Fundamentals of Building Construction Management

FUNDAMENTALS OF BUILDING CONSTRUCTION MANAGEMENT

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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 construction project. This book closely aligns with the topics and learning objectives of the AE 372 class at Penn State. The book is a resource for the class that does not carry the cost of a typical textbook, and even better, it is free. The content will continue to grow and mature. Please share any errors or suggestions for improvement. Instead of purchasing a textbook, I hope that all students will be able to use your funds to support learning experiences, for example, field trips to see construction projects or other educational experiences. And most important, please ensure that you have the proper Personal Protective Equipment (PPE) to be safe when visiting and working on construction sites.

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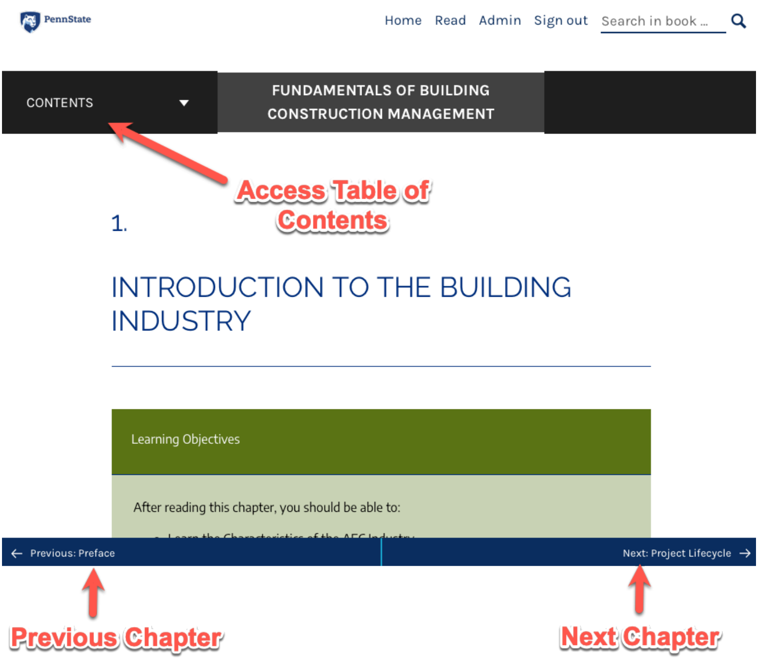
Navigating this Book Online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1.

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 U.S. 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

November 2021

	Seasonally Adjusted Annual Rate (millions of dollars)			Not Seasonally Adjusted (millions of dollars)		
Total	1,625,882	XLS (39k)	PDF (57k)	136,498	XLS (39k)	PDF (61k)
Private	1,273,607	XLS (42k)	PDF (69k)	107,605	XLS (43k)	PDF (73k)
Residential	796,308	XLS (35k)	PDF (42k)	67,044	XLS (35k)	PDF (42k)
Nonresidential	477,299	XLS (35k)	PDF (42k)	40,560	XLS (35k)	PDF (41k)
Public	352,275	XLS (39k)	PDF (53k)	28,893	XLS (39k)	PDF (57k)
State and Local	325,581	XLS (42k)	PDF (71k)	26,647	XLS (42k)	PDF (76k)
Federal	26,694	XLS (35k)	PDF (26k)	2,246	XLS (35k)	PDF (27k)

Figure 1-1: Construction Spending with Private and Public Breakdown (Source: U.S. Census Bureau accessed Jan. 8, 2021)

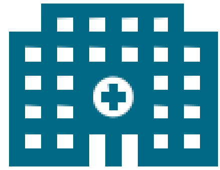
One challenge when discussing our industry is to define the scope and terminology used to describe the industry, or in some cases, subsets of the industry. At a broad level, some people refer to the industry as the Construction Industry, Building Industry, Architecture / Engineering / Construction (AEC) 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, and 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. But, there are also many residential construction companies that fail each year.

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 number 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. It is interesting to note that the recent COVID-19 pandemic has been the latest impact on employment in our industry. The initial onset of the pandemic in early 2020 caused a very abrupt, significant negative impact on employment, but that impact was very short-lived. Figure 1-4 shows the employment trend that includes more recent data, although the time periods are not displayed well in the image. It is interesting to note that the current employment (as of December 2021) is almost the same as the employment prior to the COVID-19 pandemic.

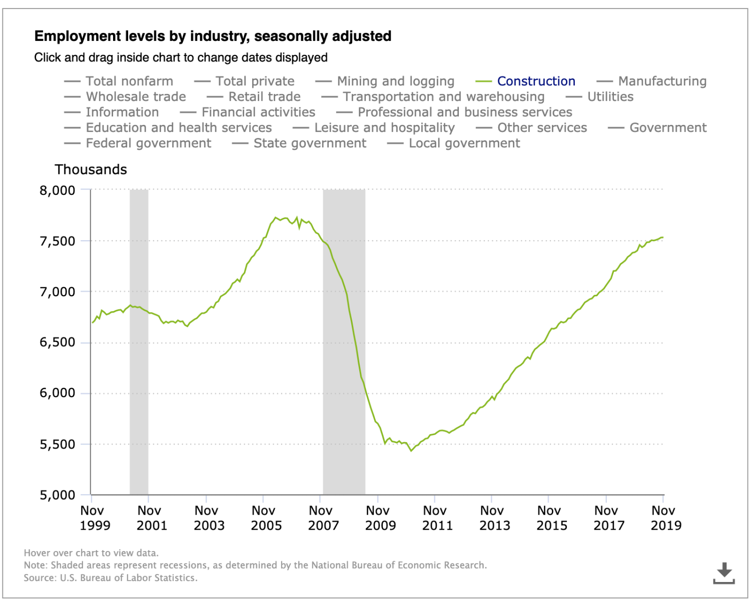


Figure 1-3: Employment Trend for Construction Employment from 1999-2019 (Source: US Bureau of Labor Statistics accessed July 1, 2022)

Figure 1-4: Employment Trend for Construction Employment from 1985 to 2022 (Source: US Bureau of Labor Statistics accessed Jan 8, 2022)

While the size and scale of the industry are 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 the 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 of 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%. It is important to note that the recent *Infrastructure Investment and Jobs* Act federal funding bill will significantly increase this funding for transportation.

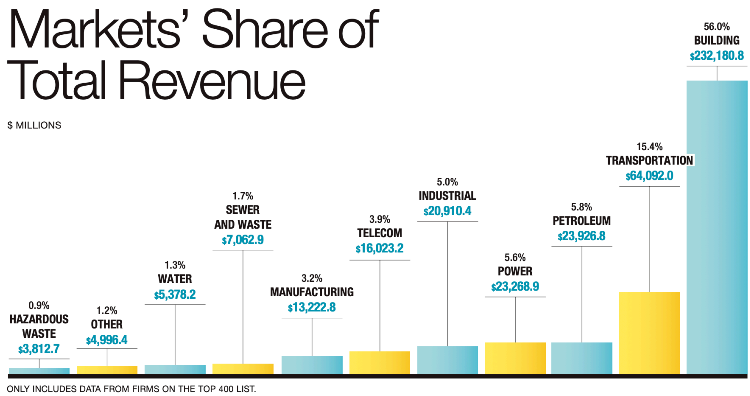


Figure 1-4: Top 400 Contractors – Revenue by Project (Source: ENR 2021)

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 degrees 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 U.S. administer 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

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://psu.pb.unizin.org/buildingconstructionmanagement/?p=29#h5p-2

Independent Activity:

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?

2.

THE LIFECYCLE OF A BUILDING PROJECT

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 define 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.

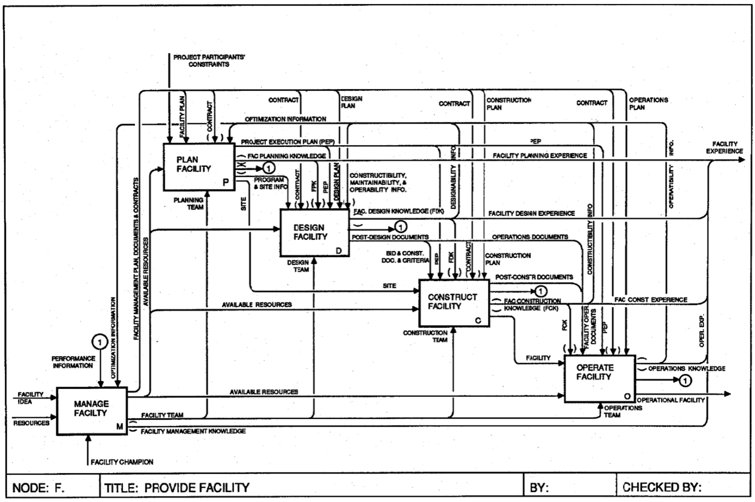


Figure 2-2: Integrated Building Process Model (IBPM) – Level 1 – Provide Facility (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

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 pages 6 – 8 of this online sample document for the definitions of each phase).

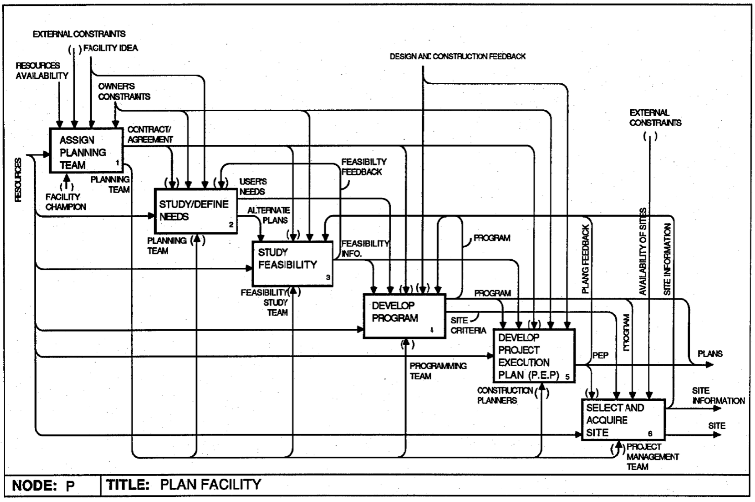


Figure 2-3: Integrated Building Process Model (IBPM) – Plan Facility (Level 2) (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

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 the 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 its intended purpose. For a building project, the primary construction phase typically 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.

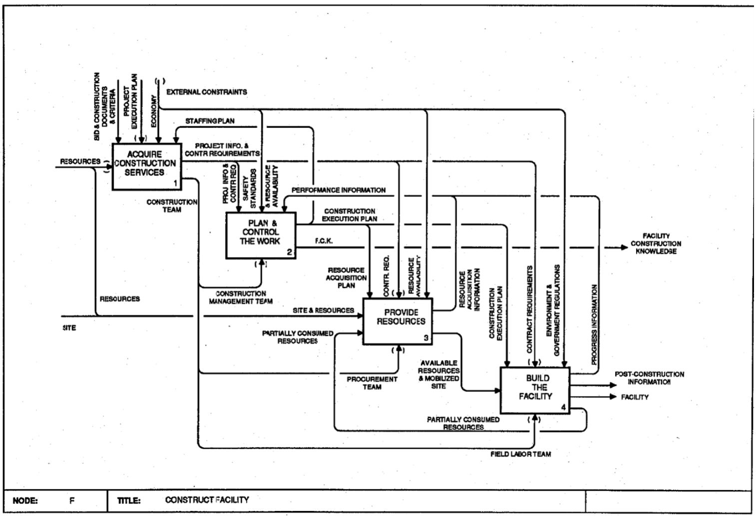


Figure 2-5: Integrated Building Process Model (IBPM) – Construct Facility (Level 2) (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

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.

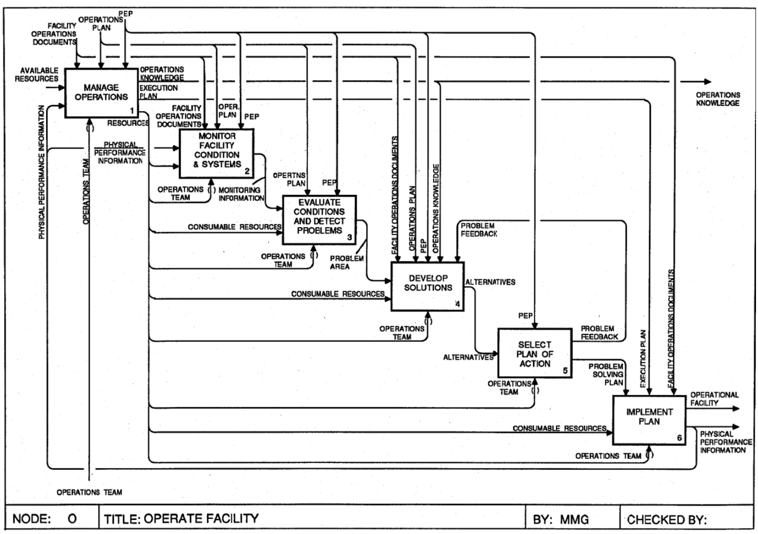


Figure 2-6: Integrated Building Process Model (IBPM) – Operate Facility (Level 2) (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

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.

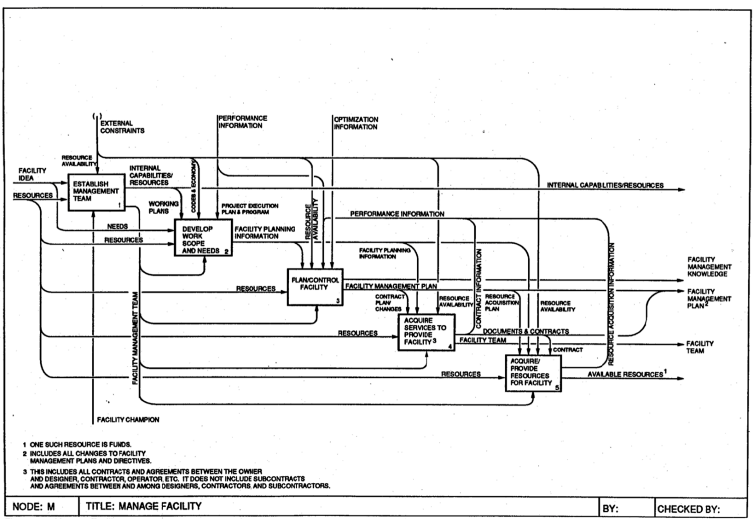


Figure 2-7: Integrated Building Process Model (IBPM) – Manage Facility (Level 2) (Source: Sanvido et al. (1990) An Integrated Building Process Model, Penn State, University Park PA)

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 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 (TCO) perspective, which considers the 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 on 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).

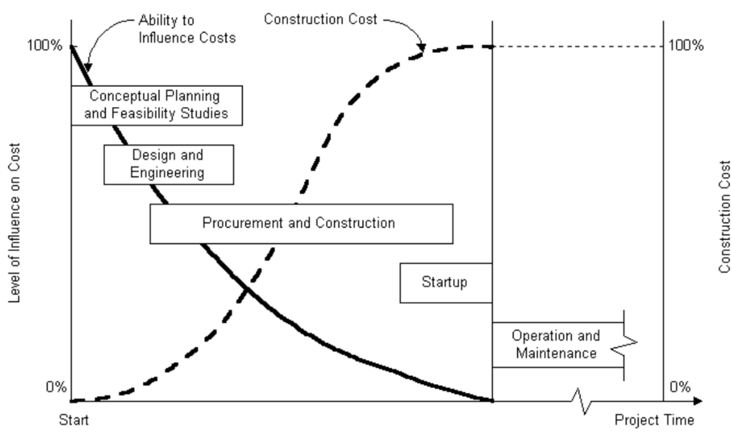


Figure 2-8: Cost / Influence Curve (Source: https://www.cmu.edu/cee/projects/PMbook/02_Organizing_For_Project_Management.html)

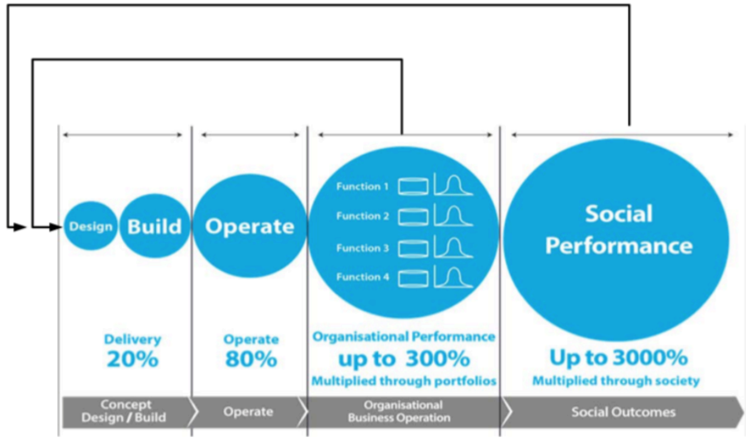


Fig. 2-9: Relative cost of Design and Construction compared to Operations, Performance, and Social Impact (Source: Mark Bew Presentation (available at https://www-smartinfrastructure.eng.cam.ac.uk/files/moving-from-productivity-to-social-outcomes-mark-bew.pdf))

Chapter Review Questions

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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.

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 speculative 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, the Commonwealth of Pennsylvania, the State College Borough, the State College Area School District, and 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 that defines the overall scope and contractual structure for hiring all other participants on the project. It is critical that core services providers spend time understanding 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 people's 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 into 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 structural 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, including 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

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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
- Define the impact of various organizational structures on delivering a project
- Describe the different payment methods for contractors on a project
- Explain the types of award methods for selecting team members
- Draw an organizational chart for multiple types of organizational structures

- Describe the meaning of ‘partnering’ and ‘fast-tracking’

Project owners use many different approaches to procure the services needed to design and 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 organizations. 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 is a second project or multiple additional projects. These decisions define the extent 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 method(s)*** (payment method(s)); and
3. Defining the ***award method(s)***.

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

Project Organizational Structure

The project 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 include:

- Design-Bid-Build with a GC *(also known as Traditional Delivery)*
- 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 Constructor (a General Contractor) to construct the building. A diagram showing the project organizational structure for DBB with GC is shown in Figure 1. This figure shows solid lines for contracts. It includes a dashed line between the design and contractor to illustrate the influence that the Designer has on the Constructor based on the owner's contracts. For example, the architect will typically review the constructor's payment request prior to payment. The architect will also typically review the completed work of the constructor 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.

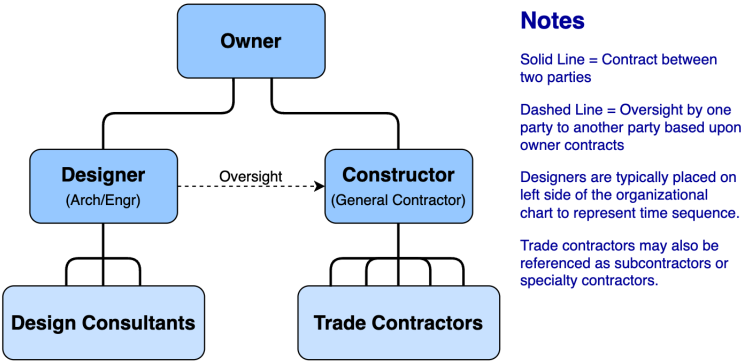


Figure 1: Design – Bid – Build with General Contractor (Project Organizational Chart)

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 competitively bid on 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 on 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 Constructors

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 (see Figure 2). 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 coordination and administrative effort for the Owner. For less experienced owners, this additional burden can be quite challenging.

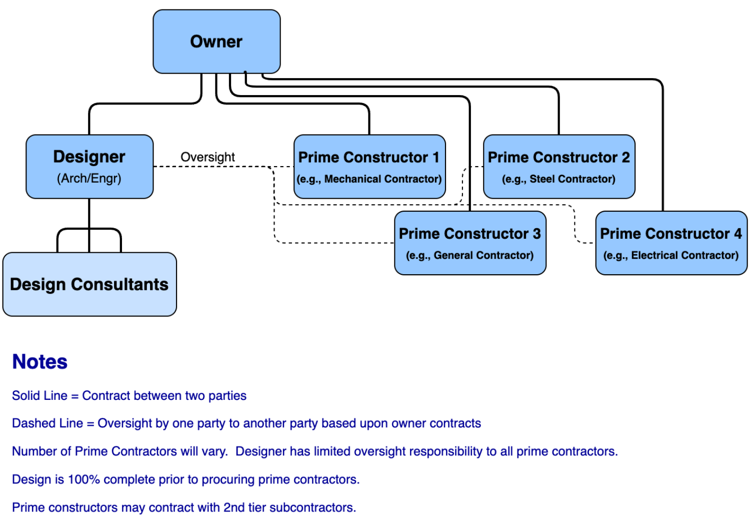


Figure 2: Design – Bid – Build with Multiple Prime Constructors (Project Organizational Structure)

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 state-funded projects in Pennsylvania, there is a minimum requirement per the Separations Act, 71 P.S. §1618 that the owner use a multiple-prime delivery system with each prime construction contract being competitively bid. The minimum number of prime contractors includes 1) general construction, 2) electrical, 3) plumbing, and 4) heating and air conditioning. 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.

