An Introduction to the Building Industry for Architectural Engineers

AN INTRODUCTION TO THE BUILDING INDUSTRY FOR ARCHITECTURAL ENGINEERS

JOHN MESSNER

The Pennsylvania State University
University Park, PA

CONTENTS

PREFACE

This book provides an overview of the building industry, the projects performed within the industry, and methods to plan and manage the delivery of a project. This book has been developed to closely align with the topics and learning objectives of the AE 372 class at Penn State. The book is developed as a resource for the class, and frankly, to provide a book for the students that does not carry the cost of a typical textbook, and even better, free. This book will continue to mature. Please feel free to share any suggestions for improvement, or identify any errors which may be contained within the chapters. Instead of spending money on a textbook, I hope that you will be able to use your funds to contribute to future field trips to see some construction projects along with other educational experiences, and to ensure that you have the proper Personal Protective Equipment (PPE) to be safe when visiting and working on construction sites.

1.

CHAPTER 1: INTRODUCTION TO THE BUILDING INDUSTRY

Learning Objectives

After reading this chapter, you should be able to:

- Learn the Characteristics of the AEC Industry
- Understand the variety of projects performed within the industry
- Describe the scope and scale of the industry

The Building Industry is large, in fact, very large. The overall industry is the 2nd largest industry in the United States economy, 2nd only to the healthcare industry. Within the United State market, the industry accounts for 6.1% (2016 data) of the annual Gross Domestic Product (GDP) of the economy (Market Realist Website). The GDP is the value of all goods and services within an economy. Therefore, the Industry accounts for the same percentage of the economic transactions in the economy.

A reliable source of information on the construction sector is the US Census Bureau. They maintain monthly data related to work put into place along with employment (see sample data from website image in Figure 1). Visit the link to see the most recent data reported.

Value of Construction Put in Place at a Glance

October 2019

	Seasonally Adjusted Annual Rate (millions of dollars)			Not Seasonally Adjusted (millions of dollars)		
Total	1,291,069	XLS (11k)	PDF (31k)	115,501	XLS (11k)	PDF (31k)
Private	956,272	XLS (15k)	PDF (36k)	84,234	XLS (15k)	PDF (36k)
Residential	508,198	XLS (8k)	PDF (16k)	45,064	XLS (8k)	PDF (16k)
Nonresidential	448,073	XLS (8k)	PDF (18k)	39,170	XLS (8k)	PDF (18k)
Public	334,797	XLS (11k)	PDF (24k)	31,267	XLS (11k)	PDF (24k)
State and Local	310,404	XLS (11k)	PDF (31k)	29,273	XLS (11k)	PDF (31k)
Federal	24,393	XLS (8k)	PDF (18k)	1,994	XLS (8k)	PDF (18k)

Figure 1-1: Construction Spending with Private and Public Breakdown (Source: US Census Bureau accessed Jan. 2, 2020)

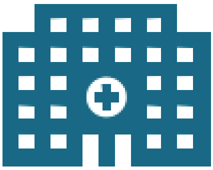
One challenge when discussing our industry is to define the scope and terminology used to describe the industry, or in some cases, subsets of the industry. At a broad level, some people refer to the industry as the Construction Industry, Building Industry, Architecture / Engineering / Construction

(AEC) Industry, or even the Architecture / Engineering / Construction / Operation (AECO) Industry. People frequently use these terms interchangeably, and I will also do so throughout this book. The industry typically focuses on all the employees and tasks required to plan, design, construct, operate, and manage the delivery and operations of the built environment (commercial buildings, infrastructure and industrial facilities). It is important to note that when people use the term 'Construction Industry', they are typically referring to the design, construction and operations of facilities, not just the process to deliver a new facility. And when they use the term 'Building Industry', they are typically discussing all types of facilities, not just commercial and residential buildings.

The industry can be separated into different categories. One common breakdown is by the type of owner, and in particular, if the owner is a private entity (an individual or company) vs. a public (or government) entity. Another is to separate the industry by the type of facilities that are constructed. In this manner, we can separate the industry into four broad areas:

1. Commercial Buildings;
2. Infrastructure;
3. Industrial; and
4. Residential.

See the following information for some common definitions of these sectors.



Commercial Buildings: Buildings and enclosures that contain a structure with enclosed space with an enclosure system with a non-industrial purpose. They may be fully enclosed, such are apartments or office buildings, or they may be partially open such as stadiums or monuments. Examples of buildings include office buildings, apartments, hospitals, rail stations, stadiums, arenas, and many more. Commercial buildings are typically designed by an architect. There may be many different types of owners.

Infrastructure: Infrastructure facilities serve as core facilities that serve the public, which are not buildings. This category is sometimes referred to as 'heavy' construction. Examples include roads, bridges, dams, locks, and tunnels. These facilities are typically funded by the government. The design is typically led by an engineer such as a civil engineer. New infrastructure projects typically require a long planning and design phase.

Industrial: Industrial facilities house core industrial processes, and the design of the facility is focused on the industrial process. Examples include refineries, power plants, chemical plants, manufacturing facilities. The design of these facilities is heavily dependent on the process that they support, so they are frequently designed by specialty engineers in collaboration with civil engineers. Most of these projects are privately funded. Many of these projects are schedule-driven in order to start the process as soon as possible.

Residential: Residential buildings are built to house individuals or families. For the purpose of defining markets, the residential sector is focused on single-family detached housing or duplexes. These structures are typically wood, and they may be designed by an architect, or even a residential builder. While there are large-scale residential developers, many residential buildings are built by smaller companies. The barriers to entry into the residential market are less than other sectors since the buildings have a lower cost and lower level of sophistication.

Note that this is not a perfect set of categories since it is sometimes difficult to define clear lines between the categories, as well as defining how to separate a large project into smaller components, but these categories do help us define the types of players in each market, and the typical characteristics of these different market sectors. Residential construction is a unique sector of our industry, and the market conditions for residential construction can vary significantly from the rest of the industry.

The construction industry is a major source of employment, especially if you also consider all the manufacturing industries that are supported by construction. In the United States, in 2016 it was estimated that the Industry was employing 7.3 million workers (2018 data) (see Fig. 1-2). This is 4.5% of the overall workforce. The Bureau of Labor Statistics is estimating that the workforce will grow at a rate of 1.1% per year between 2018 and 2028 (https://www.bls.gov/emp/tables/employment-by-major-industry-sector.htm). In more recent statistics (see Figure 3), the industry employs over 7.5 million people. 14% of these jobs are current employees who are members of a union, which is down from 17.5% in 2000, although quite steady over the past 7 years. Note that these employment figures do not include all professional service employment related to the industry, nor do they include all the manufacturing jobs related to building supplies or transportation services for products to be shipped to the jobsite.

Employment by major industry sector

Other available formats: (XLSX)

Table 2.1 Employment by major industry sector

Industry Sector	Thousands of Jobs			Change		Percent Distribution			Compound Annual Rate of Change	
	2008	2018	2028	2008 - 2018	2018 - 2028	2008	2018	2028	2008 - 2018	2018 - 2028
Total[1][2]	149,276.0	161,037.7	169,435.9	11,761.7	8,398.2	100.0	100.0	100.0	0.8	0.5
Nonagriculture wage and salary[3]	137,991.0	149,803.7	157,662.0	11,812.7	7,858.3	92.4	93.0	93.1	0.8	0.5
Goods-producing, excluding agriculture	21,277.9	20,661.3	20,872.7	-616.6	211.4	14.3	12.8	12.3	-0.3	0.1
Mining	709.9	683.3	727.9	-26.6	44.6	0.5	0.4	0.4	-0.4	0.6
Construction	7,162.5	7,289.3	8,096.8	126.8	807.5	4.8	4.5	4.8	0.2	1.1
Manufacturing	13,405.5	12,688.7	12,048.0	-716.8	-640.7	9.0	7.9	7.1	-0.5	-0.5
Services-providing excluding special industries	116,713.1	129,142.4	136,789.3	12,429.3	7,646.9	78.2	80.2	80.7	1.0	0.6
Utilities	558.8	554.6	537.2	-4.2	-17.4	0.4	0.3	0.3	-0.1	-0.3
Wholesale trade	5,875.0	5,852.5	5,754.0	-22.5	-98.5	3.9	3.6	3.4	0.0	-0.2
Retail trade	15,289.1	15,833.1	15,679.4	544.0	-153.7	10.2	9.8	9.3	0.4	-0.1
Transportation and warehousing	4,513.6	5,419.1	5,741.4	905.5	322.3	3.0	3.4	3.4	1.8	0.6
Information	2,983.8	2,828.1	2,833.7	-155.7	5.6	2.0	1.8	1.7	-0.5	0.0
Financial activities	8,206.1	8,568.8	8,849.4	362.7	280.6	5.5	5.3	5.2	0.4	0.3
Professional and business services	17,792.3	20,999.5	22,661.9	3,207.2	1,662.4	11.9	13.0	13.4	1.7	0.8
Educational services	3,039.8	3,727.5	4,201.0	687.7	473.5	2.0	2.3	2.5	2.1	1.2
Health care and social assistance	16,188.6	19,939.3	23,335.4	3,750.7	3,396.1	10.8	12.4	13.8	2.1	1.6
Leisure and hospitality	13,436.2	16,348.5	17,904.9	2,912.3	1,556.4	9.0	10.2	10.6	2.0	0.9
Other services	6,320.5	6,622.4	6,716.7	301.9	94.3	4.2	4.1	4.0	0.5	0.1
Federal government	2,762.0	2,796.0	2,670.2	34.0	-125.8	1.9	1.7	1.6	0.1	-0.5
State and local government	19,747.3	19,653.0	19,904.0	-94.3	251.0	13.2	12.2	11.7	0.0	0.1
Agriculture, forestry, fishing, and hunting[4]	2,071.4	2,310.0	2,320.6	238.6	10.6	1.4	1.4	1.4	1.1	0.0
Agriculture wage and salary	1,208.6	1,547.2	1,587.2	338.6	40.0	0.8	1.0	0.9	2.5	0.3
Agriculture self-employed	862.8	762.8	733.4	-100.0	-29.4	0.6	0.5	0.4	-1.2	-0.4
Nonagriculture self-employed	9,213.6	8,924.0	9,453.4	-289.6	529.4	6.2	5.5	5.6	-0.3	0.6

Footnotes:

1 Employment data for wage and salary workers are from the BLS Current Employment Statistics survey, which counts jobs, whereas self-employed and agriculture, forestry, fishing, and hunting are from the Current Population Survey (household survey), which counts workers.

2 Individual sectors do not necessarily add to major sectors due to rounding.

3 Includes wage and salary data from the Current Employment Statistics survey, except private households, which is from the Current Populations Survey. Logging workers are excluded.

4 Includes agriculture, forestry, fishing, and hunting data from the Current Population Survey, except logging, which is from Current Employment Statistics survey. Government wage and salary workers are excluded.

Figure 1-2: Employment Projections for Industry Sectors from the US Bureau of Labor Statistics (Source: https://www.bls.gov/emp/tables/employment-by-major-industry-sector.htm accessed Jan. 2, 2020)

It is important to note that the numbers of employees within the construction industry can be significantly impacted by economic conditions. Figure 3 shows the construction sector employment against time. As you can see from the graph, the economic recession in 2007 and 2008 had a very significant impact on employment, going from approximately

7,600 employees in 2006 to 5,500 in 2009. This significant employment fluctuation can be a significant challenge. Once people leave the industry, it can be challenging to hire new workers. In fact, the most frequently cited challenge of general contractors right now is the lack of a skilled workforce.

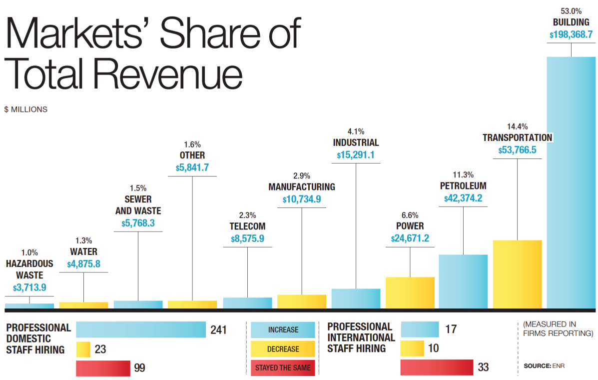
Figure 1-3: Employment Trend for Construction Employment from 1985 to 2018 (Source: US Bureau of Labor Statistics accessed Jan 2, 2020)

While the size and scale of the industry is impressive, this overall size and the nature of developing the built environment can also have significant negative impacts on environmental sustainability. Buildings account for 39% of all greenhouse gas emissions, and 70% of all electricity use (http://www.eesi.org/

files/climate.pdf). The construction of the built environment can also add to noise, light, water, air quality and other pollutants. These negative impacts can be substantial, and there is a very important need for all members in the industry to focus on minimizing the negative environmental impacts of our industry. There are increasing efforts to address these impacts through increased awareness along with metric systems that provide recognition, and sometimes stipulations through zoning regulations and code requirements, for improved sustainability measures. Examples of these metric systems include the US Green Building Council's LEED rating system (the most frequently used in the US), the Green Building Initiative's Green Globes certification, the Living Building Challenge by the International Living Futures Institute, and Building Research Establishment Environmental Assessment Method (BREEAM).

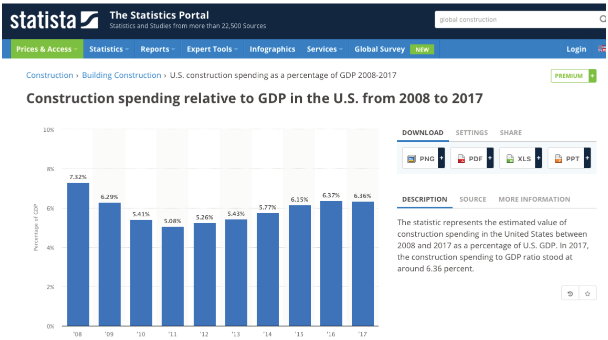
Each year, Engineering News Record (ENR) performs a survey to all larger contractors, as well as designers and owners. ENR then compiles lists of the largest companies by category. One of the reports that they perform is the Top 400 Contractors list. It is important to note that this list is compiled from company self-reported data, not audited financial statements, and the rankings within the list are specific to revenue, which is the value of the revenue that the company receives for annual work performed. For large construction management firms, much of the revenue that they receive is then paid to their subcontractors and suppliers.

But this data does show some interesting information. Figure 1-4 shows the breakdown of the revenue by ENR's project categories. This shows that in 2017, 53% of the revenue from the Top 400 contractors was from Buildings. It also shows that the second-largest category is Transportation, but it is a significantly smaller percentage, at 14%.



Top 400 Contracto rs – Revenue by Project

Figure 1-4: Top 400 Contractors – Revenue by Project (Source: ENR 2018)



Construction Spending Relative to GDP in the US (Source: Statista: The Statistics Portal (2018) Website: https://www.statista.com/statistics/226361/us-construction-spending-relative-to-gdp/ Accessed on July 26, 2018)

Figure 1-5: Construction Spending Relative to GDP in the US (Source: Statista: The Statistics Portal (2018) Website: https://www.statista.com/statistics/226361/us-construction-spending-relative-to-gdp/ Accessed on July 26, 2018)

Professional Engineering Licensure

Professional Engineering Licensure plays an important role to ensure that engineers who develop designs and manage the processes to bring them into reality are competent and qualified. Architectural Engineering and Civil Engineering students who complete their degree should strongly consider a pathway toward becoming a licensed Professional Engineer (PE). For some disciplines, a PE is required to perform certain work tasks, e.g., structural plans must be verified by a PE for submission for a building permit. A PE can also be helpful to illustrate your capabilities when applying for job opportunities or to show your engineering background in a job that may or may not require an engineering degree.

The National Council of Examiners for Engineering and Surveying (NCEES) was established to provide uniformity across states related to obtaining a PE license, although individual states within the US administers the licensing process per their laws and rules, which may have additional requirements.

To obtain a PE License, a professional must:

- Pass the Fundamentals of Engineering (FE) exam (after completing 2 years of an ABET Accredited Engineering Degree program);
- Graduate from an ABET Accredited Engineering Program;
- Gain four years of progressive experience (note that a graduate degree can count for a year of experience);
- Complete an application to qualify to take the Principles and Practices Exam; and
- Pass the Principles and Practices Exam.

After you receive your PE in Pennsylvania, you are required to obtain at least 24 hours of continuing education per each 2 year time period to maintain your licensure status. Also note that once a candidate has taken and passed the FE exam, they will be notified that they have passed. At this point, it is up to the individual to apply for certification as an Engineer In Training, EIT. When you have graduated, go to the following Professional Credential Services website and follow the instructions on the webpage. The progressive experience only starts following receipt of your EIT status.

For additional information, please see the following online resources:

- NCEES Fundamentals of Engineering Webpage along with FE Exam study and practice materials
- Guide to Professional Engineering Licensure for Construction Engineers

Review Questions

1. List the four primary sectors within the AECO Industry.
2. Employment within the construction industry is very steady with little variation from

economic cycles. (True / False)

3. For each project type below, please select the appropriate industry category for the project type.
   a. Natural Gas Power Plant
   b. Office Building
   c. Large Single-Family House
   d. Highway
   e. Chemical Processing Plant
   f. Duplex House
   g. Bridge
   h. Apartment Building
4. The construction industry is composed of many companies. (True / False)
5. Go online to see the latest reported construction market information from the US Census Bureau. Using seasonally adjusted annual rates, answer the following questions.
   a, What is the current annual size of the Construction Market within the US?
   b. How much has the market grown or declined in the last year?
   c. What percentage of the market is public sector construction?
6. The AECO Industry has historically made

significant investments into research and development, when compared to other industries. True / False

7. For the largest 400 contractors within the US (from ENR Top 400), their biggest market is in Commercial Buildings. True / False

Review Question Answers

2.

CHAPTER 2: THE LIFECYCLE OF A BUILDING PROJECT

John Messner

Learning Objectives

After reading this chapter, you should be able to:

- Define the four primary phases of the lifecycle of a building project
- Describe various unique aspects of a building project in relation to the manufacturing industry
- Define the total cost of ownership, and the impact of decision timing on overall lifecycle

cost

The Construction Industry is composed of projects. A core skill set for everyone within the industry is the ability to manage projects, whether you work in project development, architectural design, engineering design, construction or facilities management. Project Management is 'the application of knowledge, skills, tools, and techniques to project activities to meeting project requirements' (PMBOK Guide 2000). Projects are not unique to construction. For example, some other industries are also very project-focused, e.g., aircraft, computer software, shipbuilding, etc. The Project Management Body of Knowledge Guide (PMBOK) has been developed by the Project Management Institute (PMI) as a general set of knowledge for managing a project. The core management areas identified in PMBOK includes the following (from PMBOK Guide and the Construction Extension of the PMBOK Guide):

- Project Integration Management
- Project Scope Management
- Project Time Management
- Project Cost Management

- Project Quality Management
- Project Resource Management, including Human Resources (Construction Extension highlights additional resources beyond the standard Human Resources in PMBOK)
- Project Communications Management
- Project Risk Management
- Project Procurement Management
- Project Health, Safety, Security, and Environmental Management (in Construction Extension, but should be in every project)
- Project Financial Management (in addition to cost) (in Construction Extension)
- Management of Claims in Construction (in Construction Extension)

The Process to Deliver a Facility

A building project is composed of processes. A process is 'a series of actions bringing about a result' (PMBOK). Each process is performed by a person or organization Generally, there are two broad categories of processes: project management processes and product-oriented processes (PMBOK).

A project proceeds through a lifecycle. A facility is planned, designed, constructed, and operated (see Figure 2-1). This lifecycle, and the importance of taking a lifecycle perspective on projects, has sometimes been referenced as a Cradle-To-Grave perspective. From a lifecycle perspective, all materials and systems should be evaluated relative to their value in supporting the lifecycle goals of a building or facility.

Figure 2.1: Facility Lifecycle Phases

Some have expanded upon the concept of Cradle to Grave by considering the lifecycle as a continuous process and proposing a reference to Cradle to Cradle (C2C). C2C emphasizes the need to consider the reuse or recycling of products that are used within the delivery of a building.

Sanvido et al. (1990) developed a detailed process model to define the various tasks that need to be completed to deliver and operate a facility. The process model is titled the 'Integrated Building Process Model' (IBPM). This model is created using the IDEF0 process modeling approach. Each 'process' (a box) can be expanded into another more detailed process map showing additional detail. The Level 1 process map shows five main activities within the process:

1) Plan Facility
2) Design Facility
3) Construct Facility
4) Operate Facility
5) Manage Facility

Note that the Manage Facility process interacts with the remaining four project phases, so we will not consider this as a primary product-oriented process of the project lifecycle, but instead, a map that shows typical management tasks that need to be completed (a project management-oriented process). Also, note that IDEF0 process mapping does not necessarily indicate a linear sequence. Many of these processes can overlap, and they may not be in the specific order in which they will be performed. The Level 1 process map is included in detailed process maps are included in Figure 2-1. The more detailed process maps for each of the 5 phases are included in Figure 2-2 through 2-6 within the following sections describing each phase. If you wish to see detailed information about any process, you can reference the Integrated Building Process Model technical report.

Planning Phase

During the planning stage, the Owner of the facility will need to define their project needs, identify the general budget and schedule, and potentially identify a site for the building. The owner may employ the services of an architect, contract developer, or other professional to help them defined their needs, and identify the resource requirements. The final outcome of the planning phase is a ‘Program’, or in some countries, a ‘Brief’, which clearly defines the owner’s needs and a plan to design and construct the facility. They will also need to identify, and sometimes purchase, a site for the facility.

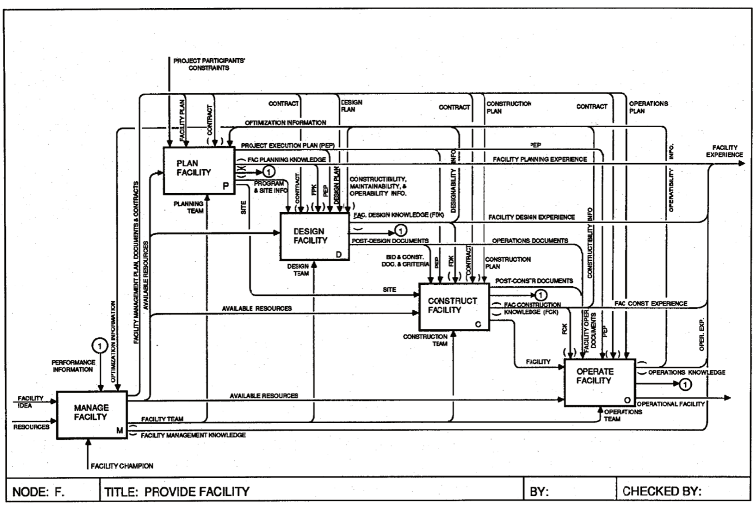


Figure 2-2: Integrated Building Process Model (IBPM) – Level 1 – Provide Facility (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

Design Phase

Within the design phase, a designer will interpret the needs of the owner into a design for the facility which is to a level of detail that it can be built. The design phase is frequently divided into three levels of design:

- ***Schematic Design (SD):*** Perform an evaluation of the owner's needs, and develop an initial design concept. Typically, the industry has considered this level of design to be approximately 30% complete.
- ***Design Development (DD):*** Expand the initial concept to define the systems that will be used and general materials. Typically, this has been considered approximately 60% design completion.
- ***Construction Documents (CD):*** Finalize the design details to a level that they can be built. Complete all design specifications and construction drawings.

The full scope of these design tasks will typically be defined within the contract with the designer (or integrated team if using a more integrated delivery approach). To see the typical definitions of the scopes within these phases, you can view the typical Owner – Architect Agreement from the American Institute of Architects (AIA) within their AIA B101 document (see page 6 – 8 of this online sample document for the definitions of each phase).

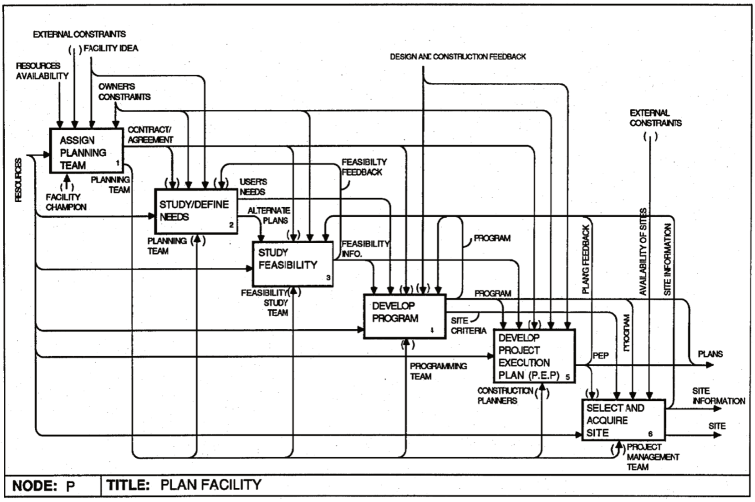


Figure 2-3: Integrated Building Process Model (IBPM) – Plan Facility (Level 2) (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

Construction Phase

Within the construction phase, a contractor will lead the assembly and construction of the facility. This will include the procurement of all the elements needed to build the facility, including arranging for the elements to be transported to site. After arrival, the building component will be assembled on-site and tested to ensure the appropriate level of quality. The constructed facility will also require any inspections by governing authorities to ensure that it is safe to use for it’s intended purpose. For a building project, the primary construction phase typical ends when the contractor obtains a ‘Certificate of Occupancy’. The Certificate of Occupancy is issued by the local governing authority or code office, and it certifies that the building complies with the codes and requirements and that the owner can occupy the building.

