturer may add a profit markup to a product's production cost to establish its selling price. The problem with this method is there is no guarantee that buyers will be willing to pay the asking price. The process of target costing, by contrast, implements a reverse strategy; the market price is *first* established by determining how much buyers might be willing to pay, by using focus group research, or by looking to similar products on the market, for example. A desired profit is then subtracted to give product designers the cost to which they must design the final product:

Target cost = Target Price-Target Margin (Clifton et al. 2004)

The concept of target costing, as applied to product design, can also be envisioned diagrammatically, as shown in Figure 3.16.

TVD builds on the concept of target costing but represents target costing applied to construction rather than product design. While it is helpful to understand the genesis of target costing in product development, the terms used by the TVD community differ somewhat in their meaning and include four distinct components, as defined by Glenn Ballard: *Market cost*, *allowable cost*, *expected cost*, and *target cost*. They are defined as follows (Figure 3.17).

Market cost is a benchmark cost; it consists of the cost per square foot that would be expected for comparable construction projects. *Allowable Cost* represents the maximum cost that must not be exceeded; if the project team cannot design to allowable cost, the project must be canceled because it would, by definition, become financially unfeasible. *Expected cost* is the estimated cost of the project in its current state during the TVD process; the expected cost is continually recalculated with each new

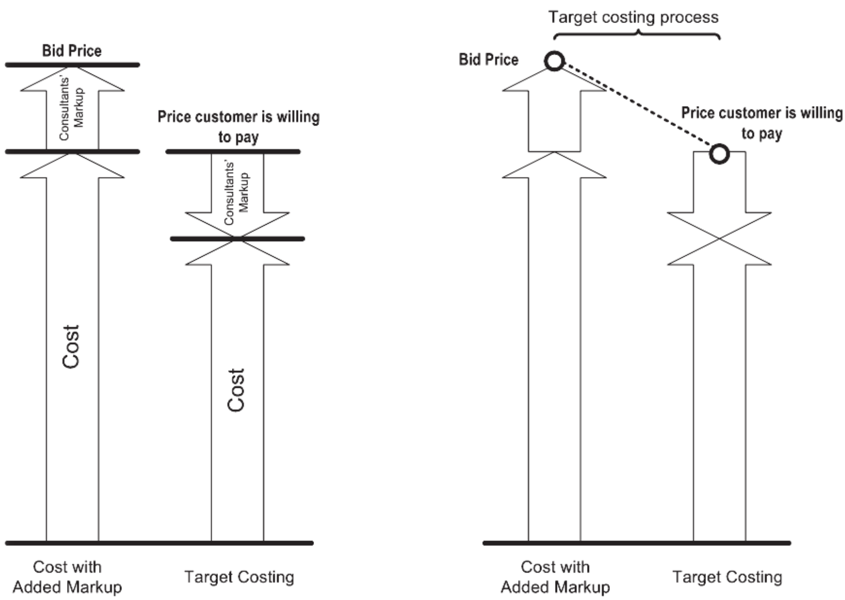


FIGURE 3.16 Cost with added markup.

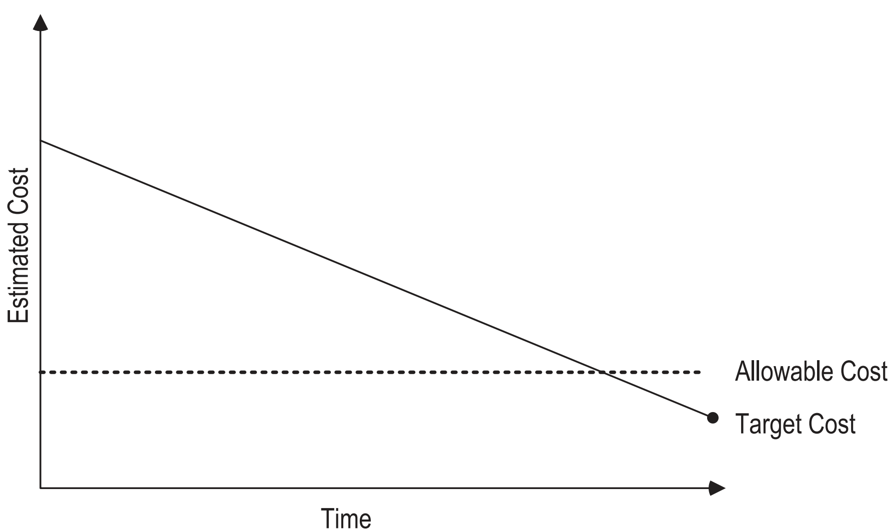


FIGURE 3.17 Diagram of the target value design process.

iteration of design. *Target cost* is the stretch goal for the project, meaning it is usually set below allowable cost (Ballard 2009; Rybkowski 2009).

TVD also proposes that designers should "do it right the first time" and build constructability into their designs, as opposed to designing first and then evaluating constructability later. TVD recommends concurrent design, with various disciplines in ongoing contact, as opposed to periodic reviews. Solution sets should be carried forward in the design process to ensure that good alternatives can be available later—a process known as *set-based design*.

Macomber et al. (2005, 2008) proposed a number of foundational practices for target value design. These practices promote "design conversation" as they see design as a social activity that involves several professionals focusing on meeting the needs of the client. This approach is especially effective in light of the fact that the client's needs can change over time and value assessments need to be repeatedly made to ensure that design decisions meet these needs.

1. Conduct design activities in a big room (*obeya* in Japanese). (Refer to Section 4.3.2.3.2—"The Role of the Big Room in TVD"). Toyota has used the obeya concept successfully, especially in product development, to enhance effective and timely communication. The obeya is similar in concept to traditional "war rooms."
2. Work closely with the client to establish the *target value*. Designers should guide clients to establish what represents value, and how that value is produced. They should ensure that clients are active participants in the process, not passive customers.
3. Once the *target value* is established, use it to work with a detailed estimate. Have the design team develop a method for estimating the cost of design alternatives as they are developed. Deviations should not continue unchecked; if a particular design feature exceeds the budget allocated for it, that design should be adjusted promptly in order not to abort further design work that cannot be accepted.
4. Apply concurrent design principles to design both the product and the process that will produce it. This work should be done as a collaboration between architects/engineers, specialty designers, contractors/subcontractors and the owner. Be flexible to include innovation in this process. Practice reviewing and approving design work as it progresses.
5. Practice set-based design where multiple potential design solutions are carried forward, ensuring time and resources are not wasted if scope changes or previously unknown constraints are discovered later in the design process.
6. Work in small, diverse groups. Groups of eight or fewer people facilitate better group dynamics—it is easier to create a spirit of collegiality and trust that leads in turn to more innovation and learning.
7. Design with the "customer" in mind. Focus on designing in the sequence of the discipline that will use it. Use the "pull" approach with each design assignment to serve the next discipline. Lean is obtained by meeting downstream needs as opposed to producing what is convenient. Overproduction increases the possibility that the work so produced may not be what is

needed for the next discipline to maintain its schedule, and it may lack the collaboration necessary for constructability.
8. Collaboratively plan and re-plan the project. Planning should involve all stakeholders to continually maintain an actionable schedule. Joint planning will refine practices of coordinating action. This will avoid delay, rework, and out-of-sequence design.
9. Lead the design effort for learning and innovation. Expect the team to learn and produce something surprising. Also, expect surprise events to upset the current plan and require more re-planning.
10. Learn by carrying out conversations on the results of each design cycle. Include all project participants in order to capture knowledge on success factors. Use this information as a part of the PDCA cycle, and use formal measurement systems, if possible.

The steps involved in TVD are shown in Figure 3.18. Note that each step of the TVD process requires a re-evaluation of whether or not the project team should proceed based on a realistic assessment of whether or not the stakeholder group can meet the agreed allowable cost that had been validated during the project definition phase.

3.3.4.3.1 Integrated Project Delivery and TVD

Waste in design-bid-build construction occurs mostly in the interaction between trades. Traditional contracts are written with the intent of transferring risk to one party at the expense of the others. The result is multiple parties working for their own self-interest rather than for the good of the project. By contrast, IPD contracts are written to provide financial incentives for behavior that is good for the overall project, harnessing natural self-interest as a beneficial project delivery driver. IPD involves a contractual combination of Lean Project Delivery and an integrated team that is expected to improve project performance in a number of dimensions. If the process is successfully executed, owners benefit from reduced time and cost as well as improved quality and safety. Designers and contractors derive increased profits, improved owner satisfaction as well as greater employee satisfaction.

With traditional design-bid-build delivery, stakeholders are often brought into the process too late—after the ability to affect cost and function has already passed. By contrast, with IPD, key stakeholders are involved early enough in the process to influence critical design decisions. This relationship is famously represented by the MacLeamy curve (Figure 3.19).

IPD is designed to support the values and principles of Lean Project Delivery, that is, to reduce waste and provide value for the owner. Whereas traditional contracts anticipate adverse events and focus on transferring risk, the integrated agreement seeks to reduce risk by empowering team members to use lean thinking and collaborative approaches. In fact, the collaborative problem-solving skills of the project leadership team, that is, the owner, designer, and contractor enable it to transcend unexpected challenges and function as an agile, high-performing team that delivers projects successfully.

IPD was developed to improve innovation by moving money across boundaries (Alarcón et al. 2013). IPD is defined as a delivery system that seeks to align interests,

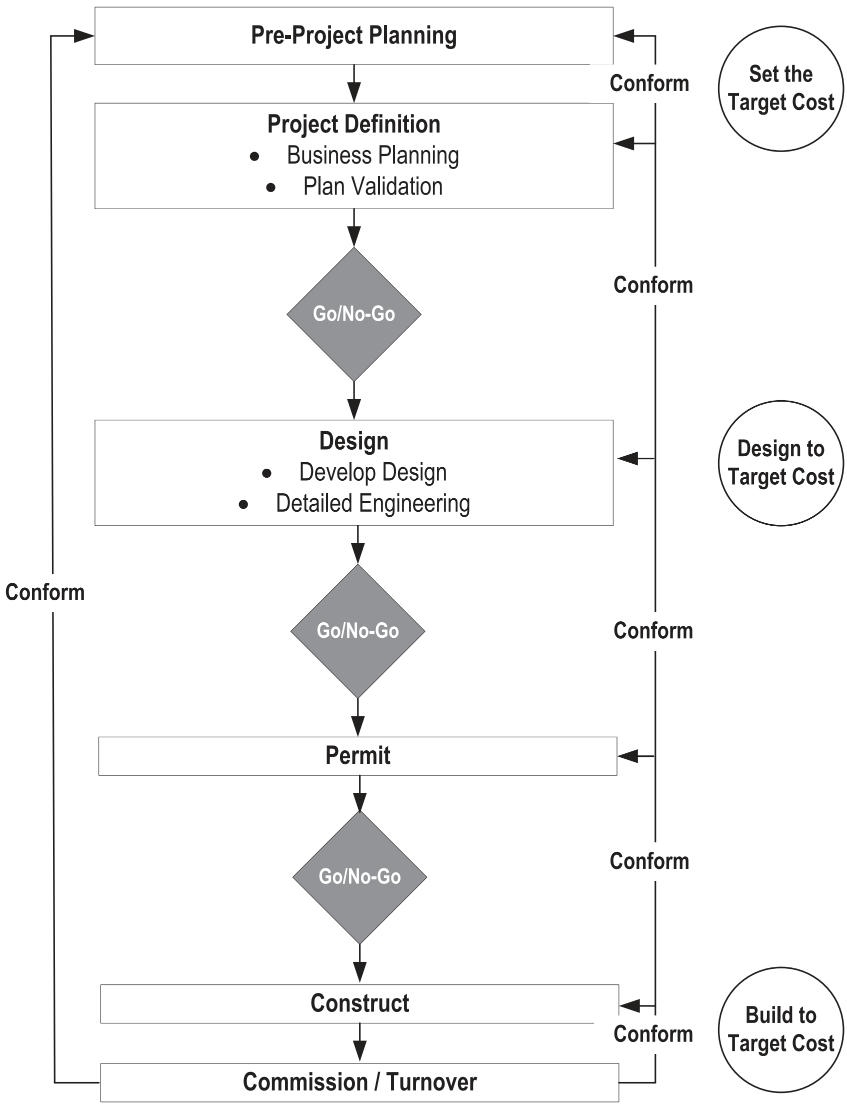


FIGURE 3.18 Target value design process.

objectives, and practices, even in a single business, through a team-based approach (LCI 2011). The primary team members include the owner, architect, key technical consultants, a general contractor and key subcontractors. An organization is created that is able to apply the principles and practices of the Lean Project Delivery System™. The American Institute of Architects (AIA) has recognized IPD as an effective project delivery method and defines it as:

> a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and

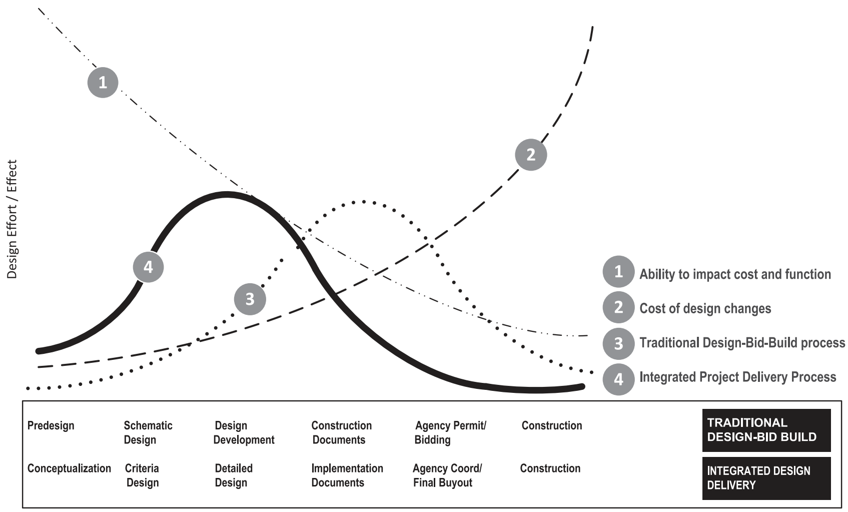


FIGURE 3.19 The MacLeamy curve.

insights of all participants to optimize project results, increase value, to the owner, reduce waste, and maximize efficiency through all phases, design, fabrication, and construction.

The first IPD application involved a central chilled water plant built by Westbrook Air Conditioning and Plumbing of Orlando, Florida (Forbes and Ahmed 2010); Matthews and Howell 2005). Westbrook held a design-build contract with the owner but developed a separate business entity with design professionals and construction subcontractors, termed Primary Team Members (PTMs). Through teamwork, innovation, and optimization, work and costs moved between different companies to improve performance and reduce overall costs. The team saved 10% of the contract cost (Matthews and Howell 2005).

Some versions of IPD involve an Integrated Form of Agreement (IFOA) as a single contract between the owner, the architect, and the construction manager or general contractor. The IFOA involves a core group of representatives of the owner, architect, and GC/CM to administer the project. As shown in Figure 3.20, the core group selects the remaining members of the IPD team including engineers, technical consultants, key subcontractors, and suppliers.

Sutter Health is a not-for-profit community-based healthcare and hospital system headquartered in California. Faced with a state mandate (and penalties) to upgrade inadequate facilities, they embarked on a very tightly budgeted \$6.5 billion design and construction project starting in 2004. Sutter Health embraced the lean philosophy (as a leap of faith) and engaged Lean Project Consulting Inc. to guide the adoption of IPD. McDonough Holland & Allen PC, Attorneys at Law, provided legal services, especially in developing an early version of the IFOA. In order to derive the greatest synergy from team integration, the CM/GC entity was engaged immediately

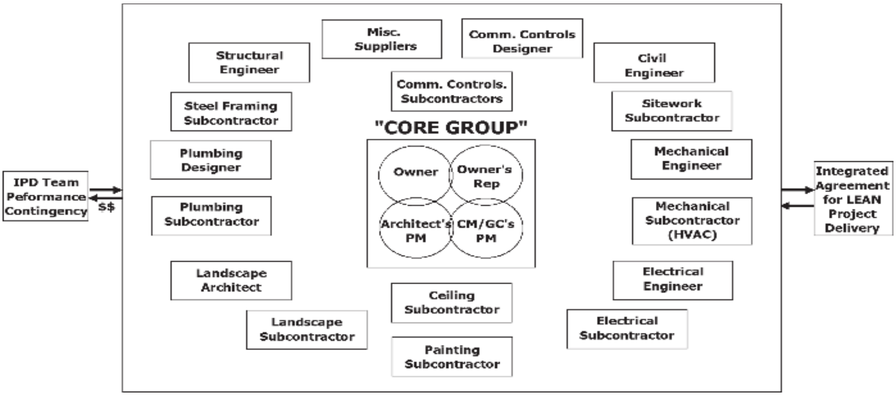


FIGURE 3.20 The Sutter Health integrated project delivery system.

after the architect selection. Major subcontractors were also engaged as early as the schematic design phase. While this approach incurred expenditure for professional services earlier than traditional construction practice, the Sutter organization felt that the resulting collaboration led to improved constructability and savings that far exceeded the added cost.

The core group served in an administrative oversight role, scheduling meetings and problem-solving sessions. The group maintained an open information flow and ensured that all parties worked together harmoniously, using 3-D BIM, target value design, and the Last Planner System™. They promoted the network of commitments needed to achieve reliable workflow. In IPD, this reliability is critical to maintaining a smooth hand-off of work from one crew to another. Cost savings and owner satisfaction attest to Sutter Health's lean project successes (Forbes 2009, 2014).