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. To assist with the tasks that need to be completed by an owner, and provide significant expertise to deliver a project effectively, 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 manage the project effectively.

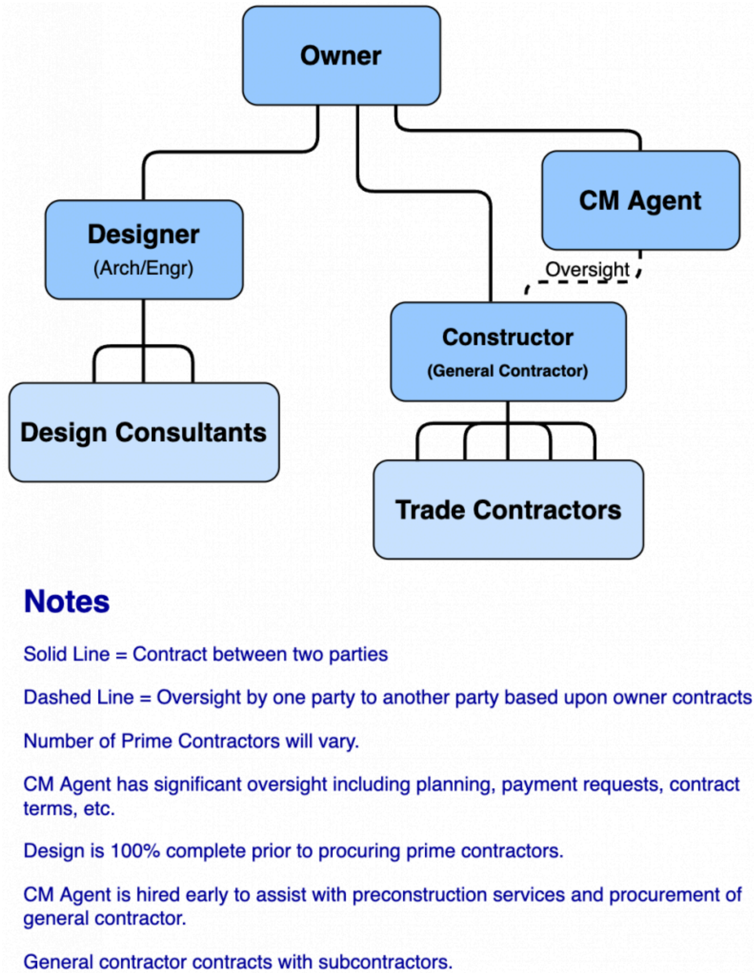


Figure 3: Construction Management (CM) Agent with a General Contractor (GC) (Project Organizational Chart)

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 the 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.

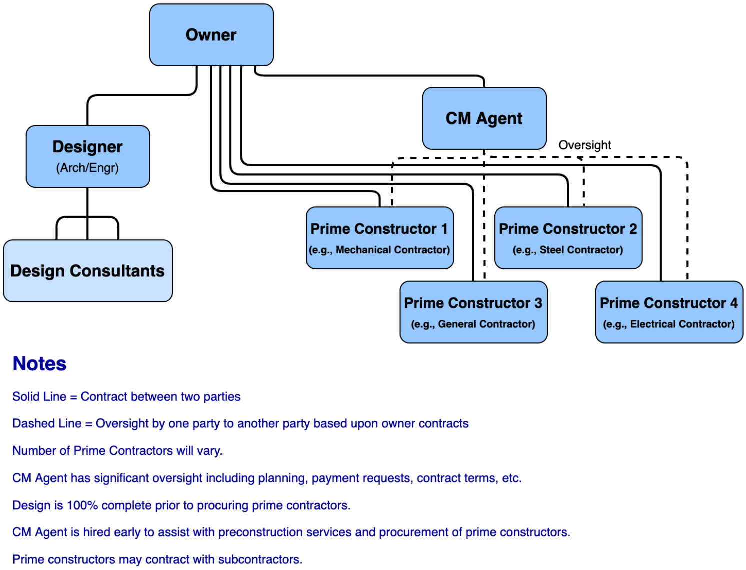


Figure 4: Construction Manager (CM) Agent with Multiple Prime Constructors (Project Organizational Chart)

Construction Management at Risk

Construction Management at Risk is an approach where the owner will hire a designer to develop the facility design, and sometimes, 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 designer, 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.

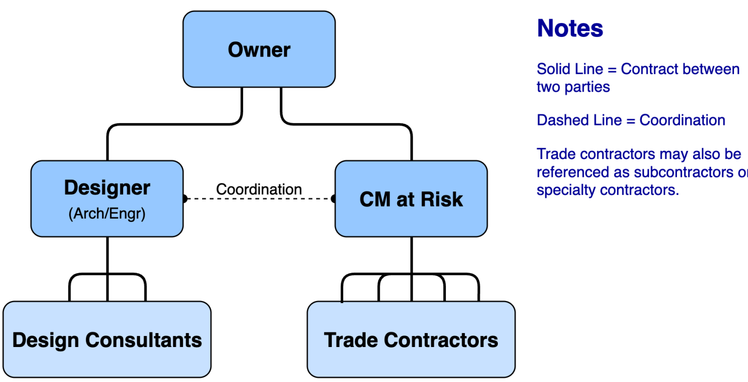


Figure 5: Construction Management (CM) at Risk (Project Organizational Chart)

This delivery method may also be referenced by different names. In particular, within the highway construction sector, this delivery method is known as Construction Management/ General Constructor (or CMGC).

Design-Build

Design-Build (DB) 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, which 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.

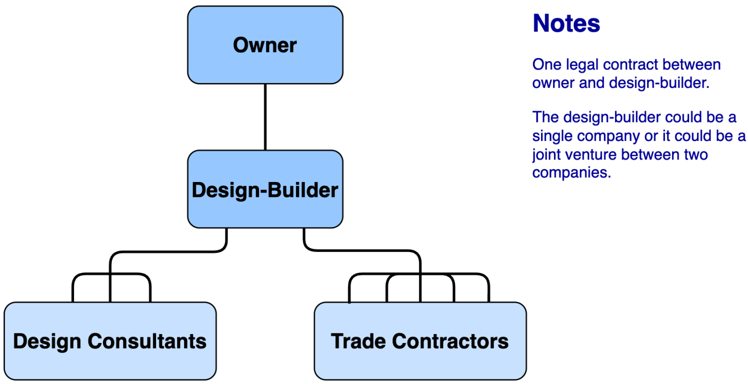


Figure 6: Design-Build (Project Organizational Chart)

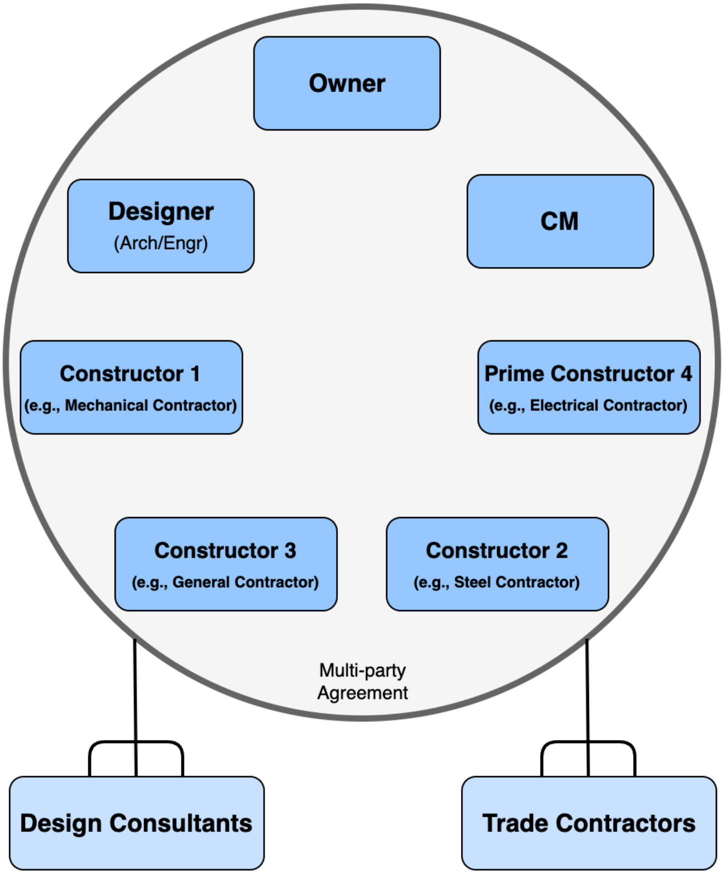
This single entity approach for both design and construction allows for many potential benefits. It allows for a very tight integration of construction means and methods with the design of the facility. It also allows the team to develop accurate cost estimates throughout the early design phases, and 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 potentially 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 its 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 that 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.



Notes

All entities within the circle sign into a multi-party agreement

All primary IPD parties share in the profit or loss of the project

They will hire additional consultants and trade contractors for portions of the project scope

Figure 7: Integrated Project Delivery (IPD) (Project Organizational Chart)

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.

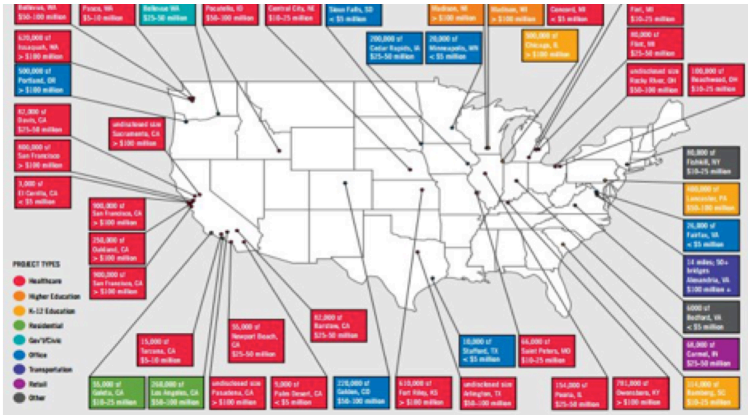


Figure 8: IPD Projects in 2010

There are typically 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 chapter. A good discussion of the IPD delivery approach is included in *Integrated Project Delivery: A Guide* by AIA (2007).

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. For the prime contractor(s), a Lump Sum arrangement typically corresponds with a traditional, design-bid-build delivery approach, although it can be used with other organizational structures. 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. A lump sum payment arrangement may also be referenced as a stipulated sum arrangement. It is also important to note that many owner-designer contracts have a stipulated sum (or lump sum) amount. This value may be estimated as a percentage of the total project costs, but the value is frequently incorporated into the contract as a stipulated sum. The design firm may also have additional compensation amounts, e.g., reimbursement for travel to the site or meetings.

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 are 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 no 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 cost qualified bidder. This approach is very commonly used for public projects, along with many private projects.

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 weigh 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.

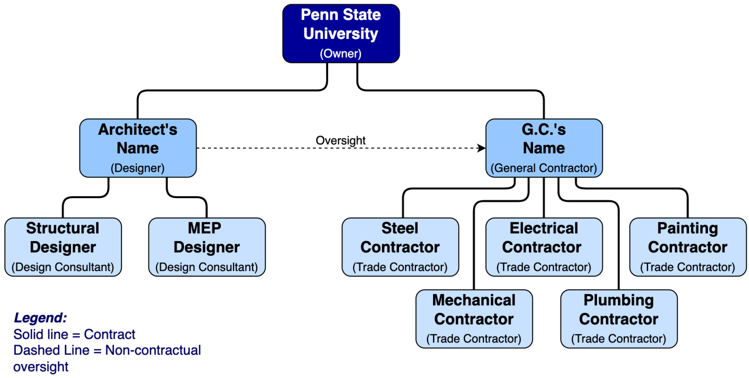
Negotiated Selection

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 acceptable agreement with the entity. This has the benefit of being able to select the entity directly, 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.

Project Organizational Charts

It is very common to draw a project organizational chart (sometimes simply called an 'org' chart) that identifies all primary parties on a project. These charts also show the contractual relationships between the parties, indicated by lines in the diagram. Note that project organizational charts focus on the relationships between the organizations on the project, unlike an organizational chart for personnel within a single organization.

Project 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 the examples that follow, we will keep the project organizational charts simple, and simply show the core attributes of the delivery strategy. Figure 9 shows a relatively simple sample organizational chart for a design-bid-build structure. Figure 10 includes a more comprehensive organizational chart that you would see for larger projects with more trade contractors and more design consultants. Also, note that each sample has a legend that you would want to include with an organizational chart. In addition to showing the contract lines, you could also include the contract type on these lines, e.g., LS for a lump sum, or Cost+ for cost plus a fee. These are not included in the samples below.



Notes

Add the actual names for each organization into the box, along with their role on the project.

Represent all contractual lines with a solid line.

If there are oversight relationships, e.g., a designer oversees payments for a GC, or a CM Agent oversees payment and planning for prime contractors, these relationships can be represented using dashed lines.

Avoid using logos or images unless specifically desired by the client.

Figure 9: Sample project organizational chart showing the owner at the top with several specific firms as the designer, general contractor, and other designers and trade contractors (link to template draw.io file)

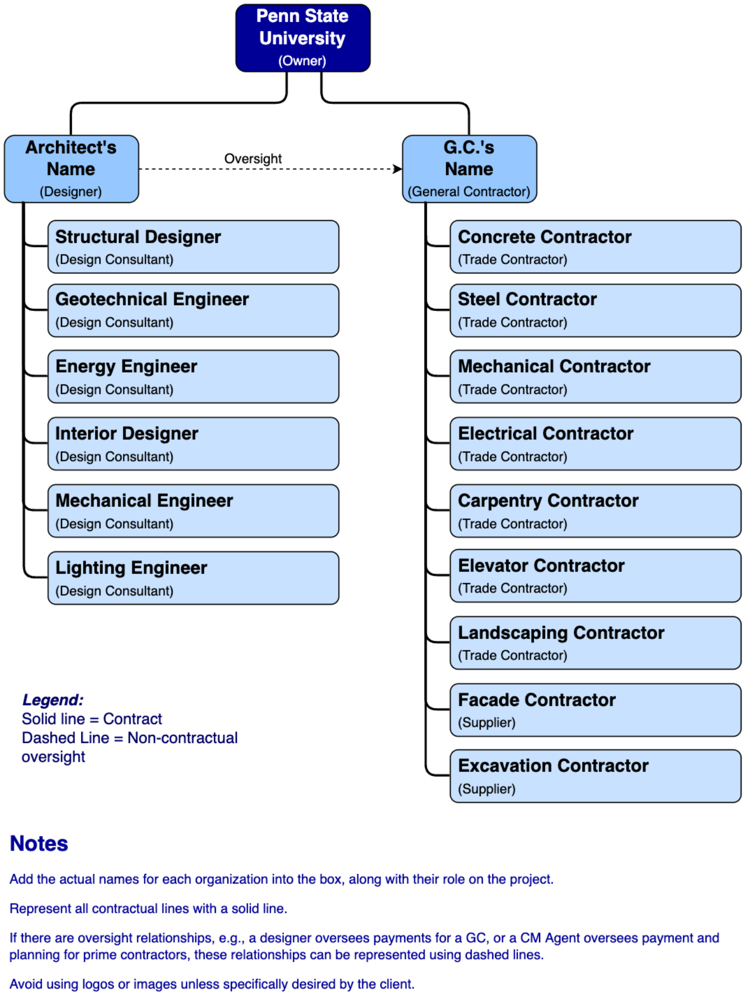


Figure 10: Sample project organizational chart with different format to show a larger number of design consultants and trade contractors (link to template draw.io file)

When drawing a project organizational chart, 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 project 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 subcontractor. This means that the subcontracted party has a direct contract with a prime contractor. Then, if a subcontractor initiates a separate contract with a trade contractor, 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 trade would be a subcontractor. The mechanical specialty trade may then contract with a controls contractor who would be a second-tier subcontractor. The sample project organizational charts in the figures above only have prime and subcontractor parties, they do not include any second-tier subcontractors.

Payments, roles, and responsibilities follow these contract lines. In the above example, the owner would pay the prime contractor, the prime constructor will then pay the subcontractors, and the subcontractors will then pay the second-tier subcontractors.

It is helpful to use a graphics program when developing a project organizational chart. The charts used in this book were developed in diagrams.net. This is a free, open-source software application. You can either download the application locally or you can use a browser-based version of the application at https://diagrams.net The sample organizational charts in this chapter can be downloaded as a template document at this link. There are multiple pages in this file that you can easily use to select the appropriate organizational structure and modify the template organizational chart as needed.

Related Topics

There are several related topics that some may consider within the project delivery methods area. The following items focused on partnering and fast-tracking are **NOT** project delivery methods, but instead, they are related to the delivery of projects and the relationships of the project team members.

Partnering

The Construction Industry Institute (CII) (1996) defined ***partnering*** as "a long-term commitment between two or more organizations as in an alliance or it may be applied to a shorter period of time such as the duration of a project. The purpose of partnering is to achieve specific business objectives by maximizing the effectiveness of each participant's resources." International Partnering Institute (IPA) defined "*construction partnering* as a structured process that brings a design and construction team together regularly throughout the life of a project. Partnering provides a space for communication, improved strategy, and issue resolution."

The partnering process, which may be contractual or non-contractual, puts in place a series of collaboration approaches aimed at improving the relationships between project participants, regardless of the formal delivery method used. For example, on projects with a formal partnering agreement, the partnering program will typically work to develop a formal partnering charter for the project, focused on defining how the team seeks to work together and how they will ensure valuable collaboration. Items that may be included in a comprehensive partnering program include (IPA 2022):

- Partnering Specification: To guide the partnering process and balance the power of everyone in the room
- Charter: Co-created by the team in kick-off session(s) to establish goals and strategies to meet the goals
- Issue Resolution Process: To define an approach to the fair resolution of issues
- Anonymous Surveys: To collect feedback on progress toward goals
- Follow-up Sessions: To update goals, and identify and resolve issues, held at least quarterly
- Lessons Learned Session(s): To capture and learn from experiences

- A neutral professional facilitator: To guide the team through the partnering process

IPA presents the timeline for partnering as shown in Figure 11.

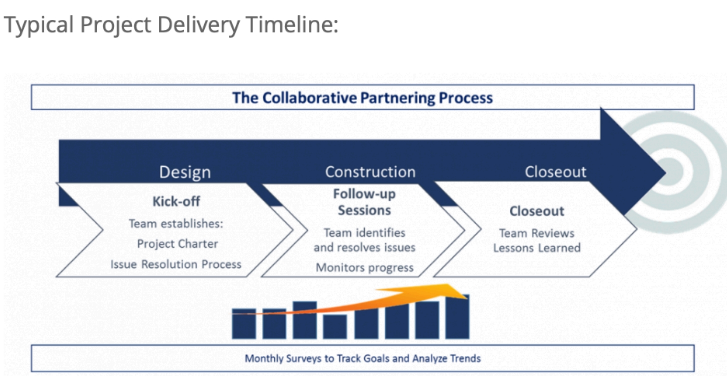


Fig. 11: The Collaborative Partnering Process (Source: IPA 2022)

Partnering can be implemented across all delivery methods. Partnering has been shown to aid in timely issue resolution and improved schedule, cost, and quality. It can help the teamwork, together, to focus on core project goals, and to learn from the project experience, as a team.

Fast-Tracking

Simply put, fast-tracking is the overlapping of the design and the construction process. If a project is fast-tracked, then the constructors will start to build some portions of the project, e.g., demolition, excavation, foundation, and possibly structural elements while the designers continue to develop the more detailed design. This fast-tracking will reduce the overall schedule, but it must be managed well to reduce the risks associated with building portions of the project prior to design completion. Fast-tracking can be achieved in many different delivery methods provided the contractors are procured prior to the completion of the design. Therefore, by definition, we can not fast-track in a design-bid-build delivery approach since we need the design to be 100% complete prior to procuring a contractor. But, we can fast-track a project using the CM-at-Risk, CM Agency, Design-Build, and IPD delivery approaches. With the CM approaches, it is important that the CM procure the trades needed to complete the fast-tracked work tasks prior to completion of design.