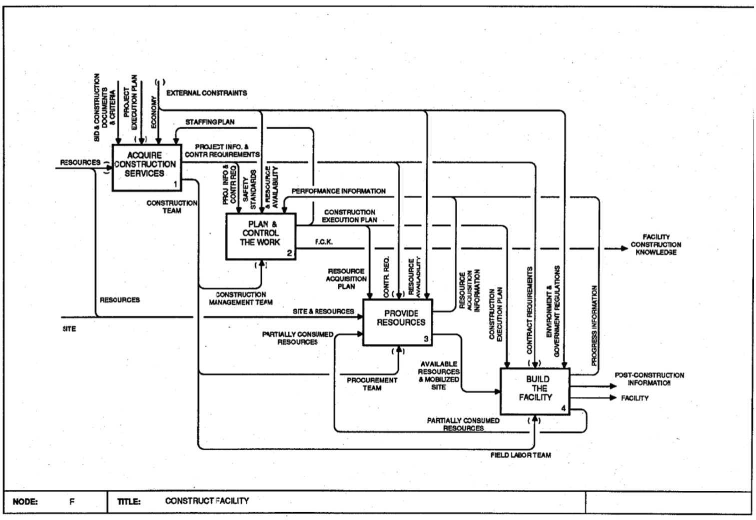


Figure 2-5: Integrated Building Process Model (IBPM) – Construct Facility (Level 2) (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

Operations & Maintenance Phase

The Operations & Maintenance (O&M) phase is typically the longest phase within the facility lifecycle. In this phase, the owner will use the facility for its intended purpose, and they will need to operate and maintain the functionality of the facility. In some research, up to 80% of the entire lifecycle cost of a facility is spent in the operations phase. Activities that occur within the phase include the maintenance of equipment, the replacement of materials and equipment that require replacement, and minor renovations to allow for revisions of facility use. This phase is also sometimes referred to as Facility Management (FM), and an owner may perform the facility management services within their own internal employees, or they may hire a 3rd party FM service provider.

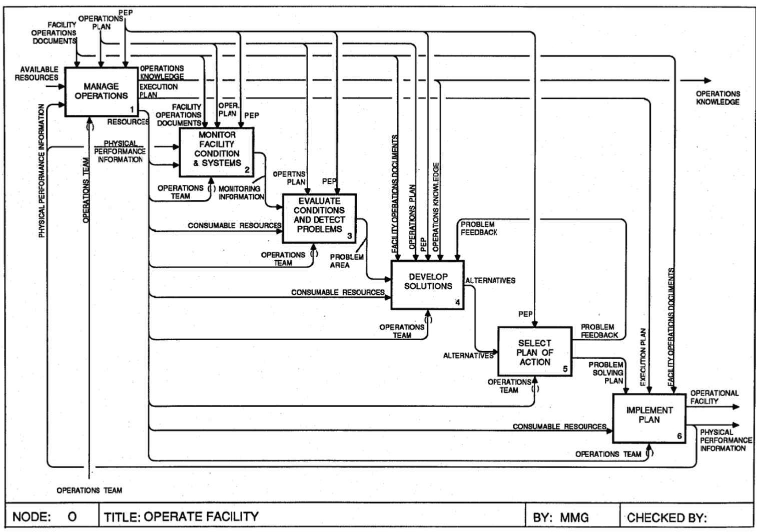


Figure 2-6: Integrated Building Process Model (IBPM) – Operate Facility (Level 2) (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

Manage Facility

In addition to the unique four phases, there is a need to coordinate and manage the process and resources throughout the lifecycle. These processes were defined within the IBPM within the Manage Facility process (see Figure 2-7). Note that this is NOT a phase of a project, but instead tasks that are performed throughout the lifecycle process.

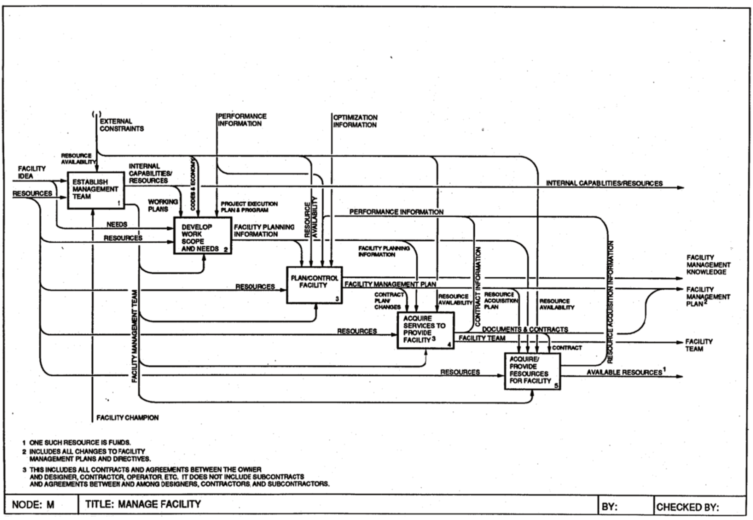


Figure 2-7: Integrated Building Process Model (IBPM) – Manage Facility (Level 2) (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

Unique Aspects of Construction

Projects and the structure of the industry have several unique characteristics that influence our management approaches. Several characteristics include:

- All projects are unique. Even if a project is a duplicate design of another project, the project will be located on a unique site, which includes unique constraints.
- Projects are performed outside, at least until an enclosure is developed. This is different from manufacturing which may occur within a controlled environment. Therefore, construction is influenced by the environmental conditions of the geographic location of the project.
- The Construction Industry has many companies. The AGC states that there are over 650,000 companies that employ workers within the construction industry. This is a very large number of firms, and some of these companies may only have one employee. But it is also important to note that the largest contractors are quite large, but it is still a fragmented industry with many companies.
- There are many organizations that work together to deliver a project. It is not uncommon to have more than 20 companies working on the construction of a project, with workers in the field, and there are many other companies involved in designing the facility, and supplying materials and equipment to the project.
- Design and Construction companies do not tend to perform much research and development. Due to the lower profit margins in the industry, and a shorter-term focus, most firms do not invest in research. There are

certainly exceptions, but as a percentage, the industry has very low investments in R&D.

- The industry is impacted by geographic ties. Since buildings are constructed in many different locations, there are different code requirements in different locations and different companies with employees and experience in working in the local markets.
- The industry has a high rate of business failures. Due to a large number of smaller firms, it is not uncommon for businesses to fail.
- There is a low barrier to entering the construction market. In fact, it is quite easy for an individual to open a construction company. It may only require some simple paperwork, or they may need to apply for a contractor license.
- Organizations change from project to project. It is very rare to have the same organizations to work together on multiple projects. This requires members in the industry to specialize in working with new team members since the mix of team members, including designers and contractors, will change on each project.
- Construction is a hybrid industry. Some tasks are service tasks, e.g., the design of a facility or managing the delivery of a facility. Other tasks are closer to manufacturing, with a focus on producing the facility. Examples of these tasks include building the structure, installing the mechanical/electrical/plumbing (MEP)

equipment, or installing the facade. Therefore, the industry is a hybrid between a service and manufacturing industry.

Total Cost of Ownership

It is critical for the owner, and the entire project team, to view a project from a total cost of ownership perspective, which considers that costs, along with overall environmental impact, of all phases of the project lifecycle. It is very important to note that the vast majority of the decisions that influence the lifecycle cost of a facility are made in the earliest phases of a project, e.g., planning and early design phases. This concept has been included in quite a few different diagrams. Figure 2-8 is a simple representation that shows the construction costs over time (dashed line) where the costs are low in the beginning, and accumulate over time. The ability to influence the cost is represented by the solid line which shows that it is much more difficult to influence costs as the project design and construction continue. For example, in the early stages of a project it is much easier to alter a system to reduce costs, but after the design is developed and the materials are ordered, then it can be very difficult to reduce overall costs, even if it is a less expensive system, due to the costs of making the change. It is also interesting to consider the overall business and societal costs and impacts of a facility. Some have estimated (although not with much data) the overall impact of facilities to organizations and society, and they show that the societal impacts of facilities are significantly greater than the initial cost of design and construction (see Figure 2-9).

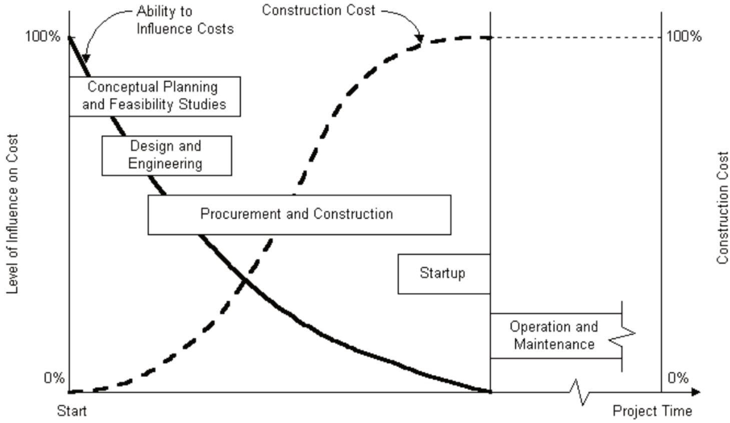


Figure 2-8: Cost / Influence Curve (Source: https://www.cmu.edu/cee/projects/PMbook/02_Organizing_For_Project_Management.html)

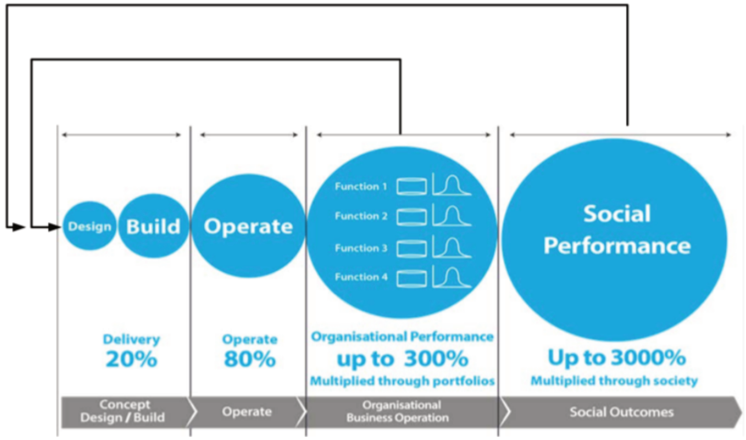


Fig. 2-9: Relative cost of Design and Construction compared to Operations, Performance, and Social Impact (Source: Mark Bew Presentation (available at https://www-smartinfrastructure.eng.cam.ac.uk/files/moving-from-productivity-to-social-outcomes-mark-bew.pdf))

Chapter Review Questions

1. What are the four primary phases of the lifecycle of a facility?

2. As the project progresses through time, the ability to influence the cost of the project increases. (True / False)
3. There are many different companies within the Construction Industry. (True / False)
4. Every construction project is unique. (True / False)
5. What are the three traditional levels of the design completed within the design phase, and what is the percentage of design completion that is typical for each level?

Review Question Answers

3.

CHAPTER 3: PROJECT PARTICIPANTS AND ROLES

Learning Objectives

After reading this chapter, you should be able to:

- Define the types of companies and organizations that exist in the Construction Industry
- Identify typical tasks and activities performed by the different types of organizations

Introduction

It takes many different organizations and individuals to develop, design, build and operate a building project. This chapter will focus on the different types of organizations and the various roles that an organization may perform on a project.

The Owner

Every building project has one or more owners. The owner is the organization, or individual, who has legal title to the building, and typically, the land upon which the building occupies. There are many (many) different types of owners. Some are individuals, e.g., it is typical for an individual or multiple individuals to own a single-family detached residential house. In other instances the owner may be a private company, e.g., a corporation may own its headquarters building and manufacturing plants. Other projects are initially built by a speculative developer who owns the building during construction but intends to sell the building and property after it is complete, aiming to profit from the development. An example of a speculative developer is a company that develops a new apartment building, and then, following occupancy (or possibly earlier), sells the building to a separate company that will own and operate the building. These speculatuive developers take on the risk of delivering the project, but they can make high profits if the project is delivered successfully and they sell the property for a profit. Other projects are owned by public (government) owners, which could be federal, state, or local owners, or even international government entities. Examples of public owners include the General Services Administration (GSA), the different branches of the military, the Department of Veterans Affairs, Commonwealth of Pennsylvania, State College Borough, State College Area School District, or the Pennsylvania Department of Transportation (PENNDOT).

Many of our core facilities that form that support the public, e.g., roads, bridges, schools, correctional facilities, airports, parks, and dams are owned by a public owner. It is interesting to note that there has been an acceleration of more collaborative public projects through Public-Private Partnerships (P3). Through a Public-Private Partnership, the government may provide some long term concessions, or payment guarantees, to a private sector partner, and then the private sector partner develops and frequently operates and maintains the project. An example is the Dulles Greenway project in Leesburg, VA. For this project, a private company (TRIP II) purchased land to construct a private toll road from Dulles Airport to Leesburg, VA. The organization was provided a 37 1/2 year concession from the Virginia Department of Transportation to allow the private company to collect a toll from each vehicle that used the road. After

37 1/2 years, the road ownership will revert to the Virginia Department of Transportation. The owner was able to leverage the future toll revenue stream to raise the funds needed to construct the project. This specific type of Public-Private Partnership has also been r referred to as a Build-Operate-Transfer (BOT) project. This approach can be used for schools (guaranteed payment per student per year) or correctional facilities (guaranteed payment per inmate). In addition to operating the facility, sometimes these awards also include providing all services, e.g., a prison operator may manage the entire facility.

Some projects have a separate 3rd party developer who is not the owner. A contracted developer can help an owner by guiding them through the delivery process and helping to perform tasks that are the responsibility of an owner.

The owner has a very unique role on the project since they will pay for the facility, and they are the entity who defines the overall scope and contractual structure for hiring all other participants on the project. It is critical that core services providers spend time to understand the core business and values of the owner so that they can provide high-quality service to them.

Service Providers

Most projects, potentially excluding privately developed small residential projects, have many different companies that are engaged in delivering and operating a facility. These companies may be very targeted, with a strong specialty in a very specific area. Examples include a specialty lighting design firm that only performs lighting design, or a specialty controls company that only focuses on installing Heating, Air Conditioning, and Ventilation (HVAC) control systems. But there are many firms that can perform a number of roles on a project. For example, some architectural firms will perform architectural design, mechanical system design, electrical system design, structural design, and site design. Some contractors will manage the delivery of the entire project along with performing concrete construction, framing, and other specific trades on a project. These companies that can perform many different roles on a project do not fit into one specific category of company.

Overall, everyone who performs services for an owner are service providers (and in some peoples terminology 'contractors' since they are contracted to perform work for the owner). To identify some typical categories of companies, the later sections will divide the different roles performed by companies in the following categories: Designers, Design Consultants, Contractors, Specialty Contractors, and Vendors & Suppliers.

Designers

There is typically a lead designer(s) on a project who takes responsible charge of delivering a comprehensive, integrated design for the project. On commercial building projects, this company is typically an Architectural firm, but on industrial or infrastructure projects, it is most likely to be an Engineering firm. The designer typically engages in a contractual relationship directly with the owner, and their responsibility is to manage and produce the design documents within the design phase of a project. Some design firms are quite specialized, e.g., a residential architect who focuses only on single-family houses. Other design firms may be very diverse and operate in many different market sectors, e.g., offices, hospitals, hospitality, and correctional facilities. Design firms can also vary in the market geographic market that they serve. For example, some designers will focus on a local market, and specialize in the codes and construction methods within that market, and they will also build relationships with the local code enforcement and governmental approval agencies, which can be helpful when aiming to gain fast approval of designs. Other designers will work across many geographic markets, and may have multiple offices either within one country or internationally. These companies may form a joint venture with a more local designer when working on complex projects to ensure that there is local representation on the project. Finally, some designers work on very specific scopes of work within the design process, e.g., architectural design or early schematic design, while others may perform many different scopes of work within their organization, e.g., architecture, structural, mechanical, interior design, and lighting design, to name a few. These more full-service designers will need to hire and maintain a diverse team of architects and engineers within their organizations to be successful.

Design Consultants

A lead designer will typically hire additional design consulting firms to perform targeted scopes of design work. These may include scopes such as the structure design, lighting design, mechanical system design, electrical design, landscape design, or other specialty areas. Design consultants are typically smaller firms with a specialty in an area, although there are certainly several large design consulting firms. Many students within the structural, mechanical and lighting / electrical options within Architectural Engineering will work for these design consulting firms, as well as possibly working for more integrated lead design firms.

Contractors

The prime contractor(s) focus on the management of the construction of the project, along with potentially performing specific trade work. The prime construction contractor may be referenced by a diversity of names depending upon the project delivery approach (discussed in the next chapter) and upon the scope of work that they self-perform with their own workforce. For example, if they simply manage the construction activities performed by others, they may be referenced as a Construction Management firm. If they are self-performing work, along with coordinating the work of other trades, they may be referenced as a General Contractor. Overall, the services performed by a prime contractor vary significantly.

Similar to design firms, there are many different types of construction companies. Some are very small, while others are very large. Some focus on targeted geographic markets or types of buildings/facilities. And some perform significant scopes of work on a project while others focus on the management and planning of the construction activities while subcontracting a very large portion of the work.

One distinguishing characteristic of the prime contractor(s) is that they hold a direct contract with the owner. They accept the primary responsibility and risk related to constructing the facility.

Specialty Contractors

A Specialty Contractor performs a specific scope(s) of construction within the project. Examples of specialty contractors are concrete contractors, mechanical contractors, drywall contractors, masonry contractors, roofing contractors, electrical contractors, etc. The companies typically focus on self-performing (with their own labor force) the work for a single trade, or sometimes multiple trades. Specialty contractors will be responsible for purchasing the materials, procuring the equipment, installing, and testing the construction activities for their scope of work. Specialty contractors can be a great source of knowledge within a specific trade or system. They accept a fair amount of risk since they are financially responsible to put their work into place, and they may be able to get a good profit margin if successful, but also may lose a fair amount of money when things do not go as planned. On some projects, you will hear people referring to specialty contractors as 'subcontractors' or 'trade contractors'. Their contract is typically with the lead contractor for the project (which is why they are sometimes referred to as subcontractors), but it can be more appropriate to recognize their specialty area by referencing them as specialty contractors.

Vendors and Suppliers

Vendors and suppliers are companies that support the project by providing different building materials or equipment to the project. Examples include concrete suppliers, lumber suppliers, mechanical equipment manufacturers, electrical equipment manufacturers, excavation equipment rental companies, etc. Some of these vendors and suppliers are very large, and others may be smaller, local vendors. The key difference between a vendor or a supplier, as compared to a specialty contractor, is that they do not have a workforce located on the construction site. Instead, they may manufacture or purchase items, and then deliver them to the site for others to use or install.

Concluding Comments

It is very important to realize that companies can perform many roles on a project, so it is quite difficult to define the specific company type for some organizations. For example, some companies perform both design and construction services, such as integrated design-build firms. Some developers will both owner properties and develop them as speculative (at risk) developments, while also being a 3rd party contracted developer. Some industrial contractors will perform all engineering services on a project, procure all the material (and maybe even own several supply chains such as piping) and perform the fabrication and assembly. The important takeaway is that companies can enter either one very specific role on a project, or series of projects, or they can enter into many different roles. In the next chapter, we will discuss typical project delivery methods used on projects.

This chapter has also not discussed many other participants in the delivery of a project. Projects must always interface with the local government authorities, include the code office, zoning office, and other services, e.g., fire department. Projects will also have insurance, and potentially bonding, companies involved. And most projects have some financial agencies involved in lending money to the owner during the delivery of the project.

Chapter Review Questions

1. A speculative developer plans to build a building and own if for a long time period. (True / False)
2. Specialty contractors are sometimes called 'subcontractors', depending upon their contractual role on a project. (True/False)
3. A vendor will typically have workers on the construction site performing installation work. (True / False)
4. A prime contractor holds a direct contract with the owner or developer of a project. (True / False)
5. A large design firm may form a joint venture with a local design firm to gain local experience and relationships for a building project. (True / False)

Review Question Answers

4.

CHAPTER 4: PROJECT DELIVERY METHODS

Learning Objectives

After reading this chapter, you should be able to:

- Understand the different aspects included in typical project delivery methods
- Be able to define the impact of various organizational structures for delivering a project.
- Be able to define the impact of various

There are many different approaches used by project owners to procure the services needed to design-build a facility. Some facilities are quite easy to build, relatively speaking, such as a simple single-family detached house. This type of building may allow an owner to simply hire one entity to both design and build their building. Others are very complex facilities, such as a large industrial facility or a complex hospital or lab. These can engage many organization. But no matter how complex, the owner, and other project participants, have many decisions to make related to developing their strategy to acquire the services that they need to deliver their facility. These decisions can be developed into an overall Project Delivery approach.

It is important to note that prior to developing the overall project delivery strategy, an owner must clearly define the scope boundaries of a project. For example, sometimes an owner will seek to build multiple buildings on a large parcel. If so, then the owner will need to decide whether to make each individual building a project, or group the buildings into a single project. For office buildings, the owner may need to decide whether to have the core and shell be one project, and the tenant fit-out be a second, or multiple additional projects. These decisions define the extents of the project scope.

Primary Elements of a Project Delivery Strategy:

Several core project delivery decisions that will influence the project include:

1. Defining the ***organizational structure***;
2. Defining the ***contracting methods*** (payment method); and
3. Defining the ***award method***.

These decisions are certainly related to each other, and we will explore some typical combinations.

Organizational Structure

The organizational structure focuses on the approach that is used to organize the team members. This structure can have a significant impact on team responsibilities, roles, level of risk, and interactions. The organizational structure is defined by the contracts that are put into place by the team members. For example, in a Design-Bid-Build approach, the Owner will sign separate contracts (or agreements) with a Designer and a General Contractor. Each contract will clearly define the scope of services to be performed by each entity. The 7 organizational structures that may be used

- Design-Bid-Build with a GC (also known at Traditional)
- Design-Bid-Build with multiple prime contractors
- CM Agent with GC
- CM Agent with multiple prime contractors
- CM at Risk
- Design-Build

- Integrated Project Delivery (IPD)

Design – Bid – Build with a General Contractor

Often referred to as 'traditional' delivery, the design-bid-build with a General Contractor (DBB with GC) remains quite commonplace. In this approach, an owner will initially hire a design firm (typically an Architect for a commercial building project). The designer will fully develop the design documents, through the completion of the Construction Documents phase (100% complete), and then the Owner will release the documents for the bid for a single organization (the General Contractor) to perform all scopes of work in the project. The potential general contractors will provide a bid to the owner. Typically, the owner will then select the lowest bidder, although they may use a different award method (see later in the chapter). The owner will then enter into a contract with the General Contractor to construct the building. A diagram showing the organizational structure for DBB with GC is shown in Figure 4-1. This figure shows solid lines for contracts. It includes a dashed line between the design and general contractor to illustrate an influence that the Designer has on the GC based upon the owner's contracts. For example, the architect will typically review the GC's payment requisition prior to payment. The architect will also typically review the completed work of the GC to ensure that it meets the defined quality in the contract. If it does not, the architect will develop a deficiency list (frequently referred to as a punchiest) that will need to be addressed prior to acceptance of the GC's work by the owner. It is critical to understand that the architect will have influence over the GC, but the Architect will not hold any contract with the GC. This becomes very important if there is a claim on the project since claims will typically only follow contract relationships.