3.3.4.3.2 The Role of the "Big Room" in TVD

The "Big Room" (obeya) is a term that describes a space where project team members can work collaboratively and in close proximity as opposed to being located remotely. While it may not be feasible for all teams to co-locate continuously, the Big Room environment can be created for project meetings through the use of site trailers that are appropriately equipped with adjacent meeting rooms for "break-out" sessions. The equipment may consist of wall-mounted schedule boards, A3 charts, flip charts mounted on easels, dry-erase whiteboards, projection equipment such as a smart board, and audiovisual equipment for long-distance meetings with remote locations.

The Big Room houses project leaders and key staff in close but comfortable proximity to shorten the communication path and promote an effective PDCA cycle. Spontaneity comes easily as specialists can collaborate readily in key design or construction decisions

Big Room activities include:

- Revolving schedules with agendas for meetings of the complete team including designers, suppliers, subcontractors, the management team, last planners, and others;

- Agendas vary with the needs of each project and ensure the right people are included;
- Status reviews, presentations and pull planning sessions;
- Learning opportunities, such as orientation, onboarding, and ongoing lean training;
- "Gemba Walks" to the site to "Go and See" —a lean practice; and
- "Plus/Delta" discussions for continuously improving the meeting process.

3.3.4.3.3 The Role of BIM in TVD

The continuous improvement culture of lean means that a lean project team is potentially willing to consider adopting any approach or tool that may reduce waste and add value—within a culture of respect—and so improve performance in terms of time, cost, quality, safety, and morale. For example, BIM supports initiatives that are critical to lean design and construction. As the fundamental principle of lean is to reduce or eliminate waste, BIM addresses many aspects of waste that occur first in the design phase, and later in the construction phase.

Lean design promotes the active participation of construction stakeholders as early as the project definition phase. As the design concept is developed, designers, owners, and constructors work interactively to make decisions that influence the overall project—concurrently and in real time. Traditional design reviews are treated as sequential events, long after significant design decisions have been made. At that point, changes can quickly become time-consuming and expensive. Furthermore, as many disciplines are involved in the design of a project, changes in some elements of the design may not be fully represented by all the disciplines. In traditional projects, that oversight often manifests itself as errors and omissions—classic examples of waste.

A lean construction process known as target value design is enhanced with BIM. Cost impacts of the design are quickly determined in a concurrent manner, instead of relying on the traditional estimating approach. The "Big Room" or *obeya* concept is adopted in lean construction from the Toyota Production System and brings together cross-functional teams under one roof to explore problems. During TVD, team members generate synergy by collaborating on not just the design but also on the construction process required to bring it to fruition. BIM provides a critical platform for Big Room meetings. "What-If" games can be played with various design approaches, and the results can be evaluated immediately.

Clash detection is easily accomplished with BIM—design errors often include having different building systems compete for the same limited space in ceilings and building penetrations from floor to floor. Air conditioning ducts and plumbing/fire protection piping typically compete for that space. When these clashes are detected during field installation, corrective action can have significant consequences. Bends in ducts and pipes that were not part of the original design increase their equivalent length and may restrict the flow of air or water below the design levels defined by the mechanical engineer. That, in turn, leads to suboptimal building performance.

BIM has features that promote prefabrication—an important component of lean construction. As the BIM data is machine-readable, CNC machines can be readily provided with instructions for making sections of ductwork, piping, or other building elements under controlled conditions in fabrication shops. Such off-site work is more cost-effective and more accurate than on-site work, yet the accuracy provided with BIM allows such prefabricated components to literally be unloaded from a truck and mounted in place with fewer work hours than otherwise possible with traditional methods.

Lean design with BIM was successfully used on the El Camino Medical Group's campus in Mountain View, California. A 250,000 SF medical office building was included in the project, as well as a 420,000 SF parking structure, at a cost of $94.5 million. The project schedule was highly accelerated for early occupancy; hence, it was necessary to utilize concurrent engineering approaches to start construction activity while the design was still in progress. The general contractor and a number of mechanical subcontractors were engaged during the design phases at approximately the same time as the architect and the structural engineers. The contractors and designers collaborated on the design to derive maximum constructability, lower cost, and an aggressive construction schedule. The team collaborated with a virtual model of the project. Design focused not only on the product but also on the construction schedule, including material supply and prefabrication activities

Results at the end of the project were as follows:

- The project was completed six months earlier than would have been achieved using the traditional design-bid-build project delivery method without BIM and lean techniques;
- It was completed under budget;
- Labor productivity was 15% to 30% better than the industry standard;
- There were no change orders related to field conflict issues; and
- There were no field conflicts between the systems coordinated using BIM.

As was experienced in this project, 3-D modeling is one of the tools used to improve both the design and construction processes. It not only helps designers to visualize and avoid potential design conflicts between different trades, it simultaneously generates bills of materials. 3-D modeling can also be used to simulate facility design and the construction and fabrication process.

3.3.4.4 Lean Tools and Techniques

The fundamental engine of lean thought—continuous improvement (Kaizen) —requires a project manager to think clearly about the meaning and nature of improvement and standardization. The promise of lean thinking is that if improvement is done collaboratively with key team members in a culture of respect, with an aim to reduce waste and add value, then all project metrics—that is, time, cost, quality, safety, and morale—should improve simultaneously. If only four of the five metrics improve, the recommended improvement is *not* lean and needs to be rethought. This is why lean construction may be considered to be a paradigm shift. For example, although both Frederick Taylor and Henry Ford developed early theories of production flow on which lean theory is partially based, Taiichi Ohno sharply criticized Ford for his disrespect of the worker. As Norman Bodek wrote in his foreword to Ohno's book: "Manufacturing must be both efficient and also have respect for the person running the machine" (Ohno 1988, p. x: publisher's *Foreword*).

3.3.4.4.1 *Plan-Do-Check-Act (PDCA) Cycle: The Continuous Improvement Engine*

The design engine of lean construction—the plan-do-check-act cycle—operates within a culture of continuous improvement, as suggested by Figure 3.21, and played a central role in the work of Shewhart and Deming (1939). For this reason, the PDCA cycle is also variously called the "Deming" or "Shewhart" cycle.

The PDCA circle really represents the scientific process of developing a hunch or hypothesis of how a challenge may be met (plan), testing the hypothesis through experimentation (do), checking to see if the results of the experiment validate the hypothesis (check), and then modifying the hypothesis to better explain the results obtained (act). Since there is ever more to know, the circle is perceived as continuous and never-ending.

The PDCA engine (Figure 3.22) may be represented as part of an overall chain of continuous improvement and standardization, as shown previously in Figure 3.3.

In lean construction, the process of continuous improvement, also known as *Kaizen*, is conducted collaboratively and often in a big room, so that key stakeholders

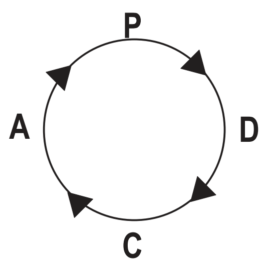


FIGURE 3.21 PDCA or Deming cycle.

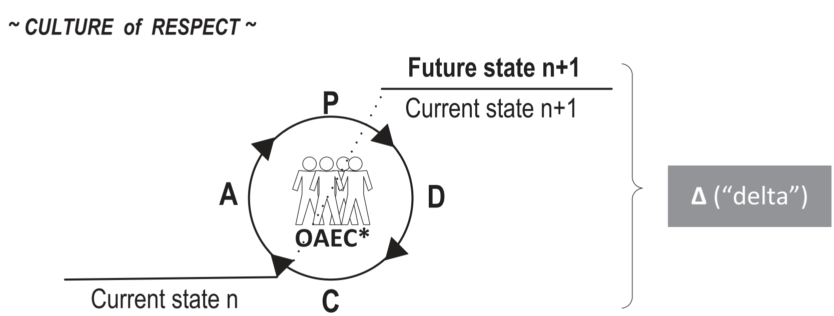


FIGURE 3.22 Graphic definition of the lean construction PDCA engine.

+	Δ

FIGURE 3.23 Plus delta chart.

representing the owner, architect, engineers, and constructors participate in the process.

3.3.4.4.2 Plus Delta Chart (+/Δ)

To feed the PDCA cycle and recognition of areas that can be improved, a number of tools have been developed.

Before improvement can take place, the current state situation needs to be documented, and a desired future state proposed. Several tools are used by lean construction stakeholders to facilitate this. One of the most popular tools is called a *plus delta chart* (+/Δ; Figure 3.23).

Most lean construction meetings end with a +/Δ debriefing exercise. Although seemingly simple, a +/Δ exercise is quite effective. During a +/Δ session, a facilitator invites all meeting participants to openly offer what they feel worked effectively during a meeting as well as what they feel can be improved. Several rules must be obeyed: the facilitator *must* record all comments proffered (i.e., they may paraphrase but not edit). This is important because doing so motivates participants to speak up; some of the best ideas emerge when an environment is perceived as safe and nonconfrontational. In the plus (+) column, the facilitator records those items that participants feel worked well and that should be repeated. Note that the column headings are written as +/Δ rather than +/-. The distinction, though seemingly subtle, is actually significant. While minus (-) implies fault-finding, lean principles are designed to reinforce a culture of collaboration and to motivate teams to continually improve toward a higher future state—a process that is antithetical to fault-finding. Unlike (-), (Δ) involves visioning an improved future situation. The distinction is exemplified by the difference between saying "the meeting food was terrible" (-), and instead saying "it would be nice to serve more vegetables at future meetings" (Δ).

3.3.4.4.3 The Ishikawa (Cause and Effect) Diagram

The fishbone diagram or cause and effect diagram was developed by Kaoru Ishikawa. The diagram also bears his name. It serves as a tool to find the sources of quality problems, or in fact, almost any type of problem (Forbes and Ahmed 2010). It focuses attention on causes, not just symptoms. The diagram looks like the skeleton of a fish, with the problem represented by the head of the fish. The ribs represent possible causes, and the smaller bones are sub causes. The process works best with a group of people who are familiar with the problem, or who may be involved with it. A facilitator works with the group, helping them to work backward from the observed effect caused by the problem, asking "Why." The diagram serves as an important communications tool as users examine target processes in great detail in order to find a solution to the problem that is associated with it.

Typical "ribs" might include: Machines, materials, methods, and people, as many problems can be traced to the influence of one or more of those factors.

Guidelines for problem-solving with the diagram are:

1. State the problem clearly in the head of the fish.
2. Draw the backbone and the ribs.
3. Working with the facilitator, work backward from the head of the fish, and write along each rib a potential cause of the problem.

A generic diagram is shown in Figure 3.24.

3.3.4.4.4 Pareto Analysis

Not all causes are equal in their impact. After a fishbone diagram is constructed, it is important to identify the causes that have the greatest impact and to focus on developing countermeasures to address the most significant causes. This can be done by creating a Pareto chart.

The Pareto chart is named for an Italian economist, Vilfredo Pareto (1848 to 1923), who studied the distribution of wealth in Europe. He proposed an economic

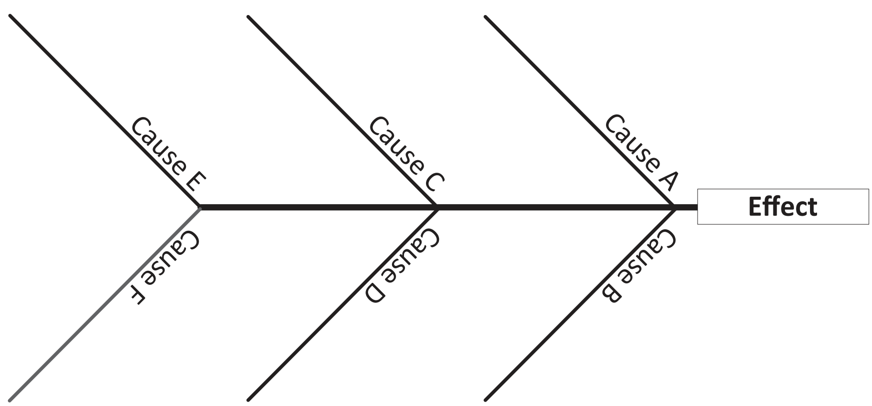


FIGURE 3.24 Ishikawa fishbone diagram.

theory based on the observation that a few people were very wealthy, while a large number of people had relatively little means. Essentially, 20% of the people in Italy held 80% of the wealth, hence the "80–20" rule. Joseph Juran applied this concept to the field of quality distinguishing between the "vital few" and the "useful many." The Pareto chart helps users to identify those 20% attributes that represent 80% of the benefit. Faced with a variety of problems, a user can find the 20% that, when addressed, provides 80% of the benefit.

The example shown in Table 3.4 represents a window installation operation (Forbes and Ahmed 2010). The data provided list the number of problems relating to window installation and their unit cost. For example, when a window is installed in a manner that violates the code, it costs $1,100. Four occurrences are priced at $4,400. In performing Pareto analysis, one has to decide whether to use the number of occurrences or the costs of these occurrences. In this case, the analysis was based on total costs.

The procedure for creating a table and Pareto chart is as follows:

1. Set up a table to record the values of the factors that are being studied.
2. List the values of the factors in descending order of magnitude (i.e., the largest cost first, and the smallest last. The category "not finished on time" costs $19,625. By contrast, the category "crew very rude" costs $800 and is listed last).
3. Total the cost for all categories (i.e., $44,824.10).
4. For each category, divide its cost by this total to obtain a percentage.

For the Pareto chart, plot the table values onto a combined histogram and superimposed graph where the left-hand y-axis is used to scale histograms for each factor and the right-hand y-axis is to scale a superimposed cumulative cost graph, where total cumulative cost reaches 100% (Table 3.4 and Figure 3.25).

The completed chart shows that the first four factors represent 80% of the cost of complaints.

TABLE 3.4
Example of Tables Used to Develop a Pareto Chart

Item*	Category	Cost ($)	Percentage	Cumulative Percentage
c	Not finished on time	19,625.00	44%	44%
g	Wrong window installed	7,000.00	16%	59%
f	Job not done properly	5,000.00	11%	71%
a	Code infraction	4,400.00	10%	80%
h	Damage during installation	3,500.00	8%	88%
e	Not starting on time	2,250.00	5%	93%
b	Leave job site dirty	2,249.00	5%	98%
d	Crew very rude	800	2%	100%
		44,824.00	100%	

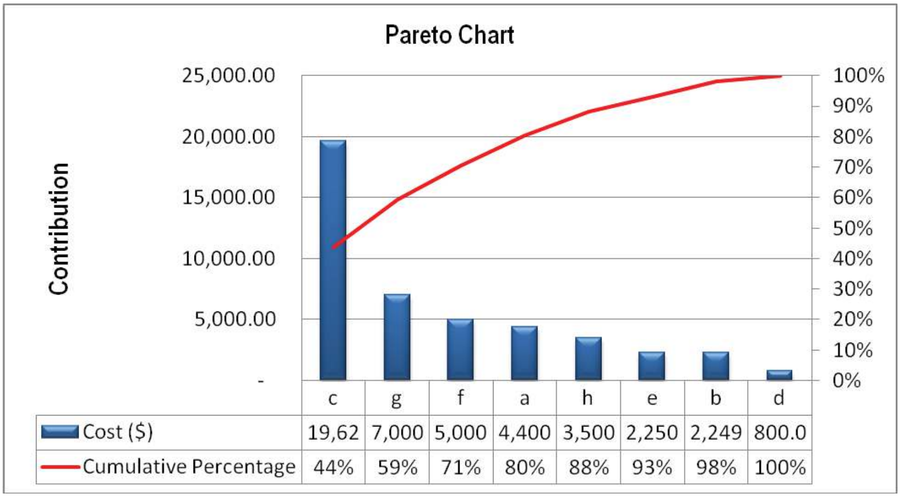


FIGURE 3.25 Pareto chart.

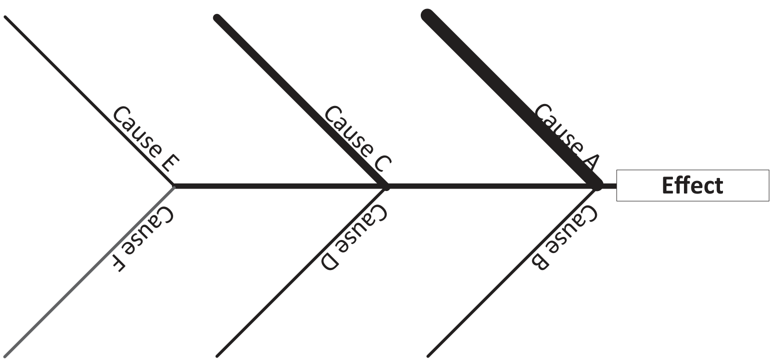


FIGURE 3.26 Causes transferred from the Pareto chart to Ishikawa diagram.

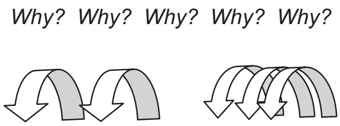
In essence, the Pareto chart allows the team to focus on the largest ribs of the fish—thus mitigating 80% of the problems (Figure 3.26).

3.3.4.4.5 Five Whys/Root Cause Analysis

Once the team agrees on the most significant possible causes, the next step is to identify strategies and set countermeasures that address the largest causes. This can be done using a root cause analysis, also known in the lean community as the "Five Whys."