It is important to note that some people may use the terminology of fast-track and design-build interchangeably, but they are very different topics. Fast-tracking is focused on the parallel scheduling of activities. Design-build is a project delivery approach.

Recent Research

Research has supported the value of more integrative delivery methods. An initial study, performed by 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 on 351 projects. The conclusions of the study clearly illustrated that Design-Build projects outperformed other delivery methods when comparing cost, schedule, and quality metrics. Specifically, the data indicated that DB has 6% less cost growth than DBB, DB projects were completed 33% faster than DBB, and DB projects had a 10% higher rating for quality than DBB (Konchar and Sanvido, 1998).

More recently, a new dataset of 212 U.S. projects was developed and analyzed (Molenaar and Franz, 2018). In 2018, this data was analyzed to evaluate relative cost, schedule, and quality metrics based on the delivery method adopted for a project. A summary of the quantitative data from the study is shown in Figure 12 (extracted from the study's final report). Note that the column titled 'This Study' is the data analyzed in 2018. This data shows general consistency with the original data from 1998, with Design-Build generally outperforming the CM at Risk, and CM at Risk outperforming the Design-Bid-Build delivery approach.

Table 5: Comparison of results between 1998 CII study and this study

	1998 CII Study				This Study			
Performance Measure	**DB vs. CMR (%)**	**CMR vs. DBB (%)**	**DB vs. DBB (%)**	R^2	**DB vs. CMR (%)**	**CMR vs. DBB (%)**	**DB vs. DBB (%)**	R^2
Unit Cost	4.5 less	1.5 less	6 less	99	1.9 less	1.6 more	0.3 less	99
Cost Growth	12.6 less	7.8 more	5.2 less	24	2.4 less	1.4 less	3.8 less	22
Schedule Growth	2.2 less	9.2 less	11.4 less	24	3.9 less	2.2 more	1.7 less	21
Construction Speed	7 faster	6 faster	12 faster	89	13 faster	20 faster	36 faster	88
Delivery Speed	23 faster	13 faster	33 faster	87	61 faster	25 faster	102 faster	89

Fig. 12: Comparison of Performance Metrics by Delivery Method – Comparing 1998 and 2018 Data (Source: Molenaar and Franz, 2018)

It is important to note that these 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 leverage higher levels of integration of team members and budget transparency can yield high levels of success.

Selecting a Project Delivery Method

Several guides and tools have been developed to assist owners in the selection of delivery methods. One of the earliest tools developed was the Project Delivery Selection System (PDSS) by Vesay (1991). This simple decision matrix aimed to point an owner to potential delivery approaches that may be most appropriate for their project given a series of project characteristics. In particular, Vesay developed a decision tree using 6 project characteristics which include:

1. Scope Definition: Is the scope of the project clearly defined at the time of procurement? (Well Defined/ Poorly Defined)
2. Time Criticality: Is time critical to achieving project success? (Yes/No)
3. Owner Experience Level: Is the owner experienced with managing the delivery of projects? (Yes/No)
4. Team (or potential team) Experience Level: Is the team, or the pool of potential team members, experienced with the delivery of similar projects? (Experienced/ Inexperienced)
5. Quality Level: Is the level of desired quality equivalent to industry standards or above industry standards? (Industry Standard (i.s.) or Above Industry Standards (a.s.))
6. Cost Criticality: Is the first cost of the facility critical to success? (Yes/No)

From the answer to these six questions, the PDSS recommends the consideration of one or more potential delivery methods and payment methods. Note that it may point to one suggested method, multiple suggested methods, or suggest that a characteristic be revised prior to proceeding, e.g., more clearly develop the scope prior to proceeding with the project. The decision trees from Vesay (1991) with some additional revisions to include the IPD delivery method are shown in Figure 13 (delivery method) and Figure 14 (payment method). These decision trees are simply meant to guide an owner. Specific project characteristics may limit the potential selection of methods (e.g., a procurement law or restriction). Characteristics may also guide an owner to one method over another, e.g., previous history with a successful team.

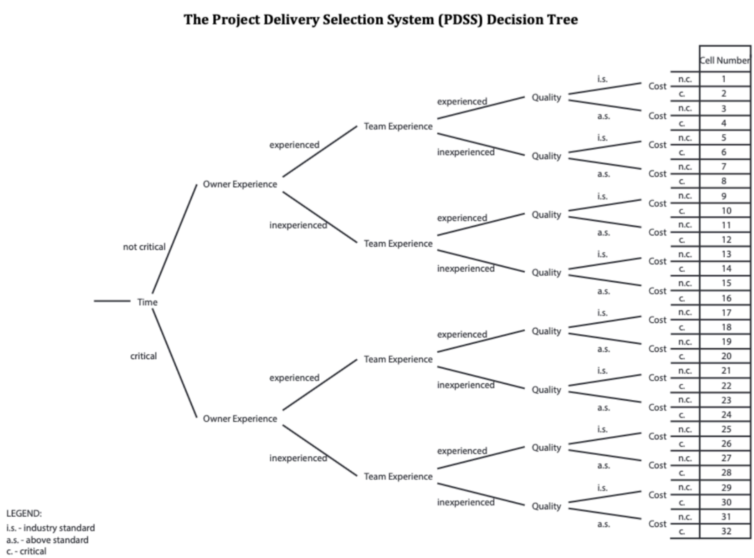


Figure 13: Project Delivery Selection System (PDSS) Decision Tree

The PDSS Tabulated Solutions

	Scope Definition			
	Well Defined Scope	Undefined Scope	Well Defined Scope	Undefined Scope
	1	2	3	4
Cell Number	Organizational Structure	Organizational Structure	Contract Strategy	Contract Strategy
1	TD	CMA, CMGC	LS	GMP, CPF
2	TD, D-B, IPD*	CMGC, CMA, IPD*	LS	GMP
3	TD	CMA, CMGC	LS	GMP, CPF
4	TD, D-B, IPD*	CMGC, IPD*	LS	GMP
5	TD	CMA	LS	GMP
6	TD	CMA	LS	GMP
7	TD, CMA	CMA	LS	GMP
8	TD, CMA	CMA	LS	GMP
9	TD	CMA, CMGC	LS	GMP
10	TD, D-B, IPD*	CMGC, CMA, IPD*	LS	GMP
11	TD	CMA, CMGC	LS	GMP
12	TD, D-B, CMGC, IPD*	CMA, CMGC, IPD*	LS	GMP
13	DON'T BUILD	DON'T BUILD	DON'T BUILD	DON'T BUILD
14	DON'T BUILD	DON'T BUILD	DON'T BUILD	DON'T BUILD
15	DON'T BUILD	DON'T BUILD	DON'T BUILD	DON'T BUILD
16	DON'T BUILD	DON'T BUILD	DON'T BUILD	DON'T BUILD
17	CMA, D-B, IPD*	CMGC, CMA, D-B, IPD*	GMP, CPF	CPF, GMP
18	CMGC, D-B, IPD*	CMGC, CMA, D-B, IPD*	GMP	CPF, GMP
19	D-B, CMA, IPD*	CMGC, CMA, IPD*	CPF	CPF, GMP
20	CMGC, D-B, IPD*	CMGC, CMA, IPD*	GMP	CPF, GMP
21	CMA	CMA	GMP, LS	GMP
22	CMA	CMA	GMP, LS	GMP
23	CMA	CMA	GMP	GMP
24	CMA	CMA	GMP	GMP
25	D-B, CMA, IPD*	CMGC, D-B, IPD*	GMP	CPF, GMP
26	D-B, CMGC, IPD*	CMGC, D-B, IPD*	GMP	CPF, GMP
27	D-B, CMA, IPD*	CMA, D-B, IPD*	GMP	CPF, GMP
28	D-B, CMGC, IPD*	CMA, D-B, IPD*	GMP	CPF, GMP
29	DON'T BUILD	DON'T BUILD	DON'T BUILD	DON'T BUILD
30	DON'T BUILD	DON'T BUILD	DON'T BUILD	DON'T BUILD
31	DON'T BUILD	DON'T BUILD	DON'T BUILD	DON'T BUILD
32	DON'T BUILD	DON'T BUILD	DON'T BUILD	DON'T BUILD

LEGEND (Organizational Structure):
TD - Traditional (Design-Bid-Build)
D-B – Design Build
IPD - Integrated Project Delivery*
CMA - Construction Management (Agency)
CMGC - Construction Management (General Contractor/CM @ Risk)

LEGEND (Contract Strategy):
LS - Lump Sum
GMP - Guaranteed Maximum Price
CPF - Cost Plus Fee

The PDSS Model - Tabulated Solutions
*Adapted from Vasey, T. and Sanvido, V.E. (1992) to include IPD Organizational Structure

Figure 14: Project Delivery Selection System (PDSS) Tabulated Solutions

A more recent study yielded the *Maximizing Success in Integrated Projects: An Owner's Guide* by Leicht et al. (2016). This guide outlines additional items to consider when selecting and managing the delivery of a project. This document highlights the importance of three critical features when delivering projects:

1. ***Early involvement:*** When possible, get the primary builder, and if possible, the trade contractors involved early in the project design phase;
2. ***Qualifications-based selection:*** When possible, employ some form of qualifications-based selection, not just low-cost; and
3. ***Cost Transparency:*** When possible, select a contracting approach that provides cost transparency between the owner and the prime constructor(s). This would include payment methods such as cost plus fee or cost plus fee with a guaranteed maximum price.

Review questions

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://psu.pb.unizin.org/buildingconstructionmanagement/?p=51#h5p-4

References:

AIA. (2007). Integrated Project Delivery: A Guide. American Institute of Architects, California Chapter. Available at https://www.aia.org/resources/64146-integrated-project-delivery-a-guide

Leicht, R. M., Molenaar, K. R., Messner, J. I., Franz, B. W., and Esmaeili, B. (2016). Maximizing Success in Integrated Projects: An Owner's Guide. Version 1.0, January, The Pennsylvania State University. Available at http://bim.psu.edu/delivery

Molenaar, K. and Franz, B. (2018). Revisiting Project Delivery Performance. Final Report, Charles Pankow Foundation, Available at

https://www.pankowfoundation.org/our-work/research-grants/project-delivery/integrated/02-18-revisiting-project-delivery-performance/

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 types of cost information available to various participants within the industry
- Describe relative levels of accuracy for different estimating approaches

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 Systems) 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 it can relatively easily develop estimates for similar future projects that are quite accurate.

3. Historical Cost Data: National / Regional Averages

For organizations that 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., the 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.

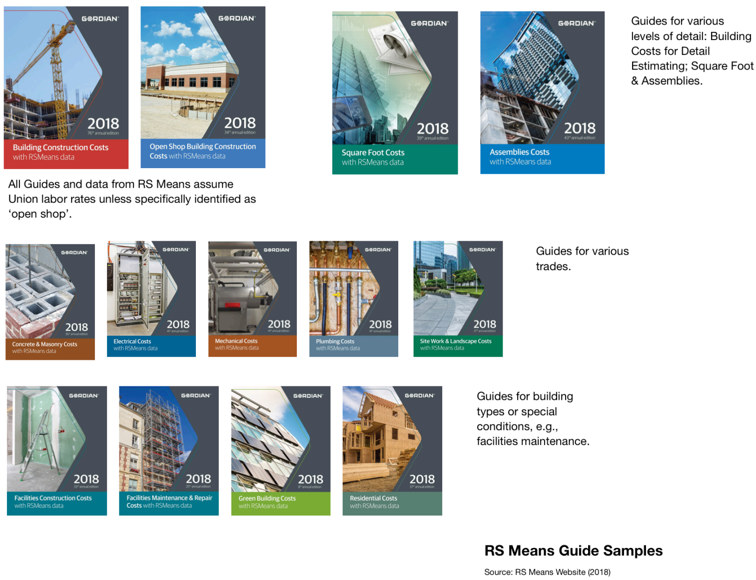


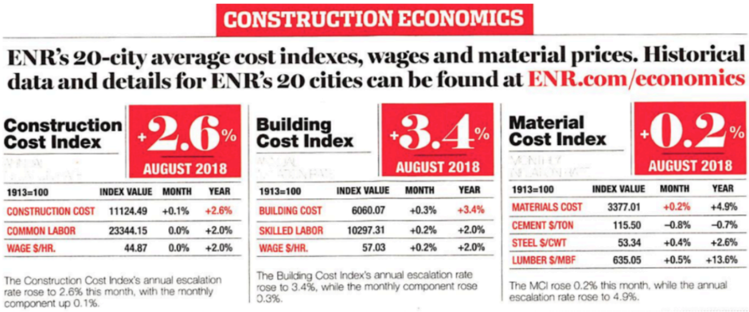
Figure 1: Cover Pages for R.S. Means Estimating Manuals (for Penn State students, most manuals are available in the Engineering Library)

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 2). Monthly and annual averages are also available on the ENR website and are included in Figure 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 2: Construction Economics Section from Engineering News Record (reported weekly in ENR)

ENR'S BUILDING COST INDEX HISTORY (1915-2021)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG.
2022	7359.09												
2021	6459	6493	6545	6612	6754	6876	7006	7201	7214	7244	7255	7289	6912
2020	6214	6217	6218	6234	6239	6247	6258	6268	6300	6344	6392	6445	6281
2019	6107	6108	6110	6110	6112	6118	6131	6147	6147	6169	6179	6199	6136
2018	5921	5932	5942	5954	5995	6005	6043	6060	6081	6093	6093	6105	6019
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

Fig. 3: ENR's Building Construction Cost (BCI) Index History (partial) from 2022 to 2004

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 2021 RS Means Building Construction Cost Guide, all cost data will be statistically modified to be consistent with the January 2021 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. These cost variations can be caused by many factors, including local costs of resources, site conditions (e.g., urban construction tends to cost more than rural), availability of contractors, taxes, and overall region or country economics. In the 2021 International Construction Market Survey by Turner & Townsend, they found Tokyo, Hong Kong, and San Francisco to be the 3 most expensive cities in the world to build (see Figure 4 for the top 10 most expensive places to build). It is interesting to see that 4 of the top 10 most expensive locations are major cities within the United States.

Figure 4: Top 10 Most Expensive Places to Build (Source: International Construction Market Report 2021 by Turner & Townsend)

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 Gordian Guides with RS Means data (see Figure 5). The national average is 1.0, 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. Gordian 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 considered 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.

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: 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, or extensive site work. These inclusions and exclusions vary by the 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 their ability to draw future projections from the data. Therefore, each of the 4 estimating methods defined in RS Means approaches has 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 estimates:

- 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. From the tables in this chapter, what was the

Building Construction Cost (BCC) index value in January 2015?

5. Based on the location factor data in Figure 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.

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 (ROM) Estimate with RS Means Data

The tables and information for performing a ROM estimate with RS Means cost 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 is '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 the 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 that 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 COSTS			% OF TOTAL			
			UNIT	1/4	MEDIAN	3/4	1/4	MEDIAN	3/4	
01	0000	**Auto Sales with Repair**	S.F.							01
	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.							02
	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.							03
	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.							04
	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.							05
	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.

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.

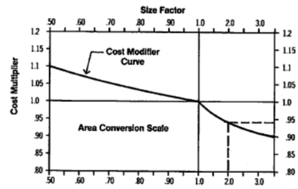
The Size Factor for your project is determined by dividing your project area in S.F. by the typical project size for the particular Building Type. With this factor, enter the Area Conversion Scale at the appropriate Size Factor and determine the appropriate cost multiplier for your building size.

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



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 cost data, e.g., land and financing costs. It does include the contractor's general conditions and fee since these values are 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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://psu.pb.unizin.org/buildingconstructionmanagement/?p=63#h5p-10

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 in the Gordian Guide for SF Estimating with RS Means data. 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 1 and 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 individual assemblies included toward the end of the guide, along with other tables and information.

COMMERCIAL/INDUSTRIAL/INSTITUTIONAL | **M.010** ❶ | **Apartment, 1-3 Story** ❷

Costs per square foot of floor area

Exterior Wall ❸	S.F. Area	8000	12000	15000	19000	22500	25000	29000	32000	36000
	L.F. Perimeter	213	280	330	350	400 ❹	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** ❺	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 ❻	Per 100 L.F.	15.60	10.40	8.25	6.55	5.55 ❼	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

❽ ***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 ❾

Description	Unit	$ Cost	Description	Unit	$ Cost
Appliances			Closed Circuit Surveillance, One station		
Cooking range, 30" free standing			Camera and monitor	Ea.	1475
1 oven	Ea.	610 - 2775	For additional camera stations, add	Ea.	665
2 oven	Ea.	1200 - 3725	Elevators, Hydraulic passenger, 2 stops		
30" built-in			2000# capacity	Ea.	74,100
1 oven	Ea.	995 - 2550	2500# capacity	Ea.	76,600
2 oven	Ea.	1575 - 3125	3500# capacity	Ea.	81,600
Counter top cook tops, 4 burner	Ea.	475 - 2150	Additional stop, add	Ea.	8375
Microwave oven	Ea.	281 - 855	Emergency Lighting, 25 watt, battery operated		
Combination range, refrig. & sink, 30" wide	Ea.	2075 - 2625	Lead battery	Ea.	330
72" wide	Ea.	3075	Nickel cadmium	Ea.	550
Combination range, refrigerator, sink,			Laundry Equipment		
microwave oven & icemaker	Ea.	7100	Dryer, gas, 16 lb. capacity	Ea.	1025
Compactor, residential, 4-1 compaction	Ea.	885 - 1475	30 lb. capacity	Ea.	4100
Dishwasher, built-in, 2 cycles	Ea.	685 - 1225	Washer, 4 cycle	Ea.	1325
4 cycles	Ea.	800 - 2025	Commercial	Ea.	1700
Garbage disposer, sink type	Ea.	260 - 370	Smoke Detectors		
Hood for range, 2 speed, vented, 30" wide	Ea.	370 - 1450	Ceiling type	Ea.	244
42" wide	Ea.	450 - 2650	Duct type	Ea.	585
Refrigerator, no frost 10-12 C.F.	Ea.	580 - 750			
18-20 C.F.	Ea.	895 - 2075			

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.

❶ **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.

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

❸ **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.

❹ **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.

❺ **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.

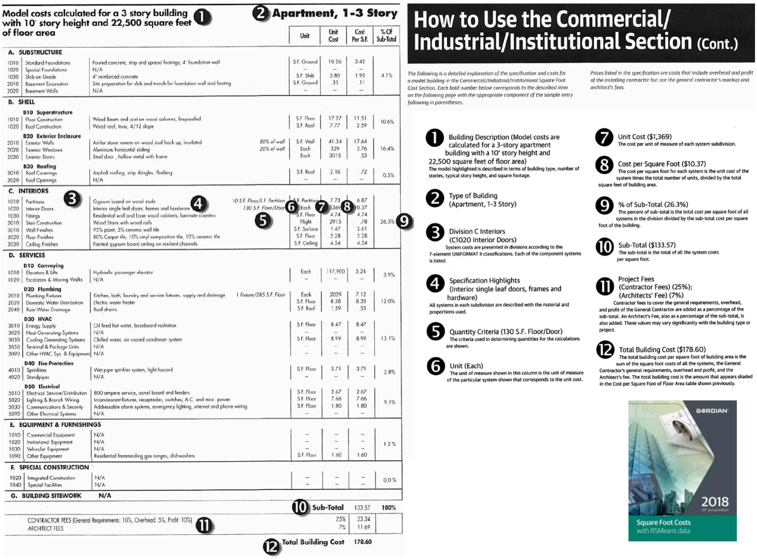
❻ **Building Perimeter and Story Height Adjustments**
Square foot costs for a building with a perimeter or floor-to-floor story height significantly different from the model used to calculate the base cost may be adjusted (add or deduct) to reflect the actual building geometry.

❼ **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.

❽ **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.

❾ **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 1: Introduction of the Modeled Square Foot Estimating Approach (Source: Gordian 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	4.1%
1020	Special Foundations	N/A		–	–	–	
1030	Slab on Grade	4″ reinforced concrete		S.F. Slab	5.80	1.93	
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	16.4%
2020	Exterior Windows	Aluminum horizontal sliding	20% of wall	Each	529	3.76	
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 ❹	10 S.F. Floor/L.F. Partition	S.F. Partition	7.73	6.87	26.3% ❾
1020	Interior Doors	Interior single leaf doors, frames and hardware	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	
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	12.0%
2020	Domestic Water Distribution	Electric water heater		S.F. Floor	8.38	8.38	
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	13.1%
3020	Heat Generating Systems	N/A		–	–	–	
3030	Cooling Generating Systems	Chilled water, air cooled condenser system		S.F. Floor	8.99	8.99	
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	9.1%
5020	Lighting & Branch Wiring	Incandescent fixtures, receptacles, switches, A.C. and misc. power		S.F. Floor	7.66	7.66	
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		–	–	–	1.2%
1020	Institutional Equipment	N/A		–	–	–	
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 2: Continuation of Introduction of the Modeled Square Foot Estimating Approach (Page 2 of each building) (Source: Gordian 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.