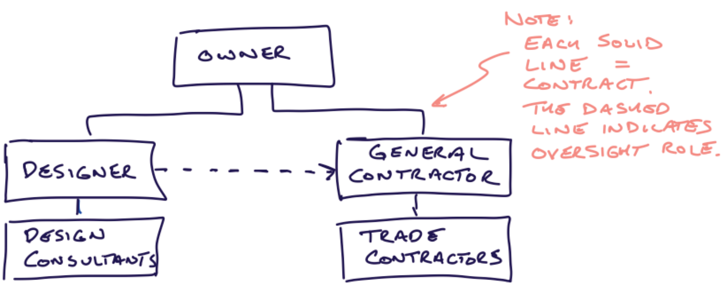


Figure 4-1: Design – Bid – Build with General Contractor (Organizational Structure)

The DBB with General Contractor (GC) approach is a common method for public procurement. It has been viewed by many in the public sector as an approach to provide fair competition for entities who bid the project, and a clear selection criterion (low bid) when delivered with a competitive bid award method. There are also many other entities that use this approach.

Some benefits of DBB with GC are:

- The GC knows the full scope of the project, as defined in the construction documents, prior to providing a bid for the work;
- The Owner can select a design firm independent of their ability to construct a project;
- The Owner has clear criteria to select the constructor (low bid) since the Design-Bid-Build approach almost always aligns with a low bid selection process. The bidders may need to prequalify to bid on the project.
- The Owner may get a lower price if the scope is well defined and there is strong competition for bidding the project.

But there are some significant challenges with this approach. These include:

- There is no opportunity for a contractor to provide input into the design process, which can limit the potential for gaining early cost estimates, constructability feedback, and feedback to improve opportunities for modularization or prefabrication.
- It is not always clear that the low bidder will yield the lowest final cost since there tend to be higher rates of change orders given this approach.
- This is a slow delivery approach since the design must be 100% complete prior to putting the documents out to bid.

Design – Bid – Build with Multiple Prime Contractors

One variation of Design-Bid-Build is for the owner to separate the scope of work into multiple trade or scope packages, and then independently bid each package. This yields a similar structure to DBB with GC, but instead of a single GC, there are multiple trade contractors. This approach carries many of the same advantages and disadvantages as the DBB with GC. One envisioned additional advantage of this approach is that the Owner will not pay overhead costs for a GC to manage the other prime trade contractors. But, one additional disadvantage is that the Owner will now take on additional responsibility in the management of the various prime contracts. This will require additional coordinate and administrative effort for the Owner. For less experienced owners, this additional burden can be quite challenging.

Note that this delivery approach is sometimes required by public procurement regulations in a small number of public owners. One public owner that sometimes requires DBB with Multiple Prime is the Commonwealth of Pennsylvania. For this reason, there are a number of schools and other public projects funded by the Commonwealth of Pennsylvania that must be delivered with this approach.

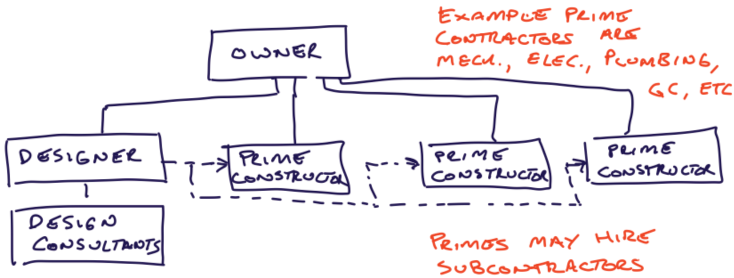


Figure 4-2: Design – Bid – Build with Multiple Prime Constructors (Organizational Structure)

Construction Management Agent with General Contractor

The Design-Bid-Build delivery approach requires significant interactions by the owner of the project during the delivery process. In order to assist with the tasks that need to be completed by an owner, and provide significant expertise to effectively deliver a project, some owners will deliver a project with a Construction Management Agency. This CM Agent will be a paid entity that helps an owner perform their required activities in the delivery process, including the oversight of procurement of entities throughout the project, administering of contracts, planning and coordinating construction activities, approving payment requisitions, overseeing overall project safety and quality, providing constructability input into the design, along with many other tasks. This CM Agent arrangement is particularly valuable for complex projects, or for projects that have an owner who may not have the resources or expertise to effectively manage the project.

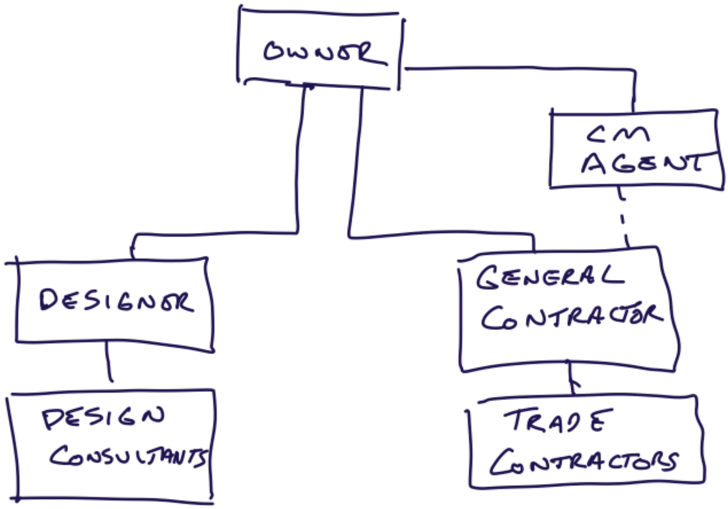


Figure 4-3: Construction Management Agent with General Contractor (Organizational Structure)

The CM Agent will review the operations of the General Contractor (GC), and report important information to the Owner. It is important to note that the CM Agent has no direct contract with the General Contractor. This limits that liability and responsibility between the General Contractor and CM Agent. If the GC were to file a claim, they would need to do so with the Owner, since claims will follow the contractual relationships. In some instances, the CM Agent with a GC arrangement may pose a scenario where one market competitor will be overseeing another market competitor, which can be a challenging dynamic.

Construction Management Agent with Multiple Prime Contractors

This approach places a CM Agent into the organizational structure of the DBB with Multiple Prime Contractors. This can be quite helpful in assisting with some of the challenges inherent in the DBB with Multiple Primes. For example, the CM Agent can be hired early in the process, and then provide construction input into the design, and monitor cost estimates throughout the design phases. The CM Agent can also organize and prepare the different bid documents to hire multiple trade contractors. Finally, the CM Agent can supplement the owner's resources to coordinate the contractors and administer their contracts. This is a common method to use when there are procurement regulations that require DBB with Multiple Prime Contractors.

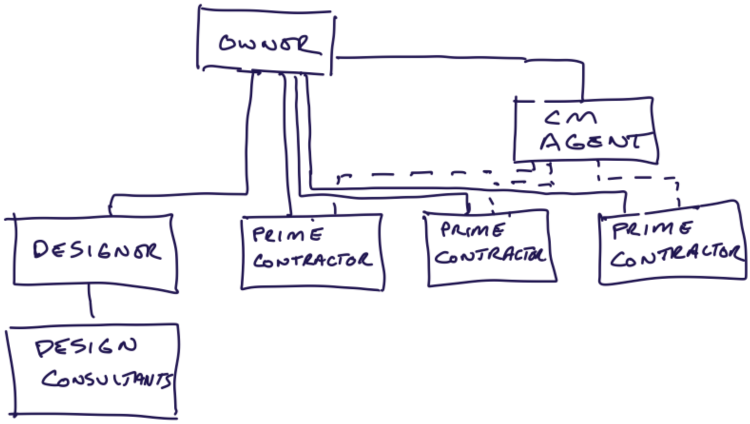


Figure 4-4: Construction Management Agent with Multiple Prime Constructors (Organizational Structure)

Construction Management at Risk

Construction Management at Risk is an approach where the owner will hire a designer to develop the facility design, and sometime, usually early in the design process, they will hire a construction management company to perform both construction services during design along with managing the overall construction of the facility. The services that they will provide during design will include reviewing the design for constructability, developing bid packages for the hiring of trades, identifying and prequalifying trades, and performing cost estimates. A CM at Risk will eventually Guarantee a price for the project. This is frequently performed through a Cost + Fee with a Guaranteed Maximum Price (GMP) contract, but it could also be through a lump sum contract (see details later in this chapter). The CM is at risk since they directly hold all contracts with the trade contractors, in contrast to the CM Agency where the Owner holds the contracts with the trade contractors. A CM at Risk is a good delivery method to allow an owner to hire a preferred design, still have some checks and balances in the system, yet also gain benefits from early constructor involvement. This approach allows for collaboration between the design and CM, although this collaboration is not always as close as some of the more integrated approaches of Design-Build or IPD.

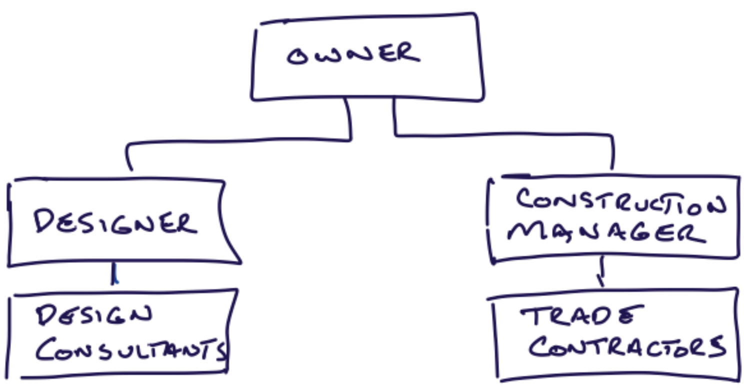


Figure 4-5: Construction Management at Risk (CM at Risk) (Organizational Structure)

Design-Build

Design-Build is focused on having a single entity perform both the design and construction of a project. Within the Design-Build approach, an Owner will hire a single entity after developing a program for the project. The program will outline the requirements for the project, e.g., space requirements and other designed outcomes. The design-build entity will then perform the design of the facility and be responsible for construction.

A core and unique aspect of design-build is the single contract between the Owner and the Design-Build entity. The design-build entity will be a legal entity but could take many different forms. For example, it could be an integrated design-build company, or a single purpose joint venture developed between a design firm and a construction firm to pursue a project. In many instances, the design-build entity is a construction company, who then subcontracts the design tasks to a designer. Or in some cases, the design-build entity is a designer, who subcontracts construction to a construction company, although this is rare.

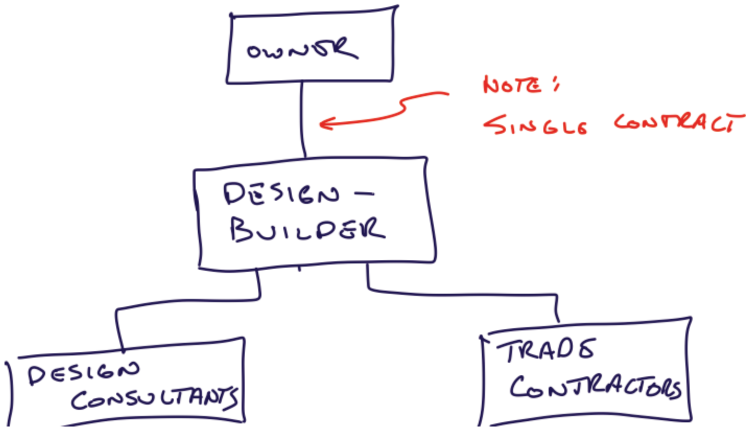


Figure 4-6: Design-Build (Organizational Structure)

This single entity approach for both design and construction allows for many potential benefits. It allows for a very tight integration of construction means and methods with the design of the facility. It also allows the team to develop accurate costs estimates throughout the early design phases, and identify approaches to save costs and provide added value within the construction process.

While there are many benefits to the integration that can occur in Design-Build, there are also some potential negative aspects. A primary concern that may be expressed within design-build is that the owner may not have an independent advocate within the checks and balances of having both a design and construction contract. In a more traditional approach, the design firm frequently has some oversight role of the contractor, and the contractor has an opportunity to share their opinions regarding the designer with the owner. In a design-build project, the owner does not have a second opinion in the same manner, and therefore, may not receive the same feedback. The owner may also have concerns that the design-build firm is trying to maximize their success to the detriment of the project. While these are valid concerns that must be appropriately managed through project control systems and hiring a high-quality team, many owners find design-build to be a very effective method to deliver a project.

Integrated Project Delivery (IPD)

Integrate Project Delivery (IPD) is a newer contracting format where the entire team is engaged in the successful delivery of the project, including the owner, designer(s), and contractor(s) through a very integrated, shared risk / reward approach. Projects delivered using the Integrated Project Delivery organizational structure have core members enter into an Integrated Form of Agreement (IFoA). This IFoA is a single contract for the project that is signed by all core team members, including the owner. This is a very unique structure which is unlike other delivery methods. Typically, all core members will share the risks of designing and delivering the project, along with the potential financial rewards if the project is delivered on or below the target budget while meeting the other project goals.

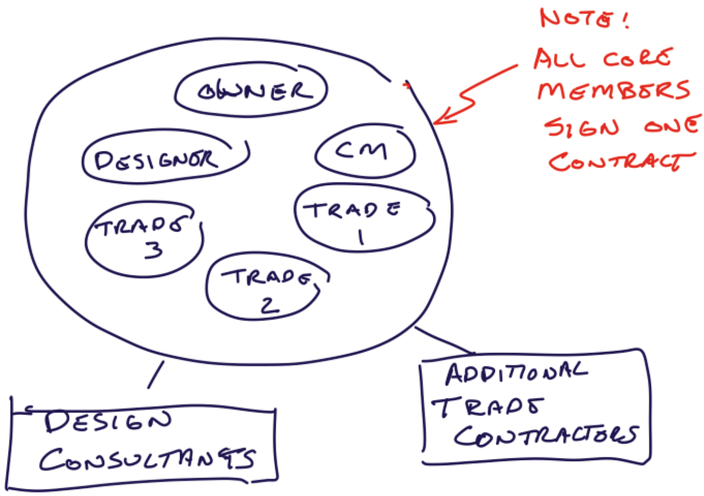


Figure 4-7 Integrated Project Delivery (one view of the organizational structure)

Figure 4-8 shows a survey of IPD projects that were performed in 2010. While adoption has continued to increase since 2010, there are still very few projects that are delivered using the IPD approach.

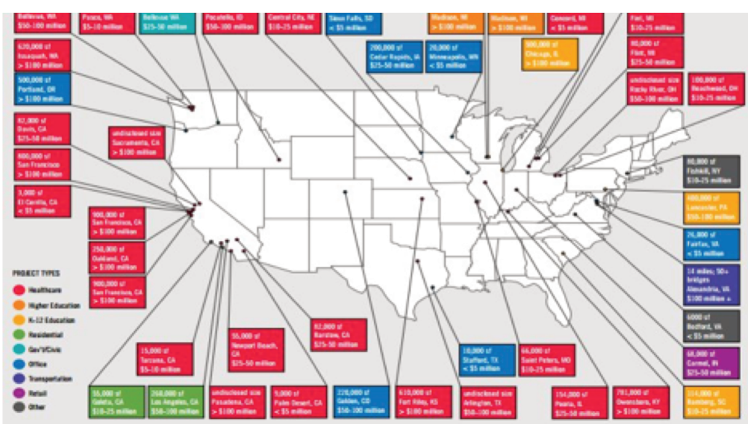


Figure 4-8: IPD Projects in 2010

There are typical many unique management aspects associated with IPD projects. For example, the integrated team will frequently form a cluster group at the beginning of the project to manage particular scopes of work or focused issues. They will frequently set up a 'big room' to collocate the team to a common location to better integrate the design and construction team members. During design, the team will frequently use target value design approaches to ensure that they are designing the project to budget. They will also frequently leverage lean construction methods, including pull planning and the Last Planner System, to manage production. These different systems will be discussed in more detail in a later section.

Contracting Method

There are many items covered within a contract. One of the most significant items in the contract in relation to the delivery approach is the payment terms, which define how payments are made from one party to another. Common payment terms include: lump sum, cost plus a fee, cost plus a fee with a Guaranteed Maximum Price (GMP), or unit cost.

Lump-Sum

In a lump sum payment approach, the owner will pay a fixed amount to the contractor for the work performed. This amount is paid on a periodic basis, typically each month. A Lump Sum arrangement typically corresponds with a traditional, design-bid-build delivery approach, although it can be used with other organizational structure. Within a Lump Sum contract, the contractor will either make a profit, if they can construct the building for less than the lump sum value, or they will lose money if they can not construct the building for the value. This transfers a significant amount of the risk for financial performance to the constructor. If the contract scope is changed or there are errors in the construction documents that increase the cost of construction, the constructor can file for a change order to increase the lump sum value.

Cost Plus a Fee

The Cost Plus a Fee approach leaves the final contract value open. It is a contractual arrangement where the owner (or a separate prime contractor) pays for all costs of performing the work, including labor, materials, equipment, and potentially other costs, plus an agreed-to fee. The fee may be a lump sum fee or it may be a percentage of the cost of work. A Cost Plus a Fee arrangement is typical for projects where the full scope is not well defined, and the owner wishes to start the work. This contracting method carries a significantly lower risk to the contractor. The contractor will need to account for all of their costs, and share these details with the owner. This approach is frequently referred to as Open Book since the contractor will share their accounting with the owner, and the owner typically has the right to perform a full audit of the books.

Cost + Fee with Guaranteed Maximum Price (GMP)

To overcome one of the challenges with Cost + Fee contracts, many Owner – Construction Manager (or some others) contracts have a Cost + Fee with GMP. In this approach, an owner will pay all the costs of work along with a fee to a maximum agreed to value. If the contractor exceeds the value of the GMP, then they will only receive the GMP value. If they spend less than the GMP value, then there are savings. Cost + Fee with GMP contracts will define what happens with savings. In many instances, they shared between the owner and the contractor at some percentage, e.g., 50-50 or 75-25. In other instances, all the savings may go to the owner. With the Cost + Fee contract, the contractor will provide invoices accounting for all the costs that they have incurred. This is an Open Book approach since the owner can audit the accounting on the project.

Unit Price

For some scopes of work, although not typically an entire project, an owner or contractor will pay a supplier or subcontractor a unit price amount for a scope of work. For example, the contractor may pay for concrete by a cubic yard of a specific mix design, or an excavation subcontractor may be paid by the cubic yard of excavated material. A benefit of the unit price payment method is that you can set up a project with a clear cost per unit, while not necessarily knowing the full scope of the work. A downside for the contracting entity is that there is not guaranteed final cost since it is dependent on the quantity, and there must be a quality method to document the actual quantity performed.

Award Method

When one party would like to hire another party to perform a service or provide a product, the party must decide how they will select the other party. There are many different approaches to selecting the method that they will use to award the contract. For design and construction contracts, these methods can be broadly categorized into a) competitive bid, b) prequalified competitive bid, c) best value selection, and d) negotiated selection.

Competitive Bid

One traditional method to select a contractor is to select the lowest cost contractor in a competitively bid arrangement. In this approach, all contractors will submit a bid, and the Owner, or selecting entity, will review the bids and select the lowest qualified bidder.

Prequalified Competitive Bid

One challenge of an open competitive bid is that the owner may select a contractor who technically fits the qualifications, but that the owner does not feel has more advanced qualifications. In some instances, an owner will proceed with a 2 step process. They will first prequalify a subset of the potential bidders, through the review of a qualification submission for each potential bidder. Then, they will ask each of the prequalified bidders to submit a bid for the cost of the project, and they will select the lowest cost bidder from the prequalified contractors.

Best Value Selection

Another approach to selecting a contractor is to develop a best-value selection process. In this approach, the owner will identify the criteria that they value, and develop an approach to weight each of the criteria. These criteria may include the quality of the team, experience on a similar project, plan for approaching the project, and other criteria. They will also include cost as a factor, but not as the only selection factor. Once these criteria are identified, then the owner will review the submissions from potential contractors and rate each of the criteria. The final item to be reviewed and weighted will be the cost. The selection will occur based upon the contractor who rates the highest in the combined weighted equation. This approach can yield the selection of a contractor who aligns more closely with the values of the project.

Negotiated Selection

A final approach to selecting a contractor is to identify an entity (or entities) that you would like to hire, and then directly negotiate a mutually accepted agreement with the entity. This has the benefit of being able to directly select the entity, but this may not be allowed in many public organizations due to a lack of competitive selection. There are exceptions in public procurement laws, but this is typically not allowed.

Organizational Charts

It is very common to draw an organizational chart (sometimes simply called an 'org' chart) which identifies all primary parties on a project, and shows the contractual relationships between the parties. Organizational charts can sometimes be quite graphic, with companies using their logos or other symbols, or they may simply show the entities and their relationships. In this class, we will keep the organizational charts simple, and simply show the core attributes of the delivery strategy.

When drawing an organizational chart for a construction project, it is typical to have the owner at the top of the chart. The owner initiates all of the prime contracts on the project. By saying 'prime' contracts, that means that an entity is directly contracted with the owner. As we proceed vertically through the organizational chart, the levels of contracts are sometimes referenced by their relationship to the prime contractors. For example, a party that contracts with a prime contractor is sometimes referenced as a 'subcontract', or sometimes (but not often) a first-tier subcontract. This means that the subcontracted party has a direct contract with a prime contractor. Then, if a party contracts with a subcontractor, they may be referred to as a 'second-tier subcontractor'. For example, an owner may contract with a general contractor as a prime contractor. Then, the general contractor may contract with a Mechanical specialty trade contractor via a subcontract. The Mechanical specialty trade may then contract with a controls contractor via a second-tier subcontract.

Payments, roles and responsibilities follow these subcontracts. In the above example, the owner would pay the prime contractor, the prime will pay the subcontractor, and the subcontractor will pay the second-tier subcontractors.

Recent Research

Research has supported the value of more integrative delivery methods. An initial study, performed in Konchar and Sanvido (1995) focused on comparing three broad delivery methods (Design-Bid-Build, CM at Risk, and Design-Build). The study reviewed a significant amount of data related to overall project performance. The conclusions of the study clearly illustrated that Design-Build projects outperformed other delivery methods when comparing cost, schedule and quality metrics.

It is important to note that the study results do not suggest that every project should use a design-build delivery approach. In fact, the study was performed prior to the advent of the more recent Integrated Project Delivery (IPD) approach. A more recent study evaluated the different project delivery attributes that influenced the overall project performance on projects.

Overall, it is clear that well-managed projects that can leverage the integration of team members and budget transparency can yield high levels of success.

Review questions

1.

Review Question Answers

5.

CHAPTER 5: INTRODUCTION TO CONSTRUCTION COST ESTIMATING

Learning Objectives

After reading this chapter, you should be able to:

- Define typical cost estimating methods that are used within the Construction Industry
- Describe the typical types of cost information available to various participants within the industry

Introduction to Cost Estimation for Construction Projects

Construction cost estimating is both an art and a science. To be an effective estimator, you need to be able to interpret a facility design, and visualize and plan the approach toward building the facility. The best estimators are also very good at understanding previous construction costs, and interpreting the conditions that will add or reduce future costs.

Construction cost estimates ('estimates') are created at many different points in time throughout a project. The owner may develop very early feasibility estimates to determine if a project is economically viable. A designer or construction manager may develop a series of progressively detailed estimates during the design process to ensure that the project is being designed to the owner's budget. A general contractor or trade contractor will develop estimates to determine their bid or budget values for a project. And there may be multiple estimates developed to determine the impact of various design options, or develop a cost estimate for a design change during the construction process.

Construction cost estimates are also developed to different levels of detail, and different levels of accuracy. One method of defining levels of detail is to follow the RS Means levels of detail. They define 4 different types of estimates at progressive levels of detail as follows:

Rough Order of Magnitude (or Averaged Square Foot) Estimate

These estimates leverage average statistical values for the cost per unit or cost per square foot for a building. They are projected to be accurate to within +/- 20%, although this accuracy can be highly variable. This estimate can be performed with very limited information, e.g., how many cars for a parking garage or an approximate number of square feet for an office building. This estimate can be performed in the planning phase, and should only take approximately 10 minutes to perform.

Modeled Square Foot Estimate

These estimates leverage predefined model buildings to aim to develop a building that is representative of the future building. This approach is projected to be accurate to within +/- 15%, but again, this can be very variable depending upon the levels of assumptions. The Modeled Square Foot estimating approach requires that you have an approximate building footprint, know the structural system, and know the facade system. This estimating approach can be implemented in the Schematic Design phase and will typically take approximately 1 hour to perform.

Assemblies (or System) Estimate

An assemblies estimate is developed by identifying, quantifying, and pricing each of the assemblies within a project. They are projected to be accurate to within 10%. To perform an assemblies estimate, you need to know the system-level design and be able to perform quantity takeoffs for the various systems. This typically can occur within the Design Development phase. It will typically take approximately 1 day to develop this type of estimate, with much of the time spent on performing quantity takeoffs (quantifying the amount of each item).

Unit Price (Detailed) Estimate

A unit price estimate is a very detailed estimating approach where you define each of the items contained within the project, and price these items after defining the specific construction methods that will be used to construct them. This approach can be accurate to within +/- 5% of the cost, although this depends on the complexity of the project. To perform this type of estimate, the design must be quite complete, so it is typically done near or at the end of the construction documents phase. It can take up to 3 weeks to perform a detailed estimate of all items in a building, with a significant amount of time spent on performing quantity takeoffs.