The intent of a root cause analysis is to "drill down" to the root of a problem. The assumption is that, by eliminating the root cause of a problem, the problem itself can be resolved. Lean construction borrows heavily from lean manufacturing, described by Jeffrey Liker in *The Toyota Way* (Liker 2004). Liker offers an example of root

TABLE 3.5
Example of Root Cause Analysis



Level of Problem	Corresponding Level of Countermeasure	Result if Take Action at This Point
There is a puddle of oil on the shop floor.	Clean up the oil.	Short-Term Solution
Because the machine is leaking oil.	Fix the machine.	”
Because the gasket has deteriorated.	Replace the gasket.	Midterm Solution
Because we bought gaskets made of inferior material.	Change gaskets specifications.	”
Because we got a good deal (price) on those gaskets.	Change purchasing policies.	”
Because the purchasing agent gets evaluated on short-term cost savings.	Change the evaluation policy for purchasing agents.	Long-Term Solution

cause analysis in the form of a “Five Whys” chart (Liker 2004), after presenting a challenge: “There is a puddle of oil on the shop floor” (Table 3.5).

If we ask, “Why is this so,” the answer may be: “Because the machine is leaking oil.” If we are to again ask, “Why is *this* so,” the response may be “Because the gasket has deteriorated.” Each time we reach a new level of causal understanding, we decide whether or not to take action at that point or to continue with our line of inquiry. For example, a “knee-jerk” response following the discovery of leaky oil might be to clean up the oil. Or, upon realizing that the gasket has deteriorated, we may elect to replace the gasket. Each level of causal analysis brings with it a new potential solution. However, note that upper-level solutions are often temporary. Cleaning up the oil will not arrest the leak; the oil will likely need to be cleaned up again. Although replacing the gasket will stop the leak from recurring for a while longer, a poor-quality gasket replaced by another poor-quality gasket only forestalls another leak. In other words, each successive level of inquiry brings with it a longer-term solution. Not until we reach the lowest level of the Liker figure do we arrive at a solution of some permanence.

The logic behind the five whys technique is that short-term solutions require that fixes must be repeated multiple times over a given period while a long-term solution demands a singular fix. Despite its sometimes larger first cost, the five whys solution is often less expensive than the short-term one in the long run—and should therefore be preferred (Figure 3.27).

The question then may be at what stage in the cascade of questioning does one stop a root cause analysis? The five whys technique is not intended to literally suggest

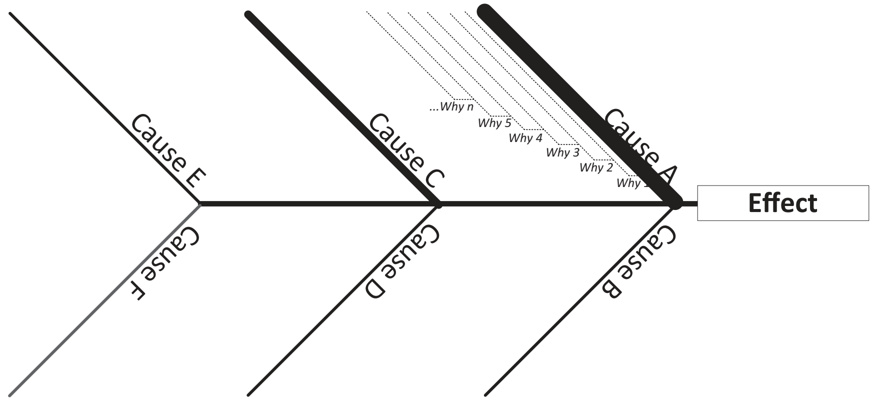


FIGURE 3.27 Conducting five whys/root cause analysis.

specifically stopping after asking "why" five times, but rather after reaching "an actionable cause." Ideally, one should take action at the moment when the number of repeated fixes matches the needs of the situation at hand. For example, in the case of the oil leak, the short-term solution might be most appropriate if the machine needs to be fixed only long enough to use it for two hours (as opposed to two years).

In lean construction, +/Δ charts, Pareto charts, and "Five Whys" root cause analysis are tools used following PPC exercises on the Last Planner System of Production Control to determine the causes of failure when PPC objectives have not been met so that adjustments may be made when encountering a similar situation in the future. Incorporating learning after each activity facilitates an organization's improvement. Once a process has been bettered, it needs to be standardized. The cycle is then repeated. This is how the continuous improvement stairway is climbed.

3.3.4.4.6 Swimlane Diagrams

Lean practitioners are aided by tools such as *value stream maps* and *swimlane diagrams* to document and analyze *current states* of processes and to propose desired *future states* that eliminate constraints and wasteful practices. For example, a swimlane diagram documenting the RFI process required by traditional, design-bid-build contracts reveals unnecessary causes for delay (Figure 3.28).

In this circumstance, a subcontractor working on-site, finding an error, cannot query an owner directly but must communicate in writing along the document chain required by a legal contract. By contrast, if critical stakeholders instead meet collectively in a *Big Room* meeting, communication is liberated, and issues can be resolved much more quickly. Lean tools such as swimlane diagrams help lean project managers visualize and quantify before-and-after impacts of their interventions. In the RFI example just discussed, project managers can collect data from time stamps on documents to benchmark their system's current state—and then map a recommended and improved future state. In this way, the swimlane diagram can help a manager quantify actual savings.

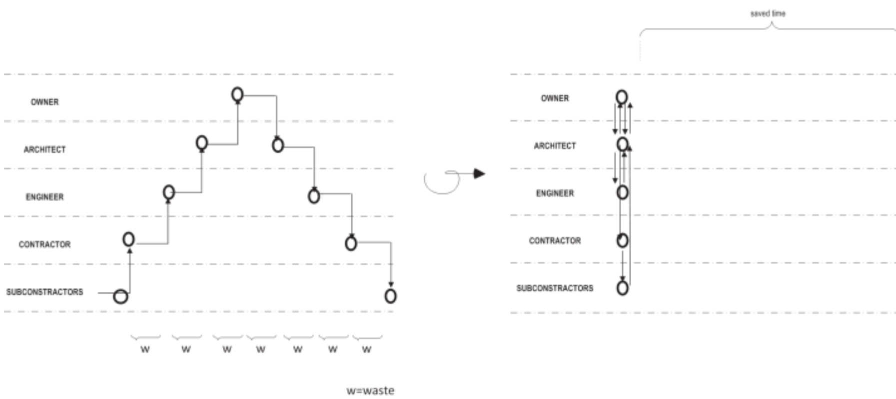


FIGURE 3.28 Swimlane diagram.

3.3.4.4.7 The Five-Step Plan (5S)

The Five-Step Plan is a Japanese approach to improving operations. It helps to create an organized environment that promotes the application of lean thinking. It involves a sequential process based on the Five S's.

Step 1: *Seiri* ("sort"): This involves getting rid of unnecessary items in order to be more organized. This step is applied to such areas as tools, work in process, products, documents, etc.

Step 2: *Seiton* ("set in order"): Neatness is obtained by rearrangement of the work area and identification of proper locations. The object of the exercise is not just to maintain a neat appearance. Workers can reliably find what they need to do a job without wasting time by looking. They should put tools, equipment, etc. in a manner that will improve the flow of work. Everything should be kept in its designated location. Equipment should be returned to its proper place at the end of each job.

Step 3: *Seiso* ("shine"): Cleaning and daily inspection avoid the confusion of an untidy work area. Unnecessary items should be disposed of properly in order not to create clutter that inhibits the effective execution of work tasks. After each job, tools and equipment should be cleaned and restored to their proper locations. Note that when items such as tools and equipment are kept clean, malfunctions, such as leaks, are easier to detect. The root causes of waste and uncleanliness should be investigated to ensure that they do not re-emerge.

Step 4: *Seiketsu* ("standardize"): This refers to standardizing locations for tools, files, equipment, materials, etc. Color coding and labeling can help to standardize locations. Employees' creativity is tapped by having them actively involved in developing standardized systems.

Step 5: *Shitsuke* ("sustain"): This "S" provides motivation for employees to sustain the other four S's. Management can use recognition programs to provide motivation.

Note that the order in which these tasks are accomplished generally *does* matter. A bit of thought will make this apparent. For example, it is usually wasteful to clean items before they are sorted and set in order.

3.3.4.5 Collaboration and the Culture of Lean

As discussed in Section 3.4.4.4.1, *the* lean model of continuous improvement is based on Shewhart and Deming's PDCA Circle—an acronym for plan-do-check-act. *Kaizen* is also the Japanese concept of continual incremental improvement. Literally, *kai* means "change," and *zen* means "good;" hence Kaizen stands for ongoing changes for beneficial reasons on a never-ending basis. It involves all members of an organization actively participating in making improvements on an ongoing basis. Masaki Imai of Japan credits Kaizen as the "single most important concept in Japanese management, and Japan's competitive success." Kaizen is rooted in Japanese philosophy that regards improvement as being closely related with the concept of change. According to Masaki Imai (1986), in the Japanese way of thinking, change is a basic condition of life and should be incremental in order to be healthy, whereas sudden change is seen as unnatural.

The Kaizen approach encourages employees/stakeholders to develop and implement ongoing improvements to the systems that they are most involved with, thereby improving their job performance. It seeks to standardize processes and eliminate or reduce waste. It starts with recognizing a problem, and subsequently a need for improvement. It has been said that complacency is the arch-enemy of Kaizen.

One important consideration for the adaptation of Kaizen to construction-related activities is that improvements should be followed by a period of time for new methods or processes to be standardized.

3.3.4.5.1 Role of People in the Kaizen Process

Kaizen practitioners study a process firsthand by visiting the involved work area (*gemba*) and observing the activities involved. This approach clarifies the difference between value-added and non-value-added process steps (Forbes and Ahmed 2010). Kaizen teams reduce non-value-added steps through a prescribed approach: to combine, simplify, or eliminate in order to reduce waste. Documenting current processes using swimlane diagrams and value stream maps is helpful to identify areas of waste.

There are two primary approaches to Kaizen improvement activities—Flow Kaizen and Process Kaizen. Flow Kaizen emphasizes value stream improvement while Process Kaizen focuses on the elimination of waste. While Kaizen involves ongoing, long-term dedication to improvement of the organization and its people, the process periodically conducts short-term activities termed "Kaizen events" or "Kaizen Breakthrough" methodology. These events are a cross-functional, team-based process for rapid improvement, and are often a weeklong in duration. They involve a bias for action that harnesses creativity to obtain results. The areas selected for Kaizen events have a direct impact on organizational performance.

Full engagement of employees' hearts and minds to the Kaizen philosophy is critical for the needed organizational transformation. Kaizen events are selected for maximum visibility and impact. They have several advantages. Benefits of Kaizen events are obtained very rapidly and include, for example:

- Quick implementation sends a positive message to all stakeholders;
- The events provide hands-on training for participants; and
- The events allow management to gauge workers' resistance to change.

To be effective, multiple layers of management and staff should be engaged in the Kaizen process as follows:

Senior executives and managers must first embrace Kaizen as an organizational strategy and communicate this policy to all stakeholders. As with other performance improvement initiatives, top management's commitment, leadership, and active support are critical to the success of Kaizen.

Middle managers need to deploy the Kaizen policies established by senior executives. They ensure that staff members have the appropriate training and preparation. They establish implementation milestones for supervisory staff.

Supervisors should work closely with frontline workers to implement Kaizen at the functional level. They need to be actively involved in collecting Kaizen suggestions for improvement from employees and coaching respective teams to promote success.

Employees should be expected to actively pursue self-development through education and training in order to support Kaizen team activities.

3.3.4.5.2 Typical Structure of the Kaizen Process

The following steps are recommended when engaging participants in a Kaizen event. They include:

1. Select an area/work unit for the Kaizen event based on business requirements and potential for improvement.
2. Establish project objectives: document baseline data and set metrics for improvement (i.e., numerical goals).
3. Appoint Kaizen team members: a team leader and a sub-team leader.
4. Publicize the event: Meet with the involved work unit team, explain roles and expectations, engage hearts and minds for the event (Forbes and Ahmed 2010, p. 122).

A typical Kaizen event lasts one week and brings everyone together in a focused series of activities, starting with orientation and training on the first day. It often culminates on day five with a presentation of recommendations and results to management, followed by a celebration of Kaizen event accomplishments. Kaizen events are short-term in duration but have proven to be very effective. They focus everyone's effort for a few days, but the benefits in improved performance far outweigh the cost of lost production. They are also one of the primary reasons that adoption of lean thinking in an organization improves morale as well as efficiency. The adage is: "With every pair of hands comes a free brain."

3.3.4.5.3 The Role of Leadership

Leadership plays an indispensable role in the successful implementation of the lean philosophy to construction projects. Consultants and coaches can provide knowledge and expertise, but success depends heavily on the hearts and minds of the project team being both invested and engaged. Therefore, the leaders of the stakeholder organizations—owners, designers, and constructors—must lay the groundwork with their respective teams. Leaders need to address the top three barriers to successful lean implementation. As observed in a UK study (Sarhan and Fox 2012), three key issues influence the readiness of organizations for undertaking a lean journey. They are: lack of adequate lean awareness and training; lack of top management commitment; and culture and human attitudinal issues.

Leaders must ensure that their respective organizations are ready for the lean journey and that they meet the following attributes (Forbes 2009):

- A willingness to change. Lean methods are a departure from conventional methods and their adoption requires changing the behavior of people. Cultural change is the most compelling quest along with the physical transformation of an organization. One cannot force change on people; they have to be engaged so that the intrinsic satisfaction of outstanding performance will motivate them.
- A commitment to training and learning: Stakeholders at all levels need to be trained in lean techniques in order to become successful participants in lean projects. Lean implementation also requires that completed assignments have to be continually examined as a source of learning for future improvements instead of being a search for sources of blame.
- A quality-oriented culture is needed for successful application of lean techniques. Just-In-Time (JIT), in particular, demands discipline, as there is no room for unreliable suppliers. JIT does not work in an atmosphere of suspicion, distrust, and internal competition.
- A "shared vision" is essential to have all stakeholders on the same page. Macomber and Howell (2005) promote the importance of a "shared vision" in which a workforce aligns itself with the direction set by a leader. This alignment is far different from carrying out orders. It is based on a sharing of beliefs and a common view of a future state that benefits everyone and makes them receptive to the changes necessary to reach that future state.
- A commitment to reducing or eliminating waste is a fundamental principle of lean construction (Polat and Ballard 2004). A commitment to improving safety is critical to lean implementation as construction accidents are rivaled only by the mining industry.
- A commitment to cost and performance measurement. These measurements are important indicators of the impacts of lean in construction projects. Measurements of the PPC are essential as a foundation for continuous improvement.
- A willingness to implement lean during the design stages: The Lean Project Delivery System (LPDS) links designers with constructors, beyond the

norms of traditional practice to include elements of construction process design in their scope of work. Lean designers also engage in "target value design" to meet the client's value proposition within a defined budget.

- Collaborative relationships: Lean requires close collaboration between the parties whereas the standard forms of contract are adversarial in nature. Lean projects apportion responsibilities and benefits of the contract fairly and transparently, based on trust and partnership between the parties. Working relationships are improved, and the improved efficiency and reduction in conflict generally lead to improved financial returns for all stakeholders.
- Leaders must develop clear and explicit Conditions of Satisfaction (CoS) in collaboration with key stakeholders. IPD is based on a network of promises, commitments, or agreements among the project team. A promise can only be meaningful when it has clear, mutually agreed CoS. They are measurable statements that explain what tests must be passed to create success. They represent the customer's value proposition in measurable terms and should be posted for all to share in understanding.

3.4 CONCLUSION

The definition of lean construction is not static. Similar to a Wikipedia page, its definition grows and evolves through the communal input of interested parties.

When Lauri Koskela published the now seminal *Technical Report Number 72*, he wrote of a "new production philosophy" being applied to manufacturing that might solve the safety and productivity problems facing construction (Koskela 1992, 2000). Koskela's report and theory of TFV came to the attention of like-minded thinkers Greg Howell and Glenn Ballard, who also saw the need to revamp a highly unproductive and litigious construction industry. They developed the *Last Planner System of Production Control*™—a planning method that stabilizes projects and is almost routinely the first step companies now adopt when deciding to implement lean. Early lean construction pioneers drew on lessons learned from lean manufacturing, to be sure, but also from productivity improvement advances made by Frederick Taylor and Henry Ford, the time-motion studies of Frank Gilbreth, an underlying respect for the individual advocated by pioneering industrial psychologist, Lilian Gilbreth, and the continuous improvement control cycles (PDCA, plan-do-check-act) put forth by statisticians Shewhart and Deming.

In 1993, the International Group of Lean Construction (IGLC) was founded and held its first conference in Espoo, Finland with a handful of participants. Proceedings from the first three IGLC conferences were published in a book entitled *Lean Construction* (Alarcón 2013). In 2014—twenty-one years after the first conference—125 lean construction research papers were presented and published, and hundreds of academic as well as industry-related attendees, participated in presentations, at the IGLC conference in Oslo, Norway. The Lean Construction Institute was founded in 1997 (LCI 2013), and today hosts regular training and meetings; these sessions openly welcome multiple stakeholders, including building owners, architects, engineers, attorneys, constructors, trade partners, and suppliers. In 2004, *The Lean Construction Journal* was founded and has become a publishing venue for dissemination of research results from lean experimentation (LCJ 2014).