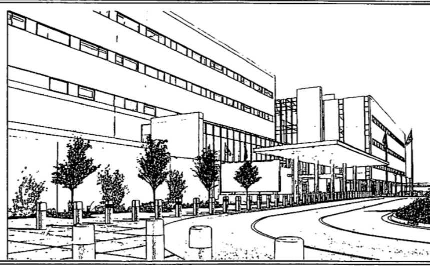
The Modeled SF Estimating approach is very different from the ROM Estimating approach described in the previous chapter. The Modeled SF Estimating approach is taking more detailed building assemblies, e.g., structural system elements, mechanical system elements, etc., and building a 'model' estimate 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 about 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 on the 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 Gordian 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 the average linear feet of the 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 3: Sample Hospital Project Square Foot Estimate (Modified from Gordian 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 joists, 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 4: Example Hospital Square Foot Cost – Page 2 (modified from Gordian 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 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 at the bottom of the 2nd page (see Figure 4). You can also modify your estimate with common additions that are listed on the first page of each of the modeled facilities (see Section 9 in Figure 1). These common additions are 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 Gordian 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 a 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 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 3, if you have a building of 200,000 SF, you would expect 866 LF of the 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 the 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 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 estimated by multiplying the cost per SF by the total SF for the building.

6. Calculate the Additional Basement Cost

The cost per SF of the basement area is identified in the estimating table, at the bottom of the table (see the yellow box in Figure 3. To calculate the basement cost, multiply the cost per SF of the 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 in Figure 1 for an 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 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 or potentially misleading if the number looks too precise when it remains an approximate amount for the project.

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://psu.pb.unizin.org/buildingconstructionmanagement/?p=69#h5p-12

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. If we refer back to our design phases, this level of estimates is primarily aligned with design development, when the systems are being designed, although some systems may be designed prior to this phase. These systems could include items as simple as the number of lavatories or toilets. It could also be more complex such as an assemblies estimate per square foot of building area for a mechanical system, such as rooftop units. It is important to note that some of the quantities used to develop the assemblies are straightforward, such as number of units for the lavatories, although others are more abstract, such as the square footage of the building for the mechanical system. An estimating team within a construction firm may have their own assemblies costs that they have historically tracked and categorized. This chapter will focus on using the Gordian guide for assemblies as a public source of cost information.

Assemblies estimates for commercial building projects are typically organized by CSI Uniformat 2 categories (see Figures 1 and 2) since they align with the overall building systems. This classification system is focused on building systems such as substructure (A), shell (B), interiors (C), services (D), equipment and furnishings (E), special construction and demolition (F), and building sitework (G) (see Figure 1 and 2 for the more detailed level 2 and 3 for each of these main – level 1 – categories).

Figure 1 - ASTM UNIFORMAT II Classification of Building Elements (E1557-97)		
Level 1 Major Group Elements	**Level 2 Group Elements**	**Level 3 Individual Elements**
A. SUBSTRUCTURE	A10 Foundations	A1010 Standard Foundations A1020 Special Foundations A1030 Slab on Grade
	A20 Basement Construction	A2010 Basement Excavation A2020 Basement Walls
B. SHELL	B10 Superstructure	B1010 Floor Construction B1020 Roof Construction
	B20 Exterior Closure	B2010 Exterior Walls B2020 Exterior Windows Exterior Doors
	B30 Roofing	B3010 Roof Coverings B3020 Roof Openings
C. INTERIORS	C10 Interior Construction	C1010 Partitions C1020 Interior Doors C1030 Specialties
	C20 Staircases	C2010 Stair Construction C2020 Stair Finishes
	C30 Interior Finishes	C3010 Wall Finishes C3020 Floor Finishes C3030 Ceiling Finishes
D. SERVICES	D10 Conveying Systems	D1010 Elevators D1020 Escalators & Moving Walks D1030 Material Handling Systems
	D20 Plumbing	D2010 Plumbing Fixtures D2020 Domestic Water Distribution D2030 Sanitary Waste D2040 Rain Water Drainage D2050 Special Plumbing Systems
	D30 HVAC	D3010 Energy Supply D3020 Heat Generating Systems D3030 Cooling Generating Systems D3040 Distribution Systems D3050 Terminal & Package Units D3060 Controls & Instrumentation D3070 Special HVAC Systems & Equipment D3080 Systems Testing & Balancing
	D40 Fire Protection	D4010 Fire Protection Sprinkler Systems D4020 Stand-Pipe & Hose Systems D4030 Fire Protection Specialties D4040 Special Electrical Systems
	D50 Electrical	D5010 Electrical Service & Distribution D5020 Lighting & Branch Wiring D5030 Communication & Security Systems D5040 Special Electrical Systems
E. EQUIPMENT & FURNISHINGS	E10 Equipment	E1010 Commercial Equipment E1020 Institutional Equipment E1030 Vehicular Equipment E1040 Other Equipment
	E20 Furnishings	E2010 Fixed Furnishings E2020 Movable Furnishings
F. SPECIAL CONSTRUCTION & DEMOLITION	F10 Special Construction	F1010 Special Structures F1020 Integrated Construction F1030 Special Construction Systems F1040 Special Facilities F1050 Special Controls & Instrumentation
	F20 Selective Building Demolition	F2010 Building Elements Demolition F2020 Hazardous Components Abatement

Figure 1: Uniformat II – Categories A to F

Figure 2 - ASTM UNIFORMAT II Classification of Building Related Sitework (E1557-97)		
Level 1 Major Group Elements	**Level 2 Group Elements**	**Level 3 Individual Elements**
G. BUILDING SITEWORK	G10 Site Preparation	G1010 Site Clearing G1020 Site Demolition & Relocations G1030 Site Earthwork G1040 Hazardous Waste Remediation
	G20 Site Improvements	G2010 Roadways G2020 Parking Lots G2030 Pedestrian Paving G2040 Site Development G2050 Landscaping
	G30 Site Civil/Mechanical Utilities	G3010 Water Supply & Distribution Systems G3020 Sanitary Sewer Systems G3030 Storm Sewer Systems G3040 Heating Distribution G3050 Cooling Distribution G3060 Fuel Distribution G3070Other Civil / Mechanical Utilities
	G40 Site Electrical Utilities	G4010 Electrical Distribution G4020 Exterior Lighting G4030 Exterior Communications & Security G4040 Other Electrical Utilities
	G50 Other Site Construction	G5010 Service Tunnels G5020 Other Site Systems & Equipment

Figure 2: Uniformat II – Element G for Building Sitework

To develop a full assemblies estimate for a project, an initial takeoff of the quantities for each type of building system is needed, along with an understanding of the type of building systems. The Gordian Assemblies Estimating Guide contains directions regarding the information provided for each assembly. Figures 3 and 4 contain the descriptions for the different information that is published for each of the assembly categories within the Gordian Assemblies Guide with RS Means data.

Each assembly is defined within the Gordian guide with a unique identifier along with a clear description of the detailed items within the assembly. For example, the stair construction assembly (A1010) shown in Figure 4 is developed by combining six more detailed items for a cast-in-place (C.I.P.) foundation wall. These six items are shown in the System Components section (noted with the number 5 in the image). These detailed items include formwork, reinforcing, reinforcing material handling, concrete, and finishing. It is important to note that you can read more details about what is included, and what is not included, in the description. For example, in Figure 4, we can see that excavation and backfill are not included in the foundation wall assembly. This assembly will be estimated with the unit of 'cost per linear foot' of the wall (see number 4 in Figure 4). It is important to note that you can not see the details for every assembly, but instead, you only see the details for one typical assembly per page. This one example is highlighted with its unique 12-character identifier (see number 1 in Figure 3 for example and the reference in number 2 in the same figure). For the remaining assemblies, you may need to assume the specific detailed items included, or you may have access to this information if you use the online version of the cost guides.

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.

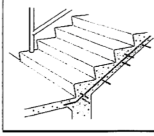
3 Narrative Descriptions

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

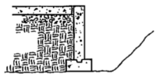
For supplemental customizable square foot estimating forms, visit: **www.RSMeans.com/2018books**

Figure 3: Description of Gordian Assemblies Guide information per Assembly (Source: Gordian Assemblies Estimating Guide)

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.

System Components (5)	QUANTITY	UNIT	COST PER L.F. (4)		
			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	(6)		.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

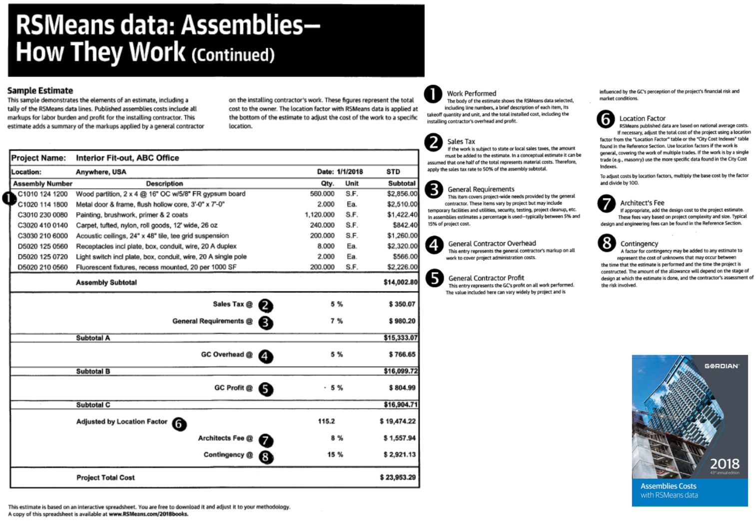
4 Unit of Measure
All RSMeans data: Assemblies include a typical **Unit of Measure** used for estimating that item. For instance, for continuous footings or foundation walls the unit is linear feet (L.F.). For spread footings the unit is each (Ea.). The estimator needs to take special care that the unit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

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

6 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.

Figure 4: Description of Gordian Assemblies Guide information per Assembly (cont.) (Source: Gordian Assemblies Estimating Guide)

Steps to Complete an Assemblies Estimate



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 it 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.

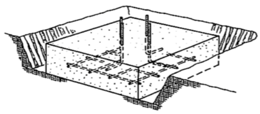
❼ **Architect's Fee**
If appropriate, add the design cost to the project estimate. These fees vary based on project complexity and size. Typical design and engineering fees can be found in the Reference Section.

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.

Figure 5: Description of Steps to Complete an Assemblies Estimate (Source: Gordian Assemblies Estimating Guide)

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

Figure 6: Example of an Assembly in the Assemblies Estimate (Source: Gordian Assemblies Estimating Guide)

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 7: Summary of CSI MasterFormat Categories

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://psu.pb.unizin.org/buildingconstructionmanagement/?p=77#h5p-16

References

Gordian. (2018). Assemblies Estimating Cost Guide.

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 Estimating with R.S. Means Data in the Gordian Guides

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 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 2 and 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 4 and 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			Crew	Daily Output	Labor-Hours	Unit	2018 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
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.	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
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 2: Gordian Cost Estimating Guide Instruction (Source: Gordian 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 3: Gordian 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 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 5: Unit Price – How They Work (Cont) (Source: Gordian 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, cm^2	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 6: Reinforcing Steel Weights and Measures (Source: Gordian Unit Price Estimating Guide)

In addition to estimating a cost for an activity, the Gordian detailed cost guides (building construction, electrical, concrete, etc.) also provide information regarding production rates and crews for each of the cost elements. Figure 7 shows a typical crew that wold be used for an activity. In this example, the crew is a Crew B-92 which has 1 foreman, 3 laborers, and several pieces of equipment. The crew has both a bare cost per day ($1,819.60 in Figure 7) and a cost including overhead and profit. In the example, you can also see that there are 32 Labor Hours (LH) per day from this crew (4 people x 8 hours per day = 32 LH per day). The total cost per individual labor hour is also presented, e.g., for Crew B-92, the cost per average labor hour, including all equipment, overhead and profit, would be $79.63 (which is $2,548.04 / 32 LH). Therefore, if an estimator wanted to estimate by a labor hour, for either the initial estimate or change order, they could use the cost per average LH for this calculation.

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

Additional Detailed Unit Price Resources

Gordian guides with R.S. Means data are not the only resources that can be used to develop detailed unit price estimates. Many companies maintain a database of their own historical unit rates for common work tasks, and they will leverage these historical costs during their estimating. They may also review, in detail, a similar project or group of projects to review specific actual costs from previous projects. This is a very valuable approach to reviewing costs, but it is also important to understand the context of the costs when estimating potential future work.

There are also several more specific cost estimating manuals that have been developed for specific trades. One commonly used guide for electrical work is the National Electrical Contractors Association (NECA) Manual of Labor Units (MLU) (see Figure 8). This Manual, developed by the trade association, publishes a typical labor unit for the detailed tasks performed by electrical workers and crews. The manual also uses a unique approach to quantifying the level of difficulty of the work activities and provides a different rate based upon normal installation, difficult installation, and very difficult installation (see Figure 9 for definitions). To identify the classification of difficulty, NECA

Figure 8: Cover Page of the NECA Manual of Labor Units

has developed a Labor Factor Score Sheet (see Figure 10), which walks an estimator through a series of categories that are rated on a scale of 1 to 5 in order to develop an overall score for difficulty. This score is then used to select one of the three difficulty columns. The Manual includes a large number of electrical installation tasks. A sample page from the Manual is shown in Figure 11. It is important to note that the labor units are for direct work, and do not include costs for supervision.

What's the difference between the three columns in the MLU?

The NECA labor unit tables include three different labor units for each item. Users of the MLU are also encouraged to consider labor units between the columns, or even lower than or exceeding the columns when appropriate.

Normal Installation Conditions
When all of the conditions associated with the installation of an item will permit the maximum productivity of the electricians on a project, these "normal" column labor units are applicable.
Difficult Installation Conditions
When one or more of the conditions associated with the installation of an item will permit less than maximum productivity of the electricians on a typical project, these "difficult" column labor units are applicable.
Very Difficult Installation Conditions
When one or more of the conditions associated with the installation of an item will permit substantially less than maximum productivity of the electricians on a typical project, these "very difficult" column labor units are applicable. The Introduction to the MLU includes a Labor Factor Score Sheet to help determine the appropriate column.

Figure 9: MLU Levels of Difficulty Definitions

NECA Labor Factor Score Sheet

Within the Labor Factor Score Sheet, score each condition between 1 and 5, with 1 being normal working conditions and 5 being the most difficult working conditions. For scores between 36 and 75 use the Normal column, between 76 and 134 use the Difficult column, and use the Very Difficult column for scores between 135 and 175.

Conditions	Considerations	Score
Working conditions	Indoor, Controlled environment, Extreme conditions	
Working height	Up to 10', 10'-20', 20' +, Ladders/lifts/scaffold, Below grade	
Building height	Number of floors 1-3, 4-7, High-rise	
Building sq. ft.	Manageable, Moderate, Excessive	
Project size in dollars	Normal, Moderate, Extreme	
Site size	Urban setting, Ample laydown space	
Job conditions	New construction, Remodel, Work while occupied	
Type of construction	Frame, Block, Concrete or exposed	
Hours worked	40 hours/week; 5, 6 or 7 day work week; 8,10 or 12 hour work day	
Shifts	Day, 2nd, 3rd	
Crew density	Normal, Moderate, Extreme	
Project duration	Normal, Compressed, Delayed, Fast track	
Safety	Standard OSHA guidelines, Customer directives, Project specific	
Clean-up	Routine, No dust, Clean room condition	
Installation	Repetitive, Moderate repetitive, No repetition	
Systems	Common systems, Special, Complex	
Conduit type	PVC, EMT, Flex or GRC, IMC, Aluminum, PVC coated GRC	
Accessibility of work area	Unlimited, Limited, Escorted	
Voltage	0-600V, 600-5Kv, Over 5Kv	
Inventory of local supplier	Adequate, Moderate, Limited	
Proximity of stored materials	On site, In general area of project, Remote	
Project continuity	Interruptions: None, Moderate, Extreme	
Construction	Standard, Poor, None	
Drawings/plans	% Complete, 100%, 95%, 50%, 35%, Less	
Information	Timely, Delayed, Limited	
Change order quantity/timing	Minimal, Moderate, Excessive/Prior to installation, During, After	
Craft coordination required	Minimum, Moderate, Extensive	
Authority having jurisdiction	Experience with type of project: Considerable, Moderate, Limited	
Decision making	Timely, Delayed, Limited	
BIM Building Integrated Modeling	General/Owner uses BIM proactively, Is moderately proactive, Just used to satisfy a contract condition	
Project schedule	As planned, Compressed/extended, Moderately, Extreme	
General contractors on same jobsite	Single prime, Two primes, Three + primes	
Job meetings	Regularly scheduled, Crisis meetings, Minimal	
Shared responsibility for project	One EC, Two EC's, Three + EC's on site	
Tools/equipment	Standard, Non-standard, Specialty	
Labor availability	Readily, Moderately, Limited, Non-available	
	Total Score	

The NECA Labor Factor Score Sheet may be duplicated by purchasers of the Manual of Labor Units for the purposes of calculating project score. This document is also available online at www.necanet.org/MLU.

Figure 10: NECA Labor Factor Score Sheet

NECA Manual of Labor Units
2021-2022 Edition

Section 8: Division 26—Electrical

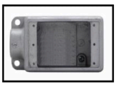
	Description	Rev	Normal	Difficult	Very Difficult	Company Experience	Unit
	**Conduit Body (Condulet) Covers - Steel, Aluminum, PVC, PVC Coated (includes gasket when required)**	X					
	1/2-inch	X	0.15	0.18	0.20		E
	3/4-inch	X	0.15	0.18	0.20		E
	1-inch	X	0.15	0.18	0.20		E
	1 1/4-inch	X	0.18	0.20	0.22		E
	1 1/2-inch	X	0.18	0.20	0.22		E
	2-inch	X	0.20	0.22	0.24		E
	2 1/2-inch	X	0.22	0.24	0.26		E
	3-inch	X	0.24	0.26	,28		E
	3 1/2-inch	X	0.26	0.28	0.30		E
	4-inch	X	0.26	0.28	0.30		E
	**Iron FS & FD Threaded 1-Gang Boxes**						
	1/2-inch One Hub		0.60	0.75	0.90		E
	3/4-inch One Hub		0.70	0.85	1.05		E
	1-inch One Hub		0.85	1.05	1.25		E
	1/2-inch Two Hubs		0.80	1.00	1.20		E
	3/4-inch Two Hubs		0.95	1.15	1.40		E
	1-inch Two Hubs		1.15	1.40	1.70		E
	1/2-inch Three Hubs		1.00	1.25	1.50		E
	3/4-inch Three Hubs		1.20	1.50	1.80		E
	1-inch Three Hubs		1.45	1.80	2.15		E
	1/2-inch Four Hubs		1.20	1.50	1.80		E
	3/4-inch Four Hubs		1.45	1.80	2.15		E
	1-inch Four Hubs		1.75	2.15	2.60		E
	**Iron FS & FD Threaded 2-Gang Boxes**						
	1/2-inch One Hub		0.65	0.80	1.00		E
	3/4-inch One Hub		0.75	0.90	1.10		E
	1-inch One Hub		0.90	1.10	1.35		E
	1/2-inch Two Hubs		0.85	1.05	1.25		E
	3/4-inch Two Hubs		1.00	1.25	1.50		E
	1-inch Two Hubs		1.20	1.50	1.80		E
	1/2-inch Three Hubs		1.05	1.30	1.55		E

Figure 11: Sample Page from the NECA Manual of Labor Units for Section 8 of Division 26 Items

Note that there are other trades that have similar resources, such as the online Mechanical Contractors of America Association (MCAA) Web-based Labor Estimating Manual, or the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Cost Reference Manual for Sheet Metal and HVAC. Many trade contractors will use these more detailed guides to calculate labor hours, and then apply multipliers to the labor hours based upon their perception of the project conditions, e.g., if it is a project that may support high levels of production due to prefabrication, good planning, and detailed modeling, they may apply a multiplier below 1.0, but if the project will be challenging, they may apply multipliers above 1.0 when calculating the overall labor hours. These hours will then be combined with detailed estimates of material, equipment, overhead and profit line items to calculate the overall cost estimate.

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://psu.pb.unizin.org/buildingconstructionmanagement/?p=85#h5p-18

10.