There is a chapter in these notes devoted to each of these estimating methods.

Sources of Estimating Data:

To develop an estimate of the cost to construct a facility, it is important to identify data sources that will be used for the estimate. There are many different potential data sources. They can be divided into the following categories:

1. Actual Cost Data:

Depending upon the level of detail, and time available, you can obtain actual price quotes and actual cost information for some, or many, of the elements that will be included in the estimate. For example, if you are going to subcontract portions of the project, e.g., the concrete or steel trade, you can request quotes from one or multiple potential trade contractors. You can also contact suppliers to get firm quotes on the cost of specific materials and equipment. Finally, you can get actual wage rates for workers on the project, although you will still need to develop estimates for how many hours the work activities will take. If you can get firm quotes from subcontractors and suppliers, with a time period to accept and contract with them for the supplies and equipment, then you have a high degree of confidence in the actual costs for the portions of the project estimate.

2. Historical Cost Data: Company Data

If you can not obtain actual cost quotations, or for work activities that a contractor will directly perform, they can leverage historical data from their own projects. For example, if you are a concrete contractor and you are developing an estimate for the concrete work on the concrete work on a future office building, you can review the actual costs and production rates from previous projects that your company has performed. When doing so, it is critical for the estimating team to fully understand the context of the previous projects, along with how the project team tracked their costs. If a company maintains good records of previous project costs and production rates, then they can relatively easily develop estimates for similar future projects that are quite accurate.

3. Historical Cost Data: National / Regional Averages

For organizations who do not have their own data available, there are organizations that collect cost data, and then report this data through online databases or cost estimating guides/books. These organizations are typically collecting data from many projects that are performed in many locations, and then averaging and modifying this data to represent average national construction costs. The data will also be compiled at different levels of detail, e.g., individual work activities, building systems, and overall building level costs. It is always important to keep in mind that the data in these cost guides/databases are averaged data, and individual site conditions, project complexity, and other factors may significantly impact potential costs. Therefore, these are the easiest source of data to find but are not as reliable as accurate, well-organized company data sources.

The most broadly used data source for historical data is the information from R.S. Means. R.S. Means has a series of books that outline costs for a variety of project types and levels of detail (see Figure 5.1 for cover pages) For example, they have guides for Unit Price estimating, Square Foot estimating, and Assemblies Estimating. They also have guides for various specific trades, e.g., concrete, steel, masonry, mechanical and electrical. And they have some guides for specific purposes, e.g., renovations, facility management, and green buildings.

Finally, they also have guides with cost differentials based upon the labor used, e.g., Open Shop cost guide for non-union labor. It is important to note that all guides unless specifically noted as 'Open Shop' are priced with wage rates for a union or prevailing wage workforce.

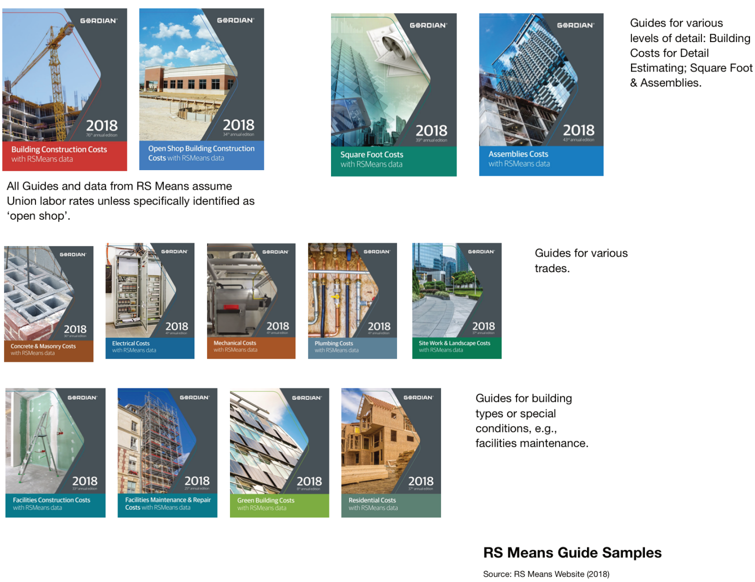


Figure 5.1: Cover Pages for R.S. Means Estimating Manuals (for Penn State students, most manuals are available in the Engineering Library)

Impact of Time on Cost

As time progresses, it is typical for costs to escalate, at least in most economic conditions. Broadly, this is known as inflation, and we typically measure this cost escalation by pricing a series of goods over time and seeing how the price changes from one time period to another. The most typical measure in the US for inflation is the Consumer Price Index (CPI), which is calculated from a typical basket of goods that an average person may buy, e.g., food, gas, etc.

When we estimate projected building costs, there are similar cost escalations that occur, but these escalations are more targeted toward the cost escalation of building materials and the labor cost for construction. Therefore, it is more accurate to consider cost escalation by calculating the escalation of a construction-related 'basket of goods'. RS Means has developed several specific cost index values, similar to CPI but focused on construction. These include the Building Cost Index (BCI) which contains typical products and labor for building construction; the Construction Cost Index (CCI) which is much broader to cover roads, bridges, and infrastructure; and the Material Cost Index for building materials.

When we perform cost estimates for building projects, we will focus on using the BCI value since it is more targeted to buildings. If you compare BCI values for two periods in time, then you can transition relative economic values between these times with a simple calculation of ratios. The BCI, CCI, and MCI are all reported in the Engineering News Record publication, which is published each week (see Figure 5-2). Monthly and annual averages are also available on the ENR website and are included in Figure 5-3.

CONSTRUCTION ECONOMICS

ENR's 20-city average cost indexes, wages and material prices. Historical data and details for ENR's 20 cities can be found at ENR.com/economics

Construction Cost Index +2.6% AUGUST 2018

1913=100	INDEX VALUE	MONTH	YEAR
CONSTRUCTION COST	11124.49	+0.1%	+2.6%
COMMON LABOR	23344.15	0.0%	+2.0%
WAGE $/HR.	44.87	0.0%	+2.0%

The Construction Cost Index's annual escalation rate rose to 2.6% this month, with the monthly component up 0.1%.

Building Cost Index +3.4% AUGUST 2018

1913=100	INDEX VALUE	MONTH	YEAR
BUILDING COST	6060.07	+0.3%	+3.4%
SKILLED LABOR	10297.31	+0.2%	+2.0%
WAGE $/HR.	57.03	+0.2%	+2.0%

The Building Cost Index's annual escalation rate rose to 3.4%, while the monthly component rose 0.3%.

Material Cost Index +0.2% AUGUST 2018

1913=100	INDEX VALUE	MONTH	YEAR
MATERIALS COST	3377.01	+0.2%	+4.9%
CEMENT $/TON	115.50	−0.8%	−0.7%
STEEL $/CWT	53.34	+0.4%	+2.6%
LUMBER $/MBF	635.05	+0.5%	+13.6%

The MCI rose 0.2% this month, while the annual escalation rate rose to 4.9%.

Figure 5-2: Construction Economics Section from Engineering News Record (reported weekly in ENR)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG.
2017	5734	5742	5789	5802	5816	5826	5844	5862	5873	5867	5902	5914	5831
2016	5561	5588	5605	5632	5637	5636	5659	5669	5657	5681	5690	5722	5645
2015	5497	5488	5487	5501	5490	5507	5510	5514	5541	5543	5563	5574	5518
2014	5324	5321	5336	5357	5370	5375	5383	5390	5409	5442	5468	5480	5387
2013	5226	5246	5249	5257	5272	5286	5281	5277	5285	5308	5317	5326	5278
2012	5120	5122	5144	5150	5167	5170	5184	5204	5195	5204	5213	5210	5174
2011	4969	5007	5010	5028	5035	5059	5074	5091	5098	5104	5113	5115	5058
2010	4800	4812	4811	4817	4858	4888	4910	4905	4910	4947	4968	4970	4883
2009	4782	4765	4767	4761	4773	4771	4762	4768	4764	4762	4757	4795	4769
2008	4557	4556	4571	4574	4599	4640	4723	4733	4827	4867	4847	4797	4691
2007	4432	4432	4411	4416	4475	4471	4493	4512	4533	4535	4558	4556	4485
2006	4335	4337	4330	4335	4331	4340	4356	4359	4375	4431	4462	4441	4369
2005	4112	4116	4127	4168	4189	4195	4197	4210	4242	4265	4312	4329	4205
2004	3767	3802	3859	3908	3956	3996	4013	4027	4102	4129	4128	4123	3984
2003	3648	3655	3649	3652	3660	3677	3683	3712	3717	3745	3765	3757	3693
2002	3581	3581	3597	3583	3612	3624	3652	3648	3655	3651	3654	3640	3623

http://www.enr.com/economics/historical_indices/building_cost_index_history

Figure 5-3: Historical Building Construction Cost Indices from Engineering News Record (ENR)

When using the RS Means data, it is valuable to know that the data within a cost guide is updated to be consistent with the index values for January of the year on the cover. For example, if you have a 2018 RS Means Building Construction Cost Guide, all cost data will be statistically modified to be consistent with the January 2018 BCI.

If you are a private organization that maintains your own cost data, you will also want to modify the data based upon the time of construction. Individual companies may maintain their own information to modify these costs. For example, Turner Construction maintains, and even publishes, its own cost index over time which is available online.

The escalation of costs over time can vary significantly, but on average, construction costs have historically risen approximately 3% per year. When we estimate future construction costs, we need to consider the projected future cost increases. Throughout this class, unless otherwise noted, a projected escalation of 3% per year can be used for future construction cost escalation. Companies will be reviewing their recent experience and projected future market conditions to establish the escalation values that they project when developing their cost estimates. This can have a significant impact on their final economic success on certain types of projects, e.g., lump-sum contracts, especially for projects that span several years.

Modify Index Values for Location

Construction costs vary by geographic location to due differences in material, equipment and labor costs. These variations can be significant. In the RS Means data, they develop all their data into a national average for publishing, and then they publish Location Factors for different cities. For example, a location factor for Dickinson, North Dakota can be identified in the Location Factor table which is included in the back of each of the RS Means guides (see Figure 5-4). The national average is 1, and the commercial construction location factor for Dickinson is 0.85. Therefore, if a building is estimated from the guide to cost 100 million, then the estimated cost in Dickinson would be 85 million dollars. RS Means publishes both residential and commercial location factors in some tables. Note that the residential location factors are targeted toward single-family detached residential, not residential apartment buildings which would be commercial construction. Some guides also publish specific City Indexes which are more specific for altering the cost for both time and location within a given city. RS Means publishes city indexes for 20 large cities in the US.

Figure 5-4: Location Factor

Location Factors

STATE/ZIP	CITY	Residential	Commercial
NORTH DAKOTA (CONT'D)			
586	Dickinson	.76	.85
587	Minot	.84	.89
588	Williston	.76	.84
OHIO			
430-432	Columbus	.94	.95
433	Marion	.91	.91

Figure 5-4: Location Factor Table from Cost Estimating Manual

There are also international indexes that allow estimates to be transitioned from one country to another, although this is certainly not as accurate for many purposes.

Understanding the Audience

One important aspect of cost estimating is to always understand and project your audience for the estimate. If you are developing an estimate for an owner, early in the project, you will want to make sure that the owner is aware of the potential variation, and that you clearly define what is included in the estimate, and which items are not included. For example, if you perform a Rough Order of Magnitude estimate using RS Means, the estimate will include construction costs, but it will not include the design fees, land cost, extensive site work. These inclusions and exclusion vary by type of estimate performed.

RS Means – What is Included?

RS Means data is collected from actual projects. This data collection approach, and the statistics performed after collection, can influence there ability to draw future projections from the data. Therefore, each of the 4 estimating methods defined in RS Means approaches have some items excluded. The following items are always excluded from RS Means data estimates due to their high level of variability on projects:

- Land cost
- Detailed site work
- Financing costs

The following additional items may be excluded from some of the types of estimate:

- Designer fee (not in ROM or Unit Cost – unless added)
- Contractor fee and home office overhead (not in Unit Price unless specifically added)
- Contractor general requirements (not in Unit Price unless specifically added)

Review Questions

1. List the four types of estimates, along with their relative accuracy levels.
2. Which of the following items are never included in an RS Means cost guide (mark all that apply):
    - Construction costs
    - Land cost
    - Designer fees
    - Financing cost
3. When modifying an estimate for time on a highway project, you can use a ratio of the Construction Cost Index (CCI) for the estimated time of cost data and the actual time for the construction. (true / false)
4. What was the Building Construction Cost (BCC) in January 2015?
5. Based upon the location factor data in Figure 5-4, the cost for construction in Columbus Ohio is higher than the average cost of construction within the United States. (true/ false)

Review Question Answers

6.

CHAPTER 6: ROUGH ORDER OF MAGNITUDE (ROM) COST ESTIMATING

Learning Objectives

After reading this chapter, you should be able to:

- Understand the benefits and limitations of the ROM estimating approach
- Develop a Rough Order of Magnitude estimate for a building project
- Perform cost estimate translations considering time factors and location factors
- Identify the appropriate locations to find the

R.S. Means cost data tables used for ROM estimates

Introduction

At the earliest stages of a project, an owner or developer will seek a general cost estimate for a facility. At this early stage, they may not have much information about a building. They may only know general information about the use of the facility, or know the general size of the building. At this earliest stage, there is a possibility to develop cost estimates based upon statistical data from the cost of buildings of a similar type. If a contractor builds a large quantity of a particular type of building in the location of a future building, they may be able to provide valuable insight into the cost of similar buildings in the area. Without this type of insight, cost guides, such as RS Means, provide a method, based upon statistical averages and deviations, to calculate a very rough cost estimate for a facility simply based upon a future use or size projection.

The Rough Order of Magnitude (ROM) estimating approach is used at the earliest stages of the project, and could also be sometimes referred to as a 'napkin' estimate since you could write it on a napkin while having lunch with a client. These estimates can be valuable to an owner or developer since they gain a relative scale of the costs which can be very valuable for determining the overall economic feasibility of a project. They can also provide insights into the impact of various levels of quality that they may be able to develop for a given budget.

Performing a Rough Order of Magnitude Estimate with RS Means Data

The tables and information for performing a ROM estimate with RS Means data are included in a section toward the end of the Assemblies Estimating Guide. The title used for these data tables within RS Means Guides are 'Square Foot Estimate' which can be misleading since the values are calculated in a significantly different manner than the Modeled Square Foot Estimates that will be included in the next chapter. The tables, simply several pages of data, provide statistical average cost data for each type of facility with a distribution showing the 1/4 (25%) of project cost and the 3/4 (75%) of project cost. With the average, 1/4 and 3/4 values, you can then develop an estimated cost per square foot for a facility based upon the expected level of quality and difficulty in construction. A detailed description of the values and how they are calculated is included in Figure 6-1 from the Assemblies Cost Guide.

Square Foot Costs **RK1010-010 Information**

Square Foot and Cubic Foot Building Costs

The cost figures in Division K1010 were derived from more than 11,200 projects contained in the Means Data Bank of Construction Costs, and include the contractor's overhead and profit, but do not include architectural fees or land costs. The figures have been adjusted to January of the current year. New projects are added to our files each year, and outdated projects are discarded. For this reason, certain costs may not show a uniform annual progression. In no case are all subdivisions of a project listed.

These projects were located throughout the U.S. and reflect a tremendous variation in S.F. and C.F. costs. This is due to differences, not only in labor and material costs, but also in individual owner's requirements. For instance, a bank in a large city would have different features than one in a rural area. This is true of all the different types of buildings analyzed. Therefore, caution should be exercised when using Division K1010 costs. For example, for court houses, costs in the data bank are local court house costs and will not apply to the larger, more elaborate federal court houses. As a general rule, the projects in the 1/4 column do not include any site work or equipment, while the projects in the 3/4 column may include both equipment and site work. The median figures do not generally include site work.

None of the figures "go with" any others. All individual cost items were computed and tabulated separately. Thus the sum of the median figures for Plumbing, HVAC, and Electrical will not normally total up to the total Mechanical and Electrical costs arrived at by separate analysis and tabulation of the projects.

Each building was analyzed as to total and component costs and percentages. The figures were arranged in ascending order with the results tabulated as shown. The 1/4 column shows that 25% of the projects had lower costs, 75% higher. The 3/4 column shows that 75% of the projects had lower costs, 25% had higher. The median column shows that 50% of the projects had lower costs, 50% had higher.

There are two times when square foot costs are useful. The first is in the conceptual stage when no details are available. Then square foot costs make a useful starting point. The second is after the bids are in and the costs can be worked back into their appropriate units for information purposes. As soon as details become available in the project design, the square foot approach should be discontinued and the project priced as to its particular components. When more precision is required or for estimating the replacement cost of specific buildings, the current edition of ***RSMeans Square Foot Costs*** should be used.

In using the figures in Division K1010, it is recommended that the median column be used for preliminary figures if no additional information is available. The median figures, when multiplied by the total city construction cost index figures (see City Cost Indexes) and then multiplied by the project size modifier in RK1010-050, should present a fairly accurate base figure, which would then have to be adjusted in view of the estimator's experience, local economic conditions, code requirements, and the owner's particular requirements. There is no need to factor the percentage figures as these should remain constant from city to city. All tabulations mentioning air conditioning had at least partial air conditioning.

The editors of this book would greatly appreciate receiving cost figures on one or more of your recent projects, which would then be included in the averages for next year. All cost figures received will be kept confidential except that they will be averaged with other similar projects to arrive at S.F. and C.F. cost figures for next year's book. See the last page of the book for details and the discount available for submitting one or more of your projects.

Square Foot Costs

Figure 6-1: Description of the Rough Order of Magnitude Estimating Approach with RS Means Data

To perform the estimate, you can either have an approximate footprint or size (square foot) for the building, or you may know the programmatic use of the facility along with a key use quantity, e.g., number of cars for a parking garage, number of beds for a nursing home. If you only know the programmatic units, you can easily convert these units to an approximate square foot value leveraging the Space Planning table provided in RS Means (see Figure 6-2).

Square Foot Costs **RK1010-030 Space Planning**

Table K1010-031 Unit Gross Area Requirements

The figures in the table below indicate typical ranges in square feet as a function of the "occupant" unit. This table is best used in the preliminary design stages to help determine the probable size requirement for the total project. See RK1010-050 for the typical total size ranges for various types of buildings.

Building Type	Unit	Gross Area in S.F.		
		1/4	Median	3/4
Apartments	Unit	660	860	1,100
Auditorium & Play Theaters	Seat	18	25	38
Bowling Alleys	Lane		940	
Churches & Synagogues	Seat	20	28	39
Dormitories	Bed	200	230	275
Fraternity & Sorority Houses	Bed	220	315	370
Garages, Parking	Car	325	355	385
Hospitals	Bed	685	850	1,075
Hotels	Rental Unit	475	600	710
Housing for the Elderly	Unit	515	635	755
Housing, Public	Unit	700	875	1,030
Ice Skating Rinks	Total	27,000	30,000	36,000
Motels	Rental Unit	360	465	620
Nursing Homes	Bed	290	350	450
Restaurants	Seat	23	29	39
Schools, Elementary	Pupil	65	77	90
Junior High & Middle	↓	85	110	129
Senior High	↓	102	130	145
Vocational	↓	110	135	195
Shooting Ranges	Point		450	
Theaters & Movies	Seat		15	

Figure 6-2: Unit Gross Area Requirements – Space Planning

RS Means also publishes a table which includes the estimated cost per square foot for many types of facilities. A sample is shown in Figure 6-3. After defining the appropriate level of quality, you can identify an approximate cost per square foot for the building. Once you know the estimated square foot, and an approximate square foot value, you will then be able to modify the cost per square foot based upon the overall size of the facility relative to the average facility size for the data within RS Means. This Size Modifier is important since the cost per unit (square foot) of a building will vary based upon the size of the building. Larger buildings have a lower cost per square foot than smaller buildings due to the crews learning the construction methods and being more productive, along with the ability to get lower material costs due to quantities purchased. In addition, there is less overhead per unit of cost, and there is typically a lower amount of facade per floor area which reduces costs. Due to all of these factors, the unit (per square foot) cost for a larger building is lower, even though the absolute cost of the building will be higher than a smaller building.

K1010 | Project Costs

	K1010 | Project Costs		UNIT	UNIT COSTS			% OF TOTAL		
				1/4	MEDIAN	3/4	1/4	MEDIAN	3/4
01	0000	Auto Sales with Repair	S.F.						
	0100	Architectural		98.50	110	119	58%	64%	67%
	0200	Plumbing		8.25	8.65	11.55	4.84%	5.20%	6.80%
	0300	Mechanical		11.05	14.80	16.35	6.40%	8.70%	10.15%
	0400	Electrical		17	21	26.50	9.05%	11.70%	15.90%
	0500	Total Project Costs		165	173	177			
02	0000	Banking Institutions	S.F.						
	0100	Architectural		149	183	222	59%	65%	69%
	0200	Plumbing		6	8.35	11.60	2.12%	3.39%	4.19%
	0300	Mechanical		11.90	16.45	19.40	4.41%	5.10%	10.75%
	0400	Electrical		29	35	54	10.45%	13.05%	15.90%
	0500	Total Project Costs		247	278	340			
03	0000	Court House	S.F.						
	0100	Architectural		78.50	78.50	78.50	54.50%	54.50%	54.50%
	0200	Plumbing		2.96	2.96	2.96	2.07%	2.07%	2.07%
	0300	Mechanical		18.55	18.55	18.55	12.95%	12.95%	12.95%
	0400	Electrical		24	24	24	16.60%	16.60%	16.60%
	0500	Total Project Costs		143	143	143			
04	0000	Data Centers	S.F.						
	0100	Architectural		177	177	177	68%	68%	68%
	0200	Plumbing		9.70	9.70	9.70	3.71%	3.71%	3.71%
	0300	Mechanical		24.50	24.50	24.50	9.45%	9.45%	9.45%
	0400	Electrical		23.50	23.50	23.50	9%	9%	9%
	0500	Total Project Costs		261	261	261			
05	0000	Detention Centers	S.F.						
	0100	Architectural		164	174	184	52%	53%	60.50%
	0200	Plumbing		17.35	21	25.50	5.15%	7.10%	7.25%
	0300	Mechanical		22	31.50	37.50	7.55%	9.50%	13.80%
	0400	Electrical		36	42.50	55.50	10.90%	14.85%	17.95%
	0500	Total Project Costs		278	293	345			

Figure 6-3: Example of ROM Estimate Tables

To account for this in the ROM estimate, you need to calculate a cost modifier by comparing the estimated size of the planned building to the average size published for the RS Means facility type. This ratio of relative sizes can then be used within the Size Multiplier graph to identify a multiplier for the estimated value (see Figure 6-4).

Square Foot Costs **RK1010-050 Project Size Modifier**

RK1010-050 Square Foot Project Size Modifier

One factor that affects the S.F. cost of a particular building is the size. In general, for buildings built to the same specifications in the same locality, the larger building will have the lower S.F. cost. This is due mainly to the decreasing contribution of the exterior walls plus the economy of scale usually achievable in larger buildings. The Area Conversion Scale shown below will give a factor to convert costs for the typical size building to an adjusted cost for the particular project.

Example: Determine the cost per S.F. for a 152,600 S.F. Multi-family housing.

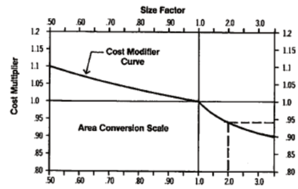
$$\frac{\text{Proposed building area} = 152{,}600 \text{ S.F.}}{\text{Typical size from below} = 76{,}300 \text{ S.F.}} = 2.00$$

Enter Area Conversion scale at 2.0, intersect curve, read horizontally the appropriate cost multiplier of .94. Size adjusted cost becomes .94 x $187.00 = $175.78 based on national average costs.

Note: For Size Factors less than .50, the Cost Multiplier is 1.1
For Size Factors greater than 3.5, the Cost Multiplier is .90

The Square Foot Base Size lists the median costs, most typical project size in our accumulated data, and the range in size of the projects.

The Size Factor for your project is determined by dividing your project area in S.F. by the typical project size for the particular Building Type. With this factor, enter the Area Conversion Scale at the appropriate Size Factor and determine the appropriate cost multiplier for your building size.