Contributors to lean construction theory are both academicians and practitioners and, unlike conventional academic conference arenas, it is common for papers from the lean construction community to be co-authored collaboratively by academics *and* practitioners. There is a fundamental acknowledgment that building project delivery is an applied science and that it is only when ideas are tested on an actual design and construction project that they are imbued with useful meaning. It is also a foundational belief that the inclusion of multiple stakeholders and the bodies of knowledge they bring to a problem-solving table contributes to lean construction's success and worldwide adoption. As of this writing, at least fourteen countries now have active, formally affiliated lean construction networks and at least twenty-one additional countries are practicing lean in some fashion (Mossman 2015). This number continues to grow.

The story of lean construction is multifaceted; as in any grassroots movement, hundreds have paved the way, but their names and specific contributions are too numerous to mention here. Like a lithe cheetah that leaves evidence of its astounding speed in the grasses that were parted during its run, one likely sign that "lean construction was here" is the orchestrated choreography of *flow* that can be wondrous to behold.

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3.6 GLOSSARY OF LEAN TERMS

A3 Report The A3 report is a disciplined and rigorous system for implementing PDCA management. As used by Toyota, the report fits on a single sheet of A3 paper, measuring 11 inches by 17 inches approximately, and documents problems and the available information about them in a manner that helps users to understand their ramifications quickly. It focuses users on improving processes and solving problems.

Autonomation Lean Construction applies the principle of autonomation that is an important ingredient of the Toyota Production System (TPS); the people closest to the work are empowered to stop production if they determine that the upstream production is defective. In using the Last Planner System, the last planners and their crews fulfill this role.

Basis of Design (BOD) The owner's Basis of Design (BOD) reflects the owner's needs and wants that must be satisfied by the design of a project. This may include the use of spaces, their sizes, finishes, and activities to be performed within them.

Benchmarking involves comparing actual or planned project practices to those of other projects to generate ideas for improvement and to provide a standard by which to measure performance.

Building Information Modeling (BIM) Building Information Modeling (BIM) is the process of generating and managing building data during its life cycle. It is a model-based technology linked with a database of project information. A BIM carries all information related to a facility, including its physical and functional characteristics and project life cycle information, in a series of "smart objects."

Buffer The means (capacity, inventory, time) used to cushion against the shock of variation in a process. Two types of buffers may be used to shield downstream construction processes from flow variation. Plan buffers are inventories of workable assignments. Schedule buffers are materials, tools, equipment, manpower, time, etc.

Commissioning A systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all facility systems perform efficiently and in accordance with the design documentation and intent and meet the owner's operational needs.

Commissioning Agent (CxA) The commissioning agent (or authority) is a professional who serves as an objective advocate for the owner and is responsible for: 1) Directing the commissioning team and process; 2) coordinating, overseeing, and/or performing the commissioning testing, and 3) reviewing the results of the system performance verification.

Commitment Planning Commitment planning is a method for defining criteria that lead to the selection of quality assignments. It results in commitments to deliver that other actors in the production system can rely on, by following a prerequisite that only "sound" assignments should be made or accepted.

Commitment Reliability Commitment reliability is a measure applied to the commitment made by producers (contractors, designers, etc.) in the design/

construction supply chain. Downstream producers depend on handoffs from upstream producers and secure their commitment to dates certain in order to meet schedules. Commitment reliability is calculated by comparing completed work (DID) with planned work (WILL).

Constraint A constraint is an obstacle that inhibits the execution of a task that is required in the lookahead plan. It should also be beyond the control of the last planner.

Constraint Analysis Foremen, project managers, schedulers, and other staff communicate to identify constraints, and the reasons for their occurrence. This enables them to guide the scheduling process and remove constraints so that "sound" work tasks can be assigned.

Consensus Docs 300 "Consensus Docs 300" is a standard form of contract for the construction industry that is based on an Integrated Form of Agreement (IFOA). Twenty-Two leading construction associations united to publish a consensus set of contract documents in 2007, which they felt was fair to all parties.

Cycle Time How often a part or product is completed by a process, as timed by observation. This time includes operating time plus the time required to prepare, load, and unload. The appropriate calculation of cycle time may depend upon context. For example, if a paint process completes a batch of 22 parts every five minutes, the cycle time for the batch is five minutes. However, the cycle time for an individual part is 13.6 seconds (5 minutes x 60 seconds = 300 seconds, divided by 22 parts = 13.6 seconds).

Continuous Flow Producing and moving one item at a time (or a small and consistent batch of items) through a series of processing steps as continuously as possible, with each step making just what is requested by the next step. Also called one-piece flow or single-piece flow.

Continuous Improvement Small improvements in products or processes to reduce costs and ensure consistency of performance of products and services.

Design-Bid-Build A traditional contracting method in which the architect and contractor secure separate contracts with the owner to provide specified services. (Construction Management Association of America, 2009)

Design-Build A contracting method in which an architect and contractor provide design and construction services under a single-responsibility contract to an owner. (Construction Management Association of America, 2009)

Design Criteria Design criteria for buildings define the owner's requirements, including those that may exceed applicable codes. They primarily serve as a performance-based guide to designers, to ensure that ensuing designs meet the functional needs and preferences of the owner. A criteria document typically describes the building systems and materials to be used. It may also define project-specific requirements such as building orientation, space descriptions, and adjacencies to meet owners' operating needs.

First Run Studies These studies involve trying out new construction ideas on a pilot basis and applying the PDCA methodology to determine their success. First-Run studies also identify the best means, methods, and sequencing for a specific activity.

Fishbone Diagram Also called the Ishikawa diagram or cause and effect diagram. The diagram illustrates how various causes and sub-causes relate to creating potential problems. It may be used to determine the root causes of observed problems.

Five Whys A method of root cause analysis whereby the investigator repeatedly probes operators and other employees with the simple question "why" until the root cause of a problem is uncovered.

Five S (5S) One of the guiding principles of lean meant to achieve standardization and stability in the workplace through visual management.

Flowcharting A flow chart is any diagram that shows how various elements of a system relate. (Cause and effect diagrams, system, or process flow charts

Gemba A Japanese term that means the place where things are actually happening. Gembashugi: Shop floor oriented (Shugi = orientation or philosophy).

Heijunka Creating basic stability in processes. Leveling short-term customer demand at a pacemaker point, to produce outputs at a constant and predictable rate.

IPD Team Performance Contingency A provision in integrated project delivery—for the sharing of costs and benefits based on the performance of the IPD team.

Integrated Form of Agreement (IFOA) The IFOA is a legal agreement that seeks to align the commercial relationships of a construction project's design and construction participants that are assembled as a temporary production system. It also requires collaborating throughout design and construction, planning and managing the project as a network of commitments. As a result, it optimizes the project as a whole, rather than any particular piece.

Integrated Project Delivery (IPD) IPD is a relational contracting approach that aligns project objectives with the interests of key participants. It creates an organization able to apply the principles and practices of the Lean Project Delivery System. The fundamental principle of IPD is the close collaboration of a team that is focused on optimizing the entire project as opposed to seeking the self-interest of their respective organizations.

Ishikawa (Cause and Effect) Diagram This line and text diagram, developed by Kaoru Ishikawa, evokes the image of a fish and its ribs. It is used to facilitate itemizing—through brainstorming—all potential causes of an effect. In the diagram, the effect is written at the location of the fish "head," and all potential underlying causes of that effect are written along the "ribs."

Just-in-Time (JIT) Production A system of production that makes and delivers just what is needed, just when it is needed, and just in the amount needed. JIT and jidoka are the two pillars of the Toyota Production System.

Kaizen Continuous improvement of an entire value stream or an individual process to create more value with less waste. There are two levels of Kaizen: 1) System or flow. Kaizen focuses on the overall value stream and 2) process Kaizen focuses on individual processes.

Kanban A signaling device that gives authorization and instructions for the production or withdrawal (conveyance) of items in a pull system. The term is Japanese for sign or signboard.

Last Planner System of Production Control™ (LPS) The Last Planner System is an important subset of the Lean Project Delivery System and is critical to its effective deployment. The LPS accommodates project variability and smoother workflow so that labor and material resources can be maximally productive. It uses lean methods to provide improved project control.

Last Planner The person or group that makes assignments that direct workers, "squad boss" and "discipline lead" are common names in design processes. Superintendent (for small jobs) or foreman are common names for last planners in construction processes.

Lean Construction Extends to the construction industry the lean production revolution started in manufacturing. This approach maximizes value delivered to the customer while minimizing waste (Lean Construction Institute 2009).

Lean Project Delivery System The LPDS (Ballard, 2000) is a model that integrates a number of phases to facilitate the design and delivery of construction projects using lean techniques. These phases are: 1) Project definition, 2) lean design, 3) lean supply, 4) lean assembly, and 5) use. The LPDS is based on a close collaboration between the members of the project delivery team. They are bound by codes of conduct—both written and unwritten—that focus on the success of the overall project, rather than individual success.

Lean Production A business system for organizing and managing product development, operations, suppliers, and customer relations that requires less human effort, less space, less capital, and less time to make products with fewer defects to precise customer desires, compared with the previous system of mass production. It was pioneered by Toyota after World War II.

Muda Seven classes of waste in process: Overproduction, delays, transportation, processing, excess inventory, wasted motion, and defective parts.

Mura (Variation) Mura internal to the enterprise does include day-to-day variation in customer demand as long as it is not part of a long-term trend. It also includes gyrations in orders and operational performance progressing up a value stream—through production facilities and suppliers—that are caused by the internal dynamics of the process. These variations are the norm in modern production systems, leading to firefighting and muri (overburden of employees and technologies).

Muri Overburden of employees and technologies.

Obeya A Japanese word that translates to "big room." At Toyota it has become a major project management tool, used especially in product development, to enhance effective and timely communication. Similar in concept to traditional "war rooms," an obeya will contain highly visual charts and graphs depicting program timing, milestones, and progress to date and countermeasures to existing timing or technical problems.

Owner's Project Requirements (OPR) See design criteria.

Pacemaker Process Any process along a value stream that sets the pace for the entire stream. (The pacemaker process should not be confused with a bottleneck process that constrains downstream processes due to a lack of capacity.)

Pareto Chart A diagram that is used to display the relative importance of each of a number of factors. In evaluating problems, it shows the types of problems and the frequency of their occurrence or cost impact based on the so-called 80/20 rule. The chart enables users to readily prioritize needed corrective actions.

Plan, Do, Check, Act (PDCA) An improvement cycle based on the scientific method of proposing a change in a process, implementing the change, measuring the results, and taking appropriate action. The PDCA cycle has four stages: 1) Plan, 2) do, 3) check, and 4) act.

Poka Yoke Japanese term that means mistake (or error) proofing. A poka yoke device is one that prevents incorrect parts from being made or assembled and easily identifies a flaw or error. Error-proofing is a manufacturing technique of preventing errors by designing the manufacturing process, equipment, and tools so that an operation literally cannot be performed incorrectly.

Percent Planned Complete (PPC) In lean construction, work accomplishment is recorded as a graphical plot of Percent Plans Complete (PPC): It shows the percentage of the assigned plans; that is, commitments that were completed (fractional completion is not considered). Some lean construction practitioners refer to PPC as commitment reliability.

Prevention Over Inspection A well-known mantra, emphasized by proponents of quality. Prior to the emergence of the quality movement, the main focus of quality was on inspection. Both research and experience pointed to the fact that the net cost of inspecting is so high that it is better to spend money on preventing problems. "Quality must be planned in not inspected in."

Productivity Productivity is the measure of how well resources are brought together and utilized for accomplishing a set of goals. Productivity is measured as the ratio of outputs to inputs. In the construction environment, it may be represented as the constant in place value divided by inputs such as the dollar value of material and labor.

Quality Assurance Planned and systematic actions to help ensure that project components are being designed and constructed in accordance with applicable standards and contract documents.

Quality Control The review of project services, construction work, management, and documentation for compliance with contractual and regulatory obligations and accepted industry practices.

Reasons for Non-Completion (RNC) In conjunction with lean-based construction projects, incomplete work plans are studied each week to determine the root causes (reasons for non-completion RNC). At each weekly meeting, time is devoted to learning why certain tasks were not completed, in order to improve the effectiveness of future work plans.

Relational Contracting Relational contracting is a transaction or contracting mechanism that apportions the responsibilities and benefits of the contract fairly and transparently, based on trust and partnership between the parties. It provides a more efficient and effective system for construction delivery in projects that require close collaboration for execution. The relationship between the parties transcends the exchange of goods and services and displays the attributes of a community with shared values and trust-based interaction.

Reliability The extent to which a commitment is fulfilled.

Reverse Phase Scheduling A strategy used in lean construction to develop the schedule of a project by first anchoring the desired delivery date and scheduling activities backward toward the start of the project. It is a detailed work plan that specifies the handoffs between trades. For each project phase, that is, what SHOULD be done at each phase.

Set-Based Design Set-Based design is a design management approach that defers design decisions to the "last responsible moment" to allow for the evaluation of alternatives that improve constructability. Toyota has used this technique to design new models in a much shorter time than the industry standard. They have learned that the best solutions are hybrids of original design options.

Supply Chain The term supply chain encompasses all the activities that lead to having an end user provided with a product or service—the chain is comparable to a network that provides a conduit for flows in both directions, such as materials, information, funds, paper, and people.

Sustainability The ability of a society to operate indefinitely into the future without depleting its resources. Sustainability includes concepts of green building design and construction, reuse and recycling of materials, reduced use of material and energy resources for building construction and operation, water conservation, and responsible stewardship of the surrounding environment.

Takt Time In a manufacturing assembly line, it is the maximum time allowed per unit to meet demand; it sets the pace of the assembly line.

Target Value Design Target Value Design (TVD) involves designing to a specific estimate instead of estimating based on a detailed design. It seeks to address the problem that affects many projects—various design disciplines work from a common schematic design to do design development in their areas of expertise.

Team Dynamics Problem-Solving, communications skills, conflict resolution.

Throughput Time (Cycle Time) The time required for a product to move all the way through a process from start to finish. At the plant level, this is often termed door-to-door time. The concept can also be applied to the time required for a design to progress from start to finish in product development or for a product to proceed from raw materials all the way to the customer.

Total Quality Management (TQM) A philosophy that encourages companies and their employees to focus on finding ways to continuously improve the quality of their business practices and products.

Toyota Production System (TPS) The production system developed by Toyota Motor Corporation to provide best quality, lowest cost, and shortest lead time through the elimination of waste. TPS is composed of two pillars, just-in-time production and jidoka. TPS is maintained and improved through iterations of standardized work and Kaizen, following the scientific method of the plan-do-check-act cycle.

Trend Analysis Involves using mathematical techniques to forecast future outcomes based on results. It is often used to monitor technical and cost/schedule performance.

Value-Added and Non-Value-Added Work Activities Value-added activities provide desirable outcomes for a customer, that is, they meet the customer's value proposition. Conversely, non-value-added activities do not contribute to meeting a customer's expectations. For example, searching for a tool to perform a task does not get the task done and does not provide value.

Value Stream All of the actions, both value-creating and non-value-creating, required to bring a product from concept to launch and from order to delivery. These include actions to process information from the customer and actions to transform the product on its way to the customer.

Value Stream Mapping (VSM) A simple diagram of every step involved in the material and information flows needed to bring a product from order to delivery. A current state map follows a product's path from order to delivery to determine the current conditions. A future state map shows the opportunities for improvement identified in the current state map to achieve a higher level of performance at some future point.

Variation The divergence of a process from an intended plan. The lean philosophy seeks to reduce process variation in order to obtain reliable flow through a process.

Visual Management Using visual displays for better communication. It works in conjunction with empowerment so that anyone, not just a supervisor, can detect process anomalies and take prompt corrective action.

Waste Any activity that consumes resources but creates no value for the customer. There are seven wastes as identified in Lean: Overproduction, excessive inventory, unnecessary conveyance, overprocessing, excessive motion, waiting, and corrections (of defects).

Workable Backlog Workable backlog is used to describe assignments that have met all quality criteria but may need other prerequisite work to be done before they can be started. Workable backlog enables crews to continue working productively if there is a constraint that prevents the completion of an item on the Weekly Work Plan (WWP).

Work Package A compilation of information regarding the availability of material, equipment, resources, and other pertinent information that is necessary to perform a specific scope of work. The work package is coordinated with other interdependent work packages and requirements.

Work Structuring The process of defining and organizing activities into logical, practical groups of work. It is a process of subdividing work so that the pieces are different from one production unit to the next to promote flow and throughput and to have work organized and executed to benefit the project as a whole.

4 Operation and Maintenance

Abdul Razzak Rumane

4.1 OPERATION AND MAINTENANCE

Once the project is completed and fully functional, then it becomes part of the operation system. The operation and maintenance (O&M) of a completed project are associated with the quality of the constructed project.

The owner may employ the same contractor(s) who built the facility or engage another specialist operation and maintenance organization to manage the operation and maintenance. It is likely that the owner may have his/her own team to operate and maintain the facility. The following documents are required to operate and maintain the completed facility. These documents are normally submitted by the contractor during the testing, commissioning, and handover phase of the construction project.

1. As-built drawings.
2. Operation and maintenance manuals.
3. Operating procedures.
4. Source information for availability of spare parts of the installed works.

The cost of operation and maintenance should be considered in the feasibility studies of the project. Postconstruction costs have a great impact on the overall life cycle cost of the project.