PROCUREMENT AND PURCHASING

Learning Objectives

After reading this chapter, you should be able to:

- Describe how various trade contractor scopes of work are procured (purchased) on a construction project
- Understand the concepts of 'scope bust' and 'bid shopping'

In earlier chapters, we have discussed the various delivery methods used on projects. This chapter focuses on the logistics of how an owner and the lead prime contractor(s) proceed through the procurement (sometimes referred to as purchasing) process. We will start with discussing how an owner procures the lead prime contractor(s) for construction scopes of work. This may vary based on the selected organizational structure for the project team (e.g., design-bid-build, CM at Risk, etc.). It will also change based upon the selection approach (e.g., low cost, best value, negotiation).

The Owner's View

In general, an owner must first identify and define the scope of the work to be procured. If the project is delivered using more integrated approaches, e.g., design-build or CM at Risk, the level of definition will most likely be less specific than if it is a design-bid-build which will have a completed design before procuring the contractor(s). Regardless, the scope must be defined to procure the entity(s) that will perform the construction.

After the scope is defined and documented, the owner will determine the qualifications needed for a contractor to submit a proposal or bid for the project. Then the owner will most likely prequalify the contractors. This may be a very simple process, or it could be extensive, requiring contractors to submit their qualifications for review and evaluation. For example, at Penn State, some projects simply require that the contractors are part of the approved bidder list, which is relatively easy for a contractor to be accepted. Others may have what is termed a 'two-step' process where the contractors are first downselected via a formal prequalification process (through a Request for Qualification (RFQ)), and then a detailed bid/proposal is submitted by the smaller number of prequalified contractors. On larger projects, this downselect may aim to reduce the number of bidders to approximately three companies. In summary, a two-step process has an initial Request for Qualifications (RFQ), followed by a Request for Proposal (RFP) or solicitation for bids from the downselected qualified bidders.

The Contractor's View

For a contractor to submit a bid (or proposal) for a project, they need to develop a detailed construction cost estimate and compile them into their bid value (or budget value if it is a Guaranteed Maximum Price payment method). When a contractor receives the scope of work for the project from the owner, they will need to determine which portions of the work they will self-perform (if selected) and which portions of the work they will subcontract to other companies. For example, if a construction manager is putting together a proposal for a large building, they may decide to subcontract almost 100% of the direct work. If it is a smaller building with a multi-trade general contractor, they may choose to self-perform nearly their entire scope of work.

Once they decide the subcontracted work scope, they will need to develop a series of 'bid packages' that define the scope of work for each trade or subset of work that they plan to subcontract. For a building project, these subcontractor scopes of work are frequently defined by the scope of work within a particular section within the project specifications. For example, a construction manager may seek bids for the structural concrete work (in CSI MasterFormat Division 03), so the bid package may be defined by the scope of work for Division 03, possibly with some exclusions and additions. If the project specifications document is well defined, it makes defining a clear scope of work for hiring a trade much easier. If the project design and specifications are not well documented, this task is more difficult since the contractor must be very clear in developing the scope documentation for any subcontracted work.

When developing the bid packages, the contractor must make sure that they have each scope of work covered within their pricing, but they should not include a scope of work in two different bid packages. If a scope of work is not covered at all, it is referenced as a 'scope bust', which means that the scope of work is not included in any trade scope and is also not planned to be self-performed. Eventually, someone will need to perform this work and be paid for this work if the contractor wins the contract. Therefore, this will cause them to incur unanticipated costs and could cause them to be over budget. A contractor also does not want to include one scope of work in two different bid packages. This would cause the contractor's bid value to be artificially high, and if they do win the project, they could inadvertently pay for a specific scope of work twice if they do not realize that there is redundant scope in two subcontracts. This is refered to as 'scope redundancy'. If they identify this redundancy, they can direct one trade to not perform the work, and request a deductive change order to the subcontract. When this occurs, it can be difficult for the prime contractor to get 100% of the value back from the subcontractor in the negotiations for the deductive change order value.

After defining the scopes of subcontracted work into documented bid packages, the prime contractor will solicit bids from potential specialty trades (sometimes referred to as subcontractors). The contractor may select specific companies that they feel comfortable working with, or they may put out a broad call for companies to bid on the specific scope. It will typically take several weeks (2 or 3) on larger projects for the specialty trades to compile and submit their bids to the prime contractor. During this time, the prime contractor will also be developing their own detailed estimate for their self-perform work scopes along with their general conditions costs, including their management and general work to maintain the site. They may also perform assemblies estimates for specialty trade scopes of work so that they have a comparison number when they receive the bids from the trade contractors.

All scopes of work with have a bid due date and time. The contractor must compile their overall cost estimate/proposal prior to the deadline. If it is a competitive bid, the due date and time are typically non-negotiable and all late bids will typically not be accepted. This is particularly true in government contracts where the owner may be legally bond to not accept any late bids. When the prime contract compiles their bids, they will obtain bids from each of the specialty trade contractors for the predefined scopes of work. They will typically seek at least three bids for each of the scopes of work that they have defined in order to ensure that they are receiving competitive pricing. Note that this is not always the situation. For some projects, the prime contractor may prefer to work with a specific company for a specific scope of work, e.g., a specific mechanical contractor. In these cases, the prime contractor may simply negotiate a price with the preferred specialty contractor.

Finally, the prime contractor will compile the final cost and submit their bid to the owner. Note that this is frequently not just one number, but a bid form will be completed by the prime contractor which may ask for a variety of values if scopes are added or removed from the project. This allows an owner to make decisions on the overall project scope based on the bid amounts along with alternative scope pricing.

Depending on the selection method, the prime contractor will be selected either based upon the low cost only or based upon the overall value, combining the cost and plus a quantitative evaluation of the contractors qualifications. Once selected, the owner will sign a contract with the contractor, possibly after some negotiation of detailed terms, and the contractor will then select and sign a subcontract with each specialty trade, potentially following some negotiation of terms with the trade contractors.

It is important to note that sometimes the prime contractor will aim to reduce the cost within a subcontract with the specialty trade through negotiations with the trade following the bidding process. Having discussions regarding costs is relatively typical, but it is important to note that contractors should not share the pricing information from one specialty trade with another specialty trade in order to try to get them to reduce their overall bid value. This is referred to as 'bid shopping', and while it may not be illegal, it certainly can be considered unethical. The prime contractor and potential subcontractors should always negotiate in good faith to come to an acceptable agreement. Examples of items that may be negotiated include the specifics of scopes, e.g., it may be lower cost or easier to move a defined portion of work from one trade to another (e.g., moving mason angle purchase from a mason to steel fabricator scope), discussions of support resources (e.g., the use of a shared crane to assist with material handling), or discussions of schedule and other requirements that may impact the work. Ideally, these would be discussed in the original bids, but this level of detailed planning may not occur until a contractor is notified of the intent to award a contract. Larger general contractors may have dedicated staff assigned to this purchasing role, focused on getting the final subcontracts negotiated and under contract.

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://psu.pb.unizin.org/buildingconstructionmanagement/?p=87#h5p-19

11.

VALUE ENGINEERING

Learning Objectives

After reading this chapter, you should be able to:

- Define Value Engineering in the context of delivering a construction project.
- Understand the core characteristics of a valuable VE element.

Defining Value

The key word in 'value engineering' is 'value'. One common definition of value is 'what an owner is willing to pay for'. This leaves a lot to be defined, but certainly clarifies that the project team should be focused on providing benefit to an owner, the entity that is ultimately paying for all costs on a project. This requires the clear interpretation of 'what provides value to the owner'.

Another way to look at value is through an equation, where value = Function Performance / Resources.

Defining Value Engineering (VE)

Value Engineering (VE) is defined by the Office of Management and Budget as 'an organized effort directed at analyzing the functions of systems, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life-cycle cost consistent with required performance, reliability, quality, and safety. (OMB, Circular No. A-131, 1993). In the Whole Building Design Guide, Cullen (2016) defined Value Engineering as 'a conscious and explicit set of disciplined procedures designed to seek out optimum value for both initial and long-term investment.' There are several commonalities in these definitions, including:

- **Life-cycle cost:** A focus beyond just design and construction costs
- **Value optimization:** Seeking cost-effective solutions to optimize the value to the owner
- **Disciplined process:** The team should apply a conscious and disciplined process

It is also important to note items that should not be considered within the definition of value engineering. Cullen (2016) states 'Value Engineering is not a design/peer review or a cost-cutting exercise.' This is very important to note since many people may refer to cost-cutting approaches as VE, when they are simply trying to reduce cost and reduce value at the same time.

The Value Engineering Process

A key element of VE is to ensure that you follow a rigorous, documented process. There is not one commonly accepted standard process, but there are several documented process descriptions that you can follow. One option is the process defined within the VE

A more concise process has been outlined by SAVE International () in their Value Methodology Guide. This process contains 8 steps

1. Preparation:
2. Information:
3. Function Analysis:
4. Creativity:
5. Evaluation:
6. Development:
7. Presentation:
8. Implementation:

https://www.value-eng.org/page/AboutVM

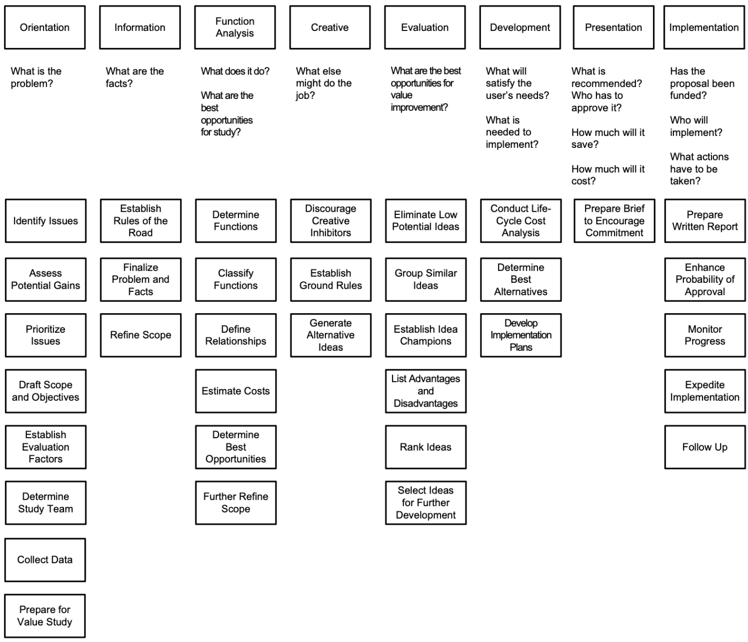


Figure 5. Depiction of VE Job Plan Phases

Fig. 1: Depiction of VE Job Plan Phases

as prescribed by SAVE International:

The VE Job Plan follows five key steps:

Information Phase

Speculation (Creative) Phase

Evaluation (Analysis) Phase

Development Phase (Value Management Proposals)

Presentation Phase (Report/Oral Presentation)
These five key steps are described as follows:

Examples of Value Engineering Proposals

VE Process Documentation

The outcome of the VE process should be monitored and managed. One part of monitoring the process is to maintain a log of the VE suggestions. Most collaborative online project management tools have a location to manage and track VE proposals in an online database. Alternatively, a designer or contractor can track VE proposals in a simple spreadsheet. An example setup with several simple sample proposals in Figure 2.

Value Engineering Proposal Log

Project Name
Project Number

VE Proposal No.	Description	Date Submitted	Date of Decision	Building Documents/ Components	Trades	Redesign Impact (Y/N)	Schedule Impact? (Y/N)	Cost Confirmed (Y/N)	Proposed Cost Revision	Decision (Accept/ Reject)	Comments
001	**Revise Roof Joist Size for Consistent Size**	7/23/22	8/30/22	Roof structural plans	Steel	Y	N	Y	$ (2,600)	**Accept**	Consistent joist size will reduce steel fabrication costs.
002	**Minor plumbing location revisions to enable prefabrication**	7/30/22	9/5/22	Plumbing plans	Plumbing	Y	Y	Y	$ (39,000)	**Accept**	
003	**Allow Viega ProPress plumbing fittings substitution**	8/2/22	9/18/22	Plumbing specifications	Plumbing	N	Y	Y	$ (32,400)	**Accept**	ProPress fittings will enable faster installation and productivity
004	**Revise flooring in lobby from terrazo to polished concrete**	8/13/22	10/2/22	Floor plans and flooring specifications	Concrete and Flooring	Y	N	N	$ (28,000)	**Reject**	Owner prefers terrazo finish. Proposed to decrease cost and improve sustainability.
005	**Add green roof to portion of roof**	8/20/22		Roof structure, roof plan, specifications	Steel, Roofing, Concrete, Plumbing	Y	N	N	$ 130,500		Added construction cost but reduced lifecycle energy cost. 9 year estimated payback.

Figure 2: Value Engineering Proposal Log Example

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://psu.pb.unizin.org/buildingconstructionmanagement/?p=99#h5p-5

References and Additional Resources:

Cullen, S. (2016). 'Value Engineering.' *Whole Building Design Guide*, National Institut of Building Sciences. accessed on May 25, 2022, available at https://www.wbdg.org/resources/value-engineering.

Office of Management and Budget. (1993). 'Subject: Value Engineering.' *Circular No. A-131*, available at https://georgewbush-whitehouse.archives.gov/omb/circulars/a131/a131.html

Office of Deputy Assistant Secretary of Defense. (2011).

12.

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 as well as the home office overhead costs. These costs do not directly contribute to the final facility, but they are necessary to manage the delivery of a 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. These costs can be separated into the Direct Overhead (specific to a project) and Indirect Overhead (related to home office expenses). Gordian has developed a checklist for the costs in each of these two categories (see Figure 1 with project overhead on the left and home office overhead on the right).

Construction Estimating Checklist

Direct Overhead Costs (Project Overhead)

Personnel

- ☐ Superintendent
- ☐ Project manager (if for that project only)
- ☐ Field engineer (if for that project only)
- ☐ Cost engineer (if for that project only)
- ☐ Scheduler
- ☐ Warehouse personnel (if for that project only)
- ☐ Watchman/guard dogs
- ☐ Tool room keeper (if for that project only)
- ☐ Tool room keeper (if for that project only)
- ☐ Timekeeper (if for that project only)
- ☐ Foreman (if for that project only)
- ☐ Site safety manager

Bonds

- ☐ Surety
  - ☐ Bid
  - ☐ Payment
  - ☐ Performance

Miscellaneous

- ☐ Vehicles
- ☐ Permits
- ☐ Licenses
- ☐ Tools and equipment
- ☐ Photographs
- ☐ Surveying
- ☐ Testing
- ☐ Job signs
- ☐ Pumping
- ☐ Dust control
- ☐ Scaffolding
- ☐ Lifting/hoisting
- ☐ Cleanup (periodic)
- ☐ Final cleanup
- ☐ Damage/repair to adjoining buildings and/or public ways

Temporary Facilities

- ☐ Field office expense
  - ☐ Set-up and removal
  - ☐ Light
  - ☐ Water
  - ☐ Telephone/internet
  - ☐ Supplies
  - ☐ Equipment
  - ☐ Fax machine
  - ☐ Copy machine
  - ☐ Blueprint machine
  - ☐ Coffee machine
  - ☐ Computers/software
- ☐ Temporary light and power
- ☐ Temporary heat
- ☐ Temporary water
- ☐ Cell phones/radios
- ☐ Toilet facilities
- ☐ Enclosures
- ☐ Storage trailers
- ☐ Fencing
- ☐ Barricades and signals
- ☐ Construction road
- ☐ Project sign

Indirect Costs (Main Office Overhead)

Salaries

- ☐ President
- ☐ Executives
- ☐ Secretaries/reception
- ☐ Estimators/schedulers
- ☐ Project managers
- ☐ Construction manager
- ☐ Cost engineers
- ☐ Purchasing agent
- ☐ Cost/bookkeeping
- ☐ Engineers
- ☐ Other office personnel
- ☐ Yard personnel
  - ☐ Tool manager
  - ☐ Mechanics/maintenance
  - ☐ Drivers
  - ☐ Equipment operators

Office

- ☐ Rent/cost of ownership
- ☐ Electricity
- ☐ Gas
- ☐ Water
- ☐ Sewer
- ☐ Telephone
- ☐ Internet
- ☐ Postage
- ☐ Office equipment
- ☐ Furniture/furnishings
- ☐ Office supplies
- ☐ Advertising
- ☐ Literature
- ☐ Club/association dues

Professional Services

- ☐ Legal
- ☐ Accounting
- ☐ Architectural
- ☐ Engineering

Vehicles

- ☐ Cars/trucks
- ☐ Cost of operation
- ☐ Mileage expenses

Insurance

- ☐ Fire
- ☐ Property damage
- ☐ Vehicles
- ☐ Public liability
- ☐ Windstorm
- ☐ Workers' compensation
- ☐ Unemployment
- ☐ Social security
- ☐ Flood
- ☐ Theft
- ☐ Elevator

Figure 1: Gordian Construction Estimating Checklist for Project and Main Office Overhead

The remainder of this chapter will focus on Direct Overhead costs, which are specific to the project. These project-related costs are typically referred to as the 'general conditions' costs. 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 defined within a separate contract document. To identify a cost for many of these items, an estimator can reference the CSI MasterFormat Section 01 within the Building Construction Cost Estimate Guide with RS Means Data. 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.

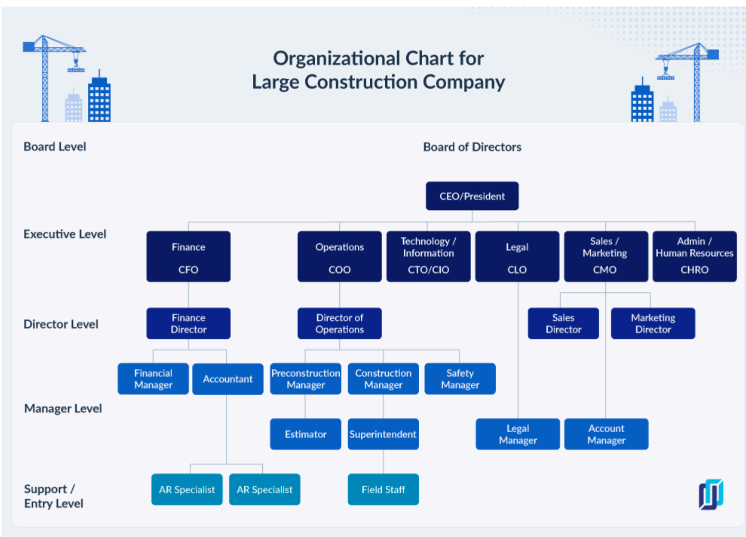


Figure : Typical Organizational Chart for Large Construction Company (Source: Levelset)

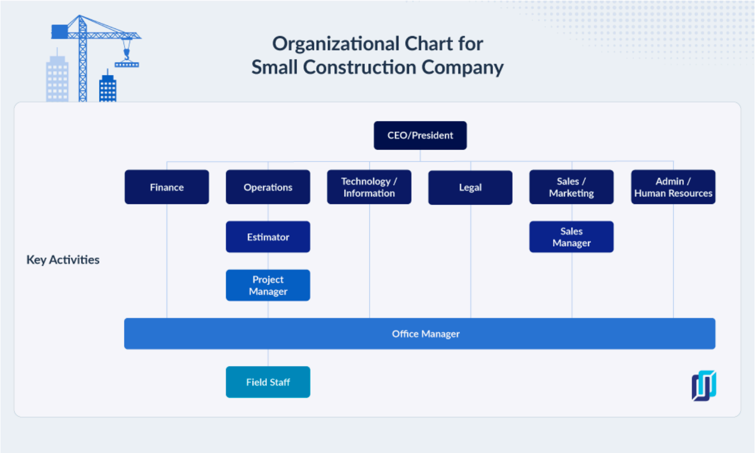


Figure : Typical Organizational Chart for a Small Construction Company (Source: Levelset)

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

The Field Supervision staff is responsible for managing the field operations along with ensuring that the field operations have everything that they need to be successful. While everyone on a project is responsible for safety, the field supervision staff has an added role of ensuring that there is a lead safety representative whenever there are field employees performing construction activities on the site.

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://psu.pb.unizin.org/buildingconstructionmanagement/?p=89#h5p-20

13.

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.
- Be able to define and draw a site utilization plan for a project.