System	Median Cost (Total Project Costs)	Typical Size Gross S.F. (Median of Projects)	Typical Range (Low – High) (Projects)
Auto Sales with Repair	$171.00	25,300	8,200 – 28,700
Banking Institutions	268.00	26,300	3,300 – 38,100
Detention Centers	283.00	42,000	12,300 – 183,300
Fire Stations	214.00	14,600	6,300 – 29,600
Hospitals	360.00	137,500	54,700 – 410,300
Industrial Buildings	$93.50	16,900	5,100 – 200,600
Medical Clinics & Offices	212.00	5,500	2,600 – 327,000
Mixed Use	194.00	49,900	14,400 – 49,900
Multi-Family Housing	187.00	76,300	12,500 – 1,161,500
Nursing Home & Assisted Living	125.00	16,200	1,500 – 242,600
Office Buildings	176.00	10,000	1,100 – 930,000
Parking Garage	42.00	174,600	99,900 – 287,000
Parking Garage/Mixed Use	157.00	5,300	5,300 – 318,000
Police Stations	273.00	15,400	15,400 – 31,600
Public Assembly Buildings	253.00	30,500	2,200 – 235,300
Recreational	275.00	2,300	1,500 – 223,800
Restaurants	273.00	6,100	5,500 – 42,000
Retail	102.00	28,700	5,800 – 61,000
Schools	204.00	30,000	5,500 – 410,800
University, College & Private School Classroom & Admin Buildings	261.00	89,200	9,400 – 196,200
University, College & Private School Dormitories	204.00	50,800	1,500 – 126,900
University, College & Private School Science, Eng. & Lab Buildings	262.00	39,800	36,000 – 117,600
Warehouses	113.00	2,100	600 – 303,800

Figure 6-4: Size Modifier Table for ROM

What is Included in the ROM Values?

The ROM estimate is simply a statistically averaged cost with some distributions for a particular type of building in the RS Means' dataset. The data is for the total construction cost. Therefore, the ROM estimated value does NOT include the designer fee for the project. It also excludes the typical items that are excluded from all RS Means data, e.g., land and financing costs. It does include the contractor's general conditions and fee since these values contained within the total construction cost values.

Please reference the course slides to see additional details regarding the Rough Order of Magnitude estimating approach.

Steps to Develop a Rough Order of Magnitude (ROM) Estimate

The following are the steps to develop a ROM estimate by using the Gardian estimating manual with the actual square foot cost data from RS Means.

1. Identify the Project Size

As previously discussed, the project size may be determined from an approximate building footprint if one exists, or you can calculate the approximate size by using the Space Planning Table in the Gardian manual (see Figure 6-2). This table includes approximate sizes for different building types based upon a unit of measure.

2. Identify the Square Foot Unit Cost

Using the Project Costs table in the Gardian guide (see Figure 6-3), identify the estimated cost per square foot for the project. You can select the median costs, or the 1/4 or 3/4 cost values, based upon the projected level of quality for the project.

3. Modify the Cost per Square Foot to Account for Project Size

Use the project size modifier graph and tables (see Figure 6-4) to identify the cost multiplier. See Figure 6-4 and the description earlier in this chapter for details regarding this calculation. After identifying the Cost Modifier from the graph, you will then calculate a modified cost per square foot for the building by simply multiplying the Square Foot Unit Cost from Step 2 by the Cost Modifier.

4. Calculate the Building Cost

The overall building cost estimate can be calculated by multiplying the cost per square foot by the estimated square foot quantity in Step 1. It is important to note that this estimated value is for an average location in the United States with a construction time of January of the year of the Gardian cost guide.

5. Modify the Building Cost for Time and Location Factors

The estimated cost should be modified for the time of construction and the location. This is performed by calculating a time multiplier and a location multiplier. Mathematically, it does not matter whether you modify for time or location first, but it is important to modify for both of them. More details regarding the time multiplier and location multiplier can be found in Chapter 5 and in our class presentations.

6. Make Additional Modifications if Appropriate

There are many other items that you may include in the ROM. The ROM calculation using the Gardian approach does not include design fees, so if a design and construction cost estimate is required, you can add approximate design fees. The estimate will also not include land and financing costs. These could be added depending upon the purpose of the estimate.

Review Questions

1. The ROM estimate using RS Means data includes all construction and land costs for a building. (True / False)
2. Using Figure 6-3, what is the average cost per square foot for the construction of a courthouse in a typical location within the United State, assuming that it is of average quality?
3. Using the space planning table, in Figure 6-4, what is the average size in gross square feet (GSF) for a typical police station?

Review Question Answers

7.

CHAPTER 7: MODELED SQUARE FOOT (SF) COST ESTIMATING

Learning Objectives

After reading this chapter, you should be able to:

- Describe the benefits and limitations of the Modeled Square Foot (SF) estimating approach
- Develop a Modeled Square Foot estimate for a building project
- Identify the appropriate locations to find the R.S. Means cost data tables used for Modeled Square Foot estimates

Introduction

As additional details are known about a building, a project team can develop a Modeled Square Foot estimate based upon previously composed model projects that have been developed by RS Means. This is defined within the RS Data as the Modeled Square Foot method. This method focuses on identifying the building type, and a small number of core building parameters (exterior facade and structural system) to define an estimated cost per square foot. Additions can then be included within the estimate.

The descriptions contained in Figures 7-1 and 7-2 show a description of the content contained on the 2 pages for each building type that are contained in the Square Foot Estimating Guide. These descriptions are referenced from the beginning of the estimating Guide. This Guide is simply composed of a series of Square Foot pages per building type. The initial part of the Guide is for Residential buildings (houses), and the latter section is for Commercial buildings. There are also some assemblies included toward the end of the guide, along with other tables and information.

COMMERCIAL/INDUSTRIAL/INSTITUTIONAL | **M.010** (1) | **Apartment, 1-3 Story** (2)

Costs per square foot of floor area

Exterior Wall (3)	S.F. Area	8000	12000	15000	19000	22500 (4)	25000	29000	32000	36000
	L.F. Perimeter	213	280	330	350	400	433	442	480	520
Fiber Cement	Wood Frame	183.45	175.45	172.30	166.50	164.95	163.90	160.90	160.25	159.25
Stone Veneer	Wood Frame	204.05	193.45	189.25	180.75	**178.60** (5)	177.35	172.65	171.80	170.40
Brick Veneer	Rigid Steel	198.80	189.15	185.25	177.75	175.80	174.60	170.50	169.75	168.45
E.I.F.S. and Metal Studs	Rigid Steel	193.20	184.60	181.15	174.75	173.05	172.00	168.55	167.90	166.75
Brick Veneer	Reinforced Concrete	220.40	208.95	204.35	194.80	192.60	191.10	185.85	185.00	183.40
Stucco and Concrete Block	Reinforced Concrete	208.10	198.15	194.20	186.30	184.35	183.10	178.85	178.10	176.70
Perimeter Adj., Add or Deduct (6)	Per 100 L.F.	15.60	10.40	8.25	6.55	5.55 (7)	5.05	4.25	3.90	3.50
Story Hgt. Adj., Add or Deduct	Per 1 Ft.	2.45	2.15	2.00	1.70	1.55	1.65	1.35	1.40	1.30

(8) ***For Basement**, add $38.70 per square foot of basement area*

The above costs were calculated using the basic specifications shown on the facing page. These costs should be adjusted where necessary for design alternatives and owner's requirements.

Common additives (9)

Description	Unit	$ Cost
Appliances		
Cooking range, 30" free standing		
1 oven	Ea.	610 - 2775
2 oven	Ea.	1200 - 3725
30" built-in		
1 oven	Ea.	995 - 2550
2 oven	Ea.	1575 - 3125
Counter top cook tops, 4 burner	Ea.	475 - 2150
Microwave oven	Ea.	281 - 855
Combination range, refrig. & sink, 30" wide	Ea.	2075 - 2625
72" wide	Ea.	3075
Combination range, refrigerator, sink, microwave oven & icemaker	Ea.	7100
Compactor, residential, 4-1 compaction	Ea.	885 - 1475
Dishwasher, built-in, 2 cycles	Ea.	685 - 1225
4 cycles	Ea.	800 - 2025
Garbage disposer, sink type	Ea.	260 - 370
Hood for range, 2 speed, vented, 30" wide	Ea.	370 - 1450
42" wide	Ea.	450 - 2650
Refrigerator, no frost 10-12 C.F.	Ea.	580 - 750
18-20 C.F.	Ea.	895 - 2075

Description	Unit	$ Cost
Closed Circuit Surveillance, One station		
Camera and monitor	Ea.	1475
For additional camera stations, add	Ea.	665
Elevators, Hydraulic passenger, 2 stops		
2000# capacity	Ea.	74,100
2500# capacity	Ea.	76,600
3500# capacity	Ea.	81,600
Additional stop, add	Ea.	8375
Emergency Lighting, 25 watt, battery operated		
Lead battery	Ea.	330
Nickel cadmium	Ea.	550
Laundry Equipment		
Dryer, gas, 16 lb. capacity	Ea.	1025
30 lb. capacity	Ea.	4100
Washer, 4 cycle	Ea.	1325
Commercial	Ea.	1700
Smoke Detectors		
Ceiling type	Ea.	244
Duct type	Ea.	585

How to Use the Commercial/ Industrial/Institutional Section

The following is a detailed explanation of a sample entry in the Commercial/Industrial/Institutional Square Foot Cost Section. Each bold number below corresponds to the described item on the following page with the appropriate component or cost of the sample entry following in parentheses.

Prices listed are costs that include overhead and profit of the installing contractor and additional markups for General Conditions and Architects' Fees.

1 Model Number (M.010)
"M" distinguishes this section of the data and stands for model. The number designation is a sequential number. Our newest models are green and are designated with the letter "G" followed by the building type number.

2 Type of Building (Apartment, 1-3 Story)
There are 50 different types of commercial/industrial/institutional buildings highlighted in this section.

3 Exterior Wall Construction and Building Framing Options (Stone Veneer with Wood Frame)
Three or more commonly used exterior walls and, in most cases, two typical building framing systems are presented for each type of building. The model selected should be based on the actual characteristics of the building being estimated.

4 Total Square Foot of Floor Area and Perimeter Used to Compute Base Costs (22,500 Square Feet and 400 Linear Feet)
Square foot of floor area is the total gross area of all floors at grade and above and does not include a basement. The perimeter in linear feet used for the base cost is generally for a rectangular, economical building shape.

5 Cost per Square Foot of Floor Area ($178.60)
The highlighted cost is for a building of the selected exterior wall and framing system and floor area. Costs for buildings with floor areas other than those calculated may be interpolated between the costs shown.

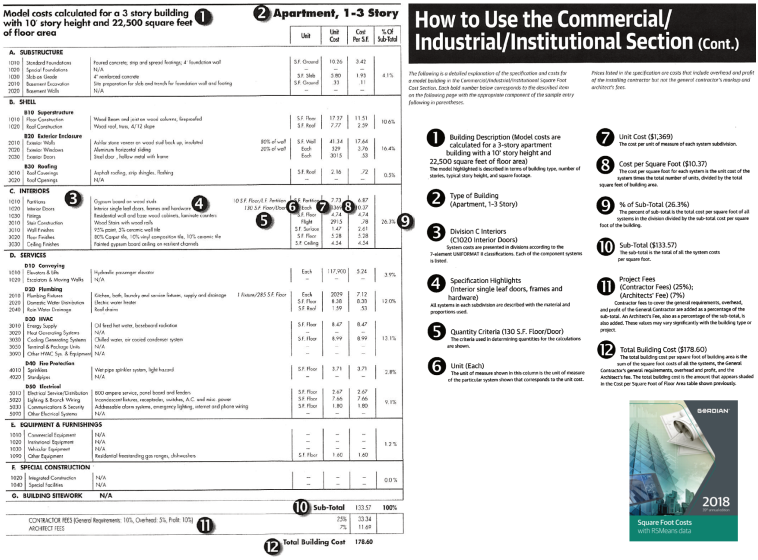
6 Building Perimeter and Story Height Adjustments
Square foot costs for a building with a perimeter or floor-to-floor story height significantly different from the model used to calculate the base cost may be adjusted (add or deduct) to reflect the actual building geometry.

7 Cost per Square Foot of Floor Area for the Perimeter and/or Height Adjustment ($5.55 for Perimeter Difference and $1.55 for Story Height Difference)
Add (or deduct) $5.55 to the base square foot cost for each 100 feet of perimeter difference between the model and the actual building. Add (or deduct) $1.55 to the base square foot cost for each 1 foot of story height difference between the model and the actual building.

8 Optional Cost per Square Foot of Basement Floor Area ($38.70)
The cost of an unfinished basement for the building being estimated is $38.70 times the gross floor area of the basement.

9 Common Additives
Common components and/or systems used in this type of building are listed. These costs should be added to the total building cost. Additional selections may be found in the Assemblies Section.

Figure 7-1: Introduction of the Modeled Square Foot Estimating Approach (Source: Gardian Square Foot Costs with RS Means Data 2018)



Model costs calculated for a 3 story building with 10' story height and 22,500 square feet of floor area ❶

❷ Apartment, 1-3 Story

				Unit	Unit Cost	Cost Per S.F.	% Of Sub-Total
A. SUBSTRUCTURE							
1010	Standard Foundations	Poured concrete; strip and spread footings; 4' foundation wall		S.F. Ground	10.26	3.42	
1020	Special Foundations	N/A		–	–	–	
1030	Slab on Grade	4" reinforced concrete		S.F. Slab	5.80	1.93	4.1%
2010	Basement Excavation	Site preparation for slab and trench for foundation wall and footing		S.F. Ground	.33	.11	
2020	Basement Walls	N/A		–	–	–	
B. SHELL							
	B10 Superstructure						
1010	Floor Construction	Wood Beam and joist on wood columns, fireproofed		S.F. Floor	17.27	11.51	10.6%
1020	Roof Construction	Wood roof, truss, 4/12 slope		S.F. Roof	7.77	2.59	
	B20 Exterior Enclosure						
2010	Exterior Walls	Ashlar stone veneer on wood stud back up, insulated	80% of wall	S.F. Wall	41.34	17.64	
2020	Exterior Windows	Aluminum horizontal sliding	20% of wall	Each	529	3.76	16.4%
2030	Exterior Doors	Steel door , hollow metal with frame		Each	3015	.53	
	B30 Roofing						
3010	Roof Coverings	Asphalt roofing, strip shingles, flashing		S.F. Roof	2.16	.72	0.5%
3020	Roof Openings	N/A		–	–	–	
C. INTERIORS ❸							
1010	Partitions	Gypsum board on wood studs	10 S.F. Floor/L.F. Partition	S.F. Partition	7.73	6.87	
1020	Interior Doors	Interior single leaf doors, frames and hardware ❹	130 S.F. Floor/Door ❺	❻ Each	❼ 1369	❽ 10.37	
1030	Fittings	Residential wall and base wood cabinets, laminate counters		S.F. Floor	4.74	4.74	
2010	Stair Construction	Wood Stairs with wood rails		Flight	2915	.78	26.3% ❾
3010	Wall Finishes	95% paint, 5% ceramic wall tile		S.F. Surface	1.47	2.61	
3020	Floor Finishes	80% Carpet tile, 10% vinyl composition tile, 10% ceramic tile		S.F. Floor	5.28	5.28	
3030	Ceiling Finishes	Painted gypsum board ceiling on resilient channels		S.F. Ceiling	4.54	4.54	
D. SERVICES							
	D10 Conveying						
1010	Elevators & Lifts	Hydraulic passenger elevator		Each	117,900	5.24	3.9%
1020	Escalators & Moving Walks	N/A		–	–	–	
	D20 Plumbing						
2010	Plumbing Fixtures	Kitchen, bath, laundry and service fixtures, supply and drainage	1 Fixture/285 S.F. Floor	Each	2029	7.12	
2020	Domestic Water Distribution	Electric water heater		S.F. Floor	8.38	8.38	12.0%
2040	Rain Water Drainage	Roof drains		S.F. Roof	1.59	.53	
	D30 HVAC						
3010	Energy Supply	Oil fired hot water, baseboard radiation		S.F. Floor	8.47	8.47	
3020	Heat Generating Systems	N/A		–	–	–	
3030	Cooling Generating Systems	Chilled water, air cooled condenser system		S.F. Floor	8.99	8.99	13.1%
3050	Terminal & Package Units	N/A		–	–	–	
3090	Other HVAC Sys. & Equipment	N/A		–	–	–	
	D40 Fire Protection						
4010	Sprinklers	Wet pipe spinkler system, light hazard		S.F. Floor	3.71	3.71	2.8%
4020	Standpipes	N/A		–	–	–	
	D50 Electrical						
5010	Electrical Service/Distribution	800 ampere service, panel board and feeders		S.F. Floor	2.67	2.67	
5020	Lighting & Branch Wiring	Incandescent fixtures, receptacles, switches, A.C. and misc. power		S.F. Floor	7.66	7.66	9.1%
5030	Communications & Security	Addressable alarm systems, emergency lighting, internet and phone wiring		S.F. Floor	1.80	1.80	
5090	Other Electrical Systems	N/A		–	–	–	
E. EQUIPMENT & FURNISHINGS							
1010	Commercial Equipment	N/A		–	–	–	
1020	Institutional Equipment	N/A		–	–	–	1.2%
1030	Vehicular Equipment	N/A		–	–	–	
1090	Other Equipment	Residential freestanding gas ranges, dishwashers		S.F. Floor	1.60	1.60	
F. SPECIAL CONSTRUCTION							
1020	Integrated Construction	N/A		–	–	–	0.0%
1040	Special Facilities	N/A		–	–	–	
G. BUILDING SITEWORK		N/A					
				❿ **Sub-Total**		133.57	**100%**
	CONTRACTOR FEES (General Requirements: 10%, Overhead: 5%, Profit: 10%) ⓫				25%	33.34	
	ARCHITECT FEES				7%	11.69	
				⓬ **Total Building Cost**		**178.60**	

How to Use the Commercial/ Industrial/Institutional Section (Cont.)

The following is a detailed explanation of the specification and costs for a model building in the Commercial/Industrial/Institutional Square Foot Cost Section. Each bold number below corresponds to the described item on the following page with the appropriate component of the sample entry following in parentheses.

Prices listed in the specification are costs that include overhead and profit of the installing contractor but not the general contractor's markup and architect's fees.

❶ Building Description (Model costs are calculated for a 3-story apartment building with a 10' story height and 22,500 square feet of floor area)
The model highlighted is described in terms of building type, number of stories, typical story height, and square footage.

❷ Type of Building (Apartment, 1-3 Story)

❸ Division C Interiors (C1020 Interior Doors)
System costs are presented in divisions according to the 7-element UNIFORMAT II classifications. Each of the component systems is listed.

❹ Specification Highlights (Interior single leaf doors, frames and hardware)
All systems in each subdivision are described with the material and proportions used.

❺ Quantity Criteria (130 S.F. Floor/Door)
The criteria used in determining quantities for the calculations are shown.

❻ Unit (Each)
The unit of measure shown in this column is the unit of measure of the particular system shown that corresponds to the unit cost.

❼ Unit Cost ($1,369)
The cost per unit of measure of each system subdivision.

❽ Cost per Square Foot ($10.37)
The cost per square foot for each system is the unit cost of the system times the total number of units, divided by the total square feet of building area.

❾ % of Sub-Total (26.3%)
The percent of sub-total is the total cost per square foot of all systems in the division divided by the sub-total cost per square foot of the building.

❿ Sub-Total ($133.57)
The sub-total is the total of all the system costs per square foot.

⓫ Project Fees (Contractor Fees) (25%); (Architects' Fee) (7%)
Contractor fees to cover the general requirements, overhead, and profit of the General Contractor are added as a percentage of the sub-total. An Architect's Fee, also as a percentage of the sub-total, is also added. These values may vary significantly with the building type or project.

⓬ Total Building Cost ($178.60)
The total building cost per square foot of building area is the sum of the square foot costs of all the systems, the General Contractor's general requirements, overhead and profit, and the Architect's fee. The total building cost is the amount that appears shaded in the Cost per Square Foot of Floor Area table shown previously.

Figure 7-2: Continuation of Introduction of the Modeled Square Foot Estimating Approach (Page 2 of each building) (Source: Gardian Square Foot Costs with RS Means Data 2018)

A square foot estimate can be performed at the early stages of a project, for example, during schematic design. To perform the estimate, you will need to have as a minimum an approximate footprint for the building, an understanding of the type of structural system, a proposed facade type, and an estimated floor to floor height. If you do not know any of these items, you could still develop an estimate using various assumptions.

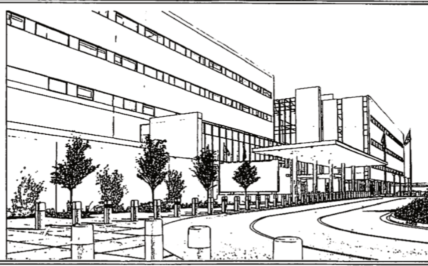
The Modeled SF Estimating approach is very different from the ROM Estimating approach described in the previous chapter. The Modeled SF Estimating approach is taking more detailed building assemblies, e.g., structural system elements, mechanical system elements, etc., and building a 'model' estimate for a fictitious building that would be similar to the facility type. RS Means leverages average assembly components when designing these model buildings, but the estimating sheets are not based upon an actual building. In this way, they can build many modeled buildings making various assumptions in overall facility size and the quantity of perimeter. The perimeter length is particularly important in this form of estimating since larger amounts of perimeter per gross square footage of the building will cause the building to be more expensive since the facade is an expensive element within a building. This method can also account for variations in floor height since increasing floor height will increase overall building cost due to extra vertical elements (e.g., plumbing, structure, elevator, etc.) along with larger amounts of the facade.

In contrast, the Rough Order of Magnitude (ROM) method presented in the previous chapter is based upon Reported Square Foot costs from a data set of many previous building projects. The Reported Square Foot method that we used for the ROM estimates simply uses average building costs across the dataset. The average costs are not calculated from any detailed characteristics or system types within the building. Therefore, the Modeled SF Estimating approach can be much more accurate than the previous ROM approach.

Figures 7-3 and 7-4 include a sample of the two pages for one of the building types. In particular, these pages provide a description of a 4-8 Story Hosptial. You will notice that the building type has a reference number, which is M.340. These reference numbers help RS Means keep track of the data that they compile, and also allow users to refer back to the assumed data. You will notice that almost all elements of data reported in the Gardian guides (based upon RS Means data) have some form of the reference number, whether it is a building, a system within a building, a component, or a construction crew type.

Figure 7-3 is highlighting, in the Blue box, the base unit cost for a typical 4-8 story hospital that is 200,000 square feet (SF). Note that the base building cost is initially pulled from the data table from the overall square footage of the entire building. You do not want to select the base cost from the linear feet of the perimeter, but instead, modify for the perimeter of the building after you have identified the base building cost from the square foot area. The table includes various exterior wall types, and some buildings also include alternative structural systems. In our example, if the hospital is 200,000 sf and has a fiber cement facade, then the projected cost for the building will be $273.80 per square foot. This number would then need to be modified for the linear feet of the perimeter with an average linear feet of perimeter in our example being 866 LF (see the second number in the Blue column). The cost would also need to be modified for story height, location, time and other quality / scope related items. If there is a basement in the facility, there is a different number provided within the Gardian guides, which is highlighted in the yellow box. A step by step procedure for developing a SF cost estimate is included in the next section.

COMMERCIAL/INDUSTRIAL/ INSTITUTIONAL | **M.340** | **Hospital, 4-8 Story**



Costs per square foot of floor area

Exterior Wall	S.F. Area	100000	125000	150000	175000	200000	225000	250000	275000	300000
	L.F. Perimeter	594	705	816	783	866	950	1033	1116	1200
Fiber Cement	Rigid Steel	282.50	280.25	278.65	274.75	273.80	273.10	272.55	272.00	271.60
Curtain Wall	Rigid Steel	301.60	298.50	296.40	289.95	288.55	287.55	286.75	286.00	285.50
Metal Panel	Rigid Steel	286.10	283.80	282.20	278.25	277.25	276.50	275.95	275.45	275.05
Brick Veneer	Reinforced Concrete	302.50	299.55	297.50	291.40	290.10	289.10	288.30	287.65	287.15
Stone Veneer	Reinforced Concrete	314.50	310.95	308.50	300.45	298.85	297.70	296.70	295.85	295.25
E.I.F.S.	Reinforced Concrete	295.45	292.80	291.05	286.05	285.00	284.10	283.40	282.85	282.40
Perimeter Adj., Add or Deduct	Per 100 L.F.	3.25	2.60	2.20	1.90	1.60	1.50	1.25	1.20	1.05
Story Hgt. Adj., Add or Deduct	Per 1 Ft.	1.10	1.05	1.05	0.90	0.85	0.85	0.75	0.80	0.75

For Basement, add $39.80 per square foot of basement area

The above costs were calculated using the basic specifications shown on the facing page. These costs should be adjusted where necessary for design alternatives and owner's requirements.