4.2 CATEGORIES OF MAINTENANCE

Following are different types of maintenance normally being carried out, depending on the nature of activity, system, or equipment, to avoid interference/interruption with essential installation operations, endanger life or property, or involve high cost for replacement of the item.

4.2.1 Preventive Maintenance

Preventive maintenance is planned, with scheduled periodic inspection, adjustment, cleaning, lubrication, parts replacement of equipment and systems in operation. Its aim is prevention of breakdown and failure. Preventive maintenance consists of many activities required to be checked and performed to ensure that the operations

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are safe and can be performed without any danger to life or facility and will not warrant high cost or long lead time for replacement. Preventive maintenance is the cornerstone of any good maintenance program.

4.2.2 Scheduled Maintenance

Scheduled maintenance includes those maintenance tasks whose cycles exceed a specified period. This type of maintenance relates to finish items, such as painting, polishing of wood, parking and road markings, roof maintenance, and testing of fire alarm systems.

4.2.3 Breakdown Maintenance

Breakdown maintenance for systems or equipment is scheduled (planned) and unscheduled (unplanned). Unscheduled (unplanned) is unanticipated maintenance because of system or component failure. If the problem relates to an essential service or has any hazardous effect, then an emergency response is necessary. If the problem is not critical, then routine response is adequate.

4.2.4 Routine Maintenance

Routine maintenance is an action taken by the maintenance team to restore a system or piece of equipment to its original performance, capacity, efficiency, or capability.

4.2.5 Replacement of Obsolete Items

Replacement of obsolete items refers to the work undertaken by a maintenance team to bring a system or component into compliance with new codes of safety regulations or to replace an item that is unacceptable, inefficient, or for which spare parts are no longer available or have had technological changes. Early detection of problems may reduce repair and replacement costs, prevent malfunctioning, and minimize downtime, for example, with communication systems, audio-visual systems, and equipment.

4.2.6 Predictive Testing and Inspection

Predictive testing and inspection refer to testing and inspection activities that involve the use of sophisticated means to identify maintenance requirements. For example, specialized tests are to be carried out:

- To locate wearing problems on bus bar bends of an electrical mains low-tension panel.
- To detect insulation cracks.
- To locate thinning of pipe walls and cracks.
- To identify vibration problems for equipment like chillers, diesel generator sets, pumps.
- To locate heat buildup (rise in temperature) in electrical bus duct.

4.3 O&M PROGRAM

Addressing operation and maintenance considerations at the start of the project contributes greatly to improved working environments, higher productivity, and reduced energy and resource costs. During the design phase of the project and up to handover of the facility, O&M personnel should be involved in identifying maintenance requirements for inclusion in the design. The goal of effective O&M is to achieve the intent of the original design team, that is, the systems and equipment delivery services to the user, enhancing a comfortable, healthy, and safe environment. O&M should also include long-term goals such as economy, energy conservation, and environmental protection. To create an effective O&M program, the following procedures should be followed:

- Ensure that up-to-date as-built drawings for all the systems are available.
- Ensure that operational procedures and manuals for the installed equipment are available.
- Prepare a master schedule for operation and preventive/predictive maintenance.
- Implement preventive maintenance programs complete with maintenance schedules and records of all maintenance performed for all the equipment and systems installed in the project/facility.
- Follow manufacturer's recommendations for maintenance of equipment and systems.
- Ensure the maintenance personnel have full knowledge of the equipment and systems installed, and for which he/she is responsible to operate and maintain.
- Ensure that O&M personnel are provided training during the testing, commissioning, and handover phases.
- Offer training and professional development opportunities for each of the O&M team members.
- Implement a monitoring program that tracks and documents equipment performance to identify and diagnose potential problems.
- Implement a monitoring program that tracks and documents systems performance to identify and diagnose potential problems.
- Perform predictive testing and inspection for critical and important items.
- Use preventive maintenance and standbys, etc. so that the failed components can be isolated and repaired without interrupting system performance, thus minimization of equipment failures.

For an effective O&M program, the following specific items should be considered:

1. HVAC system and equipment.
2. Indoor air quality system and equipment.
3. Electrical systems and equipment.
4. Water fixtures and system.
5. Life safety (fire suppression systems).
6. Cleaning equipment and products.
7. Landscape maintenance.

A guideline to prepare a preventive maintenance program, taking into consideration the most important equipment and systems of an office/commercial building is illustrated in Table 4.1.

TABLE 4.1
Preventive Maintenance Program

Sr. No.	Activities	Maintenance Frequency				
		Daily	Weekly	Monthly	Quarterly	Yearly
Chiller						
Cooling Tower						
Air Handling Unit						
Fan Coil Unit						
Exhaust Air Fan						
Supply Air Fan						
Package Unit						
DX Unit						
Split Unit						
VAVs						
Chilled Water Pump						
Condenser Water Pump						
Hot Water Pump						
Domestic Water Pump						
Booster Pump						
Sump Pump (Drainage Pump)						
Fire Pumps						
Jockey Pump						
Fire Fighting System						
Foam System						
Building Automation System						
Water Boilers						
Sanitary and Water Fixtures						
Main Low-Tension Panel						
Main/Sub Main Switch Boards						
Electrical Distribution Boards						
Bus Duct						
Automatic Transfer Switch						
Diesel Generator Set						
Uninterrupted Power Supply (UPS)						
Dimmer System						
Lamps/Fitting Accessories						

(Continued)

TABLE 4.1 Continued

Sr. No.	Activities	Maintenance Frequency				
		Daily	Weekly	Monthly	Quarterly	Yearly
Fire Alarm System						
Communication System						
Security System						
Access Control System						
Audiovisual System						
Public Address System						
Dimmer System						
Uninterrupted Power Supply (UPS)						
Cleaning Equipment						
Kitchen Equipment						
Elevator						
Escalator						
Landscape						

5 Facility Management

Abdul Razzak Rumane

5.1 FACILITY MANAGEMENT

Facility management is the process by which an organization integrates all noncore specialist services to achieve strategic objectives. It enhances the performance of the organization. It is an integration of people, place, process, and technology.

Facility management is mainly applied to buildings/properties that are complex in nature, including more complex management and operation. Construction projects are becoming more sophisticated and more technical in nature; therefore, their performance has to be maintained and the level of services has to be improved to satisfy user needs.

Facility management is effectively managing physical assets of an organization to ensure their value is realized and their repair, maintenance, and replacement are planned in an economical manner. Facility management is a multidiscipline activity. It involves a number of disciplines and services. It encompasses multidisciplinary activities within the built environment and the management of their impact on people and the workplace. It covers the development, coordination, and development of all the noncore specialist services of an organization, together with the buildings and their systems, environment, equipment, plant, health and safety, information technology, infrastructure, landscape, and all the services. Figure 5.1 illustrates the areas covered under facility management.

Facility management is gaining increasing recognition among large organizations as an important factor for business improvement. Effective facilities management, combining resources and activities, is vital to the success of any organization. At a corporate level, it contributes to the delivery of strategic and operational objectives. Facility management is a relatively new aspect in Asia and other developing countries. However, there has been an enormous growth in facility management activities worldwide. Table 5.1 summarizes facilities management market characteristics between Europe and the Middle East.

Operation and maintenance expenses are normal. However, the cost can be minimized through an aggressive facility management program and the use of applicable diagnostic tools. The key to success of facility management is that the team members must be proactive and embark on a realistic, long-range facility management program. Timely and well-planned maintenance and repair will result in cost savings. The distinction between maintenance management and facilities management is illustrated in the conceptual graph of building capability versus time shown in Figure 5.2.

The facility management function is performed by either an in-house facility management team or an outsourced team.

In both cases, the team members must have an innovative approach in day-to-day operations to reduce operating costs and add value to the business. It is essential that facility management practitioners (in-house or outsourced team) are proactive while

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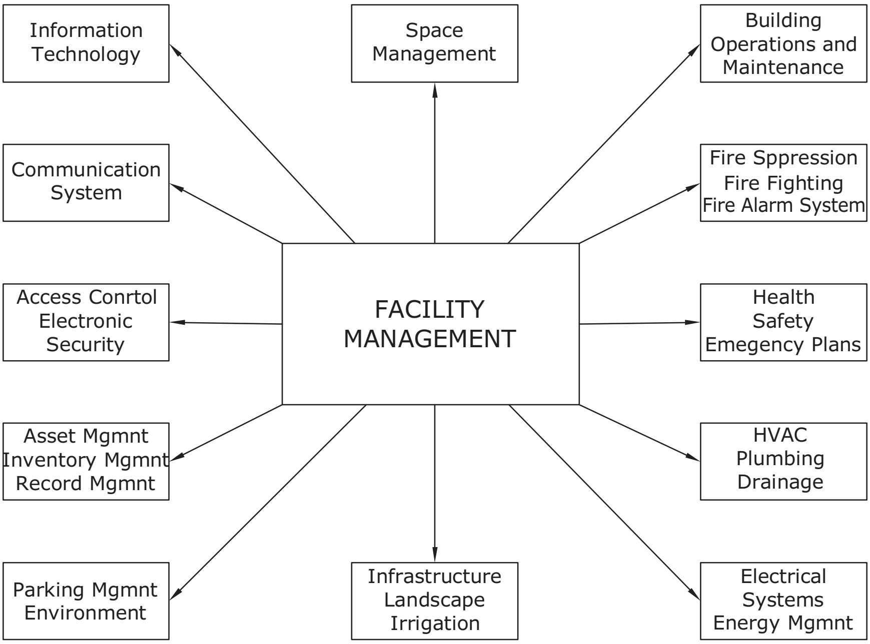

FIGURE 5.1 Areas covered under facility management.

TABLE 5.1
FM Market General Characteristics

Europe	Middle East
Matured and structured FM industry.	Immature and unstructured FM industry.
Benchmark and historical data available.	No historical benchmarking data available.
Standard RFP's and structures service level agreements are the norm. Clients and service providers conversant with requirements including performance measurement criteria.	Not generally available. Market characterized by poor quality trends and contract documentation. Clients/suppliers using "construction type" forms of contracts.
Best practice quality management system (QMS) and processes "imbedded" in service delivery models.	QMS not generally utilized or implemented.
Resources (internal and external) available and trained in FM systems and procedures.	Resources and skills available but not integrated into FM companies.
Experienced in use of systems technology as key management tools.	Lack of systems technology and understanding of application and benefits.
Experienced FM service providers available who can manage "bundled" services on single solution basis.	Lots of small players and single service providers. Some good FM companies exist but limited number with international and local experience.

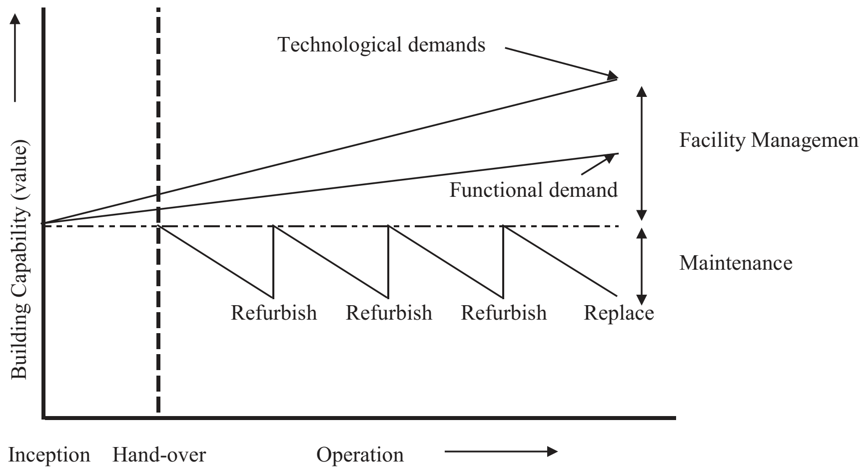

FIGURE 5.2 Conceptual graph of building capability versus time.

carrying out an innovative project, even in the day-to-day operations, and are aware of the trends and developments in facility management and related industries. The following are the pros and cons of in-house facilities management.

Pros	Cons
More responsive to corporate culture and needs of organization	Lack of flexibility and availability of multidisciplinary skills
Sense of "belonging"/being part of client culture	Too often in-house staff "transferred" from other departments without right skills or training
Easier communication and change management decisions and processes	Lack of exposure to best practice facility management processes and systems
Confidentiality issues/more secure	Specialist "in-house" skills not available

Facility managers are the professionals most responsible for integrating people with their physical environment. They come from a variety of professions. Facility management professionals are judged by their managerial capabilities rather than their technical competence. Facilities professionals need to be trained and equipped with tremendous amounts of knowledge and management ability to cope with and solve a multitude of complex problems and challenges. Table 5.2 illustrates typical requirements of a facility management professional.

5.2 FACILITY MANAGEMENT OUTSOURCING

Facility management must achieve an organization's objectives and promote an organization's growth. The facility management companies must be able to pool resources to achieve the objectives. While selecting a facility management firm, it is necessary to study the competency of the firm in the following areas:

TABLE 5.2
Typical Requirements for Facility Management Professional

Sr. No.	Requirements
1	Intuitive and managerial skills.
2	Ability to improve business performance.
3	Ability to satisfy customers.
4	Capability of seeking new methods of doing work in order to bring about marked and sustainable improvements in performance of business.
5	Ability to develop new or improved facilities, services, technologies that add to the value.
6	Ability to perform things happen with level of technical understanding.
7	Ability to accept full accountability for all actions they perform.
8	Should be flexible having visionary skills.
9	Willing to accept changes in business and social practices.
10	Leadership skills.
11	Communication skills.
12	Technical and analytical skills.
13	Knowledge of industry standards and practices as well as regulatory mandates.
14	Purchasing and contracting skills.
15	Personal and interpersonal relationship skills.

- Operation and maintenance.
- Planning and project management.
- Technology.
- Quality assessment and innovation.
- Management and leadership.
- Communication.
- Environmental factors.

Due to globalization and the competitive market, business outsourcing has become a common factor. The following are the benefits from outsourcing facility management:

- Reduce/control costs.
- Access to leading-edge technologies.
- Focus on core business.
- Free resources for other purposes.
- Availability of resources not available internally.
- Improved, proactive service.
- Meet and exceed organization strategic plans.

Before deciding to outsource, organizations must decide the following:

- What are core competencies?
- What are the current costs and quality of services provided in-house?

- Would it be better to reengineer processes internally to achieve goals?
- What services may be better delivered by an FM service provider?
- What are the goals to be achieved by outsourcing?
- Is a service readily available from suppliers who are better structured to efficiently deliver service at the right price?
- How will the contract (service level agreement) be structured?
- What "in-house" capability/management will be retained/provided to manage service relationships?

If the organization decides to outsource FM, it has to:

- Appoint a dedicated project "champion" from within client organization to define and manage the process.
- Develop a proper Request for Proposal (RFP) and evaluation criteria.
- Engage in a structured and detailed process with a "preferred bidder" to develop single source solutions.
- Properly structured Service Level Agreement (SLA).
- Ensure dedicated and ongoing management of FM services and SLA.

5.3 COMPUTER AIDED FACILITY MANAGEMENT (CAFM)

The facilities management profession has come of age. Its practitioners require skill and knowledge to manage the increasingly broad range of services included in the facilities management areas. One of the key tools of facilities management included in these different services is an integrated CAFM system. In order to achieve better results, many of the organizational functions are integrated with the help of CAFM. There is special software such as Maximo, Concept 500, Datastream7i, Frontline/Shire systems available to manage these functions. Figure 5.3 illustrates elements of CAFM.

CAFM enables the facility manager and his/her team to track the status of work, assets, and records in order to manage and communicate an organization's day-to-day operations. The system can provide reports to use in allocating the organization's resources, preparing key performance indicators (KPIs) metrics to use in evaluating the effectiveness of current operations, and for making organizational decisions. The system can be used for space planning, procurement and store management, assets management budget preparation, statistical reporting, resource allocation and management, security management, waste management, and energy management. CAFM provides integrated facility management.

5.4 BENEFITS OF FM

The following are the benefits of facility management:

- Deliver strategic and operational objectives of the organization.
- Increase profits of the organization.
- Obtain client satisfaction.
- Enhance and project an organization's identity and image.