Site Utilization Planning

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 1 provides typical items that should be included in a Site Utilization Plan. Figure 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 1: Site Utilization Plan Checklist

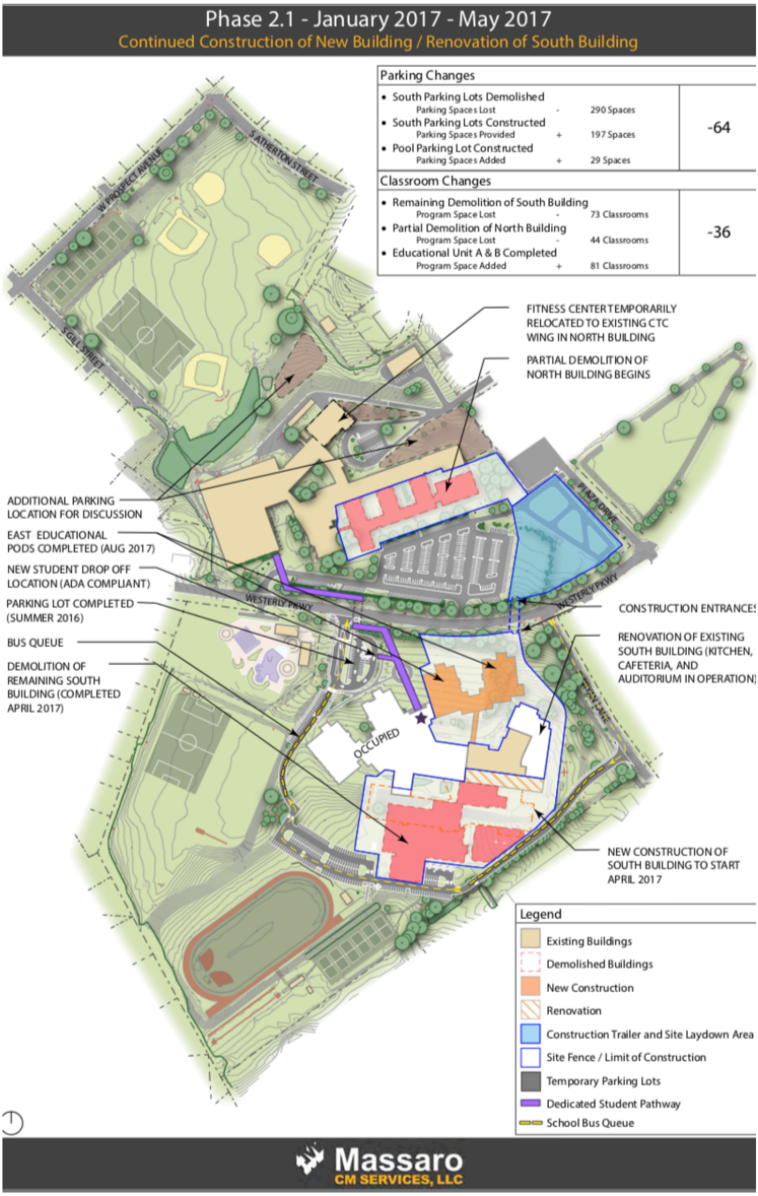


Figure 2: Sample Site Utilization Plan (Source: Massaro Construction)

4D Modeling:

A site utilization plan can be incorporated with a Critical Path Method (CPM) schedule to develop a visualization model of the construction sequence for a project, known as a 4D model (3D geometry + time as the 4th dimension). These models can be fairly simple or very elaborate depending upon the level of detail of both the 3D model and the detail contained within the 3D model. Some simply show the final building elements, while others contain temporary equipment, site elements, formwork, etc. An example of a 4D model of the U.S. Bank Stadium construction can be found at this link.

Review Questions

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14.

INTRODUCTION TO PROJECT SCHEDULING

Learning Objectives

After reading this chapter, you should be able to:

- Define the different types of schedules that may be developed for managing the activities and phases of a project
- Understand the purpose of various schedule types and presentation approaches
- Understand the complexity and planning effort required to develop different types of schedules

Introduction to Project Scheduling for Construction Projects

A project schedule …

4D Modeling:

The previous chapter defined 4D modeling as an approach to visualize the changing conditions on a project site. A 4D model can be a very valuable scheduling tool, both for developing a schedule and visualizing/analyzing the schedule.

Questions

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can view it online here:
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15.

NETWORK SCHEDULING

Learning Objectives

After reading this chapter, you should be able to:

- Define the various terms used in the development of network schedules, e.g., critical path, total float, and free float.
- Develop a network diagram of a schedule and calculate the start/finish times and float values.
- Identify the critical path activities within a network diagram which includes float time values.

Network Scheduling

Network scheduling, sometimes referred to as Critical Path Method (CPM) scheduling, is a detailed method for creating a connected schedule that calculates the schedule duration for a project. These schedules are

Developing a Network Schedule

There are multiple types of visual notations for representing a schedule. Three approaches include:

- Activity on Arrow
- Precedence Diagram (also known as Activity on Node)
- Gantt Chart View

Activity on Arrow

The least frequently used visual representation of a schedule is the Activity on Arrow notation. In this visual notation, each activity is represented by an arrow (a line with an arrowhead at the end). The relationships are represented through nodes.

It is important to note that this representation is not frequently used, and is included in this book simply to allow everyone to understand the basics of the representation. We will not use this approach in any calculation examples.

Activity	Predecessor	Duration
A	-	5
B	A	3
C	A	4
D	B	6
E	C	8
F	D, E	2

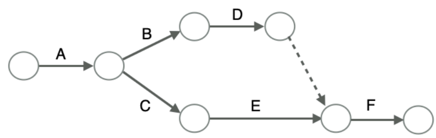

Figure 1: Network Diagram in Activity on Arrow Notation

Precedence Diagram

Precedence diagrams are the most common notation used for hand calculating a schedule, and can also be helpful in visualizing the interactions between activities. In precedence diagrams, each activity is represented as a box. In the most simple form, the box simply contains the name of the activity, but the box can also have other attributes for the activity, e.g., duration, start and end times, or float. We'll discuss these items when we start calculating schedules. The boxes are connected into the network using relationships which are represented by arrows. Some activities have durations, and others may be a milestone (an activity with no duration to represent a specific point in time). This notation is also sometimes referred to as Activity on Node, since the activities are represented by nodes (boxes) and the relationships are represented by arrows connecting the nodes.

Activity	Predecessor	Duration
A	-	5
B	A	3
C	A	4
D	B	6
E	C	8
F	D, E	2

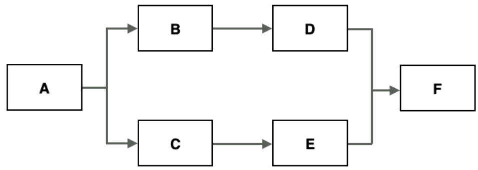

Figure 2: Activity Network in Precedence Notation

Defining the Activities

In precedence and Gantt chart representations, there are the following two types of activities:

- *Standard Activity:* Has a duration and represents a task on a project
- *Milestone Activity:* Represents a point in time, with zero duration. A milestone can be a start (with only a start date) or a finish (with only a completion date) milestone.

One of the first steps in developing a schedule is to clearly define the standard activities to be performed, and the critical milestones that are important to the project. For standard activities, these could be items such as 'place concrete in slab on grade', 'install windows on south face', 'paint corridor on 3rd floor', or 'erect tower crane'. Note that activities should always start with a verb (action) and include a clear element and/or location for the action, e.g., a building component (window), a location in the building or site, or a scope of work, such as a scope of the design. Activities can also relate to various design tasks such as 'complete schematic design', 'complete foundation design', or 'complete reinforcing steel shop drawings for slab-on-grade'.

The milestones should define discrete points in time on the project. They will not begin with a verb since it is defining a state or milestone of the project. They will have no duration, and they typically show up in a graphical schedule as a diamond with no duration. A milestone may be a start or finish milestone. It will typically only carry one date within the as-planned schedule, either a start date (for start milestones) or a finish date (for finish milestones). Examples of a start milestone may include 'Design Begins' or 'Notice to Proceed' (the date a contractor can proceed with construction). Examples of finish milestones include 'Design Complete', 'Excavation Complete', 'Steel Complete', 'Building Enclosed', 'Substantial Completion' (when the building can be used for its intended purpose) and 'Final Complete' (all work on the project is complete).

Relationship Types

Once the activities are defined, the relationships between activities need to be defined. There are four different potential relationship types between activities:

1. Finish-to-Start
2. Finish-to-Finish
3. Start-to-Start
4. Start-to-Finish

These four relationship types along with examples are defined in the following sections.

Finish-to-Start Relationship

The finish-to-start relationship is the most common relationship type within design and construction schedules. This relationship simply states that one activity must be completed prior to starting the second activity. There are many examples of this type of relationship within building projects, with some examples including 'Place Wall Foooting' prior to 'Construct Wall', or 'Install Drywall' prior to 'Paint Wall'. Examples during design could include 'Complete Schematic Design' prior to 'Complete Design Development'. Additional examples along with a graphical representation using activity on arrow, precedence diagram, and Gantt view are included in Figure 3.

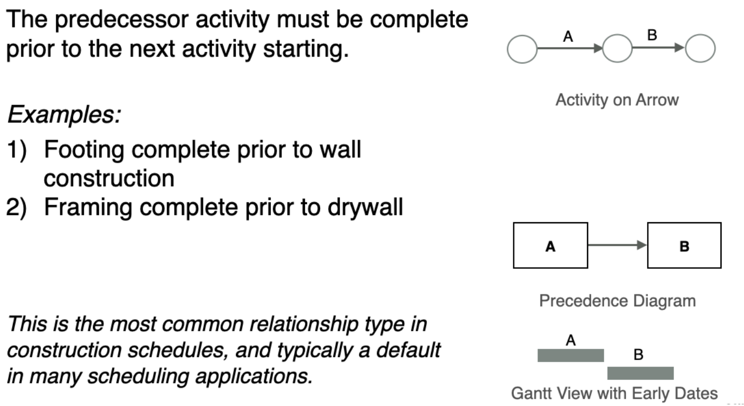

Figure 3: Finish to Start Relationship Definition and Graphical Representation

Some scheduling examples simply list 'predecessor' activities, e.g., see Figures 1 and 2. This implies that there is a Finish-to-Start relationship between the predecessor activity and the successor activity. In Figure 3, Activity A would be a predecessor to Activity B. Or, another way to state the same thing is that Activity B is a successor to Activity A.

Finish-to-Finish Relationship

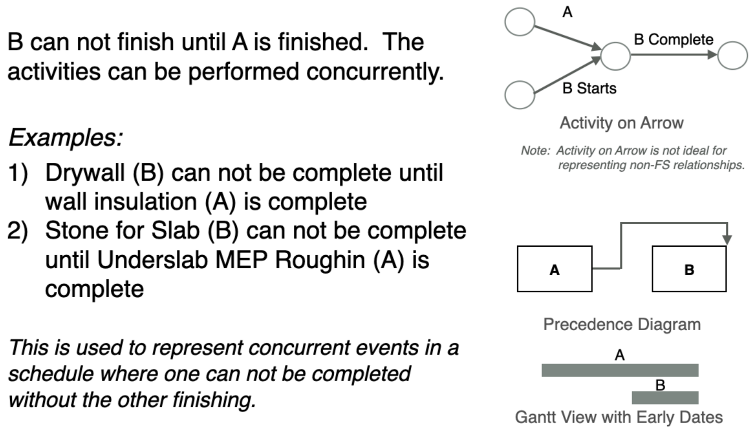

Figure 4: Finish to Finish Relationship Definition and Graphical Representation

Start-to-Start Relationship

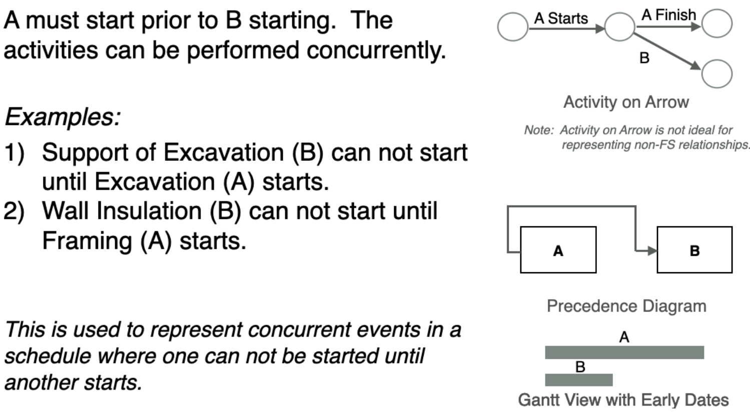

Figure 5: Start to Start Relationship Definition and Graphical Representation

Start-to-Finish Relationship

The start-to-finish relationship is very rarely used during project scheduling. It essentially states that an activity (B) can not finish unit an activity (A) has started. This activity can be used within a schedule to essentially fix the completion date of one activity (B) to the start date of another activity (A). Examples could include 'Remove Trailer' is finished when 'Perform Landscaping' is started, meaning that you are assuming that you will be removing the trailer prior to starting the landscaping. Another example could be that 'Cleanup Bulk Trash' is finished when 'Remove Trash Chute' is started, meaning that you would assume (or require) that all bulk trash be cleaned up prior to removing the trash chute. Again, this relationship type is very rarely used on projects. Graphical representations using activity on arrow, precedence diagram, and Gantt view are included in Figure 6.

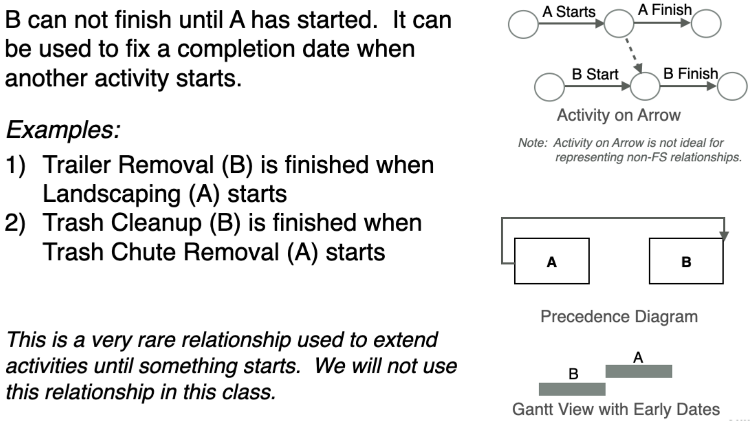

Figure 6: Start to Finish Relationship Definition and Graphical Representation

Developing a Network Diagram

Calculating the Activity Durations

Each standard activity will have a duration with some time unit (e.g., hours, days, weeks, etc.). For the purposes of this book, we will focus on the use of days as the standard time unit unless otherwise noted. For some very time critical schedules or more detailed schedules, planners may use hours or even minutes for activity durations.

Team members can use many potential information resources when determining the duration for a standard activities. They may reference their previous project data to identify the duration for some activities, e.g., the time to receive a permit within a particular municipality or the time to excavate a similar project. For more typical activities, it is beneficial to be able to identify a production rate and scope quantities for the activity. For example, if you are performing excavation for the building, you may measure the excavation quantity in cubic yards of earth. Then, a production rate per day can be used to define the overall activity duration, e.g., if you can excavate 200 cy per day, then if you have 1,000 cy of excavation, the duration will be 5 days.

Duration = Total Activity Quantity / Quantity per Time Unit

Duration = 1,000 CY / 200 CY per Day = 5 days

If you do not have historical data from previous projects to rely upon, then the R.S. Means data within the Gordian Guides can be used to estimate the daily output for a standard activity for one crew (see Figure 7). For example, if you have cast-in-place 12″x12″ square columns, a Crew C-14A can put in place an average of 11.96 CY per day (see line 03 30 53.40 0700 in Figure 7 – Crew in the column marked 5, unit of measure in the column marked 8, and daily output in the column marked 6). Note that you can also calculate the labor hours, which considers the number of people on the crew. We would not use labor hours in the schedule calculation unless you have a crew composition that varies from the defined crew sizes in the RS Means data.

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 (1)		(4)	Crew (5)	Daily Output (6)	Labor-Hours (7)	Unit (8)	2018 Bare Costs (9) Material	Labor	Equipment	Total (10)	Total Incl O&P (11)
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. (3)	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
(2) 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 7: R.S. Means Data in Gordian Guide showing Daily Output value in Column Marked with a 6

Calculating the Start and Finish Times for Activities

Once a network is developed, including all activities and the relationships between activities, then the schedule times for the network can be calculated. Th

Network Scheduling Software

While this chapter has reviewed a detailed approach to calculating a network schedule by hand, it is important to note that almost all network schedules on construction projects are performed by using some form of computer software. Two common software applications used in the industry for CMP scheduling are Microsoft Project and Oracle Primavera P6 EPPM. In general, Microsoft Project is lower cost and easier to learn, but has less functionality related to Primavera P6.

Microsoft Project is part of the Microsoft Office 365 suite of tools, but it is not a typical application that many organizations purchase within their corporate Office 365 suite. It is fairly easy to use, with many people using the default Gantt chart view to develop their schedule. There are many tutorials available online to learn how to use MS Project.

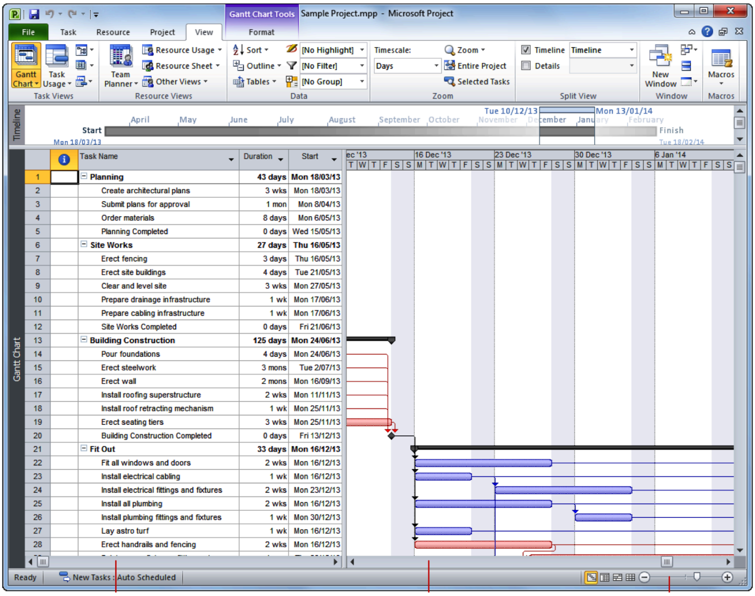

Fig : Sample Microsoft Project – Gantt View

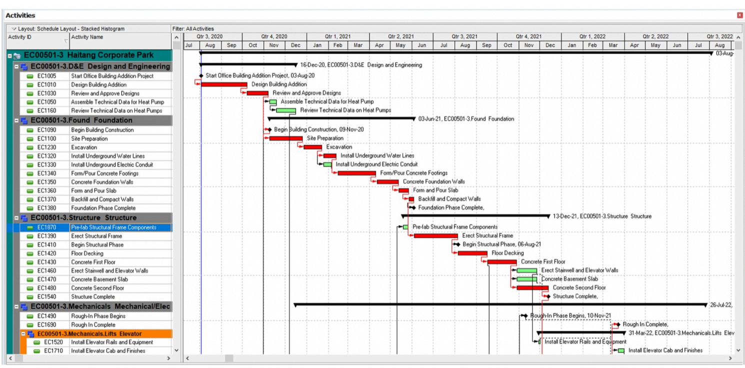

Fig : Sample CPM schedule in Primavera P6 EPPM shown in Gantt Chart view

For Penn State students, both Microsoft Project and Primavera P6 are available to you in the computer labs. We will first learn Microsoft Project in this course and then use Primavera P6 in the more advanced construction courses.

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://psu.pb.unizin.org/buildingconstructionmanagement/?p=97#h5p-25

16.

RISK MANAGEMENT

Learning Objectives

After reading this chapter, you should be able to:

- Understand the concept and core definitions related to risk management approaches for building construction projects.
- Identify the different types of risk management instruments used to manage project risks.
- Define the main types of insurance and bonds that owners, designers, and constructors may use on a project, along with understanding the frequency of use.

The Risk Management Process

Bonds and Their Application in the Delivery Process

Insurance and Their Application in the Delivery Process

Review Questions

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https://psu.pb.unizin.org/buildingconstructionmanagement/?p=101#h5p-26

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.