Figure 7-3: Sample Hospital Project Square Foot Estimate (Modified from Gardian Square Foot Costs with RS Means Data 2018)

Model costs calculated for a 6 story building with 12′ story height and 200,000 square feet of floor area

Hospital, 4-8 Story

				Unit	Unit Cost	Cost Per S.F.	% Of Sub-Total
A. SUBSTRUCTURE							
1010	Standard Foundations	Poured concrete; strip and spread footings; 4′ foundation wall		S.F. Ground	4.92	.82	1.7%
1020	Special Foundations	N/A		–	–	–	
1030	Slab on Grade	4″ reinforced slab on grade		S.F. Slab	14.85	2.48	
2010	Basement Excavation	Site preparation for slab and trench for foundation wall and footing		S.F. Ground	.18	.03	
2020	Basement Walls	N/A		–	–	–	
B. SHELL							
	B10 Superstructure						
1010	Floor Construction	Open web steel joists, slab form, concrete, fireproofed steel columns		S.F. Floor	15.16	12.63	7.2%
1020	Roof Construction	Metal deck on open web steel joints, columns		S.F. Roof	10.98	1.83	
	B20 Exterior Enclosure						
2010	Exterior Walls	Fiber cement siding on metal studs, insulated	*70% of wall*	S.F. Wall	19.25	4.20	3.8%
2020	Exterior Windows	Aluminum sliding windows	*30% of wall*	Each	589	2.45	
2030	Exterior Doors	Aluminum and glass double doors, hollow metal egress doors		Each	7340	1.02	
	B30 Roofing						
3010	Roof Coverings	Single ply membrane, stone ballast		S.F. Roof	7.02	1.17	0.6%
3020	Roof Openings	Roof hatches		S.F. Roof	.24	.04	
C. INTERIORS							
1010	Partitions	Concrete block partitions, gypsum board on metal studs	*10 S.F. Floor/L.F. Partition*	S.F. Partition	7.08	7.87	21.5%
1020	Interior Doors	Single leaf hollow metal doors, fire doors	*90 S.F. Floor/Door*	Each	1268	9.39	
1030	Fittings	Hospital curtains		S.F. Floor	1.32	1.32	
2010	Stair Construction	Concrete filled metal pan		Flight	12,600	1.63	
3010	Wall Finishes	65% Paint, 35 % ceramic wall tile		S.F. Surface	3.42	7.59	
3020	Floor Finishes	60% vinyl tile, 20% ceramic , 20% terrazzo		S.F. Floor	9.20	9.20	
3030	Ceiling Finishes	Acoustic ceiling tiles on suspended channel grid		S.F. Ceiling	6.30	6.30	
D. SERVICES							
	D10 Conveying						
1010	Elevators & Lifts	Six traction geared hospital elevators		Each	235,000	7.05	3.5%
1020	Escalators & Moving Walks	N/A		–	–	–	
	D20 Plumbing						
2010	Plumbing Fixtures	Medical, patient & specialty, supply and drainage	*1 Fixture/415 S.F. Floor*	Each	3149	7.57	9.9%
2020	Domestic Water Distribution	Electric water heater		S.F. Floor	11.60	11.60	
2040	Rain Water Drainage	Roof drains		S.F. Roof	4.56	.76	
	D30 HVAC						
3010	Energy Supply	Conditioned air with hot water reheat system		S.F. Floor	4.48	4.48	24.2%
3020	Heat Generating Systems	Steam boiler for services		Each	43,750	.55	
3030	Cooling Generating Systems	Chillers		S.F. Floor	3.19	3.19	
3050	Terminal & Package Units	N/A		–	–	–	
3090	Other HVAC Sys. & Equipment	Hot water boilers, ductwork, VAV terminals, ventilation system		S.F. Floor	40.40	40.40	
	D40 Fire Protection						
4010	Sprinklers	Wet pipe spinkler system		S.F. Floor	3.02	3.02	1.8%
4020	Standpipes	Standpipe		S.F. Floor	.57	.57	
	D50 Electrical						
5010	Electrical Service/Distribution	2000 ampere service, panel board and feeders		S.F. Floor	2.25	2.25	13.3%
5020	Lighting & Branch Wiring	Fluorescent fixtures, receptacles, switches, A.C. and misc. power		S.F. Floor	20.87	20.87	
5030	Communications & Security	Addressable alarms, emergency lighting, internet and phone wiring		S.F. Floor	2.54	2.54	
5090	Other Electrical Systems	Emergency generator, 400 Kw with fuel tank, UPS system		S.F. Floor	.97	.97	
E. EQUIPMENT & FURNISHINGS							
1010	Commercial Equipment	N/A		–	–	–	12.5 %
1020	Institutional Equipment	Laboratory and kitchen equipment		S.F. Floor	21.76	21.76	
1030	Vehicular Equipment	N/A		–	–	–	
2020	Moveable Furnishings	Patient wall systems		S.F. Floor	3.41	3.41	
F. SPECIAL CONSTRUCTION							
1020	Integrated Construction	N/A		–	–	–	0.0 %
1040	Special Facilities	N/A		–	–	–	
G. BUILDING SITEWORK		**N/A**					
					Sub-Total	200.96	100%
	CONTRACTOR FEES (General Requirements: 10%, Overhead: 5%, Profit: 10%)				25%	50.23	
	ARCHITECT FEES				9%	22.61	
					Total Building Cost	273.80	

Figure 7-4: Example Hospital Square Foot Cost – Page 2 (Modified from Gardian Square Foot Costs with RS Means Data 2018)

It is important to note that the Modeled SF Estimating approach includes the cost of all of the assemblies used in the building (see Figure 7-4 which shows the assemblies for the one highlighted model building), and it also includes the overall contractor fees and architects fees. These are included on the bottom of the 2nd page (see Figure 7-4). You can also modify your estimate with common additions that are listed on the first page of each of the modeled facilities (see area '9' of Figure 7-1). These common additions ae included for each facility type.

Steps to Develop a Modeled Square Foot Estimate:

1. Find the Correct (or closest) Model in the Square Foot Estimating Manual

The Gardian Square Foot Estimating Manual contains many different types of buildings, but certainly not all types of buildings. In particular, if you have an unusual building type, or a mixed-use facility (e.g., 3 stories of parking, 2 stories of retail, 5 stories of office and 5 stories of hotel), then you will not be able to find an exact match for your building type. Therefore, you may need to leverage several different model types, and then average, or weighted average, the building types in order to approximate either a cost per square foot for the entire building, or a cost per square foot for the sections of the building.

2. Perform Quantity Takeoffs

To complete a SF estimate, you will need to calculate the SF per floor for the buildings, along with calculating the linear foot of perimeter for a typical floor. In addition, you will need to calculate the overall SF of the building, by adding up the SF for each floor. If there are duplicate floor layouts, this can be easily performed by multiplying the floor area by the number of floors in the building. Additionally, you will need to know the overall average estimated floor to floor height.

3. Identify the Cost per Square Foot for the building

By using the main table within the estimating manual (see Figure 7-3 for example), identify the cost per SF of the building based upon the total building SF (top row) and the structural system/facade type (left column). Make sure that you use the total SF to identify the unit cost. You will use the LF of Perimeter in a later step. If the exact SF is not identified as a column in the table, you can interpolate between the lower and higher SF cost columns to calculate the overall cost per SF.

4. Adjust the Cost per SF to consider

LF of Perimeter Wall and Story Height

After identifying a base cost per square foot, you can modify the cost per square foot to account for higher or lower overall amounts of the perimeter wall and the cost of additional (or reduced) floor height. To adjust for the perimeter wall, you will first identify the estimated quantity of LF given the column that you used for your SF of building. In the example in Figure 7-3, if you have a building of 200,000 SF, you would expect 866 LF of perimeter wall. If the actual LF is higher than 866, then the building will cost more per SF due to the additional cost of the facade. Therefore, you can calculate the additional cost by looking at the adjustment factor in the next to the bottom row in the table. For our example, this shows that there is an additional $1.60 per SF for every additional 100 LF of perimeter. By using this ratio, you can easily calculate the adjustment factor.

You will also need to adjust the cost per base SF by the overall story height. If you look on Page 2 for any model, you will find the typical floor to floor (or Story) height. In Figure 7-4, you can see this typical story height for our example of 12′. By referencing the adjustment factor in the bottom row of the table, you will see that each additional 1′ of story height will add (or reduce) $0.85 per SF of building area.

5. Calculate the Total Base Cost

After modifying the cost per SF for the perimeter and story height, then the total base cost can be estmated by multiplying the cost per SF by the total SF for the building.

6. Calculate the Additional Basement Cost

The cost per SF of basement area is identified in the estimating table, at the bottom of the table (see the yellow box in Figure 7-3. To calculate the basement cost, multiply the cost per SF of basement area by the takeoff quantity for the basement. This value can then be added to the Total Base Cost.

7. Identify any Common Additions

On the first page for each model, there is a list of potential common additions (see section 9 on Figure 7-1 for example). These common additions can include items such as furnishings/appliances, elevators, etc. These additional items would be added to the total cost after calculating the estimated total cost.

8. Modify for Time and Location

You will need to modify the overall cost for both time and location, similar to the previous methods. See the previous chapters for additional details. Just a reminder that the overall Building Cost Index (BCI) or Construction Cost Index (CCI) for an estimating manual is taken as the January BCI or CCI for the year on the cover of the manual.

9. Add Additional Items

Based upon the purpose of the estimate, you may add other items to the estimated value. These could include an overall contingency for unforeseen items, land costs if purchasing the land, excavation and sitework costs, permitting fees, and financing costs for construction loans. It is important to note that the fees for the contractor and the fees for the design are incorporated into the SF estimating approach (see the blue box in Figure 7-4). It may also be beneficial to present the number as a range (e.g., $2,000,000 +/- 15%) and it is also helpful to round the final number, at least to the closest $1,000 depending upon the value and audience. It can be confusing if the number looks too precise when it remains an approximate amount for the project.

Review Questions

1. A Modeled Square Foot Estimate is typically more accurate than the Reported Square Foot cost approach used for ROM estimates. (True / False)
2. The Modeled Square Foot Estimating approach can account for different facade and structural systems types. (True / False)
3. After calculating the modeled square foot cost estimate from the modified SF cost and project area using the Gardian Square Foot Cost Guide, the total value will need to be modified to account for the project location and the timing of construction. (True / False)
4. The Modeled Square Foot Cost estimates from the Gardian manual includes the designer fees. (True / False)

Review Question Answers

8.

CHAPTER 8: ASSEMBLIES COST ESTIMATING

Learning Objectives

After reading this chapter, you should be able to:

- Describe the benefits and limitations of the assemblies estimating approach
- Develop an assemblies estimate for a building project
- Calculate the approximate cost differentials for selecting various system options for a project

Introduction

Once a project design progresses to a level where systems are defined, the team can continue with estimates that leverage the system information.

Assemblies estimates for commercial building projects are typically organized by CSI Uniformat 2 categories (see Figure 8-5).

Please reference the course slides to see additional details regarding the Assemblies' estimating approach.

1 Unique 12-character Identifier

Our assemblies are identified by a **unique 12-character identifier**. The assemblies are numbered using UNIFORMAT II, ASTM Standard E1557. The first 5 characters represent this system to Level 3. The last 7 characters represent further breakdown in order to arrange items in understandable groups of similar tasks. Line numbers are consistent across all of our publications, so a line number in any assemblies data set will always refer to the same item.

2 Reference Box

Information is available in the Reference Section to assist the estimator with estimating procedures, alternate pricing methods, and additional technical information.

The **Reference Box** indicates the exact location of this information in the Reference Section. The "R" stands for "reference," and the remaining characters are the line numbers.

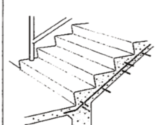
3 Narrative Descriptions

Our assemblies descriptions appear in two formats: narrative and table. **Narrative descriptions** are shown in a hierarchical structure to make them readable. In order to read a complete description, read up through the indents to the top of the section. Include everything that is above and to the left that is not contradicted by information below.

Narrative Format

C20 Stairs

C2010 Stair Construction



General Design: See reference section for code requirements. Maximum height between landings is 12'; usual stair angle is 20° to 50° with 30° to 35° best. Usual relation of riser to treads is:
Riser + tread = 17.5.
2x (Riser) + tread = 25.
Riser x tread = 70 or 75.
Maximum riser height is 7" for commercial, 8-1/4" for residential.
Usual riser height is 6-1/2" to 7-1/4".

Minimum tread width is 11" for commercial and 9" for residential.

For additional information please see reference section.

Cost Per Flight: Table below lists the cost per flight for 4'-0" wide stairs.
Side walls are not included.
Railings are included.

System Components	QUANTITY	UNIT	COST PER FLIGHT MAT.	COST PER FLIGHT INST.	COST PER FLIGHT TOTAL
SYSTEM C2010 110 0560 (1)					
STAIRS, C.I.P. CONCRETE WITH LANDING, 12 RISERS					
Concrete in place, free standing stairs not incl. safety treads	48.000	L.F.	319.20	2,104.32	2,423.52
Concrete in place, free standing stair landing	32.000	S.F.	169.60	578.88	748.48
Cast alum nosing insert, abr surface, pre-drilled, 3" wide x 4' long	12.000	Ea.	918	218.40	1,136.40
Industrial railing, welded, 2 rail 3'-6" high 1-1/2" pipe	18.000	L.F.	819	210.96	1,029.96
Wall railing with returns, steel pipe	17.000	L.F.	334.90	199.24	534.14
TOTAL			2,560.70	3,311.80	5,872.50

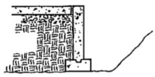
C2010 110	Stairs	COST PER FLIGHT MAT.	COST PER FLIGHT INST.	COST PER FLIGHT TOTAL
0470	Stairs, C.I.P. concrete, w/o landing, 12 risers, w/o nosing (2) RC2010 -100	1,475	2,500	3,975
0480	With nosing	2,400	2,725	5,125
0550	W/landing, 12 risers, w/o nosing	1,650	3,075	4,725
0560	With nosing	2,550	3,300	5,850
0570	16 risers, w/o nosing	2,000	3,900	5,900
0580	With nosing	3,225	4,175	7,400
0590	20 risers, w/o nosing	2,375	4,675	7,050
0600	With nosing (3)	3,900	5,050	8,950
0610	24 risers, w/o nosing	2,750	5,475	8,225
0620	With nosing	4,575	5,900	10,475
0630	Steel, grate type w/nosing & rails, 12 risers, w/o landing	5,575	1,200	6,775
0640	With landing	7,825	1,625	9,450
0660	16 risers, with landing	9,675	2,050	11,725
0680	20 risers, with landing	11,500	2,450	13,950
0700	24 risers, with landing	13,400	2,825	16,225
0710	Metal pan stairs for concrete in-fill, picket rail, 12 risers, w/o landing	8,225	1,200	9,425
0720	With landing	10,800	1,800	12,600
0740	16 risers, with landing	13,600	2,200	15,800
0760	20 risers, with landing	16,300	2,600	18,900
0780	24 risers, with landing	19,100	2,975	22,075
0790	Cast iron tread & pipe rail, 12 risers, w/o landing	8,275	1,200	9,475
0800	With landing	10,900	1,800	12,700
0820	16 risers, with landing	13,700	2,200	15,900
0840	20 risers, with landing	16,400	2,600	19,000

For supplemental customizable square foot estimating forms, visit: **www.RSMeans.com/2018books**

Table Format

A10 Foundations

A1010 Standard Foundations



The Foundation Bearing Wall System includes: forms up to 6' high (four uses); 3,000 p.s.i. concrete placed and vibrated; and form removal with breaking form ties and patching walls. The wall systems list walls from 6" to 16" thick and are designed with minimum reinforcement.

Excavation and backfill are not included.

Please see the reference section for further design and cost information.

❹

System Components ❺	QUANTITY	UNIT	COST PER L.F. MAT.	INST.	TOTAL
SYSTEM A1010 105 1500					
FOUNDATION WALL, CAST IN PLACE, DIRECT CHUTE, 4' HIGH, 6" THICK					
Formwork	8.000	SFCA	6.40	48	54.40
Reinforcing	3.300	Lb.	1.73	1.47	3.20
Unloading & sorting reinforcing	3.300	Lb.		.09	.09
Concrete, 3,000 psi	.074	C.Y.	9.84		9.84
Place concrete, direct chute	.074	C.Y.		2.53	2.53
Finish walls, break ties and patch voids, one side	4.000	S.F.	.20	4.16	4.36
TOTAL			18.17	56.25	74.42

A1010 105 — Wall Foundations

	WALL HEIGHT (FT.)	PLACING METHOD	CONCRETE (C.Y. per L.F.)	REINFORCING (LBS. per L.F.)	WALL THICKNESS (IN.)	COST PER L.F. MAT.	INST.	TOTAL
1500	4'	direct chute	.074	3.3	6	18.15	56	74.15
1520	❻		.099	4.8	8	22.50	57.50	80
1540			.123	6.0	10	26	58.50	84.50
1560	RA2020 -210		.148	7.2	12	30	60	90
1580			.173	8.1	14	34	61	95
1600			.197	9.44	16	38	62	100
1700	4'	pumped	.074	3.3	6	18.15	58	76.15
1720			.099	4.8	8	22.50	59.50	82
1740			.123	6.0	10	26	60.50	86.50
1760			.148	7.2	12	30	62.50	92.50
1780			.173	8.1	14	34	63.50	97.50
1800			.197	9.44	16	38	65	103
3000	6'	direct chute	.111	4.95	6	27.50	84.50	112
3020			.149	7.20	8	33.50	86.50	120
3040			.184	9.00	10	39	88	127
3060			.222	10.8	12	45	90	135
3080			.260	12.15	14	51	91.50	142.50
3100			.300	14.39	16	57.50	93.50	151
3200	6'	pumped	.111	4.95	6	27.50	86	113.50
3220			.149	7.20	8	33.50	89.50	123
3240			.184	9.00	10	39	91.50	130.50
3260			.222	10.8	12	45	93.50	138.50
3280			.260	12.15	14	51	95.50	146.50
3300			.300	14.39	16	57.50	98	155.50

❹ Unit of Measure

All RSMeans data: Assemblies include a typical **Unit of Measure** used for estimating that item. For instance, for continuous footings or foundation walls the unit is linear feet (L.F.). For spread footings the unit is each (Ea.). The estimator needs to take special care that the unit in the data matches the unit in the takeoff. Abbreviations and unit conversions can be found in the Reference Section.

❺ System Components

System components are listed separately to detail what is included in the development of the total system price.

❻ Table Descriptions

Table descriptions work similar to Narrative Descriptions, except that if there is a blank in the column at a particular line number, read up to the description above in the same column.

RSMeans data: Assemblies— How They Work (Continued)

Sample Estimate

This sample demonstrates the elements of an estimate, including a tally of the RSMeans data lines. Published assemblies costs include all markups for labor burden and profit for the installing contractor. This estimate adds a summary of the markups applied by a general contractor on the installing contractor's work. These figures represent the total cost to the owner. The location factor with RSMeans data is applied at the bottom of the estimate to adjust the cost of the work to a specific location.

Project Name:	**Interior Fit-out, ABC Office**			
Location:	**Anywhere, USA**	**Date: 1/1/2018**		**STD**
Assembly Number	**Description**	**Qty.**	**Unit**	**Subtotal**
❶ C1010 124 1200	Wood partition, 2 x 4 @ 16" OC w/5/8" FR gypsum board	560.000	S.F.	$2,856.00
C1020 114 1800	Metal door & frame, flush hollow core, 3'-0" x 7'-0"	2.000	Ea.	$2,510.00
C3010 230 0080	Painting, brushwork, primer & 2 coats	1,120.000	S.F.	$1,422.40
C3020 410 0140	Carpet, tufted, nylon, roll goods, 12' wide, 26 oz	240.000	S.F.	$842.40
C3030 210 6000	Acoustic ceilings, 24" x 48" tile, tee grid suspension	200.000	S.F.	$1,260.00
D5020 125 0560	Receptacles incl plate, box, conduit, wire, 20 A duplex	8.000	Ea.	$2,320.00
D5020 125 0720	Light switch incl plate, box, conduit, wire, 20 A single pole	2.000	Ea.	$566.00
D5020 210 0560	Fluorescent fixtures, recess mounted, 20 per 1000 SF	200.000	S.F.	$2,226.00
	Assembly Subtotal			**$14,002.80**
	Sales Tax @ ❷	**5 %**		**$ 350.07**
	General Requirements @ ❸	**7 %**		**$ 980.20**
	Subtotal A			**$15,333.07**
	GC Overhead @ ❹	**5 %**		**$ 766.65**
	Subtotal B			**$16,099.72**
	GC Profit @ ❺	**5 %**		**$ 804.99**
	Subtotal C			**$16,904.71**
	Adjusted by Location Factor ❻	**115.2**		**$ 19,474.22**
	Architects Fee @ ❼	**8 %**		**$ 1,557.94**
	Contingency @ ❽	**15 %**		**$ 2,921.13**
	Project Total Cost			**$ 23,953.29**

This estimate is based on an interactive spreadsheet. You are free to download and adjust it to your methodology. A copy of this spreadsheet is available at **www.RSMeans.com/2018books.**

❶ **Work Performed**
The body of the estimate shows the RSMeans data selected, including line numbers, a brief description of each item, its takeoff quantity and unit, and the total installed cost, including the installing contractor's overhead and profit.

❷ **Sales Tax**
If the work is subject to state or local sales taxes, the amount must be added to the estimate. In a conceptual estimate it can be assumed that one half of the total represents material costs. Therefore, apply the sales tax rate to 50% of the assembly subtotal.

❸ **General Requirements**
This item covers project-wide needs provided by the general contractor. These items vary by project but may include temporary facilities and utilities, security, testing, project cleanup, etc. In assemblies estimates a percentage is used—typically between 5% and 15% of project cost.

❹ **General Contractor Overhead**
This entry represents the general contractor's markup on all work to cover project administration costs.

❺ **General Contractor Profit**
This entry represents the GC's profit on all work performed. The value included here can vary widely by project and is influenced by the GC's perception of the project's financial risk and market conditions.

❻ **Location Factor**
RSMeans published data are based on national average costs. If necessary, adjust the total cost of the project using a location factor from the "Location Factor" table or the "City Cost Indexes" table found in the Reference Section. Use location factors if the work is general, covering the work of multiple trades. If the work is by a single trade (e.g., masonry) use the more specific data found in the City Cost Indexes.

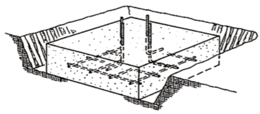
To adjust costs by location factors, multiply the base cost by the factor and divide by 100.

❼ **Architect's Fee**
If appropriate, add the design cost to the project estimate. These fees vary based on project complexity and size. Typical design and engineering fees can be found in the Reference Section.

❽ **Contingency**
A factor for contingency may be added to any estimate to represent the cost of unknowns that may occur between the time that the estimate is performed and the time the project is constructed. The amount of the allowance will depend on the stage of design at which the estimate is done, and the contractor's assessment of the risk involved.

A10 Foundations

A1010 Standard Foundations



The Spread Footing System includes: excavation; backfill; forms (four uses); all reinforcement; 3,000 p.s.i. concrete (chute placed); and float finish.

Footing systems are priced per individual unit. The Expanded System Listing at the bottom shows various footing sizes. It is assumed that excavation is done by a truck mounted hydraulic excavator with an operator and oiler.

Backfill is with a dozer, and compaction by air tamp. The excavation and backfill equipment is assumed to operate at 30 C.Y. per hour.

Please see the reference section for further design and cost information.

