



# Construction

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*Donn E. Hancher*

*University of Kentucky*

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The construction industry is one of the largest segments of business in the United States, with the percentage of the gross national product spent in construction over the last several years averaging about 10%. For 2001, the total amount spent on new construction contracts in the U.S. is estimated at \$481 billion [*Engineering News Record*, Nov. 19, 2001]. Of this total, about \$214 billion is estimated for residential projects, \$167 billion for nonresidential projects, and the rest for nonbuilding projects.

Construction is the realization phase of the civil engineering process, following conception and design. It is the role of the constructor to turn the ideas of the planner and the detailed plans of the designer into physical reality. The owner is the ultimate consumer of the product and is often the general public

for civil engineering projects. Not only does the constructor have an obligation to the contractual owner, or client, but also an ethical obligation to the general public to perform the work so that the final product will serve its function economically and safely.

The construction industry is typically divided into specialty areas, with each area requiring different skills, resources, and knowledge to participate effectively in it. The area classifications typically used are residential (single- and multifamily housing), building (all buildings other than housing), heavy/highway (dams, bridges, ports, sewage-treatment plants, highways), utility (sanitary and storm drainage, water lines, electrical and telephone lines, pumping stations), and industrial (refineries, mills, power plants, chemical plants, heavy manufacturing facilities). Civil engineers can be heavily involved in all of these areas of construction, although fewer are involved in residential. Due to the differences in each of these market areas, most engineers specialize in only one or two of the areas during their careers.

Construction projects are complex and time-consuming undertakings that require the interaction and cooperation of many different persons to accomplish. All projects must be completed in accordance with specific project plans and specifications, along with other contract restrictions that may be imposed on the production operations. Essentially, all civil engineering construction projects are unique. Regardless of the similarity to other projects, there are always distinguishing elements of each project that make it unique, such as the type of soil, the exposure to weather, the human resources assigned to the project, the social and political climate, and so on. In manufacturing, raw resources are brought to a factory with a fairly controlled environment; in construction, the “factory” is set up on site, and production is accomplished in an uncertain environment.

It is this diversity among projects that makes the preparation for a civil engineering project interesting and challenging. Although it is often difficult to control the environment of the project, it is the duty of the contractor to predict the possible situations that may be encountered and to develop contingency strategies accordingly. The dilemma of this situation is that the contractor who allows for contingencies in project cost estimates will have a difficult time competing against other less competent or less cautious contractors. The failure rate in the construction industry is the highest in the U.S.; one of the leading causes for failure is the inability to manage in such a highly competitive market and to realize a fair return on investment.

## Participants in the Construction Process

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There are several participants in the construction process, all with important roles in developing a successful project. The owner, either private or public, is the party that initiates the demand for the project and ultimately pays for its completion. The owner’s role in the process varies considerably; however, the primary role of the owner is to effectively communicate the scope of work desired to the other parties. The designer is responsible for developing adequate working drawings and specifications, in accordance with current design practices and codes, to communicate the product desired by the owner upon completion of the project. The prime contractor is responsible for managing the resources needed to carry out the construction process in a manner that ensures the project will be conducted safely, within budget, and on schedule, and that it meets or exceeds the quality requirements of the plans and specifications. Subcontractors are specialty contractors who contract with the prime contractor to conduct a specific portion of the project within the overall project schedule. Suppliers are the vendors who contract to supply required materials for the project within the project specifications and schedule. The success of any project depends on the coordination of the efforts of all parties involved, hopefully to the financial advantage of all. In recent years, these relationships have become more adversarial, with much conflict and litigation, often to the detriment of the projects.

## Construction Contracts

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Construction projects are done under a variety of contract arrangements for each of the parties involved. They range from a single contract for a single element of the project to a single contract for the whole

project, including the financing, design, construction, and operation of the facility. Typical contract types include lump sum, unit price, cost plus, and construction management.