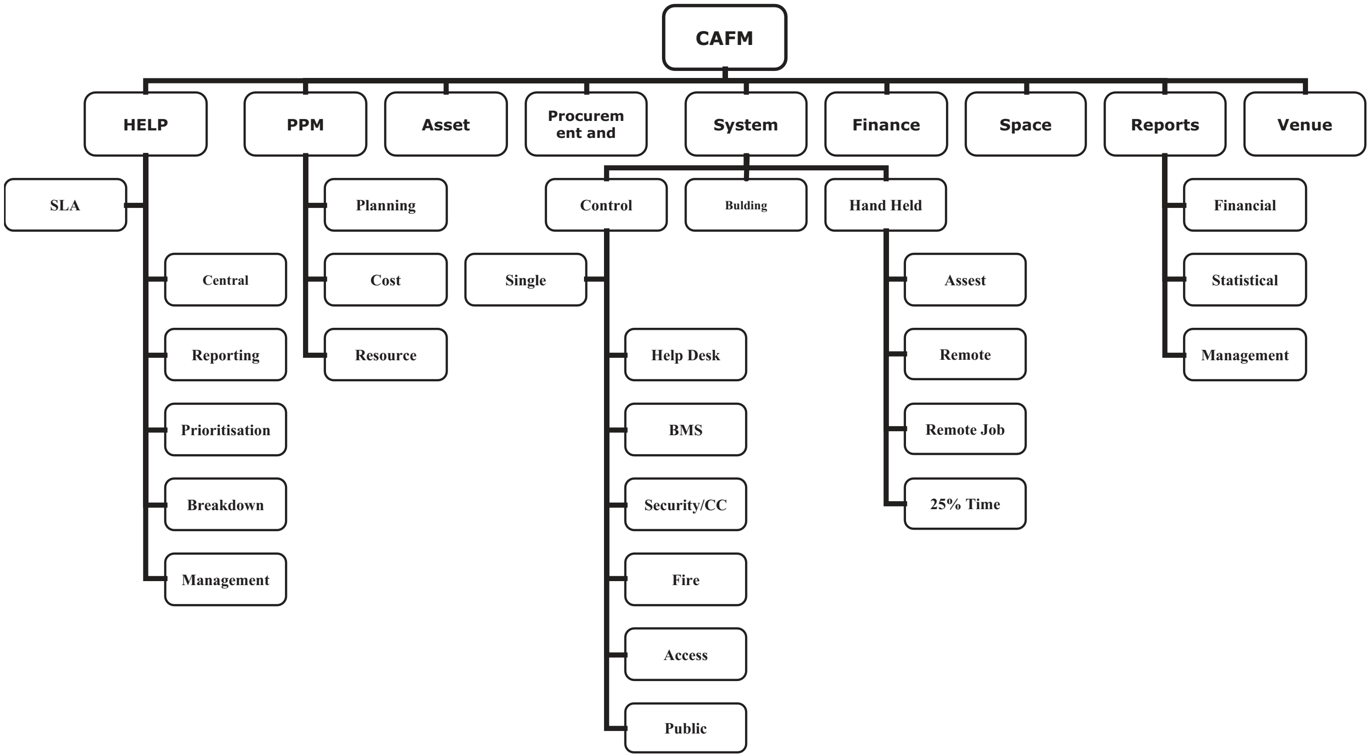

FIGURE 5.3 Elements of computer-aided facility management diagram.

- Deliver business continuity and workforce protection in an era of heightened security threats.
- Help the integration process associated with change, post-mergers, or acquisitions.
- Enable new working styles and processes—vital in this technology-driven age.
- Deliver effective management of an organization's assets.
- Manage energy efficiently.
- Bring about a safe and efficient working environment.

5.5 QUALITY REQUIREMENTS OF FM

The requirements for facility management are set by the owner of the facility. A facility management organization is required to establish a quality control system to ensure that facilities management work is performed satisfactorily and there is no interruption or breakdown of the systems. Table 5.3 illustrates an example of quality control requirements for operation and management of the facility. The actual requirements may vary from facility to facility and reflect the importance of various systems and services.

TABLE 5.3
Quality Control Requirements in Facility Management

Sr. No.	Work Area	Acceptable Quality Level	Quality Assurance Method
1	Access Control	Not more than one defect per month.	100% Inspection
2	Asset Management	No defect.	100% Inspection
3	Building Operations and Maintenance	Not more than 5% defect rate.	Random Sample
4	Communication System	Not more than 2% defect rate.	Random Sample
5	Drainage	No defect.	100% Inspection
6	Electrical System	Not more than 5% defect rate.	Random Sample
7	Electronic Security	No defect.	100% Inspection
8	Emergency Plans	Not more than one defect per month.	100% Inspection
9	Environment	As per regulatory requirements.	As Per Regulatory Requirements
10	Fire Alarm System	Not more than 5% defect rate.	Random Sample
11	Fire Fighting Plumbing	Not more than 5% defect rate.	Random Sample
12	Health and Safety	As per regulatory requirements.	As Per Regulatory Requirements

(*Continued*)

TABLE 5.3 Continued

Sr. No.	Work Area	Acceptable Quality Level	Quality Assurance Method
13	HVAC	Not more than one defect per month	Random sample Customer complaint
14	Information Technology	No defect.	100% Inspection
15	Infrastructure	Not more than one defect per month.	Random Sample
16	Inventory Management	No defect.	100% Inspection
17	Irrigation	Not more than one defect per month.	100% Inspection
18	Landscape	No defect.	100% Inspection
19	Parking Management	Not more than one defect per month.	Random Sample
20	Plumbing	Not more than one defect per month.	100% Inspection
21	Record Management	No defect	100% Inspection
22	Space Management	Not more than one defect per month.	100% Inspection

Appendix A
Content of Contractor's Quality Control Plan

CONTRACTOR'S QUALITY CONTROL PLAN

The contractor's quality control plan is prepared based on project-specific requirements as specified in the contract documents.

The plan outlines the procedures to be followed during the construction period to attain the specified quality objectives of the project fully complying with the contractual and regulatory requirements.

The following is an outline of such a plan, based on contract documents.

1.0 INTRODUCTION

The contractor's quality control plan is developed to meet Contractor's Quality Control (CQP) requirements of (project name) as specified under clause (----) and section (----) of contract documents.

The plan provides the mechanism to achieve the specified quality by identifying the procedures, controls, instructions, and tests required during the construction process to meet the owner's objectives. This QCP does not endeavor to repeat or summarize contract requirements. It describes the process M/S ABC (contractor name) will use to assure compliance with those requirements.

2.0 DESCRIPTION OF PROJECT

The owner (name) has contracted M/S ABC to construct (name of facility) located at (site plan). The facility consists of approximately (---) m^2 gross building area and approximately (---) m^2 of two basements for car parking and other services.

The facility is to be used as office premises to accommodate (---) personnel. The architecture of the building is of very high quality with a spacious atrium between two towers interconnected with a bridge inside the building, and a well-designed internal landscape area with plants and sky garden to provide a pleasant view inside the building. The building has glazed walls and curtain walling for the atrium area.

Vertical transportation is through panoramic elevators and a designated elevator for VIPs. Additionally, there is a goods elevator and a firefighters' elevator to meet an emergency situation.

The structure of the building is of reinforced concrete, and the atrium is of structured steel. External cladding includes a spandrel curtain wall for the block structure and special curtain walling for the atrium. Interior finishes are painted plastered walls, marble, and stone finish. Internal partitions have flexibility to adjust the office area. The entire building has a raised floor system, and space under the raised floor is used for distribution of electromechanical services.

The HVAC system is composed of water-cooled chillers, and electric duct heaters are provided for heating during winter. BMS takes full control of HVAC. Building is provided with all the safety measures against fire. A fire protection system, smoke exhaust fans, and fire alarm system with voice evacuation system are provided to meet an emergency situation. The fire protection system also includes automatic sprinklers, hose reels, extinguishers, and a foam system.

The building is equipped with all the amenities required for a public health system. The plumbing system is consistent with the requirements of the building and includes cold and hot water, drainage, rainwater collection, and an irrigation system. Water fountains are provided at various locations for drinking purposes.

Electrical systems consist of energy-saving lighting with centralized controls. Electrical distribution has all the required safety features. A diesel generator system and uninterrupted power supply system is provided to meet the emergency due to power failure from the main electricity provider. The building to be constructed shall be equipped with the latest technological systems. It shall have an IP-Based communication system, and all the low-voltage systems shall be fully integrated. Authorized persons shall have access from anywhere, either from within the building or outside.

The building has fully integrated low-voltage systems.

Apart from training and conference facilities, a fully functional auditorium having capacity for (---) people and conferencing is available in the building. It has a sophisticated conferencing system with a rear projection screen.

The contract documents consist of total (----) contract drawings. These are

Architectural	(---) nos.
Architectural Interior	(---) nos.
Structural	(---) nos.
Firefighting	(---) nos.
Public Health	(---) nos.
HVAC	(---) nos.
Electrical	(---) nos.
Smart Building	(---) nos.
Traffic Signage	(---) nos.
Landscape	(---) nos.

3.0 QUALITY CONTROL ORGANIZATION

The QC organization is independent of those persons actually performing the work. They shall be responsible for implementing the quality plan for the entire contract/project-related activities by scheduling the inspection, testing, sampling, and preparation of mock-up and to assure that work is performed per approved shop drawings and contract documents.

An organizational chart showing the line of authority and functional relationship is shown in Figure A.1.

Quality control in charge shall be responsible to ensure implementation of project quality. He/she will be supported by quality control engineers as follows:

1. Quality Control Engineer (Civil Work)
2. Quality Control Engineer (Concrete Work)
3. Quality Control Engineer (Mechanical Work)
4. Quality Control Engineer (Electrical Work)
5. Foreman (Concrete Work)

These engineers will be responsible for implementing three phases of the quality system at site. The quality control in charge will coordinate with the company's head

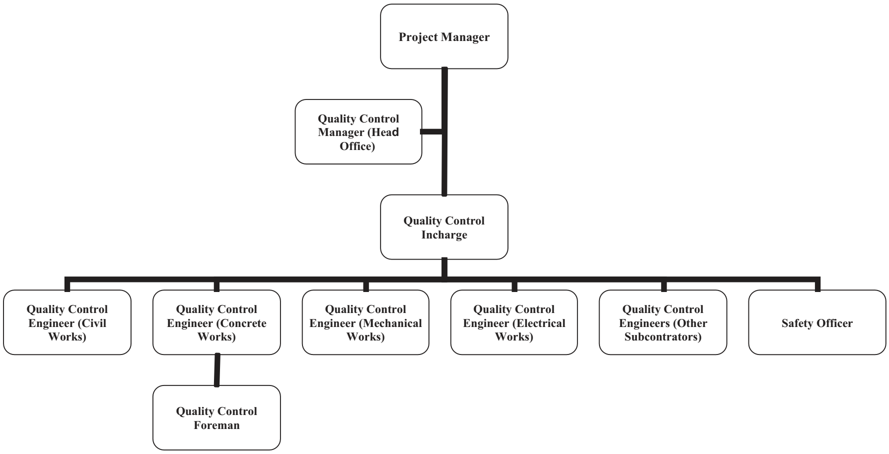

FIGURE A.1 Site quality control organization.

office for all the support and necessary actions. Respective quality control engineers shall be responsible to implement the quality program in their respective fields.

4.0 QUALIFICATION OF QC STAFF

All the QC personnel will have adequate experience in their respective fields. The following is the qualification of each of the quality control staff. Additional staff shall be provided if required.

Quality Control in Charge: He/she shall be a qualified civil engineer having minimum ten years of experience as a quality control engineer in major construction projects.

Quality Control Engineer (Civil Works): Graduate civil engineer with a minimum three years' experience as a quality engineer on similar projects.

Quality Control Engineer (Concrete Works): Graduate civil engineer with minimum years' experience as a quality engineer on similar projects.

Quality Control Engineer (Mechanical Works): Graduate mechanical engineer with a minimum three years' experience as a quality engineer on similar projects.

Quality Control Engineer (Electrical Works): Graduate electrical engineer with a minimum three years' experience as a quality engineer on similar projects.

Foreman (Concrete Works): Diploma in civil engineering with a minimum five years' experience as a quality supervisor on similar projects.

5.0 RESPONSIBILITIES AT QC PERSONNEL

Project Manager: Overall project responsibilities.

Quality Control in Charge: He/she shall be responsible for the following:

- Preparation of QC plan.
- Responsible for overall QC/QA responsibilities.
- Responsible for monitoring and evaluation CQP.
- Implementation of QC plan.
- Responsible for implementing QC procedure.
- Maintain QC records and documents.
- Inspection of work.
- Responsible for off-site inspection.
- Inspection of incoming material.
- Responsible for subcontractor's QC plan.
- Coordinating with safety officer to implement safety plan.
- Calibration of measuring instruments.
- Monitoring equipment certification.

Quality Control Engineers: Each trade shall have a responsible quality control engineer to ensure that work is carried out in accordance with the contract documents. The following quality control engineers shall be available at site. A foreman will assist the quality control engineer to maintain the quality of concrete work.

1. Quality Control Engineer (Civil Work)
2. Quality Control Engineer (Concrete Work)
3. Quality Control Engineer (Mechanical Work)
4. Quality Control Engineer (Electrical Work)
5. Quality Control Engineer (Other Subcontractors)
6. Foreman (Concrete Work)

The aforementioned personnel will be responsible for the following:

- Overall quality of the respective trade.
- Preparation of method statement.
- Preparation of mock-up.
- Monitor and inspect quality of site works.
- Inspection of incoming material.
- Coordinate with quality in charge for preparation of CQP.
- Quality control records and documents.

6.0 PROCEDURE FOR SUBMITTALS

M/S ABC shall be responsible for timely submission of subcontractors, shop drawings, and materials to be used in the project.

6.1 SUBMITTALS OF SUBCONTRACTOR(S)

Prior to submission of the subcontractor's name to the owner/consultant, M/S ABC shall review the capabilities of the subcontractor to perform the contracted work properly per the specified quality and within the time allowed. M/S ABC shall also consider the contractor's performance in the previously executed project. Companies implementing a quality management system plan and having ISO certification shall be given preference while selecting the subcontractor(s) to work on this project.

6.2 SUBMITTALS OF SHOP DRAWINGS

Before the start of any activity, M/S ABC shall submit shop drawings based on contract drawings and other related documents. The number of shop drawings shall depend on the requisite details to be prepared against each contract drawing. The shop drawings shall be prepared in the agreed format and shall have coordination certification from all the trades. All the shop drawings shall be submitted through site transmittal for shop drawings. Shop drawing approval transmittals shall be numbered serially for each section of the particular specification. M/S ABC shall be responsible for shop drawings related to subcontracted works.

6.3 SUBMITTALS OF MATERIALS

M/S ABC shall submit materials, products, and systems for owner's/consultant's approval from the recommended/nominated manufacturers specified in the contract documents. If material is proposed from a manufacturer who is not nominated, then all the documents to justify that the proposed product is approved and equal to the specified shall be submitted along with the site transmitted for materials approval.

6.4 MODIFICATION REQUEST

If during construction, the contractor observes that some work as mentioned in the contract needs modification, then such a modification request shall be submitted to the owner/consultant for their review and approval. Financial obligations shall be clearly specified in the request form.

6.5 CONSTRUCTION PROGRAM

M/S ABC shall prepare and submit a construction program based on the contracted time schedule and submit the same to the consultant for approval. Progress of work shall be monitored on a regular basis and the construction program shall be updated as and when required to overcome the delay (if any). The following reports shall be submitted to the consultant per the following schedule:

1. Daily report on a daily basis.
2. Weekly report on a weekly basis.
3. Monthly report on a monthly basis.
4. Progress photographs on a monthly basis.

7.0 QUALITY CONTROL PROCEDURE

7.1 PROCUREMENT

Prior to placing a purchase order or supply contract with the supplier/vendor, ABC will ensure that the material has been approved and it complies with the requirements of the contract. A procurement log shall be maintained for all the items for which action has been taken. The procurement log shall be submitted to the owner/consultant every two weeks for review and information.

7.2 INSPECTION OF SITE ACTIVITIES (CHECKLISTS)

All the work at site shall be performed per approved shop drawings by using approved material. At least three phases of control shall be conducted by the quality control in charge for each activity prior to submission of the checklist to the consultant.

These will be:

- Preparatory Phase
- Start-Up Phase
- Execution Phase

Preparatory Phase: The concerned engineer shall review the applicable specifications, references and standards, approved shop drawings and materials, and other submittals (method of statements, etc.) to ensure compliance with the contract.

Start-Up Phase: The concerned engineer shall discuss with the foreman responsible to perform the work and shall establish the standards of workmanship.

Execution Phase: The work shall be executed by continuous inspection during this phase.

All the execution/installation work shall be carried out per approved shop drawings utilizing approved material. All the work will be checked for quality before submitting the checklist to the consultant to inspect the work.

The following main categories of site work shall be performed by conducting quality control per the aforementioned phases.

7.2.1 Definable Feature of Work

Procedure for scheduling, reviewing, certifying, and managing quality control for a definable feature of work shall be agreed upon during the coordination meetings. The definable features of work for concrete shall include formwork, reinforcement, embedded items, design mix, placement of concrete, concrete finishes, etc.

Likewise, the detailed list for other trades shall be prepared during the coordination meetings. This will consist of embedded conducting works, embedded sleeves, ducts, underground piping, etc.

7.2.2 Earthwork and Site Work

This category shall consist of the following subgroups:

1. Excavation and Backfilling
2. Compaction
3. Dewatering

A checklist shall be submitted to consultant at every stage of work, that is, after backfilling and compaction. Samples shall be taken to make a compaction test. If the compaction test fails the required specifications, then remedial action shall be taken to obtain specified results.

7.2.3 Concrete

M/S (approved subcontractor to supply ready-mix concrete) will provide ready-mix concrete for entire concrete structural work of the project. M/S (ready-mix subcontractor) will have their own quality control system to maintain the mix design.

Reinforcement steel shall be inspected upon receipt of material at site for proper size and type, and the factory test certificates received with the supply. Small pieces of sample shall be taken from each lot and size for laboratory testing. The testing shall be performed by an approved testing laboratory.

Formwork and the reinforcement steel process shall be performed under a qualified civil engineer(s) and foreman (foremen). They will be continuously inspecting the work for each operation and checklist shall be submitted to the consultant for their approval.

Placement of concrete shall be supervised by the civil engineer along with the foreman and other team members. The respective consultant will witness concrete casting and take concrete samples during casting for laboratory testing and crushing tests. Slump tests shall be performed on the concrete to verify the strength. Curing shall be supervised by the respective foreman.