System Components	QUANTITY	UNIT	COST EACH MAT.	COST EACH INST.	COST EACH TOTAL
SYSTEM A1010 210 7100					
SPREAD FOOTINGS, LOAD 25K, SOIL CAPACITY 3 KSF, 3' SQ X 12" DEEP					
Bulk excavation	.590	C.Y.		5.21	5.21
Hand trim	9.000	S.F.		9.18	9.18
Compacted backfill	.260	C.Y.		1.02	1.02
Formwork, 4 uses	12.000	S.F.	9	67.80	76.80
Reinforcing, fy = 60,000 psi	.006	Ton	6.30	7.65	13.95
Dowel or anchor bolt templates	6.000	L.F.	6.12	28.08	34.20
Concrete, f'c = 3,000 psi	.330	C.Y.	43.89		43.89
Place concrete, direct chute	.330	C.Y.		8.41	8.41
Float finish	9.000	S.F.		3.60	3.60
TOTAL			65.31	130.95	196.26

A1010 210	Spread Footings		COST EACH MAT.	COST EACH INST.	COST EACH TOTAL
7090	Spread footings, 3000 psi concrete, chute delivered				
7100	Load 25K, soil capacity 3 KSF, 3'-0" sq. x 12" deep		65.50	130	195.50
7150	Load 50K, soil capacity 3 KSF, 4'-0" sq. x 12" deep		140	224	364
7200	Load 50K, soil capacity 6 KSF, 3'-0" sq. x 12" deep	RA1010 -120	65.50	130	195.50
7250	Load 75K, soil capacity 3 KSF, 5'-6" sq. x 13" deep		223	315	538
7300	Load 75K, soil capacity 6 KSF, 4'-0" sq. x 12" deep		113	193	306
7350	Load 100K, soil capacity 3 KSF, 6'-0" sq. x 14" deep		283	375	658

Uniformat level 1 categories [edit source]

- A SUBSTRUCTURE
- B SHELL
- C INTERIORS
- D SERVICES
- E EQUIPMENT AND FURNISHINGS
- F SPECIAL CONSTRUCTION AND DEMOLITION
- G BUILDING SITEWORK

Uniformat levels 2 and 3 categories [edit source]

An example of how the numbering system expands to provide additional detail below level 1 is shown for A SUBSTRUCTURE

```
A10 Foundations
     A1010 Standard Foundations
     A1020 Special Foundations
     A1030 Slab on Grade
A20 Basement Construction
     A2010 Basement Excavation
     A2020 Basement Walls
```

CSI MasterFormat 2016 Version

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP
- Division 00 — Procurement and Contracting Requirements

SPECIFICATIONS GROUP
General Requirements Subgroup
- Division 01 — General Requirements

Facility Construction Subgroup
- Division 02 — Existing Conditions
- Division 03 — Concrete
- Division 04 — Masonry
- Division 05 — Metals
- Division 06 — Wood, Plastics, and Composites
- Division 07 — Thermal and Moisture Protection
- Division 08 — Openings
- Division 09 — Finishes
- Division 10 — Specialties
- Division 11 — Equipment
- Division 12 — Furnishings
- Division 13 — Special Construction
- Division 14 — Conveying Equipment
- Division 15 - 19 — *Reserved for future expansion*

***Facility Services Subgroup*:**
- Division 20 — *Reserved for future expansion*
- Division 21 — Fire Suppression
- Division 22 — Plumbing
- Division 23 — Heating, Ventilating, and Air Conditioning (HVAC)
- Division 24 — *Reserved for future expansion*
- Division 25 — Integrated Automation
- Division 26 — Electrical
- Division 27 — Communications
- Division 28 — Electronic Safety and Security
- Division 29 — *Reserved for future expansion*

***Site and Infrastructure Subgroup*:**
- Division 30 — *Reserved for future expansion*
- Division 31 — Earthwork
- Division 32 — Exterior Improvements
- Division 33 — Utilities
- Division 34 — Transportation
- Division 35 — Waterway and Marine Construction
- Division 36 - 39— *Reserved for future expansion*

***Process Equipment Subgroup*:**
- Division 40 — Process Interconnections
- Division 41 — Material Processing and Handling Equipment
- Division 42 — Process Heating, Cooling, and Drying Equipment
- Division 43 — Process Gas and Liquid Handling, Purification and Storage Equipment
- Division 44 — Pollution and Waste Control Equipment
- Division 45 — Industry-Specific Manufacturing Equipment
- Division 46 — Water and Wastewater Equipment
- Division 47 — *Reserved for future expansion*
- Division 48 — Electrical Power Generation
- Division 49 — *Reserved for future expansion*

Add Figures

Review Questions

1. An assemblies estimate leveraging RS Means data will be organized by CSI Masterformat 2018. (True / False)
2. An assemblies estimate is one of the most appropriate methods to calculate the difference in cost between two systems prior to developing all of the detailed design information for each system. (True / False)

9.

CHAPTER 9: UNIT PRICE COST ESTIMATING

Learning Objectives

After reading this chapter, you should be able to:

- Describe the benefits and limitations of the unit cost estimating approach
- Develop a unit cost estimate for a portion of a building project
- Identify the detailed cost components within a unit price estimate, and how these cost elements are calculated

As the detailed information is developed within the construction documents phase of a project, the project team can develop detailed cost estimates using the Unit Price estimating approach. The Unit Price estimating approach is focused on identifying a cost for the materials, equipment, and labor for each of the components within a building. This requires an estimator to perform a detailed takeoff of all scopes of work.

Unit Price estimates for commercial building projects are typically organized by the CSI MaterFormat categories (see Fig. 9-1 for CSI MasterFormat 2016 Version categories). The detailed CSI Materformat breakdown can be found at https://www.edmca.com/media/35207/masterformat-2016.pdf. In this class, we will use the RS Means data for identifying the cost for each of the items within the estimate, but it is important to realize that construction companies will frequently use their own historical cost information for estimating each item. To be successful at using their historical information, they need to make sure that they are accurately tracking their costs on projects, and placing them in a database that can be easily searched and retrieved.

CSI MasterFormat 2016 Version

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP
- Division 00 — Procurement and Contracting Requirements

SPECIFICATIONS GROUP
General Requirements Subgroup
- Division 01 — General Requirements

Facility Construction Subgroup
- Division 02 — Existing Conditions
- Division 03 — Concrete
- Division 04 — Masonry
- Division 05 — Metals
- Division 06 — Wood, Plastics, and Composites
- Division 07 — Thermal and Moisture Protection
- Division 08 — Openings
- Division 09 — Finishes
- Division 10 — Specialties
- Division 11 — Equipment
- Division 12 — Furnishings
- Division 13 — Special Construction
- Division 14 — Conveying Equipment
- Division 15 - 19 — *Reserved for future expansion*

***Facility Services Subgroup*:**
- Division 20 — *Reserved for future expansion*
- Division 21 — Fire Suppression
- Division 22 — Plumbing
- Division 23 — Heating, Ventilating, and Air Conditioning (HVAC)
- Division 24 — *Reserved for future expansion*
- Division 25 — Integrated Automation
- Division 26 — Electrical
- Division 27 — Communications
- Division 28 — Electronic Safety and Security
- Division 29 — *Reserved for future expansion*

***Site and Infrastructure Subgroup*:**
- Division 30 — *Reserved for future expansion*
- Division 31 — Earthwork
- Division 32 — Exterior Improvements
- Division 33 — Utilities
- Division 34 — Transportation
- Division 35 — Waterway and Marine Construction
- Division 36 - 39— *Reserved for future expansion*

***Process Equipment Subgroup*:**
- Division 40 — Process Interconnections
- Division 41 — Material Processing and Handling Equipment
- Division 42 — Process Heating, Cooling, and Drying Equipment
- Division 43 — Process Gas and Liquid Handling, Purification and Storage Equipment
- Division 44 — Pollution and Waste Control Equipment
- Division 45 — Industry-Specific Manufacturing Equipment
- Division 46 — Water and Wastewater Equipment
- Division 47 — *Reserved for future expansion*
- Division 48 — Electrical Power Generation
- Division 49 — *Reserved for future expansion*

Figure 9-1: CSI Masterformat 2

If you do not have your own historical cost database, then the next best approach is to use cost data contained within published cost guides. For our estimating exercises, we will be using the Gordian Construction Cost Estimating Guide with RS Means Data. Examples of the information published in this Guide are shown in Figures 9-2 and 9-3. To develop a cost estimate for an item, you should first identify the unit of measure for the item. Then, a detailed takeoff will be performed to identify the quantity of the item within the project. After performing the takeoff, the item can be estimated. You'll notice that the Guide provides a summary for both 'Bare Costs' and 'Total Including Overhead and Profit'. The bare costs can be used in an estimate where the estimator incorporates a separate, specific overhead estimate and actual projected profits.

After identifying and compiling quantity and cost data for each of the individual items, these items can be combined into the final estimate. An example of compiling the estimate is included in Figures 9-4 and 9-5.

Please reference the course slides to see additional details regarding the Unit Price estimating approach.

RSMeans data: Unit Prices— How They Work

All RSMeans data: Unit Prices are organized in the same way.

03 30 Cast-In-Place Concrete

03 30 53 – Miscellaneous Cast-In-Place Concrete

03 30 53.40 Concrete In Place ❶		❹	Crew ❺	Daily Output ❻	Labor-Hours ❼	Unit ❽	Material	2018 Bare Costs ❾ Labor	Equipment	Total ❿	Total Incl O&P ⓫
0010	CONCRETE IN PLACE	R033105-10									
0020	Including forms (4 uses), Grade 60 rebar, concrete (Portland cement	R033105-20									
0050	Type I), placement and finishing unless otherwise indicated	R033105-50									
0300	Beams (3500 psi), 5 kip/L.F., 10′ span	R033105-65	C-14A	15.62	12.804	C.Y.	340	645	58	1,043	1,425
0350	25′ span	R033105-70	"	18.55	10.782		355	545	49	949	1,275
0500	Chimney foundations (5000 psi), over 5 C.Y.	R033105-85	C-14C	32.22	3.476		171	167	.80	338.80	445
0510	(3500 psi), under 5 C.Y. ❸	R033053-50	"	23.71	4.724		198	227	1.09	426.09	565
0700	Columns, square (4000 psi), 12″ x 12″, up to 1% reinforcing by area		C-14A	11.96	16.722		380	845	76	1,301	1,775
3540	Equipment pad (3000 psi), 3′ x 3′ x 6″ thick		C-14H	45	1.067	Ea.	44.50	52.50	.57	97.57	130
❷ 3550	4′ x 4′ x 6″ thick			30	1.600		69	79	.85	148.85	197
3560	5′ x 5′ x 8″ thick			18	2.667		126	132	1.41	259.41	340
3570	6′ x 6′ x 8″ thick			14	3.429		173	169	1.82	343.82	450
3580	8′ x 8′ x 10″ thick			8	6		370	296	3.18	669.18	860
3590	10′ x 10′ x 12″ thick		↓	5	9.600	↓	645	475	5.10	1,125.10	1,425

It is important to understand the structure of RSMeans data: Unit Prices, so that you can find information easily and use it correctly.

Figure 9-2: Guardian Cost Estimating Guide Instruction (Source: Guardian Construction Cost Estimating Guide)

1 Line Numbers

Line Numbers consist of 12 characters, which identify a unique location in the database for each task. The first 6 or 8 digits conform to the Construction Specifications Institute MasterFormat® 2016. The remainder of the digits are a further breakdown in order to arrange items in understandable groups of similar tasks. Line numbers are consistent across all of our publications, so a line number in any of our products will always refer to the same item of work.

2 Descriptions

Descriptions are shown in a hierarchical structure to make them readable. In order to read a complete description, read up through the indents to the top of the section. Include everything that is above and to the left that is not contradicted by information below. For instance, the complete description for line 03 30 53.40 3550 is "Concrete in place, including forms (4 uses), Grade 60 rebar, concrete (Portland cement Type 1), placement and finishing unless otherwise indicated; Equipment pad (3000 psi), 4' × 4' × 6" thick."

3 RSMeans data

When using **RSMeans data**, it is important to read through an entire section to ensure that you use the data that most closely matches your work. Note that sometimes there is additional information shown in the section that may improve your price. There are frequently lines that further describe, add to, or adjust data for specific situations.

4 Reference Information

RSMeans data engineers have created **reference** information to assist you in your estimate. **If** there is information that applies to a section, it will be indicated at the start of the section.The Reference Section is located in the back of the data set.

5 Crews

Crews include labor and/or equipment necessary to accomplish each task. In this case, Crew C-14H is used. RSMeans data Engineers selects a crew to represent the workers and equipment that are typically used for that task. In this case, Crew C-14H consists of one carpenter foreman (outside), two carpenters, one rodman, one laborer, one cement finisher, and one gas engine vibrator. Details of all crews can be found in the Reference Section.

Crews - Standard

Crew No.	Bare Costs		Incl. Subs O&P		Cost Per Labor-Hour	
Crew C-14H	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Carpenter Foreman (outside)	$52.70	$421.60	$80.25	$642.00	$49.36	$74.88
2 Carpenters	50.70	811.20	77.20	1235.20		
1 Rodman (reinf.)	54.65	437.20	83.45	667.60		
1 Laborer	39.85	318.80	60.70	485.60		
1 Cement Finisher	47.55	380.40	70.45	563.60		
1 Gas Engine Vibrator		25.60		28.16	.53	.59
48 L.H., Daily Totals		$2394.80		$3622.16	$49.89	$75.46

6 Daily Output

The **Daily Output** is the amount of work that the crew can do in a normal 8-hour workday, including mobilization, layout, movement of materials, and cleanup. In this case, crew C-14H can install thirty 4' × 4' × 6" thick concrete pads in a day. Daily output is variable and based on many factors, including the size of the job, location, and environmental conditions. RSMeans data represents work done in daylight (or adequate lighting) and temperate conditions.

7 Labor-Hours

The figure in the **Labor-Hours** column is the amount of labor required to perform one unit of work–in this case the amount of labor required to construct one 4' × 4' equipment pad. This figure is calculated by dividing the number of hours of labor in the crew by the daily output (48 labor-hours divided by 30 pads = 1.6 hours of labor per pad). Multiply 1.600 times 60 to see the value in minutes: 60 × 1.6 = 96 minutes. Note: the labor-hour figure is not dependent on the crew size. A change in crew size will result in a corresponding change in daily output, but the labor-hours per unit of work will not change.

8 Unit of Measure

All RSMeans data: Unit Prices include the typical **Unit of Measure** used for estimating that item. For concrete-in-place the typical unit is cubic yards (C.Y.) or each (Ea.). For installing broadloom carpet it is square yard, and for gypsum board it is square foot. The estimator needs to take special care that the unit in the data matches the unit in the take-off. Unit conversions may be found in the Reference Section.

9 Bare Costs

Bare Costs are the costs of materials, labor, and equipment that the installing contractor pays. They represent the cost, in U.S. dollars, for one unit of work. They do not include any markups for profit or labor burden.

10 Bare Total

The **Total column** represents the total bare cost for the installing contractor in U.S. dollars. In this case, the sum of $69 for material + $79 for labor + $.85 for equipment is $148.85.

11 Total Incl O&P

The **Total Incl O&P column** is the total cost, including overhead and profit, that the installing contractor will charge the customer. This represents the cost of materials plus 10% profit, the cost of labor plus labor burden and 10% profit, and the cost of equipment plus 10% profit. It does not include the general contractor's overhead and profit. Note: See the inside back cover of the printed product or the Reference Section of the electronic product for details of how the labor burden is calculated.

Figure 9-3: Guardian Cost Estimating Guide Instruction (cont.) (Source: Gordian Construction Cost Estimating Guide)

RSMeans data: Unit Prices— How They Work (Continued)

Project Name: Pre-Engineered Steel Building		Architect: As Shown						
Location:	Anywhere, USA						01/01/18	STD
1 Line Number	Description	Qty	Unit	Material	Labor	Equipment	SubContract	Estimate Total
03 30 53.40 3940	Strip footing, 12" x 24", reinforced	34	C.Y.	$5,406.00	$3,808.00	$18.36	$0.00	
03 30 53.40 3950	Strip footing, 12" x 36", reinforced	15	C.Y.	$2,295.00	$1,350.00	$6.45	$0.00	
03 11 13.65 3000	Concrete slab edge forms	500	L.F.	$145.00	$1,280.00	$0.00	$0.00	
03 22 11.10 0200	Welded wire fabric reinforcing	150	C.S.F.	$2,940.00	$4,200.00	$0.00	$0.00	
03 31 13.35 0300	Ready mix concrete, 4000 psi for slab on grade	278	C.Y.	$35,584.00	$0.00	$0.00	$0.00	
03 31 13.70 4300	Place, strike off & consolidate concrete slab	278	C.Y.	$0.00	$5,031.80	$130.66	$0.00	
03 35 13.30 0250	Machine float & trowel concrete slab	15,000	S.F.	$0.00	$9,450.00	$300.00	$0.00	
03 15 16.20 0140	Cut control joints in concrete slab	950	L.F.	$47.50	$399.00	$57.00	$0.00	
03 39 23.13 0300	Sprayed concrete curing membrane	150	C.S.F.	$1,815.00	$1,005.00	$0.00	$0.00	
Division 03	Subtotal			$48,232.50	$26,523.80	$512.47	$0.00	$75,268.77
08 36 13.10 2650	Manual 10' x 10' steel sectional overhead door	8	Ea.	$10,400.00	$3,600.00	$0.00	$0.00	
08 36 13.10 2860	Insulation and steel back panel for OH door	800	S.F.	$4,000.00	$0.00	$0.00	$0.00	
Division 08	Subtotal			$14,400.00	$3,600.00	$0.00	$0.00	$18,000.00
13 34 19.50 1100	Pre-Engineered Steel Building, 100' x 150' x 24'	15,000	SF Flr.	$0.00	$0.00	$0.00	$367,500.00	
13 34 19.50 6050	Framing for PESB door opening, 3' x 7'	4	Opng.	$0.00	$0.00	$0.00	$2,240.00	
13 34 19.50 6100	Framing for PESB door opening, 10' x 10'	8	Opng.	$0.00	$0.00	$0.00	$9,200.00	
13 34 19.50 6200	Framing for PESB window opening, 4' x 3'	6	Opng.	$0.00	$0.00	$0.00	$3,330.00	
13 34 19.50 5750	PESB door, 3' x 7', single leaf	4	Opng.	$2,620.00	$700.00	$0.00	$0.00	
13 34 19.50 7750	PESB sliding window, 4' x 3' with screen	6	Opng.	$2,550.00	$600.00	$45.30	$0.00	
13 34 19.50 6550	PESB gutter, eave type, 26 ga., painted	300	L.F.	$2,220.00	$819.00	$0.00	$0.00	
13 34 19.50 8650	PESB roof vent, 12" wide x 10' long	15	Ea.	$555.00	$3,285.00	$0.00	$0.00	
13 34 19.50 6900	PESB insulation, vinyl faced, 4" thick	27,400	S.F.	$13,152.00	$9,590.00	$0.00	$0.00	
Division 13	Subtotal			$21,097.00	$14,994.00	$45.30	$382,270.00	$418,406.30
		Subtotal		$83,729.50	$45,117.80	$557.77	$382,270.00	$511,675.07
Division 01	2 General Requirements @ 7%			5,861.07	3,158.25	39.04	26,758.90	
		Estimate Subtotal		$89,590.57	$48,276.05	$596.81	$409,028.90	$511,675.07
	3	Sales Tax @ 5%		4,479.53		29.84	10,225.72	
		Subtotal A		94,070.09	48,276.05	626.65	419,254.62	
	4	GC O & P		9,407.01	25,634.58	62.67	41,925.46	
		Subtotal B		103,477.10	73,910.63	689.32	461,180.08	$639,257.13
	5	Contingency @ 5%						31,962.86
		Subtotal C						$671,219.99
	6	Bond @ $12/1000 +10% O&P						8,860.10
		Subtotal D						$680,080.09
	7	Location Adjustment Factor			102.30			15,641.84
		Grand Total						$695,721.94

This estimate is based on an interactive spreadsheet. You are free to download it and adjust it to your methodology.
A copy of this spreadsheet is available at **www.RSMeans.com/2018books.**

Figure 9-4: Unit Price – How They Work (Source: Gordian Unit Price Estimating Guide 2018)

Sample Estimate

This sample demonstrates the elements of an estimate, including a tally of the RSMeans data lines and a summary of the markups on a contractor's work to arrive at a total cost to the owner. The Location Factor with RSMeans data is added at the bottom of the estimate to adjust the cost of the work to a specific location.

1 Work Performed

The body of the estimate shows the RSMeans data selected, including the line number, a brief description of each item, its take-off unit and quantity, and the bare costs of materials, labor, and equipment. This estimate also includes a column titled "SubContract." This data is taken from the column "Total Incl O&P" and represents the total that a subcontractor would charge a general contractor for the work, including the sub's markup for overhead and profit.

2 Division 1, General Requirements

This is the first division numerically but the last division estimated. Division 1 includes project-wide needs provided by the general contractor. These requirements vary by project but may include temporary facilities and utilities, security, testing, project cleanup, etc. For small projects a percentage can be used—typically between 5% and 15% of project cost. For large projects the costs may be itemized and priced individually.

3 Sales Tax

If the work is subject to state or local sales taxes, the amount must be added to the estimate. Sales tax may be added to material costs, equipment costs, and subcontracted work. In this case, sales tax was added in all three categories. It was assumed that approximately half the subcontracted work would be material cost, so the tax was applied to 50% of the subcontract total.

4 GC O&P

This entry represents the general contractor's markup on material, labor, equipment, and subcontractor costs. Our standard markup on materials, equipment, and subcontracted work is 10%. In this estimate, the markup on the labor performed by the GC's workers uses "Skilled Workers Average" shown in Column F on the table "Installing Contractor's Overhead & Profit," which can be found on the inside back cover of the printed product or in the Reference Section of the electronic product.

5 Contingency

A factor for contingency may be added to any estimate to represent the cost of unknowns that may occur between the time that the estimate is performed and the time the project is constructed. The amount of the allowance will depend on the stage of design at which the estimate is done and the contractor's assessment of the risk involved. Refer to section 01 21 16.50 for contingency allowances.

6 Bonds

Bond costs should be added to the estimate. The figures here represent a typical performance bond, ensuring the owner that if the general contractor does not complete the obligations in the construction contract the bonding company will pay the cost for completion of the work.

7 Location Adjustment

Published prices are based on national average costs. If necessary, adjust the total cost of the project using a location factor from the "Location Factor" table or the "City Cost Index" table. Use location factors if the work is general, covering multiple trades. If the work is by a single trade (e.g., masonry) use the more specific data found in the "City Cost Indexes."

Figure 9-5: Unit Price – How They Work (Cont) (Source: Gardian Unit Price Estimating Guide 2018)

Concrete **R0321 Reinforcing Steel**

R032110-10 Reinforcing Steel Weights and Measures

Bar Designation No.**	Nominal Weight Lb./Ft.	U.S. Customary Units			SI Units			
		Nominal Dimensions*				Nominal Dimensions*		
		Diameter in.	Cross Sectional Area, in.²	Perimeter in.	Nominal Weight kg/m	Diameter mm	Cross Sectional Area, cm²	Perimeter mm
3	.376	.375	.11	1.178	.560	9.52	.71	29.9
4	.668	.500	.20	1.571	.994	12.70	1.29	39.9
5	1.043	.625	.31	1.963	1.552	15.88	2.00	49.9
6	1.502	.750	.44	2.356	2.235	19.05	2.84	59.8
7	2.044	.875	.60	2.749	3.042	22.22	3.87	69.8
8	2.670	1.000	.79	3.142	3.973	25.40	5.10	79.8
9	3.400	1.128	1.00	3.544	5.059	28.65	6.45	90.0
10	4.303	1.270	1.27	3.990	6.403	32.26	8.19	101.4
11	5.313	1.410	1.56	4.430	7.906	35.81	10.06	112.5
14	7.650	1.693	2.25	5.320	11.384	43.00	14.52	135.1
18	13.600	2.257	4.00	7.090	20.238	57.33	25.81	180.1

* The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight per foot as the deformed bar.
** Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars.

Figure 9-6: Reinforcing Steel Weights and Measures (Source: Gordian Unit Price Estimating Guide)

Crews - Standard

Crew No.	Bare Costs		Incl. Subs O&P		Cost Per Labor-Hour	
Crew B-92	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Labor Foreman (outside)	$41.85	$334.80	$63.75	$510.00	$40.35	$61.46
3 Laborers	39.85	956.40	60.70	1456.80		
1 Crack Cleaner, 25 H.P.		55.80		61.38		
1 Air Compressor, 60 cfm		105.40		115.94		
1 Tar Kettle, T.M.		129.20		142.12		
1 Flatbed Truck, Gas, 3 Ton		238.00		261.80	16.51	18.16
32 L.H., Daily Totals		$1819.60		$2548.04	$56.86	$79.63
Crew B-93	**Hr.**	**Daily**	**Hr.**	**Daily**	**Bare Costs**	**Incl. O&P**
1 Equip. Oper. (medium)	$53.75	$430.00	$81.05	$648.40	$53.75	$81.05
1 Feller Buncher, 100 H.P.		810.40		891.44	101.30	111.43
8 L.H., Daily Totals		$1240.40		$1539.84	$155.05	$192.48

Figure 9-7: Typical Crew Details for a Crew (Source: Gordian Unit Price Estimating Guide 2018)

Review Questions

1.

10.

CHAPTER 10: PROCUREMENT

Learning Objectives

After reading this chapter, you should be able to:

- First
- Second

11.

CHAPTER 11: GENERAL CONDITIONS AND PROJECT STAFFING

Learning Objectives

After reading this chapter, you should be able to:

- Define the elements contained within general conditions for a project.
- Understand the typical organizational structure and job tasks of different participants on a project.
- Be able to define and draw a typical organizational structure for a construction firm, and understand how it differs from typical manufacturing or service organizations.

Introduction

When developing a detailed estimate of costs, the team needs to plan for the project related general conditions costs. These costs do not directly contribute to the final facility, but they are necessary to manage the delivery of the project and ensure that the site is safe and secure. General Conditions will vary on a project-based upon the size of the project, project complexity, site constraints, duration of the project, cost of management staff, as well as many other factors.