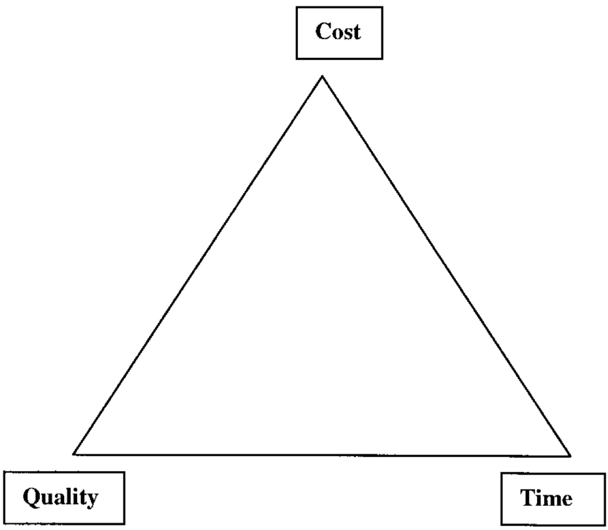

Fig. 17.1: The Iron Triangle (Source: Atkinson 1999)

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

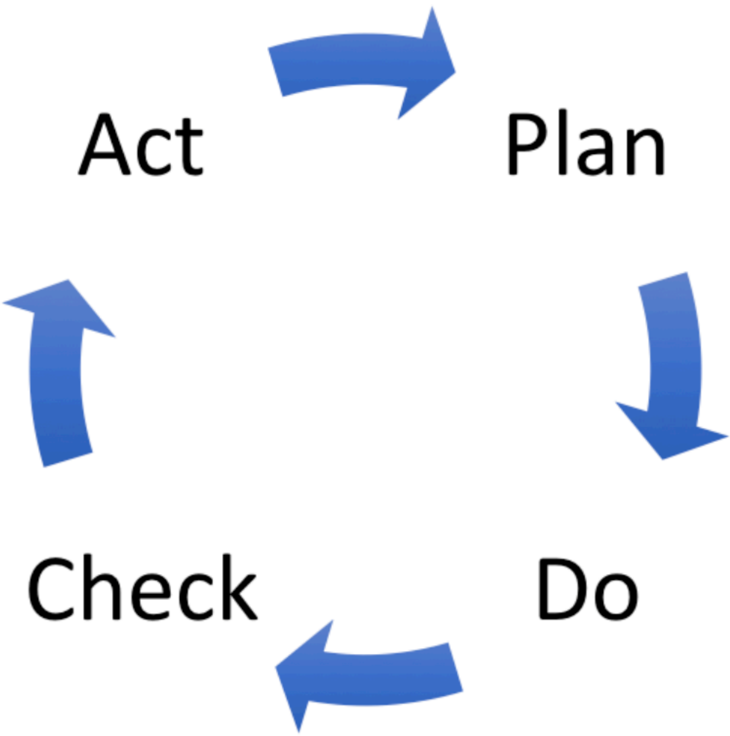

Fig. 17-2: Plan-Do-Check-Act (PDCA) Cycle (source: Skhmot 2017)

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.

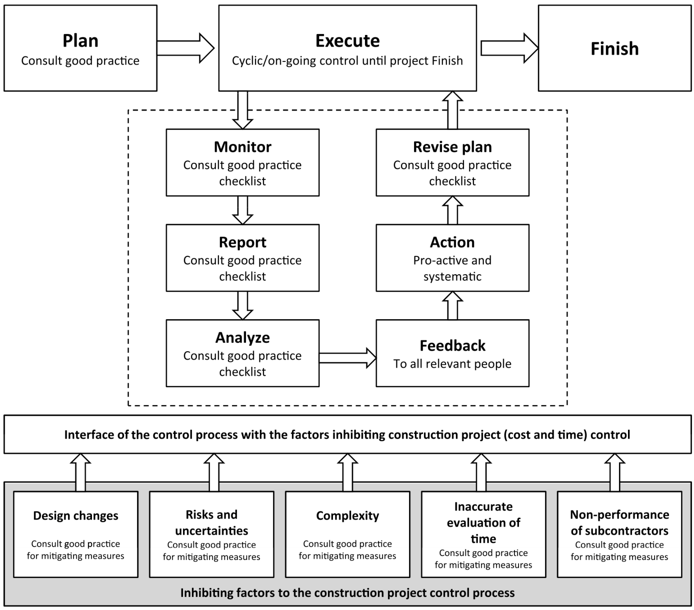

Fig. 17-3: Project Control and Inhibiting Factors Management Model (PCIM model) (Source: Olawale and Sun 2013)

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

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https://psu.pb.unizin.org/buildingconstructionmanagement/?p=106#h5p-27

18.

SCHEDULE MANAGEMENT

Learning Objectives

After reading this chapter, you should be able to:

- Understand the approach and information needed to update a construction schedule
- Identify the schedule impact of job progress on an as-planned schedule following a schedule update
- Describe the concepts related to schedule optimization, schedule reduction, and resource loading of a CPM schedule

Review Questions

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19.

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. **Cost Management** has been defined by Gartner (2022) as 'the process of planning and controlling the costs associated with running a business'.

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 its cash flow on any given project within the constraints of the contractual agreements so that it can maintain a higher level of funds within its 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 or prime contractor receives their payment.

Typical 'S Curve' Project Cash Flow

The Payment Process

On a typical general building project using common industry contracts, such as the AIA contract documents, the contractor will be paid on a monthly basis. In this section, we will review the typical payment process using the AIA contract documents in order to gain an understanding of the process along with the impact that this process has on an organization's cash flow.

Within the AIA document series, the template AIA

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Video 1: Completing a Payment Application with the AIA G703 Application and Certification for Payment

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Video 2: Completing the Continuation Sheet for the AIA G703 Application for Payment

Retainage

Common Errors in Payment Applications

1. **Late Submission:** If you submit your application late, either as a prime contractor or subcontractor, your payment may be delayed.
2. **Overbilling:** Never attempt to overbill for work that is not complete or materials that are not allowed to be included in the application for payment. Do not 'front end load' the payment application. Overbilling can cause a payment application to be rejected or delay payment due to having to revise the application.
3. **Forgetting Supporting Documents:** Make sure that you check the contract to identify all required documents and submit all required documents and backup so that the owner, and for a subcontractor, the general contractor, can easily evaluate the application.
4. **Calculation Errors:** Make sure that you double-, and triple-check your math on the payment applications. Using software can help ensure that you do not make errors on the payment application.
5. **Billing for Unapproved Change Orders:** The contractor is not due money for change orders that are not fully executed. This means that the change order is documented as a formal, signed change order by all

parties to the contract, e.g., the owner and contractor.

Review Questions

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20.

QUALITY MANAGEMENT

Learning Objectives

After reading this chapter, you should be able to:

- Understand the elements of a quality management program.
- Define quality planning, quality assurance and quality control.
- Determine core components of the various quality management program items.

Quality management is focused on planning for quality, developing processes and procedures to ensure quality design and construction, and performing testing to validate that a product meets the defined quality standard. These are defined within the Project Management Body of Knowledge as the three aspects of Quality Management (also see Figure 1):

1. Quality Planning
2. Quality Assurance
3. Quality Control

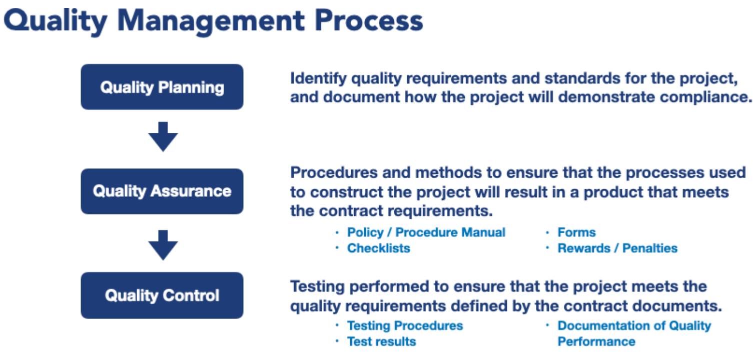


Figure 1: The Quality Management Process

Who is Responsible for Quality on a Project?

Just like everyone on a project is responsible for safety, it is also true that everyone should be participating in the management of quality. The quality management process starts very early in the lifecycle of a project.

The Owner's Responsibilities:

The owner plays a critical role in the quality management process. One of the most critical items in the delivery process is to ensure that the owner, possibly working with other service providers, develops a detailed program that outlines the overall quality goals and any specific requirements that they may have for the project. This program should set a clear picture of the expected levels of scope and quality for the project. A program can include qualitative information regarding the desired levels of quality on a project, along with specific quantitative and prescriptive descriptions, e.g., the size of various spaces or a specific material or system desired within a building. In addition to the program, many larger owners have their own set of design guidelines that outline specific requirements, e.g., preferences on material such as using rigid conduit instead of flex conduit in specific locations even if the building code would allow flex conduit. This combination of program and design guidelines informs the design process. If they are not well done, the owner may not obtain their level of desired quality (and scope).

Once a project enters the design process, the owner must continue to provide timely and decisive feedback related to the project design. Owners need to make many decisions, and for large owners, the process of managing all stakeholders can be an extensive task. For example, if a university is designing a classroom, office, and lab building, the owner will need to coordinate feedback from many user groups, including the academic units, lab managers, academic administrators, and the physical plant team that will maintain the building. Therefore, it can be challenging to get timely feedback for some decisions. Having an owner's representative who can provide timely feedback is critical to the success of projects.

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://psu.pb.unizin.org/buildingconstructionmanagement/?p=112#h5p-22

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 and general reporting requirements
- Understand the impact of construction accidents on projects

The Importance of Safety

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 development in the performance of their professional duties." (ASCE 2017)

The Top Risks and Accident Types

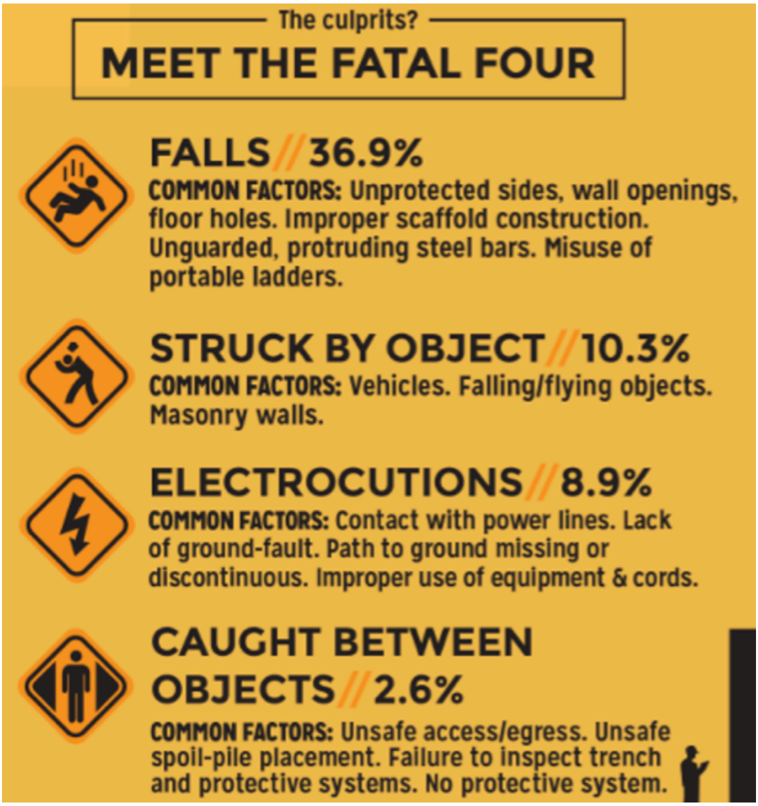


Figure : The Fatal Four: Top Four Accident Types for Construction Fatalities

Planning for Safety

Every project should have a custom project safety plan. This safety plan should include:

One important activity is to complete a Job Hazard Analysis for all core activities to be performed on the project. OSHA developed a brief booklet to outline an approach for developing a Job Hazard Analysis. The sample template included in this booklet is shown in Figure 2. The core process focuses on breaking down each core activity, e.g., bulk excavation, into specific tasks, e.g., 1) Excavate with excavator; 2) transport truck to excavation location; 3) load truck; and 4) transport truck to external site. For each of these tasks, the team should evaluate the specific hazards for the project, e.g., for task 1 related to excavation, the hazards may include overhead electrical lines in location of excavation, underground utilities in general location of excavation, and maintaining appropriate safety zone in the location of the excavation. Then hazard controls can be put into place to ensure that the hazards are minimized, e.g., marking overhead and underground utilities, etc.

Each trade on the project should be planning these details related to their activities and they should be shared with the lead constructor(s) of the project.

Sample Job Hazard Analysis Form

Job Title:	Job Location:	Analyst	Date
Task #	Task Description:		
Hazard Type:	Hazard Description:		
Consequence:	Hazard Controls:		
Rational or Comment:			

Figure : Sample Job Hazard Analysis Form (Source: OSHA)

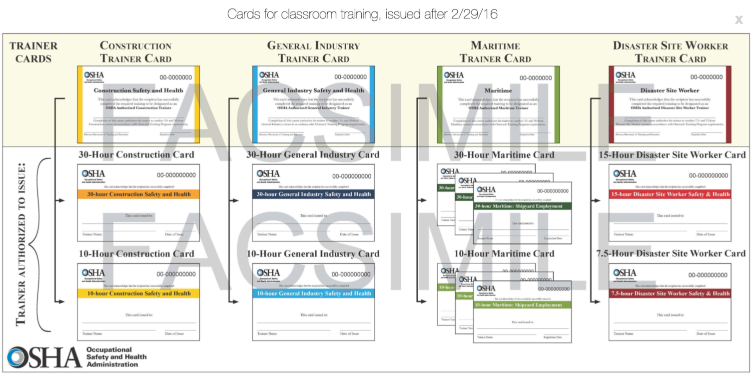


Figure : OSHA Training Cards (sample) for Construction, General Industry, Maritime, and Disaster Site Worker (Source: OSHA Website)

Safety Laws and Regulations

The Occupational Health and Safety Administration (OSHA) was initially formed by

The Impact of High-Quality Safety Programs

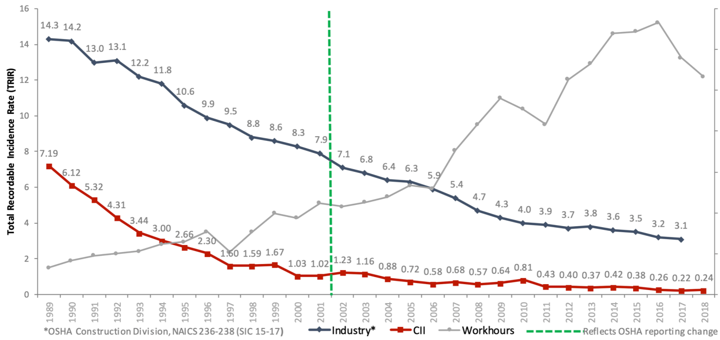


Figure 2. CII Members Reported TRIR (RIR) Rate, 1989-2018

TRIR = Total Recordable Incident Rate

Figure : CII Members Reported Total Recordable Incident Rate Compared to Industry Average (Source: CII 2019)

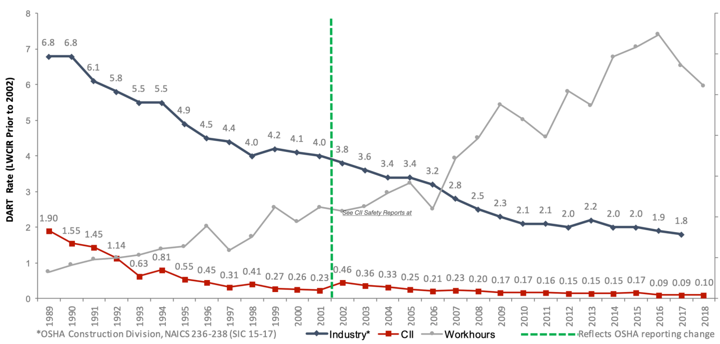


Figure 3. CII Members Reported DART (LWCIR) Rate, 1989-2018

DART = Days Away, Restricted or Transferred

Figure : CII Members Reported Days Away, Restricted or Transferred Compared to Industry Average (Source: CII 2019)

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://psu.pb.unizin.org/buildingconstructionmanagement/?p=114#h5p-30

References:

ASCE. (2017). ASCE Code of Ethics. Available at https://www.asce.org/uploadedFiles/About_ASCE/Ethics/Content_Pieces/Code-of-Ethics-July-2017.pdf

OSHA. (2022). Safety Standard for Construction, Regulation 1926, Available at https://www.osha.gov/laws-regs/regulations/standardnumber/1926

Construction Industry Institute (CII). (2019). CII Safety

Summary Report: Summary of CII 2018 Safety Rates. Construction Industry Institute, University of Texas at Austin, Available at https://www.construction-institute.org/securefile?filename=dpc2019_2.pdf#page=3

22. INFORMATION MANAGEMENT

Learning Objectives

After reading this chapter, you should be able to:

- Describe the various sources of information that are shared between project participants
- Describe the information management process
- Define the role of information management throughout the project lifecycle
- Understand the importance of contractual and non-contractual information

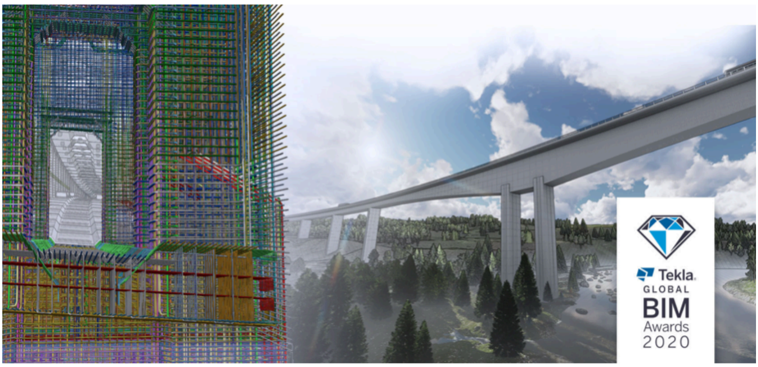
The management of the flow of information on a project is a critical task of the project management team. As one construction executive stated to our class, 'Information is the Lifeblood of a Project.'

Information Sources:

Design Information to support Construction (Construction Documents):

A core category of information on projects is the design information needed to support construction. This information has traditionally been embedded within the Construction Drawings (plans, sections, elevations, details, notes, etc.) and specifications (including the detailed product information and other requirements). Collectively, the drawings and specifications may be referenced as construction documents.

It is important to note that the use of 'documents' to transmit this construction information remains common practice, but there is a very limited number of projects that are arising that leverage a digital model as the main (or sole) source of construction information. One of the most advanced examples of the model as the legal document for construction information is the Randselva Bridge in Norway, a 2,000 feet long bridge that was constructed entirely from digital models without a single plan (see Figure 1). Again, this certainly is not common, but we are seeing more examples including several departments of transportation in the U.S. seeking to use a model as the contractual document for highway and bridge projects.



Tekla Global BIM Awards 2020 winner is Norway's Randselva Bridge – the world's longest bridge to be designed and constructed using only Bridge Information Modeling, and no traditional paper drawings.

Figure 1: Randselva Bridge: Digital Model for Construction with No Traditional Paper Drawings

Requests for Information (RFI):

A Request for Information (RFI) is …

https://www.procore.com/jobsite/the-anatomy-of-a-request-for-information-rfi/

Submittals:

Jobsite Daily Reports:

Correspondence Logs

There is a lot of correspondence (emails, notes, letters, etc.) on a construction project. This correspondence can address schedule items, permitting, construction details, financial issues, or many other topics. It is important that the correspondence between parties are captured and archived. This allows people to search for topics at a later date if needed. Ideally, this correspondence would be incorporated into a database that can be easily searched. On many projects, all correspondence is sent to a shared system via an email address to allow for the information to be filed in the project file.