In case the test results do not comply with the specification limit, the results shall be discussed with the consulting engineer. Failing tests will be followed by appropriate corrective (reworking) efforts, retesting, and remedial measures.

M/S ABC shall maintain all the records, laboratory tests, and results regarding the concrete work and submit the same to the consultants for their information.

7.2.4 Masonry

The concrete block bricks used on the project shall be procured from the approved source. Material for mortar aggregate and other accessories such as inserts, reinforcement material, wire mesh, etc., shall be submitted to the consultant for approval.

Prior to the start of masonry work, all the related and coordinated drawings shall be reviewed. Marking shall be made for masonry layout. Necessary mock-ups shall be submitted for each type of unit masonry work. A checklist shall be submitted for visual and other type of inspection.

7.2.5 Metal Work

Metal fabrication and installation work shall be carried out by certified welders, per manufacturer's recommendations, and per approved shop drawings. Samples of fittings, brackets, fasteners, anchors, and different types of metal members, including plates, bars, pipes, tubes, and any other type of material to be used in the project shall be submitted to the consultants prior to start of fabrication work at site. Finishing materials such as primer and paint shall be submitted for approval to the consultant/owner.

In case the fabrication is carried out at the subcontractor(s)'s workshop, then ABC shall take full responsibility to control the quality.

A checklist shall be submitted at different stages of work to ensure compliance with the specifications and to avoid any rework at the end of completion of fabrication and installation.

7.2.6 Wood, Plastics, and Composite

Prior to he start of any woodwork, the material shall be physically and visually inspected for timber quality to confirm its compliance with the type of the approved material and also to ensure that the wood is free from decay and insects and that necessary treatment has already been done on the wood to be used for the project. A product certificate signed by the woodwork manufacturer certifying that the products comply with specified requirements shall be submitted along with material submittal. All types of fasteners and other hardware to be used shall be submitted for approval per applicable standards, and checklists shall be submitted at various stages of work prior to applying the paint or any other finishes.

7.2.7 Doors and Windows

This category shall consist of the following subcategories:

1. Wooden doors and windows.
2. Steel doors.
3. Aluminum windows.
4. Glazing.

All doors and windows shall be fabricated from a specified type and material per approved shop drawings.

Fire-Rated types of doors shall comply with relevant standards and local regulations.

Samples of materials used in fabrication of doors and windows shall be submitted to the consultant/owner for approval.

Wooden doors and windows shall be fabricated at an approved subcontractor for carpentry work, and aluminum doors and windows shall be fabricated at an approved subcontractor for aluminum work. Finishes shall be as approved by the owner/consultant. Samples of ironmongery coating material and finishing material shall be submitted for approval. Special care shall be taken to maintain the acoustic nature of doors and their sound transmission properties.

Glass and glazing material shall be submitted for approval and shall take care of heat transfer properties to maintain the inside temperature of the building. The glass used in the project shall comply with specified strength, safety, and impact performance requirements.

Inspection at different stages shall be arranged by field inspection at the factory.

The entire fabrication shall be carried out under supervision of ABC to control the quality of finished products.

Doors and window fabrication shall be coordinated for security requirements. Mock-Ups shall be prepared before the start of installation work.

7.2.8 Finishes

This category shall consist of the following subgroups:

1. Acoustic ceiling.
2. Specialty ceiling.
3. Masonry flooring.
4. Tiling.
5. Carpet.
6. Wall cladding.
7. Wall partitioning.
8. Paints and coating.

All the finishes shall be as specified and approved. Execution of finishing work shall be coordinated with all other trades. Samples and mock-ups shall be submitted for approval before start of any finishing work. All the finishing work shall be performed by skilled workmen. Specialist subcontractor(s) shall be submitted for approval to carry out finishing works. Quality control shall be under direct supervision of ABC.

7.2.9 Furnishing

All the furnishing shall be from the specified recommended manufacturer. Special care shall be taken to protect the furnishings. Furnishing material sample(s) shall be submitted for approval. Fabrication of furniture shall be at the approved subcontractor's factory. ABC shall be responsible for controlling the quality.

7.2.10 Equipment

This category shall consist of the following subgroups:

1. Maintenance equipment such as window and façade cleaning.
2. Stage equipment.
3. Parking control equipment.
4. Kitchen equipment.

All the equipment shall be from specified manufacturers. If the items specified are commercial items—that is, the materials are manufactured and sold to the public as against the materials made to specifications—necessary precautions shall be taken to verify that materials shall be installed per manufacturer's recommended procedure under the supervision of a qualified engineer.

Items to be manufactured per contract documents shall be procured from the manufacturer producing products comply with recognized quality standards. The product and manufacturer's data shall be submitted for approval with all the technical details. Installation of the equipment shall be carried out by skilled workmen under supervision of the manufacturer's authorized representative and under the control of ABC.

7.2.11 Conveying System

This category consists of the following subgroups:

1. Passenger elevators.
2. Goods elevators.
3. Kitchen elevators.
4. Escalators.

Prior to submission of shop drawings, full technical details along with the catalogs and compliance statement shall be submitted for approval. The elevators shall be from one of the recommended manufacturers specified in the contract documents.

Fabrication of conveying systems shall comply with relevant codes and standards as applicable. Regulatory approval shall be obtained from local authorities for installation of the conveying systems to ensure their compliance with local codes and regulations.

Finishing material for the cab, landing door, car control station, and car position indicator shall be submitted for approval.

Coordinated factory shop drawings shall be submitted for approval. Size of shaft and door openings shall be coordinated during structural work. Necessary tests shall be performed by the manufacturer's authorized personnel.

Factory fabrication work shall be performed per the manufacturer's quality control plan, and installation at site shall be carried out by personnel authorized by the manufacturer.

Third-party inspection shall be arranged per specification requirements.

7.2.12 Mechanical Works

This category shall consist of the following subgroups:

1. Fire suppression.
2. Water supply, plumbing, and public health.
3. HVAC.

Mechanical work shall be executed by an approved mechanical subcontractor. All the work shall be carried out per approved shop drawings using approved material.

A mechanical engineer from the subcontractor shall be responsible for controlling the quality of work. A quality control engineer (mechanical work) shall coordinate all quality-related activities on behalf of ABC. Fire suppression or firefighting equipment shall be carried out per approved drawings by the relevant authority. Materials shall be from the manufacturers approved by the relevant authority having jurisdiction over such materials. Fire pumps and firefighting materials shall comply with regulatory requirements.

Piping for water supply, plumbing, and public health shall be installed with approved material. Leakage and pressure tests shall be performed as specified.

Checklists shall be submitted after installation of piping, accessories, and fixing of equipment. Drainage systems shall be executed per approved shop drawings.

HVAC work shall be supervised by a qualified mechanical engineer. Ductwork and duct accessories shall be fabricated at the subcontractor's workshop and shall be installed at site per approved shop drawings. A mechanical engineer from subcontractor shall be responsible to control the quality at the workshop. A quality control engineer (mechanical work) shall coordinate all quality-related activities on behalf of ABC. Duct material shall be submitted for approval prior to start of fabrication works. Chilled/hot water piping shall be from the approved manufacturer. Installation of piping shall be carried out by certified pipe fitters.

Selection of HVAC pumps shall be done with the help of performance curves and technical data from the pump manufacturer. Chillers shall be from the specified manufacturer.

Installation of chillers shall be carried out per the manufacturer's recommendation.

7.2.13 Automation System

Automation work shall be carried out under supervision of a specialist engineer. The system shall be from the specified manufacturer.

Shop drawings and schematic diagrams shall be submitted for approval configuring approved components/items/equipment.

7.2.14 Electrical Works

This category shall consist of the following subgroups:

1. Electrical lighting and power.
2. Fire alarm system.
3. Communication system (telephone).
4. Public address system.
5. Access control and security system.
6. Audiovisual system.
7. MATV system.
8. Emergency generating system.
9. Alternate energy system.

All types of electrical work shall be executed by an approved electrical subcontractor. All the materials/products to be used shall be from the specified manufacturer and shall be installed by skilled workmen under the supervision of a qualified engineer.

An electrical engineer from the subcontractor shall be responsible to control the quality at the workshop. A quality control engineer (electrical work) shall coordinate all quality-related activities on behalf of ABC. Work shall be carried out per approved shop drawings. The quality of the work shall be controlled at different stages such as after installation of conducting/raceways, pulling of wires/cables, and installation of accessories/equipment/panels. Work shall comply with the specifications and recognized codes and standards.

Specified tests shall be performed at every stage. Coordination will be done with other trades to ensure that the required power supply for their equipment will be available at designated locations.

7.2.15 Landscape

Landscape work shall be executed by a specialist-approved subcontractor per the approved shop drawings under direct supervision of ABC. Samples of each and every type of plant, tree, etc., shall be submitted for approval. Soil preparation shall be done per specified standards.

Checklists shall be submitted after completion of activities at each stage.

Work not accepted or rejected shall be repaired/reworked or replaced and checklist shall be resubmitted.

Guarantees and warranties for installed products/items shall be submitted per contract requirements during handover of the project.

7.3 INSPECTION AND TESTING PROCEDURE FOR SYSTEMS

The QC procedure for systems (low voltage/low current) and their equipment/components shall be performed in the following stages.

The proposed manufacturer's complete data giving full details of the capability of the proposed manufacturer to substantiate compliance with the specifications and to prove that the proposed manufacturer is following quality management system and producing the product to recognized quality standards as specified shall be submitted. Components/equipment data shall be submitted for all the specified items of the system.

A schematic diagram configuring all the items for the system shall be submitted along with a detailed technical specification and confirmation from the manufacturer that it complies with the contract documents and is equal to or better than the specified products.

Shop drawing(s) fully coordinating with other trades, showing the system location, and the raceways used for installation of the system shall be submitted.

All the work at site shall be submitted for inspection at different stages of execution of work.

Cable testing shall be performed prior to installation of equipment. Checklists shall be submitted to the consultant to witness these tests.

Installation of equipment shall be done according to the manufacturer's recommendations and per approved installation methods.

Checklists, along with testing procedures, shall be submitted prior to inspect final inspection and testing.

7.4 OFF-SITE MANUFACTURING, INSPECTION, AND TESTING

QC procedures for off-site manufacturing/assembling shall be per contract documents. Factory control inspection for items fabricated or assembled shall be carried out to comply with all the specified requirements and standards under the responsibility of QC personnel at the fabrication/assembly plant. Specified tests shall be carried out per the manufacturer's quality procedures and per specification requirements. Test reports for items fabricated/assembled off-site shall be submitted along with the delivery of material at site. Witnessing/observation of inspection and tests by the consultant/client, if it is required per specifications, shall be arranged. Procedure for such tests and inspection shall be submitted in advance of factory/plant visit.

Quality control for off-the-shelf items shall be standard quality control practices followed by the manufacturer.

7.5 PROCEDURE FOR LABORATORY TESTING OF MATERIALS

M/S ABC shall submit name(s) of testing laboratories for approval for performing tests specified in the contract documents.

7.6 INSPECTION OF MATERIAL RECEIVED AT SITE

All the material received at site shall be submitted for inspection by the consultant. A material on-site inspection request (MIR) shall be submitted to the consultant. Prior to dispatch of material from the manufacturer's premises, all the tests shall be carried out, and test certificates shall be submitted along with the MIR. Apart from this, all the relevant documents such as the packing list, delivery note, certificate of compliance to recognized standards, country of origin, and any other documents, shall be submitted along with the MIR.

Material received at the site shall be properly stored at designated locations and shall maintain original packing until its installation/use.

Inventory records shall be maintained for all the material stored at the site. In case of materials to be directly installed at the site upon its receipt, the inspection shall be carried out before its use or installation on the project.

In the case of concrete ready-mix, samples will be tested per contract documents before pouring the concrete for castings.

Specified tests shall be performed after delivery of material at site.

7.7 PROTECTION OF WORK

All the work shall be protected at site per specified methods in the contract documents.

7.8 MATERIAL STORAGE AND HANDLING

M/S ABC shall arrange for a storage facility on the project site to keep the material in safe condition. Material at site shall be fully protected from damages and properly stored. Necessary care shall be taken to store paints and liquid types of materials by maintaining appropriate temperatures to prevent damage and deterioration of such products. Materials, products, and equipment shall be properly packed and protected to prevent damage during transportation and handling.

8.0 METHOD STATEMENT FOR VARIOUS INSTALLATION ACTIVITIES

Method statement shall be submitted to the consultant for their approval per the contract documents. The method statement shall describe the steps involved for execution/installation of work by ensuring safety at each stage. It shall have the following information:

1. Scope of work: Brief description of work/activity.
2. Documentation: Relevant technical documents to undertake this work/activity.
3. Personnel involved.
4. Safety arrangement.
5. Equipment and plant required.
6. Personal protective equipment.
7. Permits/authorities' approval to work.
8. Possible hazards.
9. Description of the work/activity: Detailed method of sequence of each operation/key steps to complete the work/activity.

Figures A.2–A.9 are illustrative examples of the method of sequence for major activities, for different trades, performed during the construction process.

9.0 PROJECT SPECIFIC PROCEDURES FOR SITE WORK INSTALLATIONS REMEDIAL NOTICE

Quality control for such installations shall be as specified in the contract documents or as mentioned in the instructions.

Remedial notices received shall be actioned immediately and replied to inspect the work having corrected/performed per contract documents. Similarly, nonconformance report shall be actioned and replied.

All repaired and reworked items shall be inspected by the concerned engineer and quality control engineer before submitting a "request for inspection" or "checklist."

Appropriate preventive actions shall be taken to avoid repetition of nonconformance work. The following steps shall be taken to deal with any problem requiring preventive action:

- Detect.
- Identify the potential causes.
- Analyze the potential causes.
- Eliminate the potential causes.
- Ensure the effectiveness of preventive action.

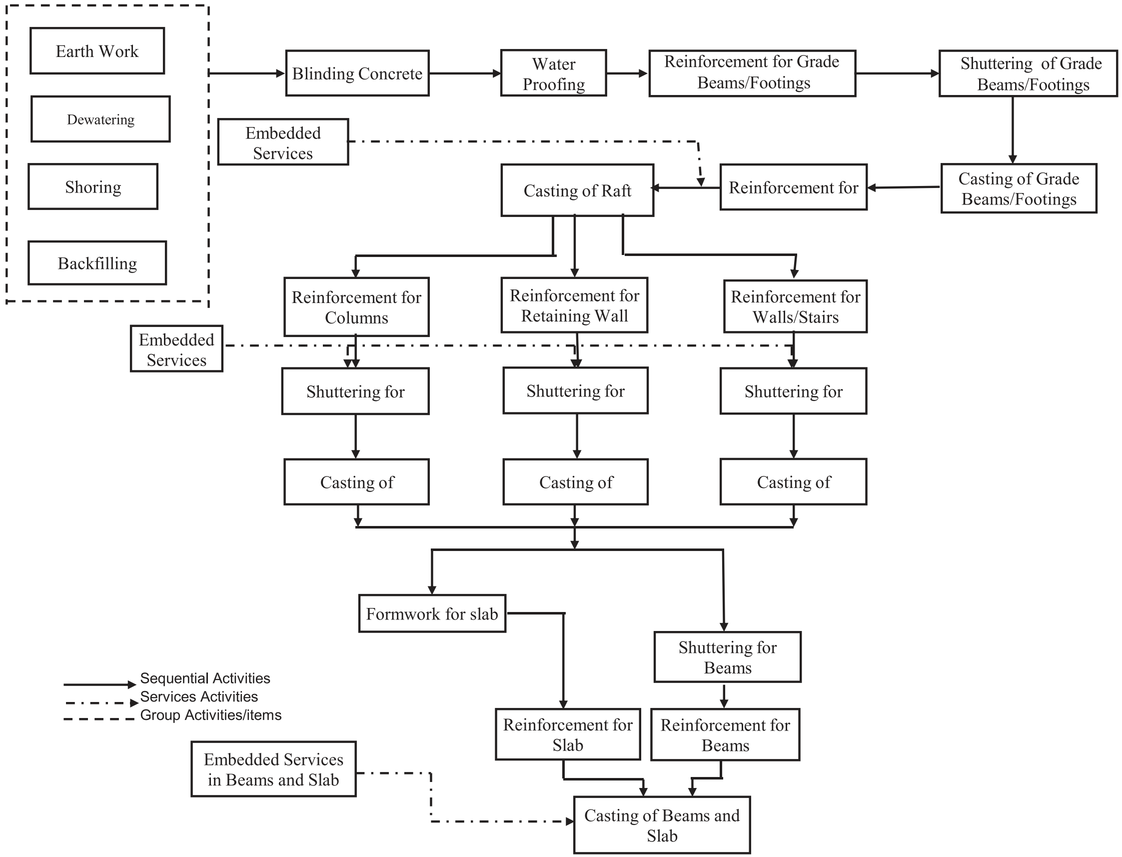

FIGURE A.2 Method of sequence for concrete structure work.

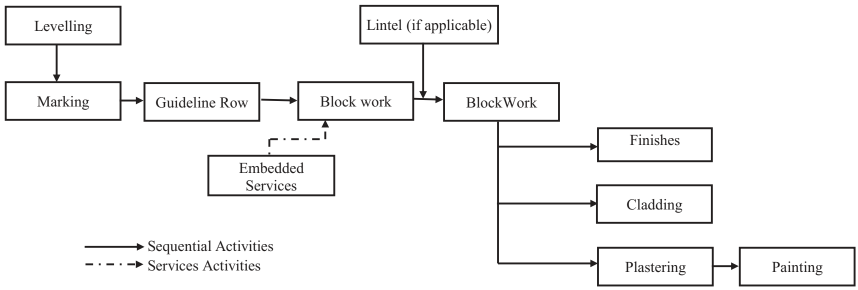

FIGURE A.3 Method of sequence for block masonry work.