General Conditions include the costs related to complying with the General Requirements for a project which are frequently outlined within a 'General Requirements' section of a contract. The minimum General Requirements are typically included in the Specification Section 01 within the Technical Specifications and may also be a separate contract document. To identify a cost for many of these items, an estimator can reference the CSI MasterFormat Section 01 within the Construction Cost Estimate with RS Means Data guide. Examples of items within the division include project management time, field supervision time, construction trailers, and jobsite fencing.

Construction Company Structure

There are many people engaged in the design and construction of a capital facility project. When we look at the tasks that are typically performed by a construction organization, we see a number of core functions, with examples including estimating, scheduling, safety management, accounting, business development, and operations. These functions can be organized in different ways within a construction company. For smaller companies, a single person may perform multiple functions, e.g., estimating and accounting. In larger companies, a function may be performed by a department within the organization, or possibly even multiple geographically located departments, e.g. an estimating department in Washington DC and an estimating department in New York.

Preconstruction Services

Operations

Some companies refer to the staff members that are responsible for the planning and delivery of a facility as the 'Operations' function (or department) within the company. The

Operations group will typically have project executives, who manage the overall delivery of a project, along with project management staff who manage the delivery of the project on a day-to-day basis, and the superintendent staff who develop and implement the detailed construction plans, spending time in the field to direct the work activities.

Project Management Staff

The Project Management staff is responsible for managing the overall contract for the project. These staff members are sometimes referred to as the 'office staff' from the perspective of the management of the project. They tend to spend the majority of their time in an office environment, frequently in a jobsite trailer or office, working on management and administrative tasks necessary to ensure that the field labor and supervision are provided everything that they need to efficiently perform the fieldwork. This includes tasks such as:

Field Supervision Staff

Review Questions

Type your exercises here.

- First
- Second

12.

CHAPTER 12: DESIGNING A SITE UTILIZATION PLAN

Learning Objectives

After reading this chapter, you should be able to:

- Define the items needed in a site utilization plan.
- Understand the core concepts for designing the site utilization plan for various stages of a project.
- Develop and draw a site utilization plan for a project.

Introduction

A site utilization plan documents the designed status of a project at a point in time. Site Utilization Plans are critical to defining the layout of a project site as it progresses through the construction process. The site is continuously changing. Therefore, there is no one representation that represents the progression of the site throughout the construction process. But, instead, it is critical to have at least several site utilization plans to define the progress of the site, for example, a site utilization plan for the excavation phase, superstructure phase, enclosure phase, and finishes phase.

The following checklist provides typical items that should be in a Site Utilization Plan. Figure 10-1 shows a quality example of a site plan for a school project.

Review Questions

1.

13.

CHAPTER 13: INTRODUCTION TO PROJECT SCHEDULING

Learning Objectives

After reading this chapter, you should be able to:

- Define the items needed in a site utilization plan.
- Understand the core concepts for designing the site utilization plan for various stages of a project.
- Be able to define and draw a site utilization plan for a project.

A site utilization plan documents the designed status of a project at a point in time. Site Utilization Plans are critical to defining the layout of a project site as it progresses through the construction process. The site is continuously changing. Therefore, there is no one representation that represents the progression of the site throughout the construction process. But, instead, it is critical to have at least several site utilization plans to define the progress of the site, for example, a site utilization plan for the excavation phase, superstructure phase, enclosure phase, and finishes phase.

The checklist included in Figure 12-1 provides typical items that should be included in a Site Utilization Plan. Figure 12-2 shows a quality example of a site plan for a school project.

Checklist for Site Utilization Plans

Documentation and Existing Conditions Requirement

- ❑ Developed as a clear plan view within a quality drawing application
- ❑ All building parameters are clearly shown (darker line weight)
- ❑ Building heights / number of stories are clearly noted on project building and adjacent buildings
- ❑ Clear labels on all existing and temporary facilities
- ❑ Property line / project boundaries are clearly identified
- ❑ North arrow clearly noted
- ❑ Existing and new utilities clearly shown - water, sewer, electrical, natural gas, communication
- ❑ Fire hydrants
- ❑ Street lights and other adjacent lighting
- ❑ Pedestrian and traffic patterns clearly shown, along with any walkways / bike paths
- ❑ Document developed with clear fonts and professional graphical quality
- ❑ Clear Legend showing all items. Be careful with color since people may print in black & white.

Content for Site Logistics Plan for a Phase of Construction

- ❑ Crane locations and limits of crane shown for lifting capacity
- ❑ CM and subcontractor office trailers and tool trailer locations
- ❑ Entrance and exit to site (can one-way traffic be used?)
- ❑ Temporary support of excavation systems and limits of excavation
- ❑ Loading docks, material hoists, personnel hoists, temporary elevators (if used)
- ❑ Temporary systems – scaffolding, pre-assembly areas, shoring towers, materials
- ❑ Dumpsters, portable toilets, material storage sheds
- ❑ Clearly note the phase of construction and scheduled dates in the title block

Optional Items Depending Upon Project / Purpose

- ❑ Parking for construction personnel
- ❑ Direction of workflow for crews (using arrows and appropriate Legend information)
- ❑ Vicinity Map with directions to / from site for construction vehicles
- ❑ 4D version of site plan including structure and neighboring buildings

Figure 12-1: Site Utilization Plan Checklist

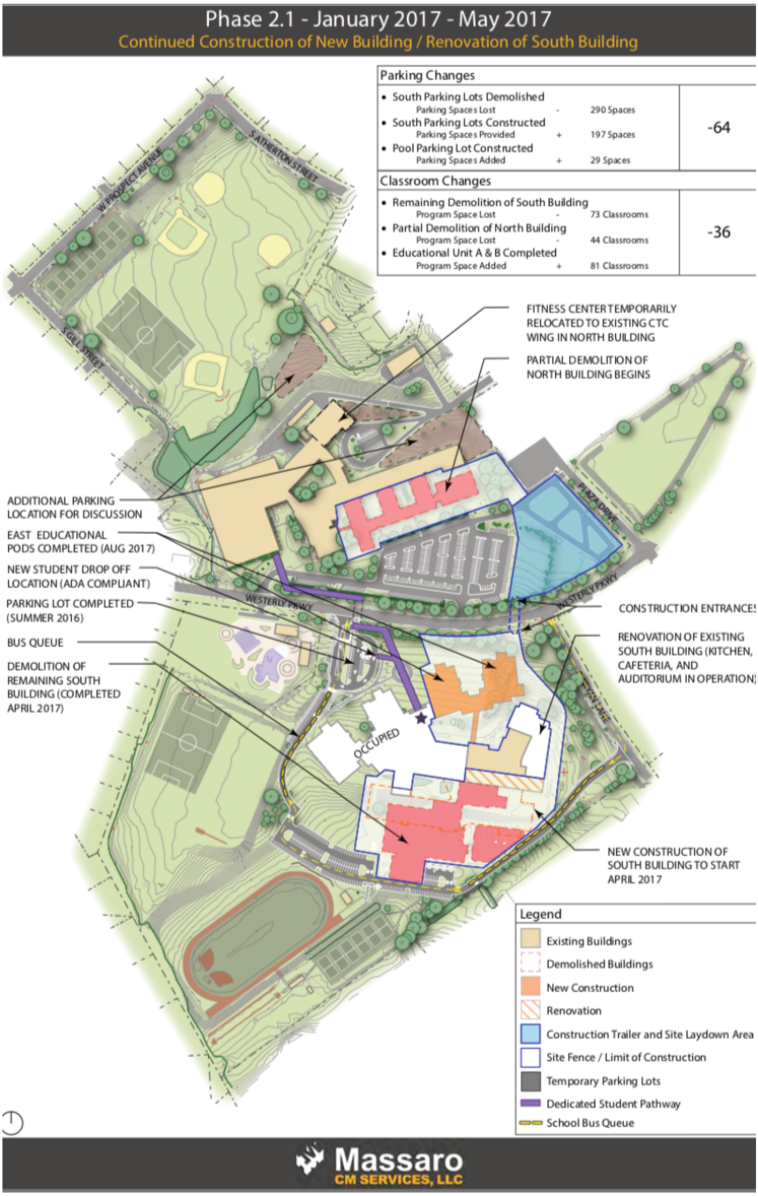


Figure 12-2 Sample Site Utilization Plan (Source: Massaro Construction)

Exercises

Type your exercises here.

- First
- Second

14.

CHAPTER 14: NETWORK SCHEDULING

Learning Objectives

After reading this chapter, you should be able to:

- First
- Second

Exercises

Type your exercises here.

- First
- Second

15.

CHAPTER 15: VALUE ENGINEERING

Learning Objectives

After reading this chapter, you should be able to:

- First
- Second

Exercises

Type your exercises here.

- First
- Second

16.

CHAPTER 16: RISK MANAGEMENT

Learning Objectives

After reading this chapter, you should be able to:

- First
- Second

Exercises

Type your exercises here.

- First
- Second

17.

CHAPTER 17: INTRODUCTION TO PROJECT MANAGEMENT AND CONTROL

Learning Objectives

After reading this chapter, you should be able to:

- Describe the many aspects of a project that need to be managed to ensure a successful construction project
- Define four management areas that are frequently referenced as the Golden Triangle,

which require close management of constraints and expectations

Introduction

The construction industry is a project-based industry where a project can be defined as the lifecycle delivery of a capital facility. It is critical for all participants on a project to be familiar with project management. The definition of a project may vary depending upon an organization's role within the delivery process. For example, to a design firm, a project may be defined as the design of a facility. Within that design firm, there would be a project manager who oversees the design process, who may have the title of Design Manager or Project Manager. Within a construction company, they may define a project to include the planning and implementation of the construction process for a project, and they would have a lead construction project manager assigned to the project. Regardless of the scope of a 'project' to an organization, there is a fundamental set of items that are critical to successfully implementing a project.

Knowledge Categories of Project

Management

Construction Projects are not the only types of projects. There are many different industries that need to manage projects. Examples include software companies that view software products as projects. Or the shipbuilding industry that views each ship as a unique project. Or the space industry that views each launch vehicle as a project. Managing projects can be divided into a common set up project management knowledge areas. The Project Management Institute (PMI) is an industry association that has defined these knowledge areas. PMI has created the Project Management Body of Knowledge which defines the following core knowledge categories:

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

They also added the following within a construction addendum, although one could certainly argue that some of these areas are common to other projects as well:

11. Project Safety Management
12. Project Environmental Management
13. Project Financial Management
14. Project Claim Management

PMBOK is a great resource for identifying each of the steps that should be performed within the management categories. It is also important to note that some management approaches cover multiple areas, e.g., cashflow analysis can be used for both cost and schedule management.

As you can see, there are many areas that must be managed on a project. Each of these areas has a planning, an implementation, and a documentation and reflection aspect to them. Within this course, we will specifically focus on four primary management categories during the project execution, although these are certainly not the only items that need to be managed, as defined in PMBOK. The four areas that will be highlighted in future chapters include:

1. Safety Management ***(always of paramount importance)***
2. Cost Management
3. Schedule Management
4. Quality Management

The Iron Triangle:

When we look at project success, Many people have defined three of the four (Cost, Schedule and Quality) within the context of the Iron Triangle. The International Project Management Association (IPMA) states that project management success relates to delivering the project's product in scope, time, cost and quality (IPMA 2006). Atkinson (1999) discussed a metaphor of the Iron Triangle with a focus on Time, Cost, and Quality. You can certainly argue that you can not maximize all three at the same time, within a defined scope. One would hope that you can achieve the desired scope, within the budget, time and quality constraints, but you can not maximize all at the same time.

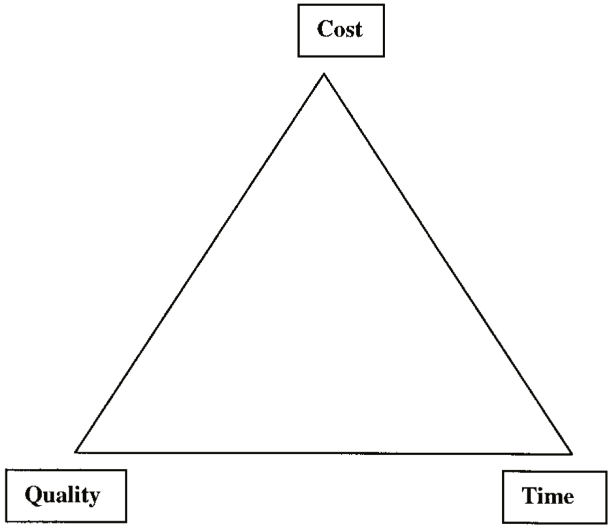


Fig. 17.1: The Iron Triangle (Source: Atkinson 1999)

Plan – Do – Check – Act Cycle

The Plan – Do – Check – Act (PDCA) Cycle is a straightforward approach for effectively managing and controlling a process. PDCA has been discussed frequently within the lean management community. PDCA is focused on ensuring a continuous improvement process for a project. A simple description of PDCA is included at https://theleanway.net/the-continuous-improvement-cycle-pdca

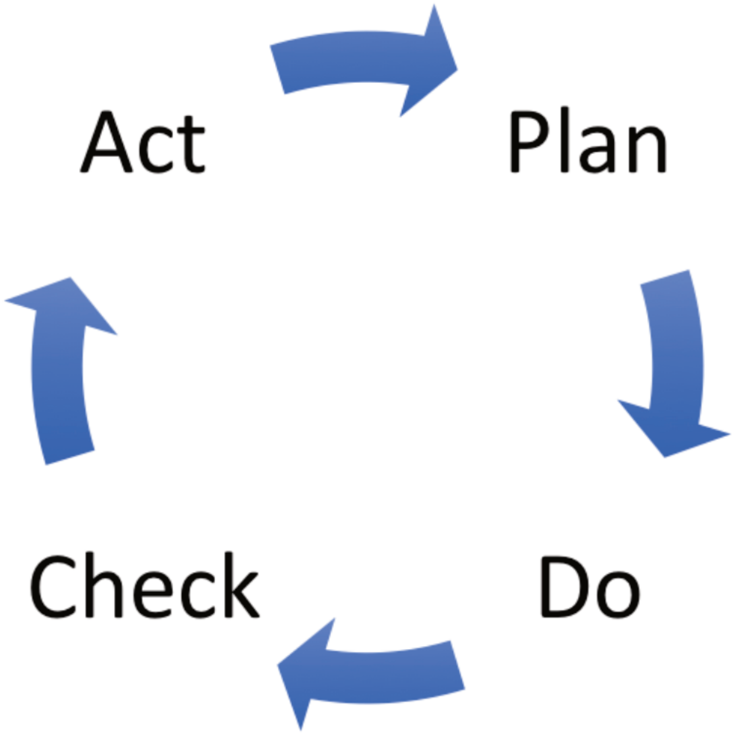


Fig. 17-2: Plan-Do-Check-Act (PDCA) Cycle (source: Skhmot 2017)

Within the PDCA Cycle, the planning is focused on identifying problems and developing potential solutions, along with experiments to test the potential solution. Within the 'Do' task, an approach is implemented and data is captured for further analysis. Within 'Check', the data is evaluated to see if the solution worked. And finally, within 'Act', the team can determine if the issue is resolved, or if another cycle should be performed. One of the main goals of implementation of a

PDCA approach within an organization is to develop a culture of problem-solving throughout the organization, supported by structure experimentation.

The Project Control Process

One part of project planning is the development of the original plan.

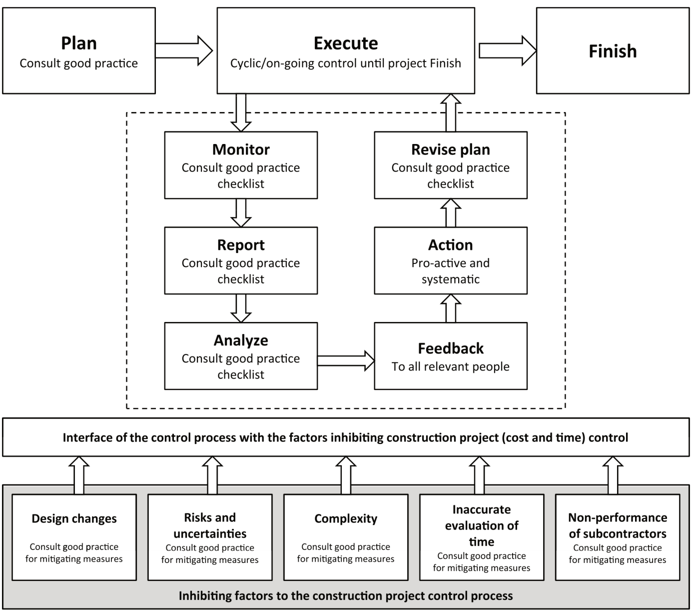


Fig. 17-3: Project Control and Inhibiting Factors Management Model (PCIM model) (Source: Olawale and Sun 2013)

References:

Atkinson, R. (1999). Project management: Cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International Journal of Project Management, 17*(6), 337–342.

International Project Management Association (IPMA). (2006). *IPMA Competence Baseline.*Version 3.0. Nijkerk, The Netherlands: International Project Management Association.

Review Questions

1.

18.

CHAPTER 18: COST AND FINANCIAL MANAGEMENT

Learning Objectives

After reading this chapter, you should be able to:

- Describe the core concepts required to effectively manage the costs and finances on a project.
- Describe the evolution of a construction cost estimate into a cost budget.
- Draw and analyze a cash flow diagram, and understand the impact of the timing of income and expenses on a project.
- Calculate the anticipated monthly payments

for a project given expenditure, a project schedule, and contractual terms related to payments.

Introduction

Throughout the project, the team must always manage the costs and project finances. We have already covered the first part of Cost Management, which is to develop an estimate for the cost of work to be performed.

Cost Budgeting:

Once an organization has developed a cost estimate, that estimate must then be converted into a budget that will be used to monitor the progress of the work versus the costs expended. While an original unit price cost estimate can be quite detailed, identifying every element of work to be performed when constructing the project, the budget needs to be organized under a work breakdown structure that allows for the management staff to receive feedback regarding progress toward the budgeted quantities. This typically requires that several estimated items be grouped into a single budget category.

Cash Flow Management

Project finances are managed at a project level. Therefore, the cash flow of a project, from one organization's perspective, is equal to the amount of funds received from the project (income) minus the amount of funds spent on project-related expenditures (expenses).

Project Cash Flow = Income – Expenses

If the Project Cash Flow is more than zero, then the company has a 'positive' cashflow on the project. If the Project Cashflow is less than zero, then they have a 'negative' cashflow. If a company has a negative cashflow, then they are either using their company reserves to support the expenditures on the project, or they need to borrow funds to cover the project expenditures. Therefore, with all things equal, an organization should seek to maximize their cash flow on any given project within the constraints of the contractual agreements so that they can maintain a higher level of funds within their own accounts. If they have negative cashflows on a number of projects, they will likely need to borrow funds for operating expenses, which then requires them to pay interest on the loans.

All organizations within a project are aiming to manage their cashflow at the same time. For example, the owner will need to pay funds to the designers and contractors. Frequently, the owner is borrowing the funds for the project, and therefore they need to know when they require the funds to pay for the work as it progresses. An owner will typically seek a cashflow projection from the contractor on a project so that they can plan for future expenditures.

Each contractor will also be managing their cashflow, including the general contractor / construction manager along with their trade / subcontractors. It is common practice to contractually arrange that subcontractors do not receive payment for their work activities until the general contractor receives their payment.

Exercises

1.

19.

CHAPTER 19: SCHEDULE MANAGEMENT

Learning Objectives

After reading this chapter, you should be able to:

-

20.

CHAPTER 20: QUALITY MANAGEMENT

Learning Objectives

After reading this chapter, you should be able to:

- first
-

Exercises

Type your exercises here.

- First
- Second

21.

CHAPTER 21: SAFETY MANAGEMENT

Learning Objectives

After reading this chapter, you should be able to:

- Understand that safety can never be compromised for other aspects of a construction project
- Be able to define the importance of safety from an ethical and an economic perspective
- Define effective safety management approaches to improve overall safety on construction projects
- Be able to identify OSHA safety guideline locations

- Understand the impact of construction accidents on projects

As stated in the Fundamental Canons of the ASCE Code of Ethics:

"1. Engineers shall hold **paramount** the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development3 in the performance of their professional duties."

Reference https://www.asce.org/uploadedFiles/About_ASCE/Ethics/Content_Pieces/Code-of-Ethics-July-2017.pdf for the more detailed version of the ASCE Code of Ethics.

Review Questions

Type your exercises here.

- First
- Second

22.

CHAPTER 22: MANAGING INFORMATION FOR PROJECTS

Learning Objectives

After reading this chapter, you should be able to:

- First
- Second

The management of the flow of information on a project is a critical task of the project management team.

Review Questions

Type your exercises here.

- First
- Second

23.

CHAPTER 23: INTRODUCTION TO LEAN CONSTRUCTION

Learning Objectives

After reading this chapter, you should be able to:

- Understand the definition of 'lean construction'
- Be able to list various methods used on projects to increase value and reduce waste

Review Questions

1.

24.

CHAPTER 24: THE FUTURE OF THE CONSTRUCTION INDUSTRY

REFERENCES

Hendrickson, C. (1998) *Project Management for Construction: Fundamental Concepts for Owners, Engineers, Architects and Builders*, Carnegie Mellon University, Pittsburgh, PA, USA, available at https://www.cmu.edu/cee/projects/PMbook/

PMI (2017). *Project Management Body of Knowledge (PMBOK) Guide 2017*, Project Management Institute, USA.

Sanvido, V. et al. (1990). *An Integrated Building Process Model*, CIC Technical Report 1, Penn State University, University Park, PA, USA, available at https://www.cic.psu.edu/download/TR_001_Sanvido_1990_IBPM.pdf.

GLOSSARY

John Messner

Building Information Modeling

Modeled Square Foot Estimate

A modeled square foot estimate, or sometimes simply referred to as a square foot estimate, uses several building characteristics related to important building systems to construct a model building cost per square foot of area. The estimate can account for varying structural systems, facade systems, perimeter quantity, and other project add-ons. The method used in this class will be from the Guardian Square Foot Estimating Guide.

prime contractor

A prime contractor holds a direct contract with the owner or developer of a facility.

Rough Order of Magnitude (ROM)

An estimating approach that provides a rough estimated construction cost. In this course, we will use the Reported Square Foot estimating approach within the

Guardian cost estimating guide for performing a Rough Order of Magnitude estimate. Note that project team members may have their own databases of previous construction costs that would allow them to perform the ROM estimates with historical cost information.

self-performing

When a construction company 'self-performs' work, they will have their own employees, e.g., carpenters, laborers, etc. putting the work in place on the construction site. It is important to note that many construction management firms do not self-perform much work on a project.

Specialty Contractor

A specialty contractor performs a specific scope of work on a construction project.

REVIEW QUESTION ANSWERS

Chapter 1: Introduction to the Building Industry

1. False
2. Commercial Building, Infrastructure, Industrial, and Residential
3. False
4. a. Natural Gas Power Plant
   b. Commercial Building
   c. Residential
   d. Infrastructure
   e. Industrial
   f. Residential
   g. Infrastructure
   h. Commercial Building (Note that even though it will house residents, this is considered a commercial building)
5. See website
6. False
7. True

Chapter 2: The Lifecycle of a Building Project

1. Plan Facility, Design Facility, Construct Facility and Operate Facility
2. False
3. True
4. True
5. Schematic Design (SD), Design Development (DD), Construction Documentation (CD)

Chapter 3: Project Participants and Roles

1. False
2. True
3. False
4. True
5. True

Chapter 4: Project Delivery Methods

1.

Chapter 5: Introduction to Construction Cost Estimating

1. Rough Order of Magnitude; Square Foot; Assemblies; and Detailed
2. Land Cost
3. True
4. 5,497

5. False

Chapter 6: Rough Order of Magnitude (ROM) Cost Estimating

1. False
2. $ 143 / SF
3. 15,400 gross square feet (GSF)

Chapter 7: Modeled Square Foot (SF) Cost Estimating

1. True
2. True
3. True
4. True

Chapter 8: Assemblies Cost Estimating

1. False
2. True

Chapter 9: Unit Price Cost Estimating

1.

Chapter 10: Procurement

1.

Chapter 11: General Conditions and Project Staffing

1.

Chapter 12: Introduction to Project Scheduling

1.

Chapter 13: Network Scheduling

1.

Chapter 14: Designing a Site Utilization Plan

1.

Chapter 15: Value Engineering

1.

Chapter 16: Risk Management

1.

Chapter 17: Introduction to Project Management and Control

1.

Chapter 18: Cost and Financial Management

1.

Chapter 19: Schedule Management

Chapter 20: Quality Management

Chapter 21: Safety Management

Chapter 22: Managing Information for Projects

Chapter 23: Building Information Modeling

Chapter 24: Introduction to Lean Construction

Chapter 25: Managing an Organization