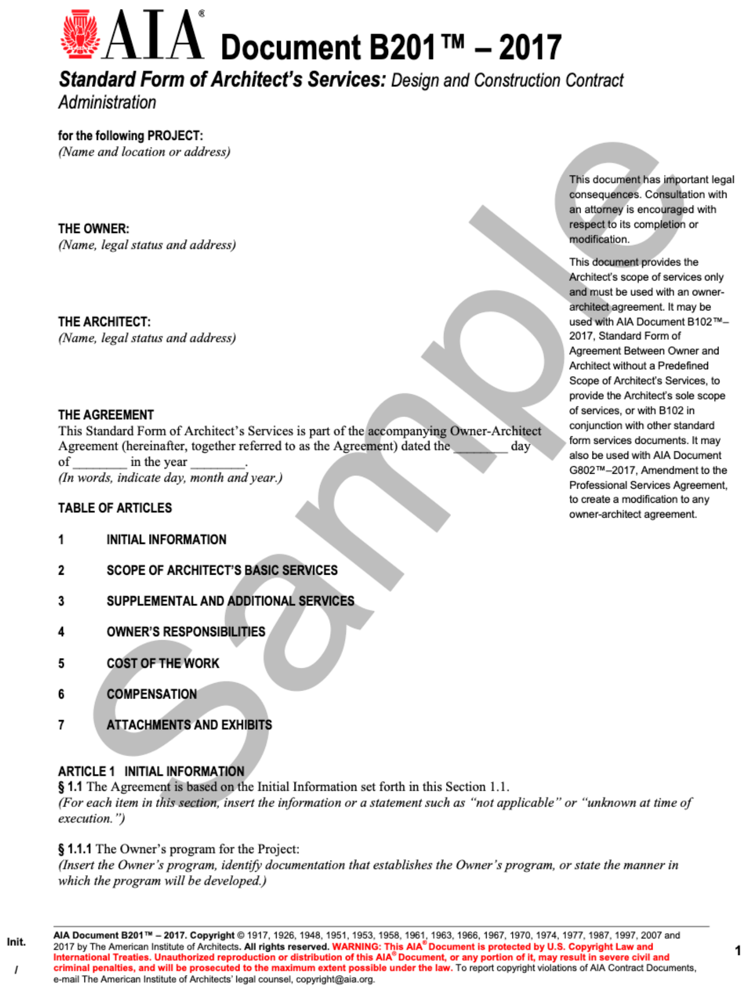
Meeting Minutes

Meeting minutes are notes that are taken to represent the discussions and decisions made during a meeting. Meeting minutes can be very important on construction projects as an approach to document the tasks that participants will perform and any decisions that are made. Meeting minutes should be documented and distributed to all participants and any other parties that may be impacted by the discussions and decisions made in the meeting. As a minimum, meeting minutes should include the time/date of the meeting, attendees, acceptance of any former meeting minutes, agenda items, a summary of discussions, identification of any future tasks with the responsible party and schedule deadlines, and documentation of any decisions or formal motions and vote outcome (if there are any votes).

Meeting minutes should ideally be posted to a collaborative project management system which allows for the easy search of any topics or decisions. It is important to note that if a decision is made within a meeting to proceed with work that is considered a change to the contract, the designer and/or constructor should notify the owner per their contractual agreement regarding the potential change.

Information Management Requirements

Whenever we seek to gain an understanding of the requirements for various parties, it is first important to review the contract(s). For the purposes of reviewing typical information management requirements, we will look at the American Institute of Architects (AIA) standard contract agreements since these are the most widely adopted template contracts for commercial building projects. Many items are defined within the General Conditions portions of the AIA Standard Documents.



AIA® Document B201™ – 2017

Standard Form of Architect's Services: *Design and Construction Contract Administration*

for the following PROJECT:
(Name and location or address)

THE OWNER:
(Name, legal status and address)

THE ARCHITECT:
(Name, legal status and address)

THE AGREEMENT
This Standard Form of Architect's Services is part of the accompanying Owner-Architect Agreement (hereinafter, together referred to as the Agreement) dated the ________ day of ________ in the year ________.
(In words, indicate day, month and year.)

This document has important legal consequences. Consultation with an attorney is encouraged with respect to its completion or modification.

This document provides the Architect's scope of services only and must be used with an owner-architect agreement. It may be used with AIA Document B102™–2017, Standard Form of Agreement Between Owner and Architect without a Predefined Scope of Architect's Services, to provide the Architect's sole scope of services, or with B102 in conjunction with other standard form services documents. It may also be used with AIA Document G802™–2017, Amendment to the Professional Services Agreement, to create a modification to any owner-architect agreement.

TABLE OF ARTICLES

ARTICLE 1 INITIAL INFORMATION
§ 1.1 The Agreement is based on the Initial Information set forth in this Section 1.1.
(For each item in this section, insert the information or a statement such as "not applicable" or "unknown at time of execution.")

§ 1.1.1 The Owner's program for the Project:
(Insert the Owner's program, identify documentation that establishes the Owner's program, or state the manner in which the program will be developed.)

Init.
/
AIA Document B201™ – 2017. Copyright © 1917, 1926, 1948, 1951, 1953, 1958, 1961, 1963, 1966, 1967, 1970, 1974, 1977, 1987, 1997, 2007 and 2017 by The American Institute of Architects. **All rights reserved. WARNING: This AIA® Document is protected by U.S. Copyright Law and International Treaties. Unauthorized reproduction or distribution of this AIA® Document, or any portion of it, may result in severe civil and criminal penalties, and will be prosecuted to the maximum extent possible under the law.** To report copyright violations of AIA Contract Documents, e-mail The American Institute of Architects' legal counsel, copyright@aia.org.
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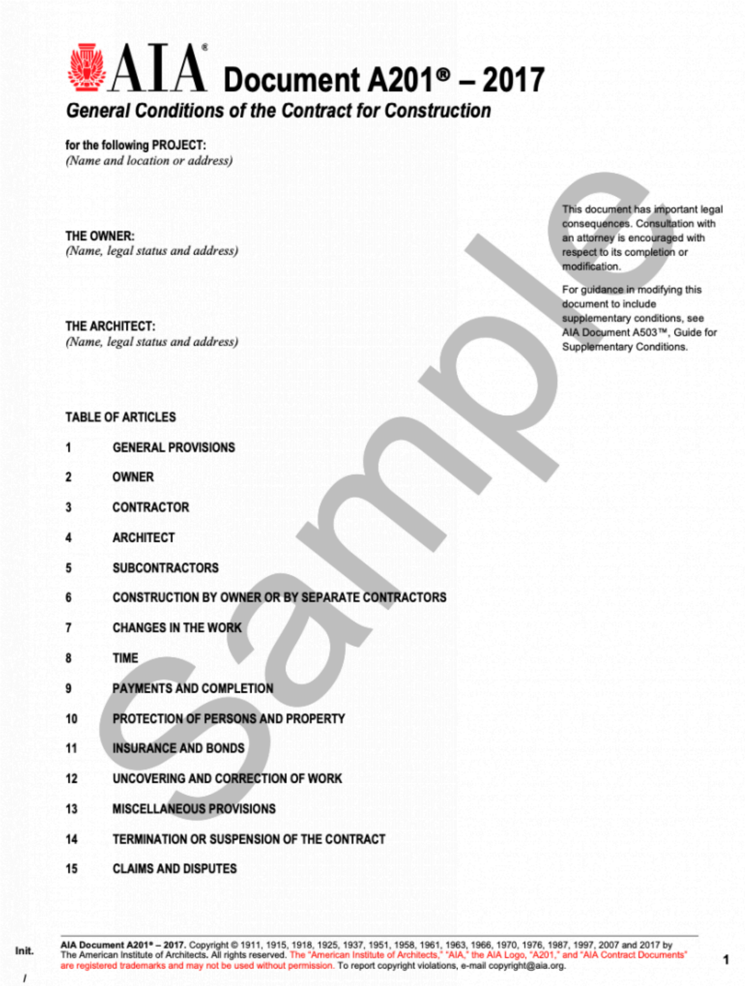
Figure : AIA B201 Cover Page, Standard Form of Architect's Services: Design and Construction Contract Administration



AIA® Document A201® – 2017

General Conditions of the Contract for Construction

for the following PROJECT:
(Name and location or address)

THE OWNER:
(Name, legal status and address)

THE ARCHITECT:
(Name, legal status and address)

This document has important legal consequences. Consultation with an attorney is encouraged with respect to its completion or modification.

For guidance in modifying this document to include supplementary conditions, see AIA Document A503™, Guide for Supplementary Conditions.

TABLE OF ARTICLES

Init.
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Figure : AIA A201 Cover Page, General Conditions of the Contract for Construction

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://psu.pb.unizin.org/buildingconstructionmanagement/?p=116#h5p-31

23.

INTRODUCTION TO LEAN CONSTRUCTION

Learning Objectives

After reading this chapter, you should be able to:

- Define 'lean construction'
- Understand the types of waste on construction projects
- Be able to list various methods used on projects to increase value and reduce waste
- Describe the Last Planner System™
- Understand the process to develop a Lean Deployment Plan for a project

Defining Lean Construction

Lean is…

Lean Construction is …

Lean concepts originated from the Toyota Production System, and many earlier references to lean concepts reflect upon Japanese terminologies, such as 'muda' for waste or 'kaizen' for continuous improvement (see https://txm.com/place-japanese-lean-jargon-place-japan/ for additional examples).

The 6 Tenets of Lean

The Lean Construction Institute (LCI) has identified six core tenets of Lean (see Figure 1). It is important to note that the foundation is 'Respect for People'. Without this respect, it is difficult to adopt a lean approach on projects or within organizations.

Figure 1: The Six Tenets of Lean (Source: Lean Construction Institute (LCI))

It is important to note that the foundational tenet within Lean Construction is 'Respect for People'. Without this respect, it is not possible to successfully achieve the other five tenets. This foundation principle is embedded throughout lean projects.

8 Wastes on Construction Projects (Muda)

One of the core tenets of lean is to eliminate waste (or muda). To do so, one must first be able to identify waste. There are many sources of waste on a construction project. Obvious waste can be include the the need to redo work that is not acceptable or wasted time due to not having the proper materials to complete a task. But there are other wastes that are less obvious, such as not leveraging the full talents of the team members.

Figure 2: The 8 Wastes of Lean (Image source: The Lean Way)

Lean Construction Methods

There are many methods that can be applied to achieve the Lean principles. These can include simple methods, such as completing each meeting with a plus-delta activity, focused on identifying what went well and what could be improved in future meetings to enable continuous improvement. Or they can include more complex, comprehensive methods such as target value design which focuses on developing a design that meets the overall project budget through frequent interactions of design and construction cost estimating.

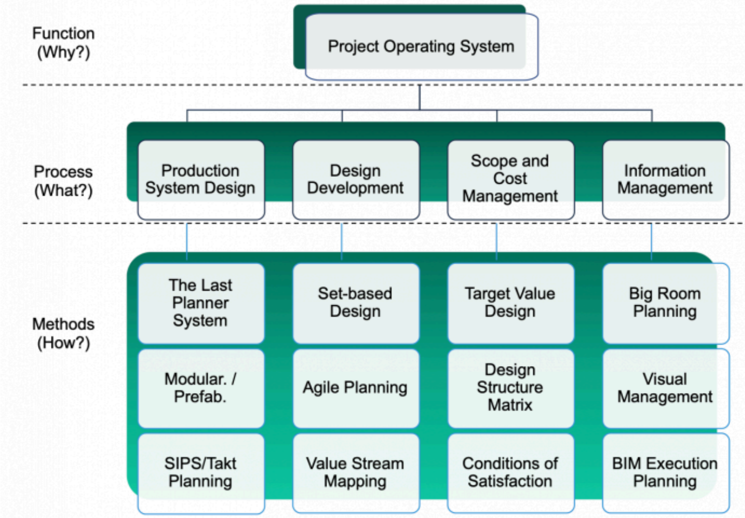

Figure 6: Operating System Methods

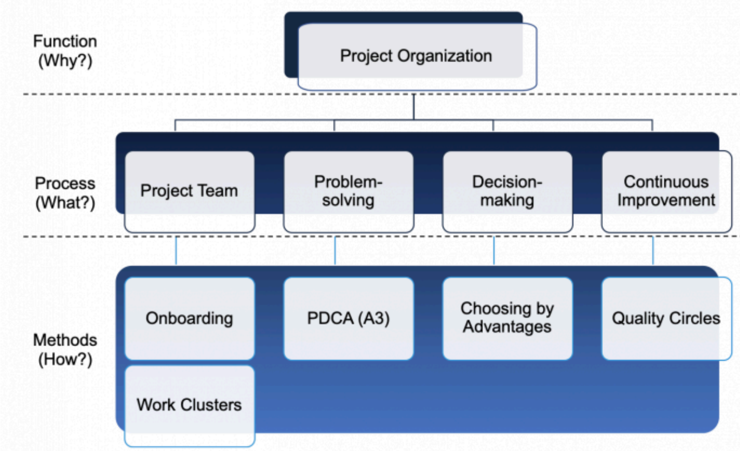

Figure 7: Organization Methods

Figure 3: Select Operating System and Organizational Lean Methods (Source: Lean Deployment Planning Guide)

The Last Planner System

The most popular lean construction system is the Last Planner System. The Last Planner System is composed of a number of integrated lean methods.

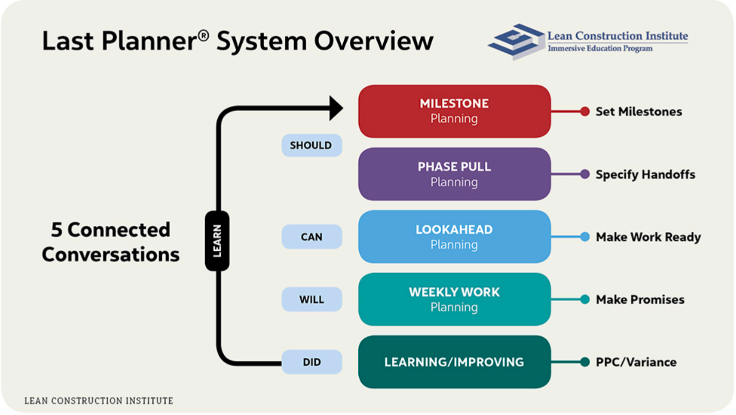

Figure 4: The Last Planner System Overview Flowchart

Lean Deployment Planning

Lean Deployment Planning focuses on the development of a detailed implementation plan for lean on a project during the earlier stages of the project. Ideally, the team members will get together and collectively develop and document this lean deployment plan.

The Lean Construction Institute through a Penn State research team developed a guide to support the creation of a Lean Deployment Plan. This Lean Deployment Planning Guide walks a project team through a structured process to design and document their plan. The main steps in this process are to initiate the plan development, select the lean methods to be adopted, plan for each method, and integrate the individual method plans and metrics into a comprehensive plan (see Figure 5).

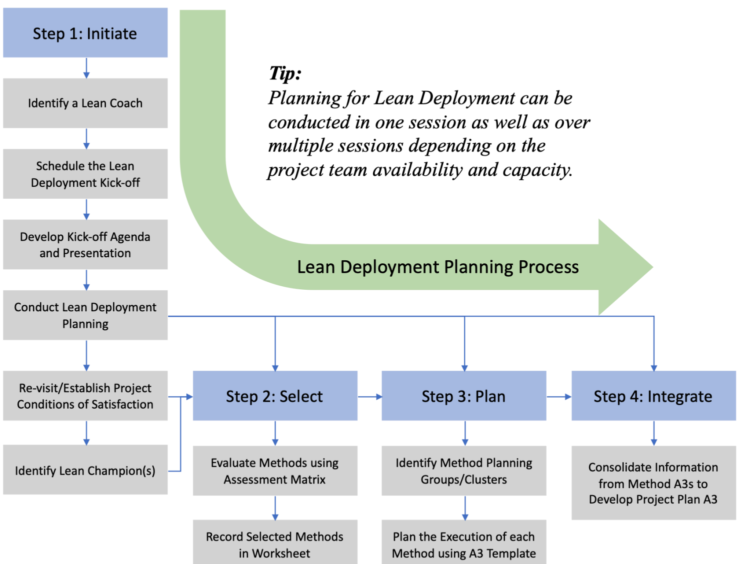

Figure 5: Lean Deployment Planning Process (Source: The Lean Deployment Planning Guide, Messner et al. 2019)

Enterprise Adoption of Lean

It is important to note that lean principles, or lean transformation, can be applied at both a project or an organizational level. The Lean Enterprise Institute has developed a lean transformation framework to conceptualize the important considerations when transforming an enterprise or company (see Video 1).

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://psu.pb.unizin.org/buildingconstructionmanagement/?p=118#h5p-17

Video 1: The Lean Transformation Framework by the Lean Enterprise Institute

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://psu.pb.unizin.org/buildingconstructionmanagement/?p=118#h5p-32

References

Messner, J., Leicht, R., and Bhawani, S. (2019). The Lean Deployment Planning Guide, Version 1.1, available at https://leanconstruction.org/download-page/lean-deployment-planning-guide/

24.

THE FUTURE OF THE CONSTRUCTION INDUSTRY

Learning Objectives

After reading this chapter, you should be able to:

- Understand the trends that are impacting the future of the construction industry
- Describe the characteristics that need to change to advance the construction industry
- Assess your role in advancing the industry and your future knowledge and skills

We started this book, in Chapter 1, discussing some ongoing trends in the construction industry. As we come to the end of this book, we will summarize some of these trends, and the role that everyone plays in transitioning our industry to improve overall value delivery.

Trends Impacting the Construction Industry

The Changes Occurring in the Construction Industry

Assessing Your Role in Changing the Construction Industry

Concluding Remarks

I hope that you have enjoyed this book to expand your technical skills related to construction management. With that said, I'll end with an important discussion of the need to expand both human and leadership skills. Bill Badger (2019) developed an interesting summary of Organizational Leadership that defined several core items to consider:

- Education and training is not an expense, it's an investment.
- Taking care of your people is the key to successful organizational leadership.
- People are the one sustainable competitive advantage every business has.
- People matter, it's all about people, unleash the power of your people.
- Organizations (leaders) must be good communicators to be successful. Communication is the "it" factor.

Badger also defined the shifting skill sets that you will need as you progress through your career, shifting emphasis from technical skills to higher degrees of human skills and leadership skills.

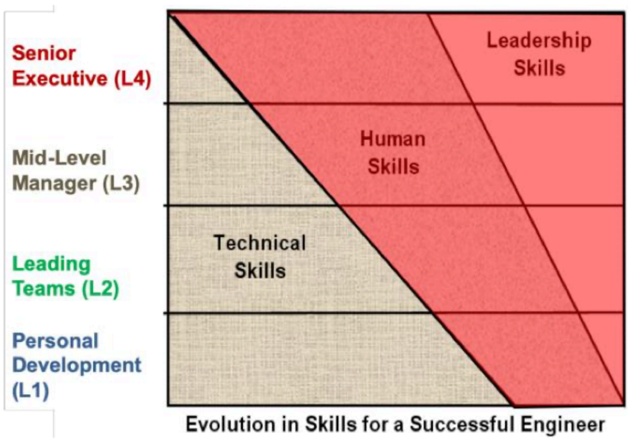

Figure 1. Evolving Technical, Human, and Leadership Skills

Fig. : Evolving Technical, Human, and Leadership Skills (Badger 2019)

Review Questions

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://psu.pb.unizin.org/buildingconstructionmanagement/?p=120#h5p-33

REFERENCES

Badger, B. (2019). *Organizational Leadership—— It's About People, Not Process.* National Academy of Construction (NAC) Executive Insights, July 22, available at https://www.naocon.org/wp-content/uploads/Organizational-Leadership-Its-About-People-Not-Process.pdf

CII (Construction Industry Institute) (1996). *Partnering toolkit.* IR102-2. University of Texas at Austin, Austin, TX. Available at https://www.construction-institute.org/resources/knowledgebase/best-practices/partnering.

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/

International Partnering Istitute. (2020). *What is Construction Partnering?*. Available at https://partneringinstitute.org/about/what-is-construction-partnering/ (accessed on June 1, 2022).

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

Building Information Modeling

Cost Management

The process of planning and controlling the costs associated with running a business. (Gartner 2022)

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.

partnering

commitment between two or more organizations for the purpose ofachieving specific business objectives by maximizing the effectiveness of each participant's resources (CII 1996)

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.

Value Engineering

An organized effort directed at analyzing the functions of systems, equipment, facilities, services and supplies for the purpose of achieving the essential functions at the lowest life-cycle cost consistent with the required performance, reliability, quality, and safety.' (Source: Office of Management and Budget, Circular No. A-131, 1993)

Value Engineering (VE)

An organized effort directed at analyzing the functions of systems, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life-cycle cost consistent with required performance, reliability, quality, and safety. (Source: OMB, Circular No. A-131, 1993)

REVIEW QUESTION ANSWERS

Chapter 1: Introduction to the Building Industry

1. Commercial Building, Infrastructure, Industrial, and Residential
2. False
3. a. Industrial
   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)
4. True
5. False
6. 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. True (for this class – note that many people use different conventions)
2. True

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: Introduction to Lean Construction

Chapter 25: Managing an Organization

ABOUT THE AUTHOR

John Messner is the Charles and Elinor Matts Professor of Architectural Engineering and the Director of the Computer Integrated Construction (CIC) Research Program at Penn State. He specializes in Building Information Modeling (BIM), digital twin, and automation in construction research and development. John led several initiatives focused on standardizing BIM planning processes and organizational adoption of BIM. He also currently chairs the U.S. National BIM Standards Project Committee at NIBS and is a member of the Lean Construction Institute Board of Directors. He teaches courses on building construction management, building information management, and immersive technologies at Penn State.