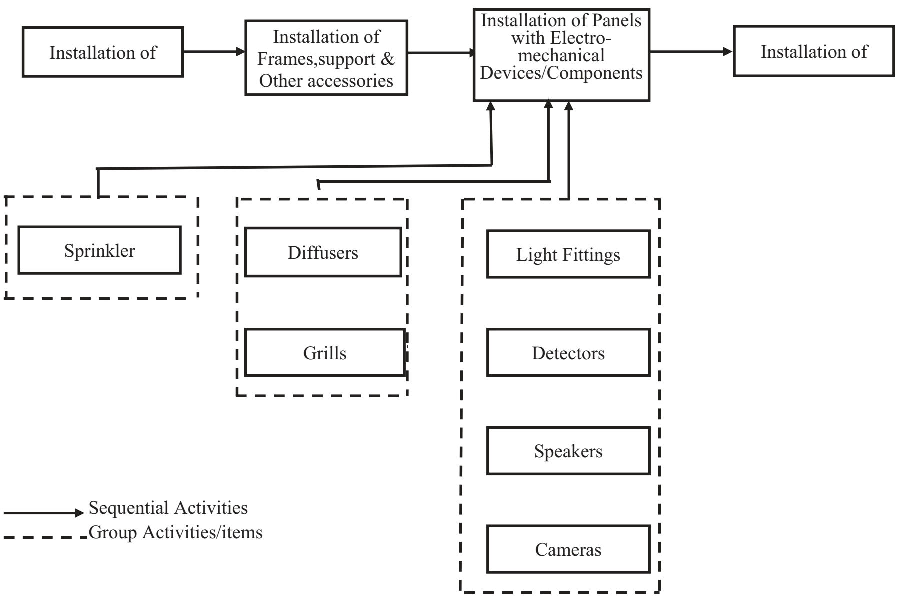

FIGURE A.4 Method of sequence for false ceiling work.

10.0 RISK MANAGEMENT

The contractor shall maintain risk register throughout the contract period and shall resolve/mitigate the risk with appropriate response(s)

11.0 QUALITY CONTROL RECORDS

Quality control records shall be maintained by the quality control in charge and shall be accessible to authorized personnel for review and information. The records shall include:

- Contract drawings and revisions.
- Contract specifications and revisions.

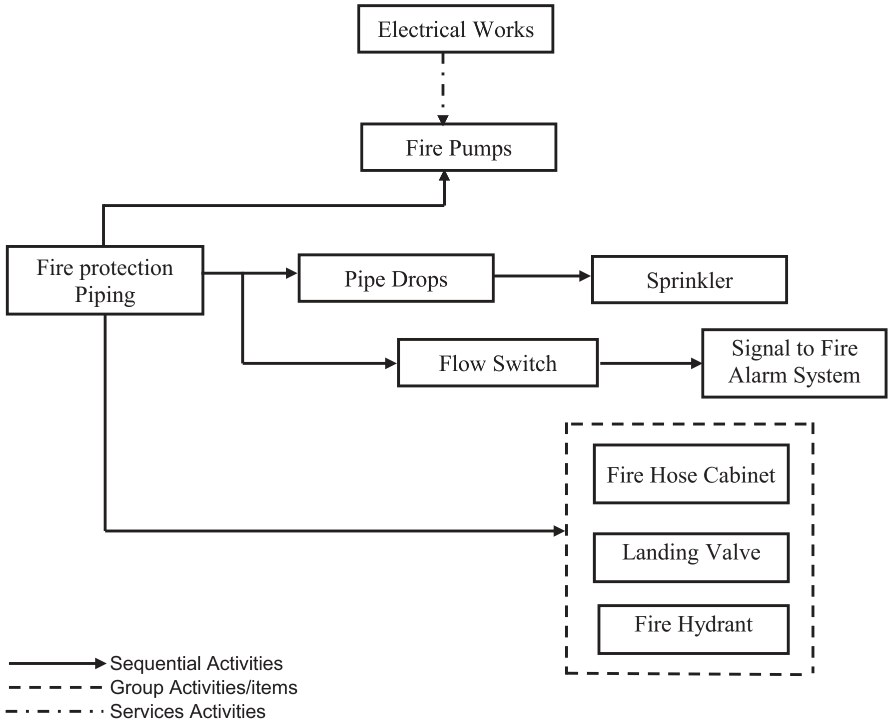

FIGURE A.5 Method of sequence for mechanical work (public health).

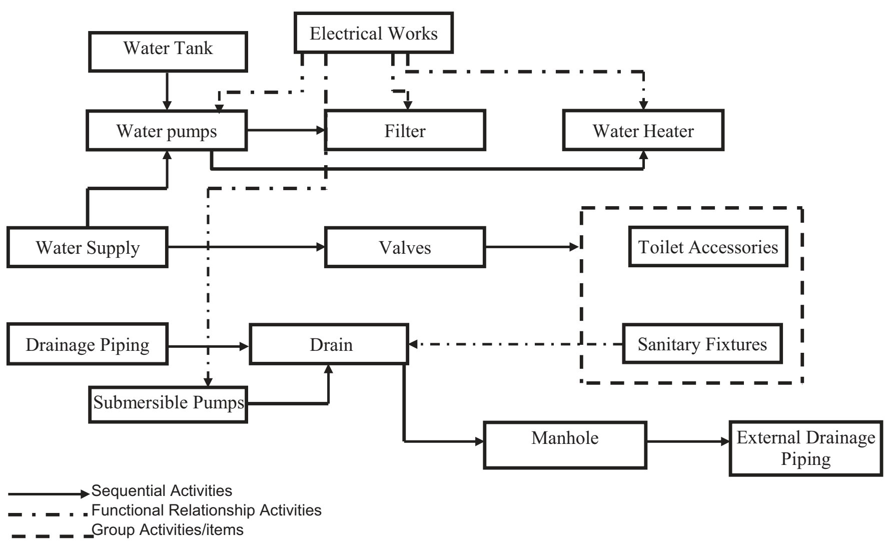

FIGURE A.6 Method of sequence for mechanical work (fire protection).

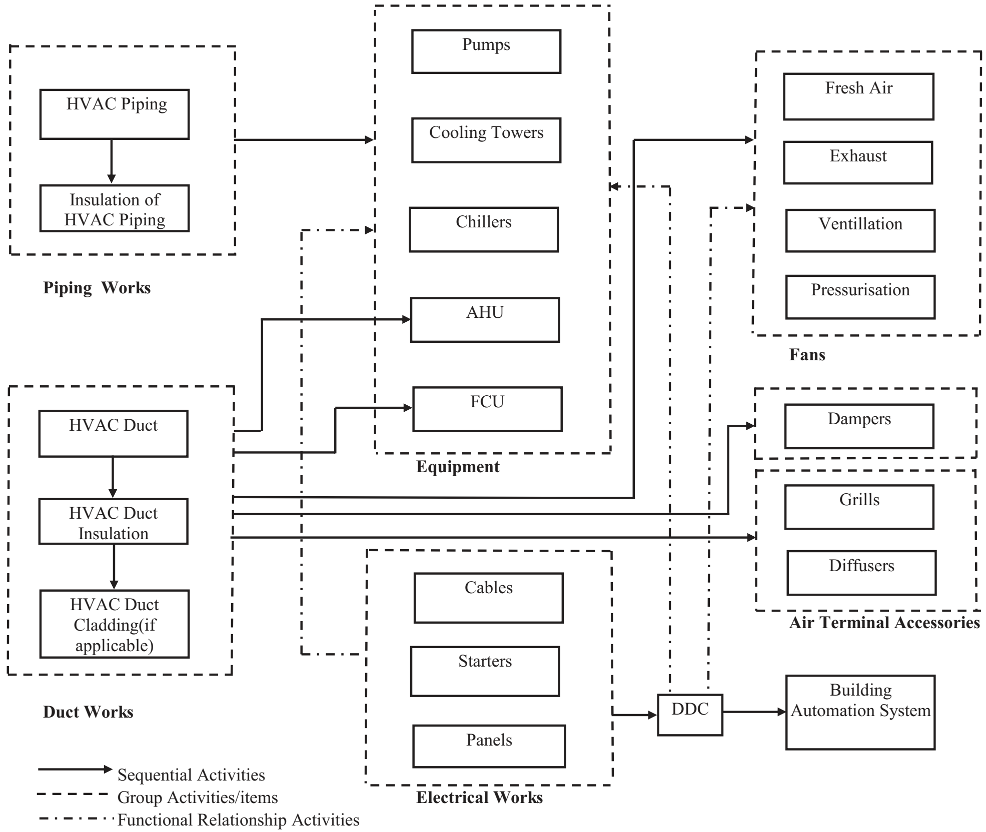

FIGURE A.7 Method of sequence for HVAC work.

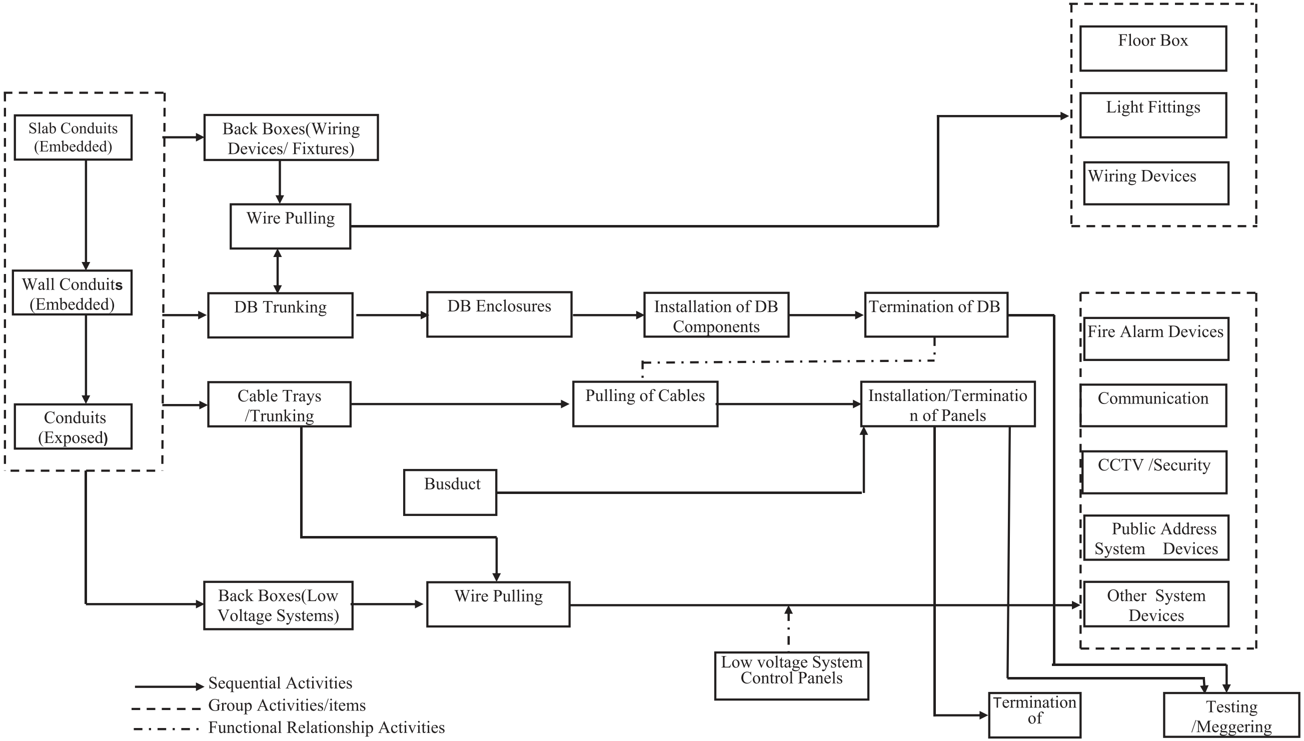

FIGURE A.8 Method of sequence for electrical work.

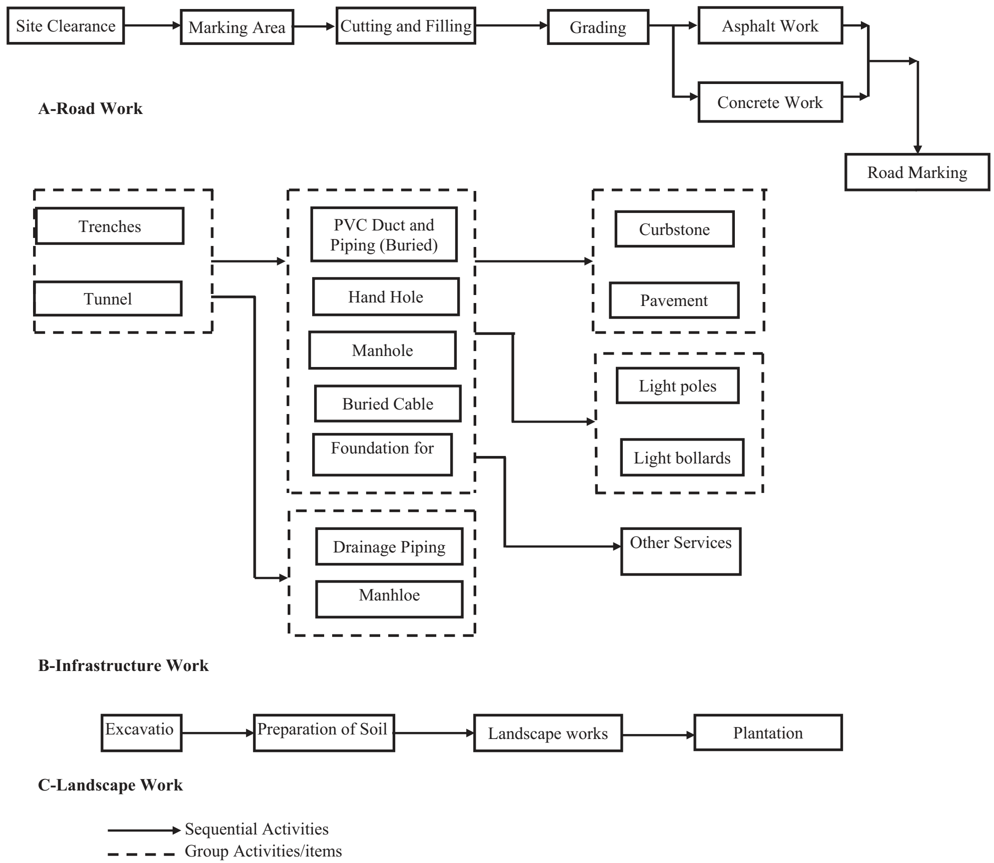

FIGURE A.9 Method of sequence for external work.

- Approved shop drawings.
- Record drawings.
- Material approval record.
- Checklists.
- Test reports.
- Material inspection reports.
- Minutes of quality control meetings.
- Site work instructions.
- Remedial notes.
- Other records specified in the contract documents or as requested by the owner/consultant.

12.0 COMPANY'S QUALITY MANUAL AND PROCEDURES

The following documents from the company's manual shall be part of contractor's quality control plan.

1. Documents for specific projects.
2. Subcontractor evaluation.
3. Supplier evaluation.
4. Client supplied items.
5. Receiving inspection and testing.
6. Site inspection and testing.
7. Final inspection, testing, and commissioning.
8. Material storage and handling.
9. Risk Management system.
10. Control of quality records.
11. Internal audit.

13.0 PERIODICAL TESTING OF CONSTRUCTION EQUIPMENT

Hoists, cranes, and other lifting equipment used at site shall be tested periodically by third-party inspection authority and test certificates shall be submitted to the consultant. Measuring instruments shall have calibration tests performed by the approved testing agencies/government agencies at regular intervals and a calibration certificate shall be submitted to consultants. Other equipment shall be tested/calibrated per contract requirements and per the schedule for such tests.

14.0 QUALITY UPDATING PROGRAM

The quality control program shall be reviewed every six months and necessary updates shall be done, if required. All such information shall be given to the consultants and a record shall be made for such revisions.

15.0 QUALITY AUDITING PROGRAM

Internal auditing shall be performed by the company's internal auditor to ensure that specified quality procedures are followed by the site quality personnel.

16.0 TESTING, COMMISSIONING, AND HANDOVER

The test shall be carried out per contract documents. Necessary test procedures shall be submitted prior to start of testing of installed systems/equipment.

Engineers from the respective trades will be responsible for arranging orderly performance of testing and commissioning of the systems/equipment.

17.0 HEALTH, SAFETY, AND THE ENVIRONMENT

The HSE officer shall be responsible for implementing health and safety measures per OHSAS 18000 and the project's environmental requirements per local regulatory authority. ABC shall prepare and submit a health and safety management and accident prevention program. The safety program shall embody the prevention of accidents, injuries, occupational illnesses, and property damage. All personnel at the site shall be provided with safety gear. Regular meetings and awareness training shall be conducted at the site on a regular basis. ABC shall ensure that first aid and emergency medical facilities are available at the site all the time. ABC shall comply with all safety measures specified in the contract documents. ABC shall take all necessary measures to comply with regulatory requirements and environmental considerations.

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