These contract systems can be used with either the competitive bidding process or with negotiated processes. A contract system becoming more popular with owners is design-build, in which all of the responsibilities can be placed with one party for the owner to deal with. Each type of contract impacts the roles and responsibilities of each of the parties on a project. It also impacts the management functions to be carried out by the contractor on the project, especially the cost engineering function.

A major development in business relationships in the construction industry is *partnering*. Partnering is an approach to conducting business that confronts the economic and technological challenges in industry in the 21st century. This new approach focuses on making long-term commitments with mutual goals for all parties involved to achieve mutual success. It requires changing traditional relationships to a shared culture without regard to normal organizational boundaries. Participants seek to avoid the adversarial problems typical for many business ventures. Most of all, a relationship must be based upon trust. Although partnering in its pure form relates to a long-term business relationship for multiple projects, many single-project partnering relationships have been developed, primarily for public owner projects. Partnering is an excellent vehicle to attain improved quality on construction projects and to avoid serious conflicts.

Partnering is not to be construed as a legal partnership with the associated joint liability. Great care should be taken to make this point clear to all parties involved in a partnering relationship.

Partnering is not a quick fix or panacea to be applied to all relationships. It requires total commitment, proper conditions, and the right chemistry between organizations for it to thrive and prosper. The relationship is based upon trust, dedication to common goals, and an understanding of each other's individual expectations and values. The partnering concept is intended to accentuate the strength of each partner and will be unable to overcome fundamental company weaknesses; in fact, weaknesses may be magnified. Expected benefits include improved efficiency and cost effectiveness, increased opportunity for innovation, and the continuous improvement of quality products and services. It can be used by either large or small businesses, and it can be used for either large or small projects. Relationships can develop among all participants in construction: owner-contractor, owner-supplier, contractor-supplier, contractor-contractor. (Contractor refers to either a design firm or a construction company.)

## Goals of Project Management

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Regardless of the project, most construction teams have the same performance goals:

**Cost** — Complete the project within the cost budget, including the budgeted costs of all change orders.

**Time** — Complete the project by the scheduled completion date or within the allowance for work days.

**Quality** — Perform all work on the project, meeting or exceeding the project plans and specifications.

**Safety** — Complete the project with zero lost-time accidents.

**Conflict** — Resolve disputes at the lowest practical level and have zero disputes.

**Project startup** — Successfully start up the completed project (by the owner) with zero rework.

## Basic Functions of Construction Engineering

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The activities involved in the construction engineering for projects include the following basic functions:

**Cost engineering** — The cost estimating, cost accounting, and cost-control activities related to a project, plus the development of cost databases.

**Project planning and scheduling** — The development of initial project plans and schedules, project monitoring and updating, and the development of as-built project schedules.

**Equipment planning and management** — The selection of needed equipment for projects, productivity planning to accomplish the project with the selected equipment in the required project schedule and estimate, and the management of the equipment fleet.

**Design of temporary structures** — The design of temporary structures required for the construction of the project, such as concrete formwork, scaffolding, shoring, and bracing.

**Contract management** — The management of the activities of the project to comply with contract provisions and document contract changes and to minimize contract disputes.

**Human resource management** — The selection, training, and supervision of the personnel needed to complete the project work within schedule.

**Project safety** — The establishment of safe working practices and conditions for the project, the communication of these safety requirements to all project personnel, the maintenance of safety records, and the enforcement of these requirements.

## **Innovations in Construction**

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There are several innovative developments in technological tools that have been implemented or are being considered for implementation for construction projects. New tools such as CAD systems, expert systems, bar coding, and automated equipment offer excellent potential for improved productivity and cost effectiveness in industry. Companies who ignore these new technologies will have difficulty competing in the future.

## **Scope of This Section of the Handbook**

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The scope of Section I, Construction, in this handbook is to present the reader with the essential information needed to perform the major construction engineering functions on today's construction projects. Examples are offered to illustrate the principles presented, and references are offered for further information on each of the topics covered.